EFFECT OF FREE-RANGE STRATEGY ON MEAT QUALITY AND EFFICIENCY OF CONVENTIONAL BROILER PRODUCTION SYSTEM

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other institution of higher learning.

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DEDICATION

This work is dedicated to my parents, Hannington and Timina Mbato for their effort to give their children the best they could: Education.

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ABSTRACT

Indigenous chicken (IC) genetic resources in Kenya constitute an integral proportion of the various classes of poultry in human settlements and positively affect national and regional food chains. Studies have shown that meat from IC is more preferred than that of convectional broilers because of it is chewy low fat content attributed to the low n-6/n-3 fatty acids ratio compared to broiler meat. The objective of this study was to design a production system strategy to produce broiler carcasses with characteristics similar to that of free-range chicken in the shortest time and at a reduced cost. In a completely randomized block design experiment, 240 day-old chicks (16 groups of 15 chicks per pen) were randomly assigned to four treatments i.e. the control group (D) where the day old chicks were fed the conventional broiler diet for the whole experimental period of 8 weeks; groups A to C which were released to free-range at 2 , 3 and 4 weeks, respectively in four pens each. Chicken live weights were recorded at 6, 7 and 8 weeks of age and 3 birds from each treatment slaughtered for carcass analysis. The results showed that the free-range strategy had a significant impact on the aroma and flavour of the meat ($P<0.0001$) with the 2-week release being the most preferred and the control the least preferred. In addition, free-range strategy had significant effects on the weight of the birds with the control being the heaviest and 2week release the lightest ($P<0.0001$). The cost of production was significantly different from one free-range strategy to another with the most expensive being the control and least expensive being the 2-week release ($P<0.0001$). Results of this study show that the longer broilers are exposed to outside access the tastier their meat.

Key words: Conventional broiler, free-range strategy, production system

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ACRONYMS

AMEn:	Apparent metabolisable energy corrected to zero N-retention
Ca:	Calcium
CF:	Crude fibre
CFRS:	Confined full-ration system
CP:	Crude protein
DCCW:	Dry crop content weight
DLPO:	District Livestock Production Officer
DM:	Dry matter
EE:	Ether extract
FRR:	Free-range strategy
FRS:	Free-range system
IC:	Indigenous chickens
MALDM:	Ministry of Agriculture, Livestock Development and Marketing
ME:	Metabolisable energy
NaCl:	Sodium chloride
NFE:	Nitrogen-free-extract
NPDP:	National Poultry Development Programme
NRC:	National Research Council
P:	Phosphorus
PREP:	Method of preparation
RIR:	Rhode Island Red
SFRB:	Scavenging feed resource base
SIS:	Semi-intensive system

SLW: Slaughter week

TME: True metabolisable energy

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CHAPTER 1

INTRODUCTION

1.1 Background

Chickens are the most widely domesticated species in the world. They are also the most numerous (Perry et al., 2002; Moreki et al., 2010). Chicken is especially important for its nutritious flesh and eggs for food. The worldwide chicken population is estimated at 19 billion birds representing three birds per person (Timothy et al., 2014). In Kenya, the population of chicken is estimated at 31.9 million birds with 6.1 million chickens raised commercially as layers or broilers and 25.8 million backyards or free-range indigenous chicken (Rosário et al., 2008). According to Sørensen (2006), poultry production is an alternative to rural livelihood and positively impacts on national and regional food chains.

Consumer preferences for meat products tend to change with increased urbanization and growing household incomes, leading to the opening of new opportunities to be exploited (Nyoro & Ngugi, 2007). One such trend is preference for lean white meat over red meat (Moschini & Meilke, 1989). Fish and poultry are the most preferred, but because captured fishery resources are dwindling and farmed aquaculture is still at an introductory stage of mass exploitation in Kenya, poultry meat then becomes a viable option. Moreover, exotic poultry is not entirely lean and thus leaving indigenous chicken as the other alternative (Nyaga, 2007). Consumers are increasingly interested in naturally produced or environmentally friendly products that they perceive as having high nutritional level of nutrition, no contaminants and good flavour. They also prefer products from systems that provide good welfare and health for the chicken (Sundrum, 2001; Owens *et al.*, 2006). Poultry meat is the fastest growing component of global meat production, consumption, and trade, with developing and transition economies contributing a leading role in the expansion (Assa, 2012). In addition to providing opportunities to increase poultry exports, rising poultry production spurs growth in global import demand for feeds and other inputs, which give rise to investment opportunities in these sectors (Landes et al., 2004). The society expects the livestock sector, poultry included, to continue to meet rising world demand for animal products cheaply, quickly and safely. Increasing access to affordable animal-based foods has the potential to significantly improve nutritional status and health for many poor people.

1.1.1 Growing broiler chicken on pasture

Broiler rearing systems have received much attention in recent years due to increasing consumer interest in organic and natural poultry production. Traditionally in free-range and organic production systems, grass is a common component in the diet of chickens (Savory et al., 2003). However, grass is hardly the main source of energy and protein in wild or domesticated chickens. Together with a rotation of the birds on pasture to sustain bird health, chickens consume only a minor part of the herbage production on pasture (Bassler et al., 2000) as they preferred the wheat meal they were being supplemented with to pasture. Pasture is mainly used for the cattle and other ungulates. Cattle grazing create a pasture with short grass, which is beneficial for poultry (Thaer 1990). Potentially, waste products of milk or whey and earthworm compost may also be available as chicken feed. The pastured chickens' manure fertilizes the grassland. Intensive animal farming systems concentrate animal production activities in a small area leading to excess accumulation of animal manure that would, otherwise, be available for crop production thus reducing its efficiency as a source of fertilizer in the regional agro-ecosystem (Oomen et al., 1998).

1.1.2 Benefits of outdoor access of broiler birds

Farm animal welfare is an important subject in high income countries particularly in the European Union, Switzerland, Canada, Australia, New Zealand and the USA especially for commercial poultry production. Birds reared in a free-range environment or with outdoor access are perceived as being natural, environmentally friendly, and animal welfare friendly (Husak et al., 2008) and the products have a distinct flavour (Latter-Dubois, 2001*)*. This has been confirmed with research findings that outdoor systems can decrease stress and increase bird comfort (Blokhuis et al., 2000), leading to stronger leg bones and walking ability (Fanatico et al., 2005a, 2008) compared to the conventional confined systems. In addition, outdoor access could improve the quality and flavour of meat products in comparison with the conventional confined system (Fanatico et al., 2005b, Wang et al., 2009). However, the effects of outdoor access remain controversial because meat quality traits depend on many factors, including genotype, age, nutrition, stocking density, as well as pasture intake (Gordon & Charles, 2002). Poultry meat quality traits include chemical (proteins, total lipids, etc.) and other traits e.g. pH, colour, water holding capacity, texture, sarcomere length (Petracci & Baeza, 2011).

The typically fast growing conventional broiler breed characteristics have a negative influence on the sensory and functional qualities of meat due to the fast growth and high yield (Dransfield & Sosnicki, 1999), pushing muscle fibres to their maximum functional size constraints (MacRa et al., 2006).

1.1.3 Poultry production and use in developing countries

In developing countries, the diet of an average person is generally composed of cereals and vegetables, which are deficient in protein especially of animal origin (Mahmood et al., 2005). This adversely affects the general health and mental development of the people. The poor nutritional status is mainly due to inadequate production of good quality food and lack of purchasing power of the average person. Animal protein sources like mutton are very expensive, whereas beef, is of late being shunned due to its perceived high cholesterol content. Broiler feed production account for 70 to 75% of total cost of production (Mahmood et al., 2005) and this cost is usually transferred to the consumers. In many developing countries, particularly Africa, poultry production in rural and peri-urban areas is based on traditional scavenging systems. It is estimated that about 80% of the Africa's poultry population, is found in traditional production systems (Branckaert et al., 2000). These systems are characterized by low inputs and contribute to household food security (Branckaert et al., 2000). The system of production in rural and peri-urban areas is based on traditional scavenging systems that play an important role in supplying local populations with additional income and high-quality food in the form of meat and eggs. In general, the rearing period for the indigenous chicken is longer (16-20 weeks), compared with that of the convectional broilers (5-6 weeks) (Tsai et al., 2006, Chen et al., 2007).

Table 1 shows the characteristics of poultry production systems in Kenya. It can be deduced from the table that an improvement in the management of this systems would immediately be reflected in improved production. This evidenced by the increase in daily growth rate from the traditional to the small-scale intensive production system. In the movement from backyard subsistence to semi-intensive, there is a regular provision of water, grains and household wastes, improved night shelters, vaccination and little medication to control diseases and parasites and to some extent exchange of cockerels between the farms. Because of better management, mortality is moderate and there is increased egg production (50-150 eggs hen^{-1} $year^{-1}$) and growth rate (10-20g day^{-1}). Some of these growth rates recorded in this system are comparable to what is currently reported for convectional broiler production systems (Kitaly et al., 1998).

Table 1. Characteristics of poultry production systems in Kenya

Characteristics	Traditional	Backyard subsistence	Semi-intensive	Small scale intensive
Flock size of birds	1-10	10-50	50-200	50-500
Type of birds	Indigenous breeds	Indigenous and few cross breeds	Local Improved	Layers or broilers
Feed resources	Scavenging	Scavenging and supplementation	Commercial local	Balanced diets
Daily growth rate (g)	5-10g	10-20	10-20	50-55

Adapted from Kitaly et al. (1998).

1.2 Problem statement

Conventional broiler meat is proportionally more affordable and available than the indigenous chicken meat in spite of the high cost of feed in conventional broiler production systems, which account for 70-80% of the total cost of production. For example, in the Kampala chicken market, the price of IC is almost triple that of chicken produced from conventional broiler production systems (Emuron et al., 2010). Additionally, chicken from traditional indigenous production systems takes longer (16 weeks or more) to reach market weight due to genetics (Chen et al., 2007, Tsai et al., 2006). There is also a high demand for the unique tasting indigenous chicken products because of their perceived health benefits and overall safety. However, there is a low supply of the IC products in the market, which can be bridged by producing broiler meat from conventional production systems that is easily available (takes a shorter time to produce), affordable and with carcass qualities comparable to those of the IC.

1.3 Justification

This research aims to improve the quality of broiler carcasses from conventional broiler production systems while lowering the cost of production. This is by utilization of the high growth rate inherent in conventional broiler breeds and the change of exposure to that of free-range chicken to ensure a faster attainment of market weight and tastier broiler meat at a lower cost of production (Berri, 2001; Halle & Danika, 2001 & Rizzi et al., 2007) than the conventional broiler. Chicken from traditional indigenous production systems takes longer to reach market weight at 16 weeks or more (Chen et al., 2007; Tsai et al., 2006). The main consideration affecting the purchase decision by consumers of IC products is taste, which is considered different from those of conventionally produced broilers; price is a secondary consideration (Zanussi et al., 2003). Since the conventional broiler production system is well developed, manipulation of chickens under this system to attain improved taste will achieve improved efficiency by faster attainment of market weights at relatively lower costs than the conventional production system.

1.4 Objectives

1.4.1 Overall objective

To design a production system strategy to produce broiler carcass with characteristics similar to that of IC free-range chicken in a shorter time and at a reduced cost.

1.4.2 Specific Objectives

1. To evaluate the effect of introduction of free-range strategy at different stages on the growth of broiler birds
2. To evaluate the taste of broiler meat produced on different free-range strategies
3. To evaluate the effect of the cooking method on taste of the broiler meat produced on different free-range strategies.

4. To compare the cost of producing the broiler birds under the different free-range strategies

1.5 Hypotheses

1. The different free-range strategies have no effect on the weight of the broiler chicken during growth.

2. The stage in the broiler production cycle at which the chicken is put on free-range diet has no effect on the desired carcass characteristics.

3. The cooking method has no effect on taste of broiler meat produced on different free-range strategies.

4. The cost of producing the broiler meat to an optimal weight would be the same for both conventional broiler and free-range strategies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Poultry production is the fastest growing component of global meat production, with developing and transitional countries assuming a leading role (Assa, 2012). In most developing countries, poultry production is mainly based on indigenous ecotypes and scavenging backyard production systems (Kitaly, 1998). It is estimated that there are about 20.8 million indigenous chickens in Kenya (King'ori et al., 2010).

In western countries, animal welfare activists are campaigning against intensive poultry production due to stresses the birds are subjected to in terms of lack of exercise (Phillips et al. 2010; Savory, 2003). Although the poultry production system in Kenya is tending towards intensive production, the trend worldwide is to increase productivity under free-range systems. Birds under free-range or organic systems have access to an outside area where an enriched environment can promote their foraging, feed selection, and activity and theoretically the welfare of the birds can be improved (Ponte et al., 2008)). Outside access encourages natural behaviours (Duncan, 1987; Newberry, 1995; Stricklin, 1995) and creates a greater number of behavioural opportunities that increase the bird's activity (Newberry, 1995; 1997; Mellen & MacPhee, 2001). There are many benefits of outside access to chickens and they include encouraging a more-even distribution of animals (Cornetto & Estevez, 2001b), reducing disturbances, aggression, and reducing fear responses and stress (Jones, 1982; Nicol, 1992; Reed et al., 1993; Grigor et al., 1995). It has, however, been reported that in free-range system broilers face increased risk from helminth (Permin et al., 1999) and Salmonella infections (Hoop & Rippinger, 1997) therefore increasing production costs. This increase in cost is, however, negligible when compared with the cost of feeding the broilers.

2.2 Production systems

Chicken production may be broadly classified into subsistence and commercial levels based on the scale of operation, the way in which outputs are used and the level of management the chickens are given (Kitaly, 1998). The indigenous chickens (IC) are managed under subsistence systems. They have shown not only a remarkable ability to perform, albeit poorly, under constant disease and parasite challenge, but also to sustain their populations through natural incubation (Kitaly, 1998). These birds (IC) are mainly kept for dual purpose, producing both meat and eggs for the family (King'ori, 2010) and sale of surplus to neighbours. Typically, based on types and levels of inputs and the various outputs, three systems are identified under the subsistence production system:

i) Free-range system (FRS) or scavenging system

ii) Semi-intensive system (SIS) or semi-scavenging system

iii) Confined full-ration system (CFRS)

2.2.1 Free-range system (FRS) or scavenging system

In free-range system (FRS) or scavenging system, feed supplementation is not provided (Kitaly, 1998). Both the chicks and mature chickens are left to forage within the homestead for whatever available feed resources. About 95% of IC raised by rural smallholder farmers is under the FRS (Tadelle et al., 2003a).

2.2.2 Semi-intensive system (SIS) or semi-scavenging system

In this system, the chickens are confined part of the time. This is especially in relation to the prevailing activities in arable agriculture (planting, weeding, harvesting). The birds, therefore, are provided with crop residues and grains from arable agriculture as well as kitchen wastes to supplement their daily feed requirements (Gunaratne, 1998)

2.2.3 Confined full-ration system (CFRS) or intensive system

The CFRS is where the flock is confined all the time and supplied with a balanced diet (Gunaratne, 1998). The IC under the FRS and SIS have limited area for foraging thus keeping their feed resource base fixed. The implication is that the fixed-feed resource base results in a fixed carrying capacity and thus extra chickens above the carrying capacity cause a reduction in productivity (Muiruri & Harrison, 1991). In both the FRS and SIS, the flock is usually not given any veterinary care (King'ori, 2010), except the use of herbal medicines (i.e. ethno-veterinary practices), which may not contribute significantly to costs of healthcare. In the CFRS, however, the flock is given prophylactic cover and vaccinated against endemic diseases (King'ori, 2010)

2.3 Indigenous chicken breeding

The formal breeding programmes to improve IC have not, largely, reached the grassroots in Kenya. However, traditional breeding knowledge exists where cocks and hens are selected from within the homestead or occasionally purchased in. There is uncontrolled mating and most of the chickens are inbred (Ndegwa et al., 1998). The hens lay about 10 to 15 eggs on average per clutch then naturally incubate and brood the chicks (Ndegwa et al., 1998; King'ori, 2004).

The hatchability is high in IC but chick survival is low due to predation and poor sanitation leading to a suggestion that some of the IC genotypes may be threatened with extinction (Maina & Tambi, 2003).

Chicken breeding has been attempted through a variety of donor-funded projects. For example, the cockerel/pullet exchange programme was implemented under the National Poultry Development Programme (NPDP) with the objectives of improving body weight and egg production (Fan et al., 2005). This programme used exotic cockerels for upgrading the IC. However, it was unsuccessful because the exotic cockerels and their progenies could not survive the harsh free-range conditions. Poultry diseases were the main culprit in this environment. The programme, therefore, recommended a more aggressive disease control regime in addressing this shortfall. Generally most programmes aimed at improving productivity have concentrated on aspects of their physiology and nutritional requirements without due regard to their genetic diversity.

2.4 Animal welfare and broiler meat marketing

Any well thought-out production system has to have the consideration of consumer's interests or preference in mind and broiler production systems are not an exception. Animal welfare is increasingly viewed as a factor affecting the quality of animal products while being an important tool of marketing strategy. The intensive management system used in highly productive farms is often subjected to harsh criticism. One of the reasons for this is its failure to provide adequate welfare to the animals. In many countries, this attitude has led to the development of poultry meat production under less intensive rearing conditions. In more developed economies such as North America, studies have shown that consumers purchased organic foods because of the systems of their production (Onyango et al., 2006). Furthermore, consumers believe that the meat from free-range chickens is healthier than that of confined in a poultry house (Fanatico et al., 2006). It is also believed that "natural", less intensive management systems provide chickens with higher welfare levels, resulting in much better product quality (Pavlovski et al., 2011) than more intensive production systems.

However, the evaluation of overall welfare of animals in a system of production is difficult. For example in pig production system, alternative less intensive housing systems allow them to display species-specific behaviour and decrease the occurrence of abnormal behaviours (Millet et al., 2005) than the more intensive systems. Therefore, systems and technologies that ensure access to free-range, low stocking density and natural lighting are attracting increasing interest among poultry producers and consumers. More natural rearing conditions and increased activity of the birds contribute to the lower lipid content in broiler meat, and pasture intake generates meat with a greater degree of consumer acceptability (Castellini et al., 2002b; Jahan et al., 2004; Ponte et al., 2008) than the more intensive production systems. Specific selection for high growth rate in broilers by the poultry industry has resulted in strains that reach a market weight within a short rearing period (Boyle, 2005). The effects of this selection are displayed in carcass composition and structure, growth pattern, metabolism, digestion, endocrine and immune functions, central nervous system functions, and even in the behaviour of broilers (Khajavi et al., 2003; Dawkins & Layton, 2012). This selection for a high growth rate is evidenced by increased breast muscles, increased carcass water content and increased carcass fat (Havenstein et al., 2003). On the other hand, studies have shown that only slow-growing chicken breeds can fully benefit from an organic rearing system or outside access because fast growing are characterized by a very low degree of adaptation (Reiter & Bessei, 1998; Castellini et al., 2002b; Branciari et al., 2009). It is for this reason that the fast growing breeds have modified their behaviour such that the birds tend to stay indoors rather than go outdoors to reduce energy cost (Branciari et al., 2009). It is also known that fast-growing broiler chickens are not adapted to less intensive systems, but they are commonly used under these conditions for economic reasons (Castellini et al., 2006). In the United States and Poland, however, alternative broiler production is based mainly on the same fast-growing birds that are used in the conventional intensive production systems (Fanatico et al., 2005a). The system of bird rearing system is one of the many non-genetic factors that can considerably affect meat quality (Bogosavljević-Bosković et al., 2006b).

2.5 Feed restriction in broilers

2.5.1 Types of feed restriction

Feed restriction in broilers can improve feed efficiency thus reducing feed cost and mortality along with the production of quality meat at cheaper rates (Mehmood et al., 2013). The high growth rate of the conventional broiler chicken causes stress on the birds and can result in metabolic diseases and skeletal disorders that lead to economic losses, reduced performance, high mortality rates and carcass condemnation at slaughter houses (Mench, 2002) . Several methods, both qualitative and quantitative feed restriction methods have been tried by several researchers in attempts to change carcass characteristics and reduce cost in conventional broilers with varying degrees of success (Leeson et al., 1997; Plavnik et al., 1991; Leeson et al., 1991). These methods include:

i) Skip-a day
ii) Feed dilution
iii) Feed removal during the day
iv) Reducing calorie: protein ratio
v) Late feed restriction

2.5.1.1 Skip-a-day feed technique

In this program there is provision of limited allotments of feed and is sometimes used by broiler breeders for growth restriction. Removal of feed for 24 hours during the starter period reduces early rapid growth and results in better meat yield in broiler chickens (Sahraei & Mohammadi, 2012). This method of limiting early growth has not been researched and it used widely for broiler chickens (Dozier et al., 2002). However, in 2015 Jahanpour et al. modified this technique to Advised daily feed intake. This is where the broilers were fed on 50 to 75% of their daily ration in the early stages of their life. This technique was found to have a neutral or slightly beneficial effect on broiler growth traits and carcass composition.

2.5.1.2 Diet dilution

This is a method where non-nutritional additives are added to the broiler feed thus reducing the nutrients available to the bird per unit feed. This method can be used as a practical method of nutrient restriction to attain more consistent growth pattern within a flock (Ali et al, 2007). Leeson et al. (1991) found that diet dilution had no effect on carcass characteristics at 42 days and concluded that broiler chickens can withstand a 7-day period of early under-nutrition without loss in performance characteristics. Rezaei et al. (2006) indicated that broiler chicks offered only ground charcoal could withstand a 7-day period (from 8 to 14 days) feed restriction without loss in performance. Feed dilutions have also been used to change the carcass composition of broiler chickens (Nielsen et al., 2003). Success of feed dilution programs is based on complete compensatory growth and the amount of body fat content (Hassanabadi & Nassiri, 2006). Rezaei et al. (2010) indicated that feed dilution with 20% rice hulls during 16 to 20 day of age had no adverse effect on broiler performance and it reduced abdominal fat pad weight and carcass crude fat proportion.

2.5.1.3 Feed removal during day time

This is a method of feed restriction where the feed is withdrawn from the birds for a period during the day. This was practiced by Petek (2000), who reported that using feed removal regimen resulted in significantly decreased body weight, but associated with better feed conversion in the six hour feed removal group.

Feed removal had no significant effect on carcass, liver, gizzard and abdominal fat weights. Feed removal during hot hours of the day may be a choice to reduce the effect of temperature during summer and to prevent the extra cost of feed restriction

2.5.1.4 Reducing calorie: protein ration

Reducing calori: protein ration in the broiler diet is another method of feed restriction that has been tried. This is where the proportion of energy to protein is reduced in the broiler diet. Manipulation of this technique by increasing dietary energy was found to have no effect on the deposition of abdominal fats in the chicken (Griffith et al., 1977).

2.5.1.5 Late feed restriction.

This is another type of feed restriction where the amount of feed supplied is restricted at a later stage in the life of a broiler (usually from the age of 4 weeks). Cabes & Waldroup (1990) found this method not to have an impact on the abdominal fat content of the broiler.

2.5.2 Benefits of early and late feed restriction

The benefits of early feed restriction are the monetary savings obtained by improved feed conversion (Proudfoot et al., 1983), reduced sudden death syndrome (Bhat & Banday, 2000), reduced death losses (Tottori et al., 1997), reduced ascites (Arce et al., 1992) and reduced skeletal disease (Robinson et al., 1992). Not only the early feed restriction regimes, but also the late feed restriction or feed withdrawal regimes before four to five weeks of age may reduce the incidence and severity of ascites (Arce et al., 1992).

2.5.3 Compensatory growth

The phenomenon of compensatory growth is known for the potential to have effects on the rate of growth and body composition of most animals. An animal whose growth has been slowed down by nutritional deprivation may exhibit an enhanced rate of growth when restriction of feed is removed. Studies have shown that the timing, duration and severity of restricted feeding has an effect on the ability of the birds to gain the same weight similar to the birds not under restricted feeding (Ballay et al., 1992; Yu & Robinson, 1992). This is a complex phenomenon as it involves genetic, physiological, nutritional, metabolic, endocrinal and behavioural relationships (Nir et al., 1996). During the period of feed restriction, growth rate is slower than that of birds given free access to feed, but when removed from the restricted diet and fed *ad-libitum*, the birds exhibit an accelerated rate of weight gain (Planvik & Hurwitz, 1985; Jones & Farrell, 1992). Previously restricted birds utilize feed more efficiently following the period of restriction because their overall feed intake and feed conversion ratio are lower than those of full fed birds (Al-Taleb, 2003). The gastrointestinal tract and its associated organs are not affected by feed restriction. They grow at higher rate than the other tissues (bones, muscles and adipose tissues) (Ali et al., 2007).

CHAPTER 3

MATERIALS AND METHODS

3.1 Study site

The study was conducted at Pwani University, Kilifi County, 62 km to the north of Mombasa town in the Kenyan between 11th November 2014 and 11th March 2015. The study site is located on 2° S latitude and 40° E longitudes at an attitude of 16 m above sea level. The annual rainfall for the study site ranges from 900 - 1100 mm and the mean annual temperature from 25 - 30° C. It has a marked dry season from January to March and a wet one from April to June. For the rest of the year there are variations in amount and distribution of the rainfall.

3.2 Experimental chicken and outside access

A poultry unit, that had a corrugated iron sheet roof, was divided into sixteen pens (2×1.5×1.2 m.) constructed from wood posts and plywood and wire netting sides (see Figure 2). Each pen was connected to an outdoor area. The outdoor area (4×2 m) was constructed from wood posts and wire netting sides that restricted the chicks (see Figure 2). The indoor and outdoor areas were separated by the house wall with one small door in each pen through which the chickens could freely access the outdoor area starting at the different stages of treatments. The round waterers and hanging feeders were used indoors. All the birds were sheltered during the night. All the experimental pens were enclosed in a bio-security compound.

240-day-old arbo acre broiler chicks were purchased from Kenchic Mombasa. On arrival, they were given water-containing glucose as an anti-stress before feeding. They were all placed in one pen for brooding where infrared light was used as a heat source. Waterers and chick-feed troughs were used to avail clean water and commercial broiler starter feed respectively (see figure 1). The chicks were fed *ad libitum* on the broiler starter. Administration of vaccines, antibiotics and multivitamin supplement was given when necessary. The sample size was arrived at using the formula in equation 1.

$n = Z^{2}_{1-\alpha/2} P(1-P)/d^2$ ………………..Equation 1

where;

n is the sample size

$Z^{2}_{1-\alpha/2}$ is confidence interval

P is estimated proportion based on previous studies or pilot studies

d is desired precision or absolute error (has to be decided by researcher)

3.3 Experimental layout and feeding of the chicken

In a completely randomized block design experiment, the 240 day-old chicks (16 groups of 15 chicks per pen) were randomly assigned to four treatments at two weeks of age. The control group (D); the day old chicks were fed the conventional broiler diet (see table 3) in mashed form for the whole experimental period of 8 weeks; groups A to C which were released to free-range at 2 weeks, 3 weeks and 4 weeks, respectively in four pens. The chicks released for outside access were not allowed access to conventional broiler feed for the rest of the experimental period. At 2-weeks of age, the diet was changed from broiler starter to broiler finisher for all the treatments that were still on commercial feed. Birds with outside access continued to have access to water in the round drinkers *ad libitum.*

The use of chicken in this study was approved by the Pwani University Ethics Review Committee.

In this study, conventional broiler production is where chicken (usually fast growing breeds) are fed on feed prepared from conventionally grown feedstuffs. It is an intensive production system where the birds are reared in an enclosure with high stocking densities throughout their life and reach market weight at 4-6 weeks of age. On the other hand, organic broiler meat production system refers to a rearing system of broilers that entirely avoids conventionally grown feedstuffs. These include genetically modified organisms, animal by-products, and synthetic additives, while using only organically grown cereals, oil, seeds and roughage. The system also provides chickens with free access to outdoor areas and applies low rearing intensity. Table 2 shows the experimental layout for the three experiments conducted.

Table 2. Experimental layout showing FRR strategy i.e. stages at which chicken were released/exposed to free-range system.

Group	Age at which chicken were released to free-range system (weeks)	Number of weeks chickens were exposed to free-range system
A	2	6
B	3	5
C	4	4
D (Control)	no exposure	none

The control (D) is where the chickens did not have outside access but continued feeding on the conventional broiler diet for all the 8 weeks of the experiment. Groups A to C were released to free-range at 2 weeks, 3 weeks and 4 weeks, respectively in four pens.

The outside access of the chicken entailed weaning them from the conventional broiler diet and allowing them to, instead, forage outside their pens for whatever feed resources were available. The feed resources available included pasture, insects, crop residues and grains from arable agriculture as well as kitchen wastes. The chicken waste was composed of mainly rice from the Pwani University Kitchen. Each pen was supplemented with an average of 10 g of chicken waste per bird. The chicken on outside exposure had access to hay *ad libitum*. Outside access also meant modification of behaviour such that the birds engaged in activities such as scavenging and chasing of insects resulting in increased exercise.

Commercial Isinya feed formulation for broiler starter and broiler finisher used in the experiments is presented in Table 3.

Table 3. Chemical composition (Label values) of commercial broiler starter and finisher feeds used in the study*

Composition (g/kg)	Broiler Starter	Broiler Finisher
DM	120.0	120.0
CP	200.0	160.0
EE	25.0	25.0
CF	50.0	70.0
Lysine	12.0	9.0
Ca	12.0	120.0
P	6.0	5.0

*Supplied by Isinya Feeds Limited Kilifi

Figure 1: Chicken pens showing outside access

Figure 2: Day-old chicks at the University farm

3.4 Experiment 1: Effects of the free-range strategy on the weight of the chickens at different slaughter times

The objective of this experiment was to evaluate the effects of the FRR on the growth of the chicken at the 6th, 7th and 8th week of age. The chickens were fed on the conventional broiler diet of broiler starter for their first 2 weeks. After the 2 weeks, they were fed on broiler finisher until their release to outside access at the different timelines as shown in Table 2. The control D however continued to feed on the broiler finisher for the rest of the experimental period. On outside exposure, the chicken had access to feed resources such as pasture, insects, crop residues and grains from arable agriculture as well as kitchen wastes. The released chicken got this food by foraging, scavenging and chasing (insects) without going back to the conventional broiler diet.

3.4.1 Data collection

Chicken from the four different treatments (FRR) were weighed (each bird was weighed individually) and the weights recorded at the 6th, 7th and 8th week of age.

3.4.2 Data analysis

The weight data was evaluated by one-way ANOVA using the GLM procedure (SAS Institute, 1998). The data was analysed using the model presented in equation 2.

$Y = \mu + \alpha + \varepsilon$……………………………Equation 2

Where;

Y = the dependable variable weight of the chicken

μ = the sample mean

α = effects of FRR on the weight of the chicken

ε = error

Significant differences among treatment means were separated using the Duncan's multiple range test at a significance limit of $P < 0.05$.

3. 5 Experiment 2: Taste of broiler meat from chicken finished on different free-range strategies

The objective of the experiment was to establish whether the different free-range strategies (FRR; i.e. when chicks were allowed free-range access) and method of preparation of the meat (PREP i.e. boiling, roasting and frying) would affect the taste of the meat in terms of aroma, flavour and overall acceptability of chicks slaughtered at different time i.e. 6, 7 & 8 weeks of age, respectively. The chickens were reared as described above.

3.5.1 Slaughter and Sample Collection

Three birds of average body weight were randomly selected from each pen (experimental unit) and slaughtered at week 6, 7, and 8. The thighs were then isolated and were subjected to the different methods of preparation i.e. boiling, roasting or frying. Boiling of the thighs entailed putting them on an open pan and adding 1 litre of water. The pan was then put on a charcoal burner and heated for 30 minutes. Roasting on the other hand involved putting the thighs on a wire mesh (10cm from the red coals) on a charcoal burner turning them over for 20 minutes. The thighs were also fried in an open pan over a charcoal burner with 5 ml of liquid cooking fat added for 20 minutes. No spices (including salt) were added to the thighs in all these preparations methods. The boiled, roasted or fried thighs were then cut into 1 × 1 cm cubes using a knife and each sample placed on individual pre-labelled trays.

3.5.2 Sensory evaluation

Ten graduate students at Pwani University served as the panellists in sensory evaluation of the meats. Previous researchers comparing similar types of chicken meat sensory evaluation have used 10 panellists (Jahan et al., 2005) and 9 members (Castellini et al., 2002) or 15 to 17 members (Fanatico et al., 2006). scale was used, 1 referring to extremely dislike, and 5 to extremely like. In the The graduate students were trained on sensory evaluation of meat and they ranked their preferences of each sample in terms of aroma, flavour, and overall acceptability. A five point ranking, the panellists looked at the general appearance of the meat. This was followed by washing their mouths with clean water. They were then required to pick the cube of meat using toothpick, smell the sample and rank its aroma (ranking immediately recorded). The piece of meat was then put in the mouth, chewed to determine its ranking on flavour and findings recorded. Ranking of the overall acceptability was then done and recorded. The mouth was then washed with clean water in preparation for the ranking of the next sample.

This type of dataset generally follows the Poisson distribution. For data with right skew, the square root (√) transformation, where P=0.5, is applicable, particularly for data that are counts (Poisson distributed) and the variance is related to the mean, transformation will often make the distribution more symmetrical to improve the fit of biological data to the assumptions of the planned statistical analyses (Quinn & Keough, 2002).

3.5.3 Statistical Analysis

The data on sensory evaluation of meat was subjected to analysis of variance (ANOVA) using the GLM procedure (SAS Institute, 1998). Because the data was not normally distributed, the data was transformed by taking the square root of the frequencies that the panellists had recorded for each treatment before data analysis. The statistical model employed in analysing the transformed data is presented as equation 3.

$Y = \mu + \alpha + \beta + \varepsilon$……………………………………Equation 3

Where;

Y = the square root of the ranking of taste variable on a scale of 1-5 where 1 is the least tasty and 5 the tastiest.

μ = the sample mean

α = the effects of the preparation method on the taste of the meat

β = the effects of the free-range strategy on the taste of the meat

ε = error.

Significant differences among treatment means were separated using the Duncan's multiple range test at a significance limit of $P < 0.05$.

3.6 Experiment 3: Cost-benefit analysis of broiler chicken produced under the different late free-range strategies

The objective of this experiment was to determine the cost of production for each FRR.

The commercial feed (broiler starter and broiler finisher) was fed *ad libitum* to the chickens that were in confinement. Weighed feed was placed in the feed troughs for the feeding of the chicken (more weighed feed was added if need be). The remaining feed after 24-hour period was weighed. The consumption for the day was calculated by getting the difference between the weight of the feed supplied and the weight of the feed after a 24-hour period (this was done every morning). The same method was used to determine the amount of hay the chicken fed on per day. Weighed hay was supplied *ad libitum* to every pen every morning. The balance was then weighed at 18:30 hours every day and the consumption per pen calculated. 10 g of kitchen waste (rice) from the university was availed every morning per chicken. Any balances were collected at 18:30 hours and weighed and consumption for the day determined. Using market prices of feeds then the cost of consumed food was then determined. The cost of the feed was then combined with other costs of production namely: labour and veterinary care to determine the cost of production per chicken.

3.6.5 Data collection

In the analysis of returns, average production costs for the different treatments were calculated by using the market values of the resources used in the outside access per pen and then per chicken in the pen per week. Based on production costs and revenue, the treatment with the highest profitability was identified. Economic analyses was carried out using current feed prices in the Kenyan poultry industry to compare the feeding costs, when feeding various free-range groups in relation to meat production.

3.6.2 Data Analysis

The FRR were analysed for costs. The model used to compare the cost of production is presented in equation 4 below.

$$Y = \mu + \alpha + \beta + \varepsilon$$

Where;

Y = Cost of production of the chicken (dependable variable)

u = the sample mean

α = effects of FRR on the cost of production of the chicken

β = effects of age of the chicken on the cost of production

ε = error

Significant differences among treatment means were separated using the Duncan's multiple range test at a significance limit of $P < 0.05$.

CHAPTER 4

RESULTS

4.1. Experiment 1: Effects of the free-range strategy on the weight of chicken at different slaughter weeks.

The mean weight of the chicken from different free-range strategies at different weeks of age is presented in Table 4. The mean weight was lowest at the 6th week followed by the 7th week with the 8th week being the highest (Also see appendix 1). A comparison between the mean weights of birds at different slaughter weeks of 6, 7 and 8 is presented in Table 5. There was a general increase in weight of the birds from the 6th week to the 8th week with this increase being significantly different between the slaughter weeks.

Table 4. Mean weight of the chicken from different free-range strategies at different weeks of age

Week	Free-range strategy	Mean weight in grams
6	A	1148.65
	B	1201.43
	C	1449.12
	D	1553.13
7	A	1269.69
	B	1323.63
	C	1593.50
	D	1712.87
8	A	1403.73
	B	1434.47
	C	1694.11
	D	1807.81

The control (D) is where the chickens did not have outside access but continued feeding on the conventional broiler diet for all the 8 weeks of the experiment. Groups A to C were released to free-range at 2 weeks, 3 weeks and 4 weeks, respectively in four pens.

Note: 8-7 implies the comparison of the mean weight of the chicken at the 8th week of slaughter with the mean weight of the chicken at the 7th week of slaughter. The same applies to row two and three.

Table 5. Comparison of the effect of the slaughter week on the weight of the chicken

Weeks of slaughter	Difference between means in grams	Simultaneous 95% confidence limits		Level of significant difference
8-7	120.55	69.74	171.36	***
8-6	267.98	267.98	316.06	***
7-6	147.43	105.56	189.29	***

Comparisons significant at the 0.05 level are indicated by ***.

Note: 8-7 implies the comparison of the mean weight of the chicken at the 8^{th} week of slaughter with the mean weight of the chicken at the 7^{th} week of slaughter. The same applies to row two and three.

The free-range-strategy adopted had significant effects on the weight of the chicken ($P<0.0001$). The 2- week and 3- week releases recorded the lowest mean weights but the FRR reflected no significant effects on the weight of the chicken between them. The difference between the means grew bigger from the 2-week release to the control (see Table 6).

Table 6. Comparison of the effects of the different free-range strategies on the weight of the chicken

Free-range strategy	Difference Between Means	Simultaneous 95% Confidence Limits		Level of significant Difference
D-C	108.91	56.85	160.96	***
D-B	379.91	322.30	437.52	***
D-A	429.23	429.23	487.70	***
C-B	271.00	213.49	328.51	***
C-A	320.32	261.95	378.69	***
B-A	49.32	- 14.06	112.69	

Comparisons significant at the 0.05 level are indicated by ***.

Note: D-C implies the comparison of the mean of the weight of the birds from the FRR D with the mean of the weight of the birds from FRR C. The same applies to row 2, 3, 4, 5 and 6.

4.2 Experiment 2: Taste of broiler meat from chicken finished on different free-range strategies.

The effect of FRR on aroma of meat at different slaughter weeks is presented in Table 7.1. The free-range strategy adopted had a significant impact on the aroma of the meat ($P<0.0001$) with the 2-week release being the most preferred and the control being the least preferred. There was no significant difference between the 2-week release and the 3-week release except at 6 weeks. There was also no significant difference between the 4-week release and the control except at week eight. See also figure appendix 3 for the general trends on the effect of FRR at different slaughter weeks on aroma of the meat.

The effects of FRR on flavour of meat at different slaughter weeks is presented in Table 7.2.The free-range-strategy had a significant effect on the flavour of the meat ($P<0.0001$) though this difference was not evident between the 2-week release and 3-week release at the

7th and 8th week. This difference was also not evident between the 4-week release and the control at the 6th and the 8th week of slaughter. There was, however, a general decrease in the flavour of the meat from the 2-week release towards the control. See also figure 5.2 for the general trends on the effect of FRR at different slaughter weeks on flavour of the meat.

Table 7.1. Effects of free-range strategy on aroma of meat at different ages of slaughter

Week of slaughter	Aroma		SE	P value
6	Free-range strategy	Means		
	A	2.0415[a]	0.1026	< 0.0001
	B	1.9411[b]		
	C	1.8339[c]		
	D (Control)	1.8199[c]		
7	A	2.0464[a]	0.0960	< 0.0001
	B	2.0337[a]		
	C	1.8137[b]		
	D (Control)	1.8113[b]		
8	A	2.0390[a]	0.0933	< 0.0001
	B	2.0338[a]		
	C	1.9466[b]		
	D (Control)	1.8187[c]		

FRR strategy i.e. stage at which chicken were released/exposed to free-range system (A at 2 weeks, B at 3 weeks and C at 4 weeks). The control (D) is where the chicken did not have outside access but continued feeding on the conventional broiler diet for all the 8 weeks of the experiment.

[a,b] Means in the same column with different superscripts within slaughter week differ ($P < 0.05$).

Table 7.2. Effects of free-range strategy on flavour of meat at different ages of slaughter

Week of slaughter	Flavour		SE	P value
6	Free-range strategy	Means		
	A	2.0516[a]	0.0916	< 0.0001
	B	1.9924[b]		
	C	1.8516[c]		
	D (Control)	1.8305[c]		
7	A	2.0273[a]		
	B	2.0223[a]	0.1017	< 0.0001
	C	1.7981[b]		
	D (Control)	1.7838[b]		
8	A	2.0581[a]		
	B	2.0384 [a]	0.0922	< 0.0001
	C	1.9348[b]		
	D (Control)	1.7877[c]		

FRR strategy i.e. stage at which chicken were released/exposed to free-range system (A at 2 weeks, B at 3 weeks and C at 4 weeks). The control (D) is where the chicken did not have outside access but continued feeding on the conventional broiler diet for all the 8 weeks of the experiment

[a,b] Means in the same column with different superscripts within slaughter week differ ($P < 0.05$)

The effect of FRR on overall acceptability of meat at different slaughter weeks is presented in Table 7.3. The FRR effects on overall acceptability were significantly different ($P<0.0001$) from strategy to strategy, with the 2-week release being the tastiest and the control being the least tasty, except at 7th week when there was no difference between the 2-week and 3-week release. See also appendix 5 for the general trends on the effect of FRR at different slaughter weeks on overall acceptability of the meat.

Table 7.3. Effects of free-range strategy on overall acceptability of meat at different ages of slaughter

Week of slaughter	Overall acceptability		SE	P value
6	Free-range strategy	Means		
	A	2.1145[a]	0.1026	< 0.0001
	B	2.0071[b]		
	C	1.8808[c]		
	D (Control)	1.8274[d]		
7	A	2.0906[a]	0.0916	< 0.0001
	B	2.0631[a]		
	C	1.7893[b]		
	D (Control)	1.7383[c]		
8	A	2.1020[a]	0.0838	< 0.0001
	B	2.0494[b]		
	C	1.9327[c]		
	D (Control)	1.7987[d]		

FRR strategy i.e. stage at which chicken were released/exposed to free-range system (A at 2 weeks, B at 3 weeks and C at 4 weeks). The control (D) is where the chicken did not have outside access but continued feeding on the conventional broiler diet for all the 8 weeks of the experiment

[a,b] Means in the same column with different superscripts within slaughter week differ ($P < 0.05$)

FRR strategy i.e. stage at which chicken were released/exposed to free-range system (A at 2 weeks, B at 3 weeks and C at 4 weeks). The control (D) is where the chicken did not have outside access but continued feeding on the conventional broiler diet for all the 8 weeks of the experiment.

The effects of the method of preparation on aroma of meat at different slaughter weeks are presented in table 8.1. The method of preparation generally had a significant effect on the aroma of the meat ($P<0.0001$) at all the slaughter points of 6th, 7th and 8th week. Whereas boiled meat had the least preferred aroma, there was no significant difference between frying and roasting the meat on the aroma. See also appendix 6 for the general trends on the effect of preparation method on aroma of the meat at different slaughter weeks. At the 8th week, the difference between the pair of roasting and frying and the other method of preparation (boiling) was the largest.

Table 8.1. Effects of method of preparation on aroma of meat at different ages of slaughter

Week of slaughter	Aroma		SE	P value
6	Preparation	Means		
	Boil	1.8961^{a}	0.1026	< 0.0001
	Roast	1.9496^{b}		
	Fry	1.9491^{b}		
7	Boil	1.9011^{a}	0.0960	0.0078
	Roast	1.9354^{b}		
	Fry	1.9423^{b}		
8	Boil	1.9294^{a}	0.0933	0.0009
	Roast	1.9738^{b}		
	Fry	1.9753^{b}		

[a,b] Means in the same column with different superscripts within slaughter week differ ($P < 0.05$)

The effects of the method of preparation on flavour of meat at different slaughter weeks are presented in table 8.2. The method of preparation generally had a significant effect on the flavour of the meat ($P < 0.0001$) at all the slaughter points of 6th, 7th and 8th week. Boiled meat had the least preferred flavour. On the other hand, there was no significant difference between frying and roasting on the flavour of the meat. See also appendix 7 for the general trends on the effect of preparation method on flavour of the meat at different slaughter weeks. At the 8th week, the difference between the pair of roasting and frying and the other method of preparation (boiling) was the largest.

Table 8.2. Effects of method of preparation on flavour of meat at different ages of slaughter

Week of slaughter	Flavour		SE	P value
6	Preparation	Means		
	Boil	1.9250^{a}	0.1026	< 0.0001
	Roast	1.9352^{a}		
	Fry	1.9339^{a}		
7	Boil	1.8854^{a}	0.1017	0.0283
	Roast	1.9181^{b}		
	Fry	1.9200^{b}		
8	Boil	1.9224^{a}	0.0922	0.0002
	Roast	1.9701^{b}		
	Fry	1.9718^{b}		

^{a,b} Means in the same column with different superscripts within slaughter week differ ($P < 0.05$)

The effects of the method of preparation on overall acceptability of meat at different slaughter weeks are presented in table 8.3. The method of preparation had a significant effect on the overall acceptability of the meat ($P < 0.0001$) at all the slaughter points of 6th, 7th and 8th week. Whereas boiled meat was the least preferred, there was no significant difference between frying and roasting the meat on the overall acceptability. See also appendix 8 for the general trends on the effect of preparation method on overall acceptability of the meat at different slaughter weeks. At the 8th week, the difference between the pair (roasting and frying) and the other method of preparation (boiling) was the largest.

Table 8.3. Effect of method of preparation on overall acceptability of the meat at different ages of slaughter

Week of slaughter	*Overall acceptability*		SE	P value
6	Preparation	Means		
	Boil	1.9291[a]	0.1026	< 0.0001
	Roast	1.9613[b]		
	Fry	1.9582[b]		
7	Boil	1.8676[a]	0.0916	< 0.0001
	Roast	1.9517[b]		
	Fry	1.9417[b]		
8	Boil	1.9257[a]	0.0838	< 0.0001
	Roast	1.9925[b]		
	Fry	1.9939[b]		

[a,b] Means in the same column with different superscripts within slaughter week differ ($P < 0.05$)

There were no significant differences between the weight of the 2-week release and the 3-week release. Since the 2-week release was the tastiest, there was a need to establish at which age the 2-week release could be slaughtered and compete favourably with the conventional broiler production system at 6 weeks. Table 9 presents the determination of the appropriate week of slaughter for the 2-week release that competes favourably with the control at the 6th slaughter week in terms of weight. Taking the control weight means at 6 weeks of age to be the control, a comparison was made with the 2-week release weight means at 6th, 7thand 8thweeks of slaughter. It was found that the 2-week release at 8 weeks was not significantly different from the control. This means that the 2-week release, if slaughtered at 8 weeks, would compare favourably with the control (control when slaughtered at 6 weeks).

Table 9. Week of slaughter for the 2-week release that competes favourably with the control at the 6th week of slaughter

Slaughter week	Difference Between Means (grams)	Simultaneous 95% Confidence Limits		Level of Significance
6-8	120.23	-0.28	240.73	
6-7	254.27	155.51	353.03	***
6-6	134.04	0.73	267.35	***

Comparisons significant at the 0.05 level are indicated by ***.

NB 6-8 means the comparison of the mean of the weight of the chicken at the 6th week of slaughter with the mean of the weight of 2 week-release of the birds at the 8th week of slaughter. The same applies to row two and three.

4.3 Cost of production benefit analysis of the different free-range strategies and age of slaughter of the chicken

The effects of slaughter week and free-range strategy on cost of production of the chicken are presented in table 10. The slaughter week had a significant effect on the cost of production of the birds. There was an increase of cost of production with time from one week to the next with the 6th week being the least costly and the 8th week being the most costly (P< 0.0001). Table 10 also shows that the free-range strategy adopted had significant effects on the feed cost of production of the chicken (P< 0.0001). The cost of production was significantly different from one free-range strategy to another with the most costly being the control and least costly being the 2-week release. The cost of production was higher from the 2-week release through 3and 4-week release to the control.

Table 10. Effects of slaughter week and free-range strategy on cost (Ksh) of production of the chicken

Treatment	Mean (Ksh)	SE	P value
Week of slaughter			
6	181.51[a]	266.915	< 0.0001
7	210.06[b]		
8	256.24[c]		
Free-range strategy	Mean (ksh)		
A	115.52[a]	266.915	< 0.0001
B	171.45[b]		
C	212.85[c]		
D (Control)	363.93[d]		

FRR strategy i.e. stage at which birds were released/exposed to free-range system (A at 2 weeks, B at 3 weeks and C at 4 weeks). The control (D) is where the chicken did not have outside access but continued feeding on the conventional broiler diet for all the 8 weeks of the experiment.

[a,b] Means in the same column with different superscripts within slaughter week differ ($P < 0.05$)

CHAPTER 5

DISCUSSION

5.1 Experiment 1: Effects of the free-range strategy on the weight of chicken at different slaughter weeks

As expected, the growth performance of chicken in the free-range strategy was less than that of chicken raised in convectional broiler production systems as the free-range strategy adopted had significant effects on the weight of the chicken (P<0.0001) except for the 2- week and 3-week releases which reflected no significant effects on the weight of the birds. Similar results have been reported previously; for example, Castellini et al. (2002b) demonstrated that growth rates and feed efficiencies were lower in outdoor organic raising systems than the conventional system. This is likely because the free-range chicken were exposed to fluctuating temperatures and increased exercise in the yards, thus increasing their energy requirement and influencing their feed conversion. Grass, insects, soil and other surroundings may attract a bird to explore its environment leading to higher activities for the chicken with outdoor access than indoor chicken. Beatie et al. (1995) also reported that broilers, layers and even pigs with outside access had better locomotory behaviour (such as preening, dust bathing, walking and investigating) than those with no outside access. This is in contrast to the findings of Mikulski et al. (2011) who reported that body weight and meat yield and quality of chickens was primarily due to genotype, and outdoor access did not negatively affect their growth performance or meat yield. Other reports have shown outdoor access to have no effect on growth performance (Fanatico et al., 2005b, Chen et al., 2013, & Mikulski et al., 2011).

Ponte et al. (2008a) on the other hand found that chicken raised outdoors with access to pasture had higher body weights when compared to chicken raised in the same setting but without outside access. It is known that many factors, including genotype, age, sex, diet, density, environment, exercise, and pasture intake, affect the growth and performance of birds (Gordon & Charles, 2002). Broilers may also favour a specific forage type, thus possibly decreasing consumption of supplemented feed when that forage type is provided.

The current study was more of a restricted feeding programme on exposure to the free-range strategy. This is because the chickens were not feeding *ad libitum* as in the conventional production system. Feed restriction programs have shown the potential to modify chicken growth patterns by decreasing their maintenance requirements, which should improve feed efficiency (Urdaneta-Rincon & Leeson, 2002). Although the current experiment was not to be used to study compensatory growth, Leeson & Summers (2005) showed that prolonged feed restriction diminishes the potential of compensatory growth. In the current experiment the free-range strategy exposure, as a form of food restriction was quite prolonged to even consider any form of compensatory growth. In many broiler production systems, restricted feeding has been adopted to avoid rapid growth rate. This rapid growth rate is associated with ascites, lameness, mortality and poor reproductive results (Mench, 2002). In this study, the FRR was a form of restricted feeding that slowed growth and therefore had a potential to reduce cost of production of broilers.

5.2 Experiment 2: Taste evaluation of broiler meat from birds finished on different free-range strategies.

5.2.1 Effects of free-range strategy on taste

Meat quality is mainly assessed by its appearance, texture, flavour, and juiciness (Jahan et al., 2005). In the current study, one of the key attributes analysed was effects of the free-range strategy on flavour. Flavour is a combination of taste and smell (aroma). Taste buds principally taste sweet, sour-acid, salt, bitter, and umami, because of compounds present in meat (Farmer, 1999). In contrast to the taste compounds, aroma compounds are largely formed by chemical reactions during cooking (Farmer, 1999). This study set out to establish whether the free-range strategy adopted had an effect on some of these attributes specifically aroma, flavour and overall acceptability. The results showed that the free-range strategy adopted had a significant effect on the flavour of the meat ($P < 0.0001$) though this difference was not significant between the 2-week release and 3-week release at the slaughter ages of the 7th and 8th weeks. This difference was also not evident between the 4-week release and the control at the slaughter age of six weeks. These observations were consistent with the findings of Jahan et al. (2005) who reported that increase in the age of the chicken is associated with increase in the meat flavour and aroma in broiler chickens. This is also consistent with Latter-Dubois (2001), Fanatico et al. (2005b) & Wang et al. (2009) who found that meat from the chicken in free- range were tastier than that of birds from the conventional production systems. However, the difference between the 2-week release and the 3-week release are not significant unless other factors of production like costs are considered (see discussion in 5.3). Similar observations were seen on the performance of the 4-week release and non-release. The panellists were not able to differentiate between the 4-week release and non-release at the 6th and 7th week of slaughter but were able to do so at 8th week of slaughter probably due to the effects of aging. Meat flavour increases with age, likely because of the increased concentration of nucleotides in muscle, which degrade to inosinic acid and hypoxanthine after death (Aberle et al., 2001). According to Farmer (1999), age has a consistent effect on flavour, whereas genotype, sex, weight, and production system have more varying effects. Meat from animals that have the opportunity to exercise, including game animals, may have more flavours, because inosine monophosphate and hypoxanthine are breakdown products of adenosine triphosphate and enhance flavour (Aberle et al., 2001). In this study, the birds had outside access at different timelines. They had an opportunity to exercise and this may be the reason why their meat tasted better than that of the conventional broilers. In addition, outside access meant that the chicken had access to pasture among other things. This access offered them the potential to enhance chicken flavour.

This observation is in agreement with Gordon and Charles (2002) who found that some forages, such as rosemary, might result in distinctive flavours being impacted on the broiler meat.

The overall acceptability of the meat followed a similar trend; the more the bird was exposed to outside access the more its meat was acceptable. This is in agreement with Castellini et al. (2002a) who found that organic production resulted in better sensory attributes than conventional production in terms of overall acceptability and juiciness.

5.2.2 Effects of method of preparation on taste of the broiler meat from the different free range strategies

Generally, raw meat has a bloody, metallic, salty taste, with an aroma similar to blood serum (Wasserman, 1972; Joo & Kim, 2011).The acceptability and volatile flavour components of poultry meat are affected by cooking (Sanudo, et al., 2000). Three reactions, the Maillard reaction, the thermal degradation of lipids and Maillard-lipid interactions are considered the main reactions, which result in flavour and aroma compounds being produced during cooking (Brunton et al., 2002). Brunton et al. (2002) has also observed that around 500 volatile compounds have been identified in cooked poultry meat, of which the majority is recognized in chicken. Like other meats, lipids play an important role in the flavour development of poultry meat (Perez-Alvarez et al., 2010). Provision of outdoor access to the birds results not only in increasing the level of Omega-3 and Omega-6 fatty acids but also increase meat in quality by enhancing the levels of higher level of polyunsaturated fatty acids, and having greater health benefits for the consumers (Castellani et al., 2002b) . In the taste experiment, frying and roasting of the meat appeared to generally produce more tasty meat than boiling. This is in agreement with (Shi & Ho, 1994; Melton, 1999) who observed that a large number of heterocyclic compounds are formed during roasting, grilling, frying, or pressure-cooking of chicken meat due to the higher temperature and lower moisture conditions. This is contrast to meat boiling where there is more moisture and less heat. The high moisture content suppresses the formation of compounds that lead to good tasting meat. The acceptability and volatile flavour components of poultry meat are therefore affected by cooking (Sanudo et al., 2000).

5.3 Experiment 3: Cost of production benefit analysis of the different free-range and age of slaughter of the chicken

In Table 9 the two (SLW, FRR) had significant effects on the cost of production of the chicken with the 2 week release being the least while the control being the highest in the cost of production and week SLW 8 being the most costly while SLW 6 the least costly ($P<0.0001$) . This means that the outside access significantly reduced the cost of production in this experiment. These findings are in contrast to other researches (Padel et al., 1997 & Rodenburg et al., 2008) who found that the cost of production of conventional production systems is lower than that in the free-range system. However, it should be noted that these researches were being conducted on organic free-range system where the chicken had access to pasture and at the same time were fed on commercial organic feeds that drove the cost of production high. Bokkers and De Boer (2009) calculated that the cost of organic feed was 54 percent higher than the cost of conventional feed. The main reason for the high cost of organic feed is that the main raw materials, such as organic cereals and soybean, are sold at prices that are 50-100% higher than conventional feedstuffs. It should also be noted that, in these researches, grass consumption in the outdoor area in the organic production system accounts for an equivalent of 12% of the chickens' total feed intake (Çınar et al., 2009). This grass consumption thus reduced their concentrated feed intake (Küçükyılmaz et al., 2007). In addition, the extended slaughter age in the organic production system (81 days vs. 56 days) and the extra feed required for these older chickens is another reason for the higher costs observed in these researches. It is therefore evident that the proportion of feed cost to total cost would be higher in organic production than a conventional system. Such determinations have been stressed in many studies (Padel et al., 1997, 2003, & Rodenburg et al., 2008). Purchasing statistics indicate that consumers are increasingly interested in naturally produced or environmentally friendly products that they perceive as having high nutritional value, no contaminants and good flavour. They also have preference for products from systems that provide good welfare and health for the birds (Sundrum, 2001 & Owens et al., 2006). These perceptions have made consumers willing to pay a premium for these products (Magdeliane & Bloch, 2004 & Crandall et al., 2009). This means that the lowered cost of production in this strategy opens up the market for more consumption of broiler meat.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

This study set out to find out if the high growth rate of breeds in the conventional broiler production system could be exploited to get a more tasty meat at a lower cost. This research has established that when conventional broilers are subjected to outside access without supplementation, the growth rate is significantly reduced. It means that to attain a certain slaughter weight of the conventional system there is a need to have a prolonged exposure of the broilers to outside access. However, the longer they are exposed to outside access the tastier they become as compared to the meat from conventional broilers. Moreover, this comes with a higher cost of production. The longer they are exposed to outside access the higher the cost of production. Therefore, a balance was found where the benefits of both systems could be exploited without incurring high production costs. Chicken from the 2-week release free-range strategy were the tastiest and if slaughtered at 8weeks of age had a weight that could compete favourably with chicken slaughtered in the conventional system at six weeks. The cost of producing the 2-week release strategy at eight weeks of slaughter was still lower than that of producing the conventional broiler at six weeks age of slaughter. However, consumers and producers could still go for 2-week release strategy and have them slaughtered earlier like at the 7th or even 6th week of age if the weight of the chicken at slaughter at this time could still meet market weight demands.

There are many methods of preparation of broiler meat. This research examined only three of them; boiling, roasting and frying. The panellists preferred roasting and frying to boiling. Other factors not examined in this research, however, need to be put into consideration as choices are made on the method of preparation to be used. Preferences are linked to what customers are accustomed to, their habits and much more.

6.2 RECOMMENDATIONS

This research has shown that the more the chicken are exposed to the outside access the better the taste attributes. However, there is need to compare these results with the taste of meat from indigenous chicken. There is also room for more research on the effects of genotype on the taste of meat by comparing meat from different fast growing breeds e.g. Cornish Rock and Rosambro breeds. Another aspect that needs to be studied on performance is to evaluate internal organ weights and whether they are influenced by type of production system. More studies are also needed to determine the effects of the free-range strategy on the nutrient composition of the meat.

One of the important attributes of chicken meat is whether it is easy to chew. In this study, the outside exposure most likely has an effect on the texture of the meat from these chickens. More work needs to be done on the effect of the outside exposure on the texture of the meat.

Though outside access encourages natural behaviours and creates a greater number of behavioural opportunities that increase the bird's activity, many aspects of this strategy have not been explored. For instance, on exposure to the new environment, birds from different free-range strategies take different time-lines to adjust to their new challenge of foraging and chasing insects leading to effects on their final weight and cost of production at their time of slaughter. The earlier released birds may adapt to their new environment faster than the later released birds possibly due to the difference in their weights. This means that the heavier later releases may take longer to begin feeding than the lighter early releases. This in turn will affect their weight and cost of production at the time of slaughter. It is therefore necessary to have a study to evaluate the effects of the adaptation time-lines of the birds to the new environment on the final slaughter weight and cost of production.

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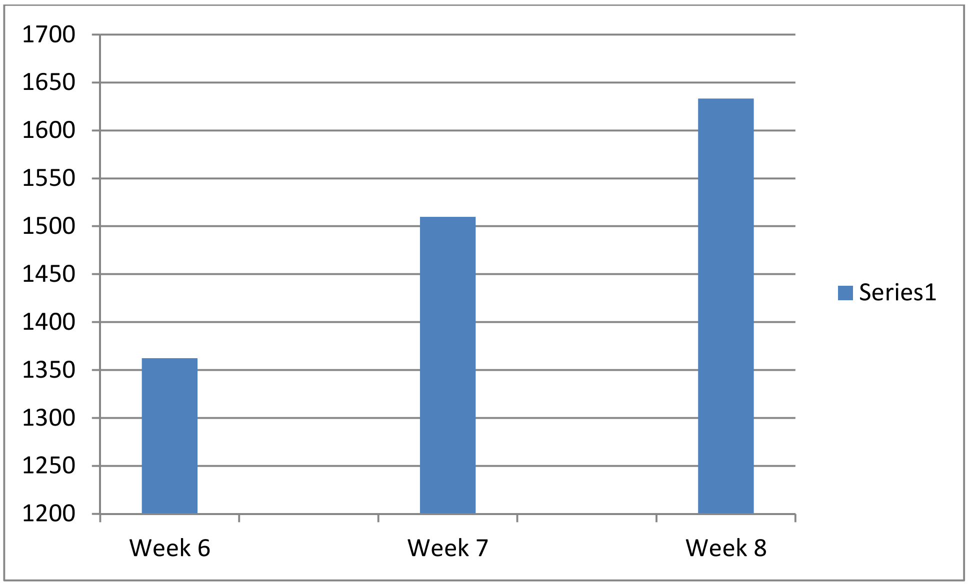
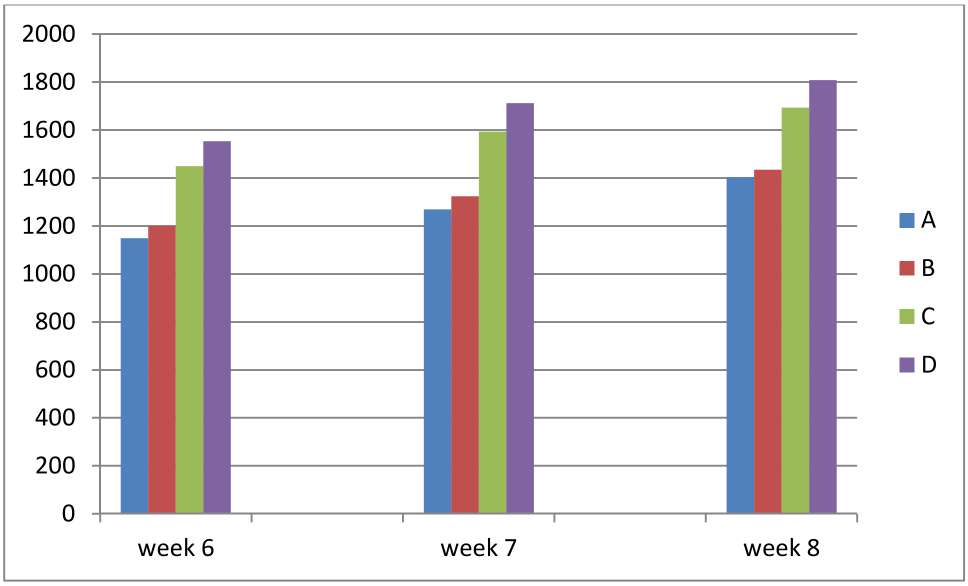
APPENDICES

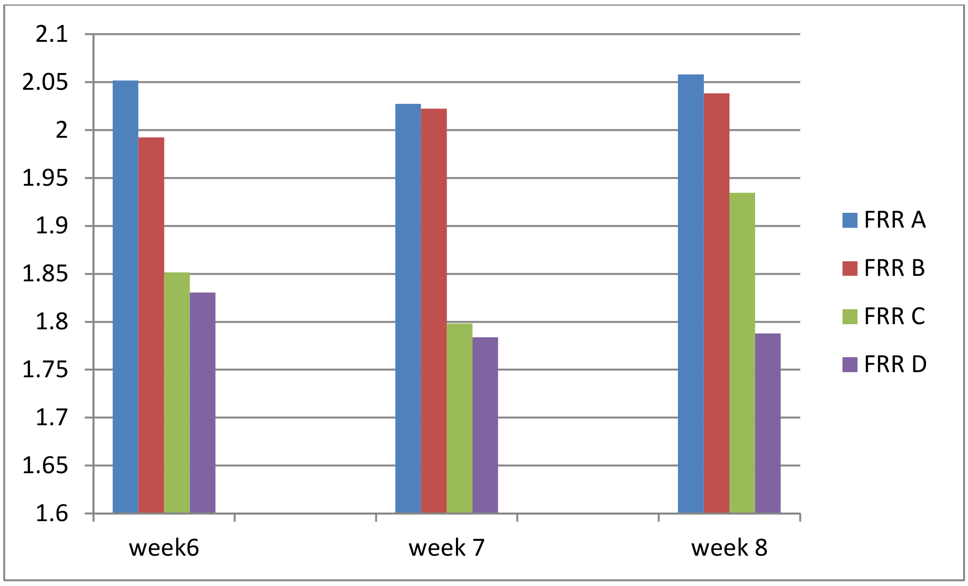


Appendix 1 Figure showing effect of slaughter week on the weight of the chicken



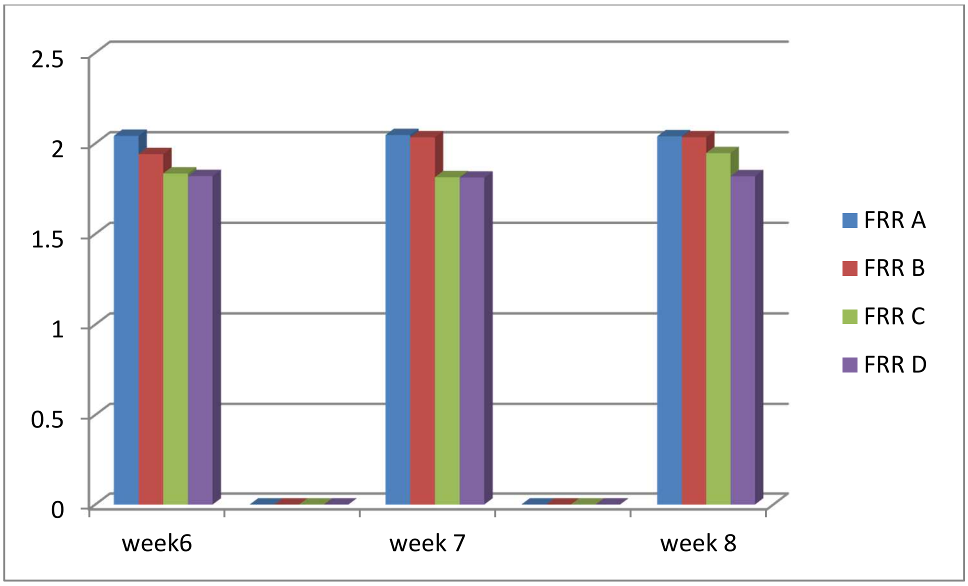
Appendix 2 Figure showing the effects of the free-range strategy on the weight of the chicken at different slaughter weeks

The control (D) is where the chickens did not have outside access but continued feeding on the conventional broiler diet for all the 8 weeks of the experiment. Groups A to C were released to free-range at 2 weeks, 3 weeks and 4 weeks, respectively in four pens.



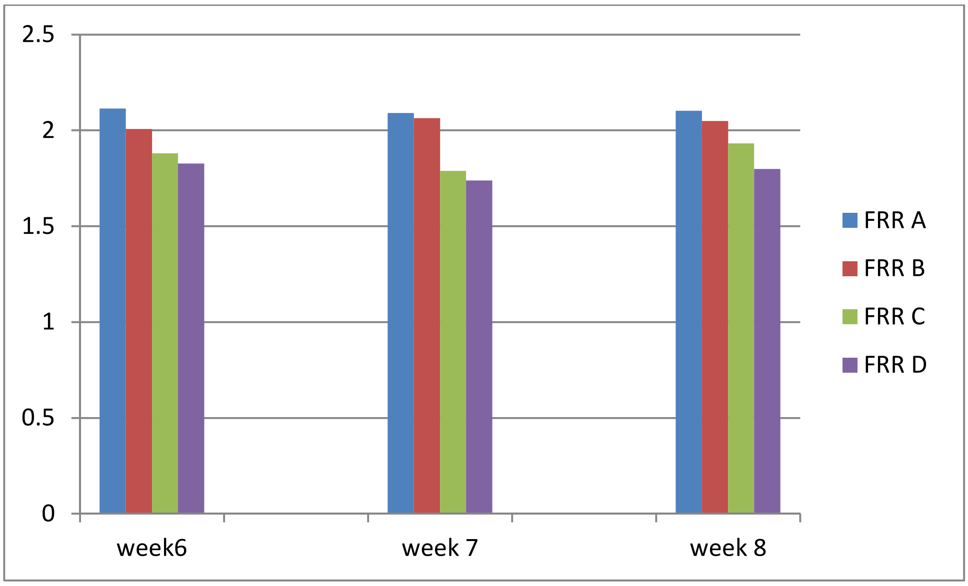
Appendix 3 Figure showing effects of free-range strategy on aroma of meat at different ages of slaughter

The control (D) is where the chickens did not have outside access but continued feeding on the conventional broiler diet for all the 8 weeks of the experiment. Groups A to C were released to free-range at 2 weeks, 3 weeks and 4 weeks, respectively in four pens.



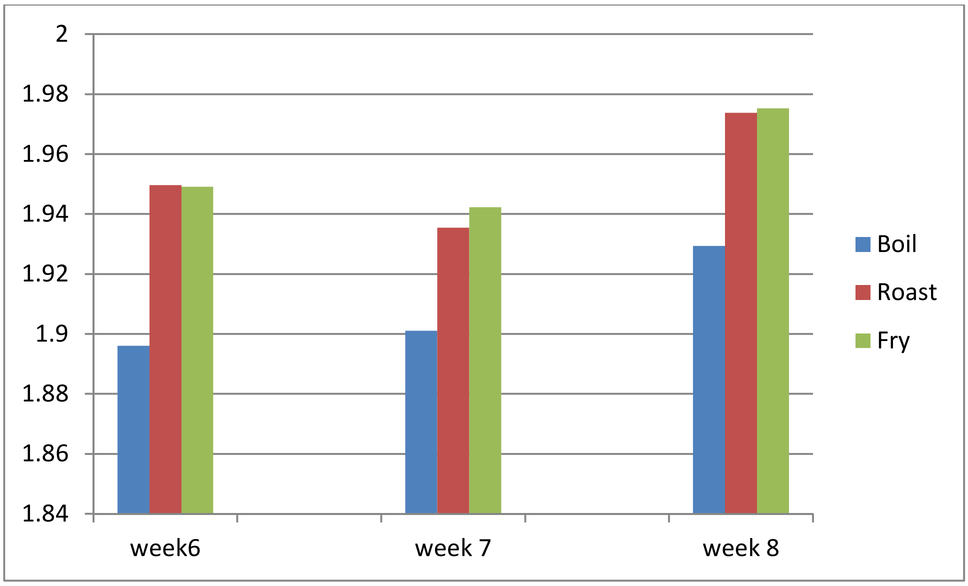
Appendix 4 Figure showing effects of free-range strategy on flavour of meat at different ages of slaughter

The control (D) is where the chickens did not have outside access but continued feeding on the conventional broiler diet for all the 8 weeks of the experiment. Groups A to C were released to free-range at 2 weeks, 3 weeks and 4 weeks, respectively in four pens.

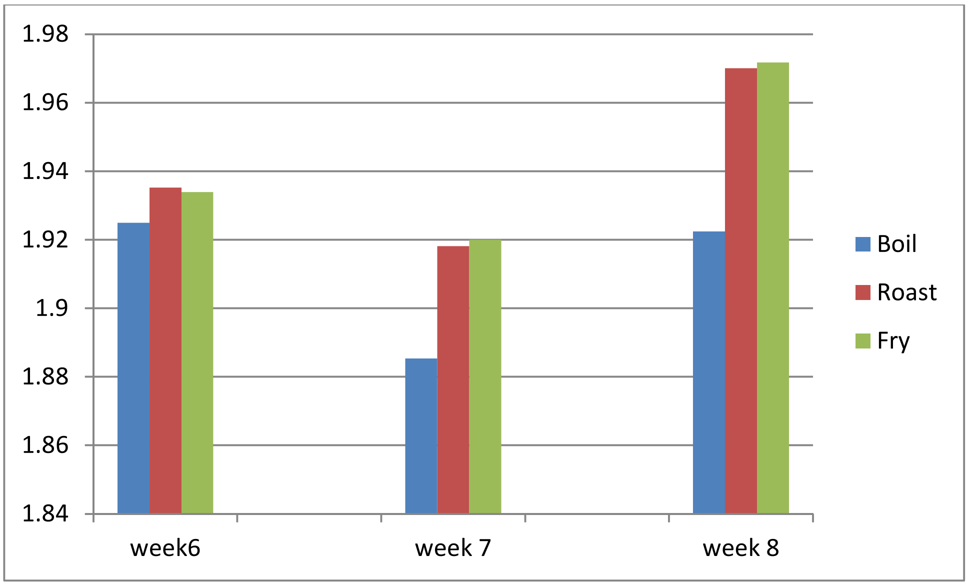


Appendix 5 Figure showing effects of free-range strategy on overall acceptability of meat at different ages of slaughter

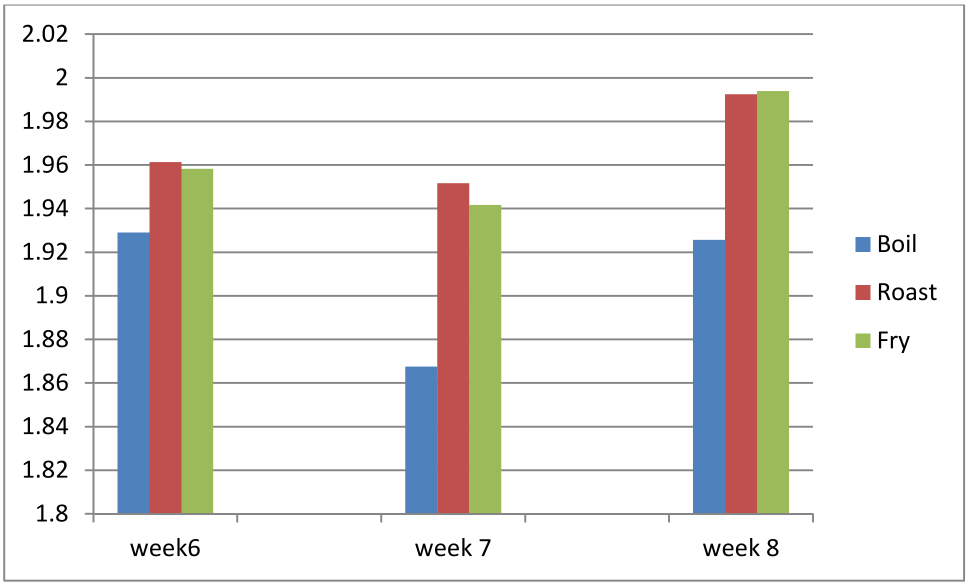
The control (D) is where the chickens did not have outside access but continued feeding on the conventional broiler diet for all the 8 weeks of the experiment. Groups A to C were released to free-range at 2 weeks, 3 weeks and 4 weeks, respectively in four pens.



Appendix 6 Figure showing effects of method of preparation on aroma of meat at different ages of slaughter



Appendix 7 Figure showing effects of method of preparation on flavour of meat at different ages of slaughter



Appendix 8 Figure showing effect of method of preparation on overall acceptability of the meat at different ages of slaughter