EFFECT OF *Prosopis juliflora* PODS-BASED DIETS ON THE PERFORMANCE AND CARCASS QUALITY OF IMPROVED GROWING INDIGENOUS CHICKEN IN KENYA

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not, wholly or in part, been presented for an award of a degree or diploma in any other university.

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Recommendation

This thesis has been prepared with our guidance and is submitted with our approval as University supervisors.

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DEDICATION

This work is dedicated to my parents, Mr. Francis Wanjohi and Mrs. Grace Wanjohi, my wife Gladys and children Mercy, Devin and Bradley.

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ABSTRACT

Chicken production faces unsustainable supply of quality and affordable feeds. Prosopis pods could be used as an alternative livestock feed ingredient. A study was designed to evaluate the inclusion of prosopis pods in improved grower indigenous chickens diets in Kenya. The objectives were to determine effects of prosopis pods-based diets in indigenous chicken on performance and meat quality. In experiment 1, diets were formulated by substituting growers' rations with prosopis at 0% (T_1), 10% (T_2), 20% (T_3) and 30% (T_4) while experiment 2 were formulated by substituting maize in the diet with GPJP at 0% (T_1), 10% (T_2), 20% (T_3) and 30% (T_4). A completely randomized design was used with four cockerels and four pullets per treatment in separate cages replicated three times. The results from experiment 1 showed a significant difference ($p<0.05$) between treatments where similar FI of 70.99, 70.56 and 69.02 g/day and weight gains of 12.91, 12.15 and 11.66 g/day were recorded in 0, 10 and 20% levels respectively while 30% recorded lower values at 61.31 and 9.08g/day for FI and weight gain respectively in pullets. In cockerels, treatments showed significant differences ($p<0.05$) with 0, 10 and 20% levels in the diets having similar FI of 94.24, 92.67 and 87.64g respectively but lower than diet with 30% level with 79.46g. Weight gain was similar in diets with 0, 10 and 20% substitution level with 20.65, 19.37 and 18.83g respectively but lower than in diet with 30% prosopis pods with 15.95g. Diet with 30% had higher values that diets with 0 and 20% level. In pullets, diet with 20% level had significantly lower ($p<0.05$) BW of 225.40g than all the other treatments. All treatments produced meat with similar ($p>0.05$) breast and drumstick pH apart from diet with 20% level which had higher pH values of 5.97 than diet with 30%. In pullet breast, diet with 0% level had higher appearance values than other treatments with 79.60. In experiment 2, FI and weight gain were similar for diets with 0-20% in cockerels. In pullets, diets with 10-30% level had similar effect on FI but diets with 0-30% had similar effects on weight gain and LWC. Feed conversion ratio was similar across all treatments in all birds. Results for diets with 0-20% and 0-10% levels were similar but significantly higher than diets with 30 and 20-30% for BW and LW respectively in cockerels. The study concluded that diets with 20% of prosopis pods could substitute improved grower indigenous chicken diet and the maize portion in experiment 1 and 2 respectively. The inclusion of mature pods in the chicken diet can contribute to sustainable and reliable supply of a feed ingredient and reduce overreliance on conventional livestock feed ingredients.

Keywords: *indigenous chicken, maize, meat quality, prosopis juliflora*

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ABBREVIATIONS AND ACRONYMS

Abbreviation	**Description**
a.s.l.	Above sea level
ad libitum	Without limit
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
ASAL	Arid and semi-arid land
CF	Crude fibre
CP	Crude protein
CRD	Completely Randomized Design
DCP	Dicalcium phosphate
DM	Dry matter
EE	Ether extracts
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed conversion ratio
FLW	Final live weight
GA	General acceptability
GDP	Gross domestic product
GOK	Government of Kenya
GPJP	Ground *Prosopis juliflora* pods
HCN	Hydrocyanic acid
Hrs	Hours
ILW	Initial live weight
IC	Indigenous chicken
KALRO	Kenya Agricultural and Livestock Research Organization
Kg	Kilogram
KNBS	Kenya National Bureau of Statistics
KES	Kenya shilling
KIIC	KALRO Improved Indigenous Chicken
kJ	Kilojoules
LWC	Live weight change
ME	Metabolizable energy
MJ	Megajoules
Ml	Milliliters
MoLD	Ministry of Livestock Development
NaCl	Sodium chloride
NDP	National development plan
NFE	Nitrogen free extract
NRC	National Research Council
NRI	Non-Ruminant Research Institute
SAS	Statistical analysis system
WHC	Water holding capacity

CHAPTER ONE
INTRODUCTION

1.1 Background information

The global demand for food is growing with the increase in human population. The high increase in human population in Kenya, estimated at 2.9% per annum (Oparanya, 2009), has resulted in extensive land subdivision. The Kenyan economy is mainly based on agriculture, which contributes 30% of the gross domestic product (GDP) and provides livelihood to over 80% of the population living mainly in rural areas (Alila and Atieno, 2006).

Conventional feeds such as agricultural and agro-industrial by-products used in livestock feed formulation results in fluctuation of quantity, quality and prices of the manufactured feeds (Ngunyen and Preston, 1997; Radull, 2000; Nyaga, 2007; King'ori *et al*., 2011). Maize, sorghum, wheat, rice and barley are the traditional livestock feed ingredients supplements used in Kenya (Irungu *et al.*, 2000). However, competition for maize and the other grains between livestock, human and biofuel, specifically for ethanol production, is on the increase globally putting pressure on the proportion available for livestock feeding. This has led to exploration of sustainable and cheaper alternatives. The use of trees and shrub pods, which thrive well in ASALs, may provide sustainable feed resources for livestock while at the same time reduce competition for conventional grains with human beings.

This study evaluated the use of ground *Prosopis juliflora* pods (GPJP) as an ingredient in KALRO Improved Indigenous Chicken (KIIC) feeds. Prosopis (*Prosopis juliflora*) has proved to be a promising tree/shrub in the arid and semi-arid areas (ASALs) of Kenya (Yusuf *et al*., 2008), which are characterized by low and erratic rainfall (<100 mm). Prosopis is widely distributed in the ASALs of Kenya (Koech *et al.*, 2010) that have low rainfall and sandy, saline, stony or lands unsuitable for cultivation (Sawal *et al*., 2004). It plays a critical role in providing feed for livestock during the dry season. Reports on the composition and nutritive value of its pods suggest that they are a potential source of protein and energy (Sawal *et al*., 2004), although this varies with location (Chopra and Hooda, 2001) suggesting environmental effect on composition. Prosopis pods are highly palatable (Anttilla *et al*., 1994; Aguiar *et al*., 2015) and have been reported to improve performance in weaner lambs (Syomiti *et al*., 2015). Prosopis seed flour replaced 50% of sesame meal in broiler diets without negative effect on performance (Zein and Mukhtar, 2011) and 20% of complete broiler diets with good performance (Odero-Waitituh *et al.*, 2016). Furthermore, replacing up to 20% maize with GPJP (Choudhary *et al*., 2005) and inclusion of 10-20% of GPJP in broiler rations (Vanker *et al*., 1998; Meseret *et al.*, 2011a; Odero-Waitituh *et al*., 2016) had no adverse effects on performance in broilers. Prosopis trees also provide many other services and products such as charcoal, fuel wood, timber for furniture, construction materials, soil stabilization, nitrogen fixation, reclaiming saline soils, bee forage and human food, among others (Kingori *et al*., 2011).

Poultry has the largest number of livestock species worldwide **(**FAO, 2000; Baracho *et al.*, 2006), providing more than 30% of all animal protein consumed worldwide (Permin and Pedersen, 2000; Moreki *et al*., 2010). Since poultry are available in large numbers, they make notable contribution to the animal protein supply (Sonaiya, 1990). Poultry production is characterized by higher conversion rate of meat from feed as compared to other animals (Wahyono and Utami, 2018). The estimated population of family-produced chickens in Africa is 700 million, compared with 191 million cattle, 182 million goats, 158 million sheep and 15 million pigs (FAO, 2000). Despite these numbers, the poultry sub-sector faces challenges in terms of continuous supply of quality feeds (RoK, 2008).

Sonaiya (1990) reviewed reports from 24 countries and reported that about 80% of the rural populace in Africa keep family poultry and most of these are for meat and egg production. Chicken largely dominate flock composition and make up about 98% (Gueye, 2003) of the total poultry numbers (chickens, ducks and turkeys) kept in Africa (Halima, 2007). In most developing countries, poultry production is mainly based on indigenous ecotypes in scavenging backyard production systems (King'ori *et al*., 2007). In Kenya, indigenous chicken (IC) are kept by 75% of the smallholder households in the rural areas of the country who have on average 13 birds per household (FAO, 2007). These households produce 46.7 and 58.3% of the total eggs and meat respectively (MoLFD, 2004). Although majority of meat and eggs consumed in Kenya are from IC (King'ori *et al.,* 2010a), the per capita productivity is low. The current low productivity may be attributed to lack of improved poultry breeds, the presence of predators, high incidence of diseases, inadequate management and inadequate and poor feeding by farmers (King'ori, 2004).

Chemjor (1998) determined energy and protein requirements of growing IC (5 to 22 weeks of age) under confinement in a cafeteria system. Birech (2002) estimated nutrient intake of free-ranging growing and laying IC. King'ori (2004) determined energy and protein requirement for growing IC and hens under confinement. In all these studies, it was apparent that nutrition in both quality and quantity was a major factor limiting the attainment of full productivity potential of IC in Kenya.

Feeds account for 60-80% of the total cost in poultry production. To reduce the feed cost and competition that is associated with the use of maize and other cereal grains in poultry diets, Prosopis pods maybe used to replace conventional energy sources such as maize, wheat and other ingredients in the basal diets of poultry.

Poultry meat demand has increased in the world (Baracho *et al*., 2006) and therefore many factors come into play in the production chain. While researchers have come up with new strains that promise faster growth rates and better performance, animal nutritionist are tasked with the role of developing new feeding strategies to address the challenges of sustainable feeds supply at affordable cost. Feed resources as factors of production are an important aspect to consider in realization of a productive poultry enterprise. To effectively address this problem in the poultry production chain, feed should be relatively affordable, sustainable in their supply, improve performance of chickens as well as give products that are readily acceptable by the consumers.

1.2. Statement of the problem

Feed cost in poultry production accounts for 60-80% of the cost of production. Agricultural land is on the decline and climatic changes have resulted in a decline in production of food/feed resources. There is also competition for feed resources between humans and livestock, especially monogastric species and in situations of scarcity, priority is for human consumption. This often leads to an increase in the prices, poor quality and inadequate supply of feed.

1.3 Objectives

1.3.1 Overall objective

The overall objective of the study was to contribute to sustainable improved indigenous chicken feeding through incorporation of mature prosopis pods in the feeds.

1.3.2 Specific objectives

To achieve this, the specific objectives were:

i. To determine the effects of replacing grower diet with graded levels of ground mature prosopis pods on feed intake, weight gain, feed conversion ratio, carcass quality and meat sensory attributes in improved indigenous chicken in Kenya
ii. To determine the effects of replacing maize in grower diet with graded levels of ground mature *Prosopis juliflora* pods on feed intake, weight gain, feed conversion ratio and carcass quality in improved indigenous chicken in Kenya
iii. To calculate the cost and benefits of feeding ground mature *Prosopis juliflora* pods-based diet to improved indigenous chicken in Kenya

1.4 Hypotheses

The following null hypotheses were tested in this study:

i. Replacing a complete grower diet with graded levels of ground mature *Prosopis juliflora* pods has no effect on feed intake, weight gain, feed conversion ratio, carcass quality and sensory attributes in improved indigenous chicken in Kenya
ii. Replacing maize in a complete grower diet with graded levels of ground mature *Prosopis juliflora* pods has no effect on feed intake, weight gain, feed conversion ratio and carcass quality in improved indigenous chicken in Kenya
iii. Feeding ground mature *Prosopis juliflora* pod-based diet to indigenous chicken in Kenya has no effect on cost and benefits

1.5 Justification of the study

Climate change has led to changes in the quantity, intensity and distribution patterns of rainfall within the year and between years. This has resulted in a decline in the supply of conventional feed ingredients such as agricultural and agro-industrial by-products for livestock feed formulation leading to fluctuation in supply, quality and prices of the manufactured feeds. Therefore, because of rising costs as well as scarcity of conventional feed ingredients there is need to identify and evaluate locally available alternative feed resources that can be used in the formulation of poultry feeds. Among the non-conventional alternative feed resources, Prosopis pods has been identified as an alternative feed ingredient for poultry feed production (King'ori *et al*., 2011). Prosopis thrives well in the ASALs, waterlogged and saline soils and produces pods all-round year. Therefore, there is need to evaluate mature prosopis pods as an ingredient in chicken feed aimed at reducing cost of poultry feeds in Kenya.

Studies conducted using mature prosopis pods incorporated in broiler diets reported positive results at 20% level of inclusion (Meseret *et al.,* 2011a; Odero-Waitituh *et al.*, 2016). However, there is limited information on the use of prosopis pods in diets of grower IC. Therefore, the objective of this study was to investigate the effect of incorporating mature ground *Prosopis juliflora* pods in indigenous grower chicken feed on feed intake, weight gain, FCR, carcass weight and meat sensory evaluation.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview of poultry industry in Kenya

The Kenyan economy is based mainly on agriculture which contributes 30% of the gross domestic product (GDP) and provides livelihood to over 80% of the population living mainly in the rural areas (Alila and Atieno, 2006). Livestock sub-sector comprises both large-scale and small-scale farmers and organized farmers' groups (Radull, 2000) and accounts for up to 12% of the GDP (Kiptarus, 2005) which is 14% of agricultural GDP and 6% of agricultural exports (RoK, 2007a). This is over 30% of the farm gate value of agricultural commodities (Kiptarus, 2005). The poultry sub-sector plays an important role in Kenya by contributing 55% to the total livestock sector and 30% to the agricultural GDP which is 7.8% of the total GDP (RoK, 2007b). Annually, the country produces about 20 metric tonnes of poultry meat worth Kenya shillings (KES) 3.5 billion and 1.3 billion eggs valued at KES 9.7 billion (FAO, 2007). Poultry has the largest population of livestock species in the world in terms of numbers (FAO, 2000), and provides more than 30% of all animal protein consumed (Permin and Pedersen, 2000) in form of white meat.

The Kenyan poultry industry is characterized by a large population of IC which is about 84% of total poultry population (Oparanya, 2009) and a smaller but more productive exotic flock of both broilers and layers (RoK, 2007a). Chicken population is estimated to be 32 million that includes 24.8 million IC and 7.2 million commercial chickens (KNBS, 2016). Other types of poultry reared in smaller numbers but gaining importance include waterfowls, duck, pigeon, quail, turkeys, ostriches, and guinea fowls making up 2.2% of the total poultry population (FAO, 2007). Poultry production in Kenya has increased due to low capital investment, readily available market, ease of access to inputs (MoLFD, 2004) and quick returns to investment and therefore an important tool for poverty reduction and food security (Mack *et al.,* 2005; King'ori *et al*., 2010b). The country has not realized its full potential in the poultry sub-sector due to many challenges which include; costly and low-quality commercial feeds and fluctuation of both eggs and meat prices (King'ori *et al*., 2007; 2010a).

Indigenous chickens are in high demand and farmers can rear them on commercial basis (Hossain *et al*., 2012). There is potential for IC production in Kenya, however, the main challenge is that majority of farmers practice subsistence IC production. The demand and market prices for IC and eggs offers opportunity for farmers to consider commercial IC production. Indigenous chicken meat and eggs fetch higher prices in the market compared to hybrid birds (Islam and Nishibori, 2009) and are widely preferred by consumers because of their lean meat, taste and pigmentation (Horst, 1991; King'ori *et al*., 2010a). Consumers are ready to pay more for IC meat as compared to broiler chicken products (Grashorn, 2007; Islam and Nishibori, 2009).

Provision of quality and sustainable feed in the market is both inadequate and expensive. The major challenge to monogastric livestock feeding is competition for maize and wheat between human and livestock. Other challenges in the sector include unreliable supply of day-old chicks, poor disease control, and lack of well-established market infrastructure for poultry meat and eggs (Nyaga, 2007). Availability of conventional feed resources is declining as livestock population increase and grazing land declines with more urbanization to satisfy increasing human population (Sawal *et al.,* 2004). Thus, it is difficult for livestock owners, especially poultry keepers, to sustain production with less land for conventional poultry feed production.

Commercial poultry consists of hybrid exotic layers and broilers, mostly kept in peri urban areas of major towns due to availability of market for the finished products and also access to inputs (Kiptarus, 2005). Day-old chicks for both layers and broilers are supplied by the privately-owned farms such as: -Kenchic, Muguku, Kenbrid and other small hatcheries (MoLDF, 2004). Nyaga (2007), points out that exotic breeds for egg production include; Shaver, Starcross, Isabrown and Ross while broiler breeds include Arbor Acres, Hybro, Cobb and Hypeco. The indigenous bird types are frizzled feathered, naked neck, barred feathered, feathered shanks and dwarf feathered birds (Nyaga, 2007).

2.2 Systems of indigenous chicken production in Kenya

Poultry production systems may be categorized into major classes based on scale of production, function, breeds, husbandry and productivity (Malanga, 2008). Chicken are reared under extensive management system characterised by low capital input (King'ori *et al.,* 2010a). Free-range system or traditional village system is an integrated farming system with low input-output features with a backyard, where birds are partly confined within a fenced yard (Gueye, 2000; FAO, 2009). Classification is broadly based on flock sizes and input-output relationships (Birech, 2002). However, according to Gueye (2000) the choice of any of these production systems depends on the availability of resources and inputs needed for a particular production system.

2.3 Feeding of indigenous chickens

Indigenous chickens are often managed under a free-range system where a major proportion of the feed is obtained through scavenging (Abdelqader *et al*., 2007; King'ori *et al.,* 2010a). Scavenged resources can be defined as all the materials that are always or seasonally available in the environment which scavenging chicken can use as feed (Yitbarek and Zewadu, 2013) including waste from the kitchen. Birds have a genetically predetermined requirement for nutrients and hence will eat to meet these requirements for the first limiting nutrients (Emmans, 1987). Chicken like other animals regulate feed intake on a voluntary basis when allowed *ad libitum* access to feed. Since scavenged resources have wide variations in ingredient and nutrient levels, free ranging birds may rightly be perceived as compounding their own diet (Birech, 2002) and in most cases do not meet their requirement for limiting nutrients.

Except for crude fibre (CF), nutrients available to the IC under a scavenging environment are generally below requirements for chicks, growers and layers for optimal performance (King'ori *et al.,* 2014). Tadelle and Ogle (2000) indicated that the DM content of the feed material is low during the rainy season restricting dry matter intake and productivity of hens.

The nutritive value of an ingredient depends on its nutrient content (Zarei, 2006). Metabolizable energy intake of IC from scavenged feed is sufficient to meet requirements for only low levels of egg production necessitating the need to supplement energy to the diets (Emmans, 1987). Protein supply may be particularly limiting resulting in the generally observed poor growth (Mwalusanya *et al*., 2002). Protein supply may be critical especially, during drier months, whereas energy is critical at all times and particularly during rainy season, thus, formulation of nutrient supplementation for scavenging chickens may even be more critical during certain seasons of the year, where scavenging feeds are limited (King'ori *et al.,* 2010b). Concentration of crude protein (CP) and calcium are below recommended requirements for egg production, and the intake from scavenging are even more unbalanced if energy to protein and calcium to phosphorous ratio are taken into account (Tadelle and Ogle, 2000).

2.4 Nutritional challenges in poultry production

Feeds are a major input cost for poultry meat and egg production while cereals remain the main ingredient in poultry diet (Leeson, 2012), human food and ethanol production (Waithaka, 1998) thus posing a major challenge in poultry nutrition. Nutrition plays a significant role in growth of animals. Proper nutrition is a key factor in determining performance and productivity of birds (Leeson, 2012). There is need, therefore, to formulate rations that will fulfill all the nutrient requirements, including energy and protein for growth. Poultry usually consume food to meet their energy requirements and therefore feed intake is based primarily on the amount of energy in the diet (Nahashon *et al*., 2006). Increasing dietary energy concentration leads to a decrease in feed intake and *vice versa* (Veldkamp *et al*., 2005), thus affecting growth. However, as suggested by Smith (1990), this is valid as long as the diet is adequate enough in all other essential nutrients, and that nutrient density, accessibility and palatability do not limit feed intake. To fulfill a diversity of functions such as growth, meat or egg production, the chicken uses amino acids obtained from dietary protein. Mahmoud *et al.* (2016) reported that protein deficiency in feeds reduces growth in chicken as a consequence of depressed appetite and overall nutrient intake.

2.5 Protein requirement for indigenous chicken

If dietary protein is inadequate, there is a reduction or cessation of growth or productivity and a withdrawal of protein from less vital body tissues to maintain the functions of more vital tissues (NRC, 1994). As such, protein requirements vary considerably according to the physiological state of the bird, that is, the rate of growth (King'ori *et al*., 2003) or egg production (King'ori *et al*., 2010b). Other factors contributing to variations in protein requirements of the chickens include age, body size, sex and breed. Matching the feed protein levels with animal protein requirements is crucial for maximizing animal performance (King'ori *et al*., 2007).

Chemjor (1998) reported that dietary protein level of 13% is adequate for ICs aged between 14 and 21 weeks. King'ori *et al.* (2003) reported that IC require a protein level of 16% to optimize feed intake and growth between 14 and 21 weeks of age. Furthermore, Ndegwa *et al.* (2001) reported that ICs offered diets containing 17-23% CP had similar growth rates and feed intakes, suggesting that a 17% CP diet was sufficient for these chickens. King'ori *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 ICs raised intensively between 14 and 21 weeks of age. Results from this study indicated that feed intake per bird increased with increasing dietary protein levels. Similarly, live weight gain increased with increasing protein levels while feed conversion ratio decreased with increasing dietary protein levels. However, feed intake, feed conversion ratio and live weight gain for birds offered diets containing 160 and 180g CP/kg DM did not differ significantly.

2.6 Description and distribution of prosopis

Prosopis is a xerophytic evergreen tree that thrives in all soil types under variable climatic conditions (King'ori *et al*., 2011). It has a tap root system to access subterranean water; stems are greenish brown, sinuous and twisted (Sawal *et al.*, 2004). Silva (1986) described prosopis trees as having stems 6-9 m in height about 45 cm in diameter with strong axial thorns.

The bark is rough and dull red in colour, while the leaves are compound, bipinnate with 12-25 pairs of green foliates. Flowers are lateral to axis and the fruit is a non-dehiscent pod. The pod is curved and about 4 mm thick, 1 cm wide and up to 15 cm long made up of light yellow hardened epicarp. It has a fleshy mesocarp and woody endocarp which contains seed.

Prosopis originated from South America (Gomes, 1961; Silva, 1986) and spread to United States of America, Central America, West Indies, Africa, Hawaii and the Asian continent. Prosopis was introduced to Eastern Africa in the 1970s to reduce soil erosion, through collaborative projects involving local governments and development partners (Aboud *et al*., 2005). In Kenya, Prosopis is commonly known as 'Mathenge' and mostly found in arid and semi-arid regions of the country such as Baringo and Tana River counties. Prosopis is drought resistant and its suitability as a soil binder as well as a windbreaker is well known (Mendes, 1986; Anderson, 2005). Pods are suitable poultry feed (Meseret *et al.,* 2011a; 2011b; Odero-Waitituh *et al.,* 2016) but leaves have low palatability (Sawal *et al.,* 2004).

2.7 Production of pods and other beneficial uses of prosopis

Peak pod production occurs at 15-20 years of age (Sawal *et al*., 2004). Prosopis starts fruiting at 3-4 years of age; a 10-year-old plant may yield up to 90 kg pods annually (Mwangi and Swallow, 2008), however, annual pod yield is up to 100 kg/tree (Gomes, 1961; Jurriaense, 1973; Felker and Waines, 1977; Felker *et al.*, 1984; Shukla *et al*., 1986). A high yield of 169 kg/tree/year has also been reported in India (Mendes, 1986).

Prosopis can be used as fire wood, charcoal, building materials, floor tiles, furniture and handicrafts. Prosopis (leaves and pods) can also be used as livestock feed (Admasu, 2008) to increase milk production and growth rate (Mahgoub *et al.*, 2005) and even as human food (Mwangi and Swallow, 2008). Other uses include medicinal gum, tanning extraction (Aboud *et al*., 2005) and as wind breaks in agricultural production (Mwangi and Swallow, 2008). Prosopis benefits should be considered since eradication can prove to be an uphill task (Aboud *et al*., 2005; Perera *et al*., 2005; Choge *et al*., 2007). Formulation of monogastric livestock feeds with Prosopis pods offers a viable alternative, which also addresses the challenge of increasing human population and diminishing arable land and thereby reducing reliance on conventional grains.

2.8 Chemical composition and nutritive value of prosopis pods

Prosopis pods are a potential source of protein and energy (Antilla *et al*., 1994), although pod composition varies with location (Chopra and Hooda, 2001). Prosopis pods have high palatability and nutritive value which includes carbohydrates (Anttilla *et al*., 1994; Choge *et al*., 2007). Prosopis pods are rich in saccharose (20-25% of DM) and reducing sugars (10-20% of DM) (Silva, 1986) which brings about dental caries as has been observed in goats found in Baringo county. Pods from the species of algarobia genus, which is the dominant weedy species in Africa, contain 7-22% CP but pods of prosopis contain 16% CP, 30 - 75% carbohydrates, 11 - 35% CF, 1 - 6% fat and 3 - 6% ash, with the variations being brought about by the changes in season and environment (Oduol *et al*., 1986). Analysis by Choge *et al*. (2007) reported that the Kenyan prosopis, Baringo type, contains 16.2% CP which corroborates findings by Abdulrazak *et al.* (1999), who reported 13% total sugars carbohydrates 69%, energy value of 1530 (KJ), CF 47.8%, fat 2.12% and Ash 6%. Other chemical compositions are shown in Table 2.1.

Prosopis pods have a high content of calcium and phosphorus but the content varies with season, soil type and year. Whole pods calcium content ranged from 0.32 - 0.60%, 0.08 - 0.41% phosphorus, 0.32 - 0.43% potassium, 0.13% magnesium, and 0.01 - 0.05% sodium (Sawal *et al*., 2004). Content of iron, zinc and copper was found to be higher in pods collected during wet season than during summer which may be due to uptake of macro minerals that prevent micro mineral uptake during summer (Imoro *et al*., 2012), while manganese content did not vary with season (Talpada *et al*., 1989). Mineral content has been reported to vary with location (Chopra and Hooda, 2001).

Table 2.1 Chemical composition of Kenyan prosopis leaves and pods

	CP (%)	NDF (%)	ADF (%)	TEP mg g^{-1}DM	TET mg g^{-1}DM	CT mg g^{-1}DM
Pods	16.30	44.80	36.20	37.60	25.50	1.20
Leaves	18.50	27.10	18.20	16.20	13.30	15.40

Source: Abdulrazak *et al.* (1999).

2.9 Negative effects of *Prosopis juliflora*

Uncontrolled grazing of prosopis pods as the sole source of feed showed deleterious effects on cattle (Felker and Waines, 1977). Consumption of green immature pods reduced appetite and caused weight loss, weakness, alopecia, nervous symptoms, diarrhoea, fever, dehydration and death of cattle (Gabar, 1986). Prosopis pods were a major source of food for Native American people in southern California and on the lower Colorado river (Felker and Waines, 1977).

Abdulrazak *et al*. (1999), reported presence of tannins in Kenyan prosopis leaves and pods as indicated in Table 2.1. Cyanogenic glycosides were also present in seed, mucilage and cotyledons but alkaloids were detected in whole seed (Escober *et al*., 1987). The levels had no adverse effects on nutrient digestibility and production. Tannin contents of seeds and whole pods were found to be 1.9 - 1.5% of DM respectively (Talpada *et al*., 1989). Makkar *et al*. (1990) reported that prosopis pods contain low levels of phenolic component and condensed tannins, the latter below harmful levels in animals making them a valuable animal feed resource. When the amounts of cyanogenic glycosides in the pods are low, they can be safely used as feed for livestock (Sawal *et al*., 2004).

Prosopis causes disfiguration of goats' jaws tooth decay and tooth decay due to consumption of hard prosopis pods and high sugar content in the pods (Mwangi and Swallow, 2008). Other problems caused by prosopis pods include reduction of pastures for livestock grazing, reduced farm lands and associated opportunities for cultivation.

2.10 Effect of prosopis pods on chicken performance

Prosopis has been harnessed and used to feed various animals. Meseret *et al*. (2011a), AL-Marzooqi *et al*. (2015), Odero-Waitituh (2015) and Yusuf *et al.* (2016) incorporated prosopis pods in broiler diets with improved performance at 20% level. Meseret *et al.* (2011b) and

Manhique *et al.* (2017) reported good performance in layers at 10% level of inclusion while Haščík *et al.* (2011) reported improved sensory attributes in meat when prosopis pods were incorporated in broiler feeds. The objective of this study therefore was to evaluate the effects of incorporating mature ground prosopis pods in KIIC grower diets and determine the effect on performance, carcass quality and sensory attributes of meat.

CHAPTER THREE

EFFECT OF SUBSTITUTING DIETS WITH PROSOPIS PODS ON THE PERFORMANCE OF IMPROVED GROWER INDIGENOUS CHICKEN

3.1 Abstract

Chicken production faces unsustainable supply of quality and expensive feeds. Prosopis pods as an emerging livestock feed ingredient has been documented. A study was designed to evaluate the inclusion of prosopis pods in improved indigenous chickens diets. The objectives were to determine effects of prosopis pods-based diets in indigenous chicken on performance and meat quality. Diets were formulated by substituting growers' rations with prosopis at 0% (T_1), 10% (T_2), 20% (T_3) and 30% (T_4). A completely randomized design was used with four cockerels and four pullets per treatment in separate cages replicated three times. The results showed a significant difference ($p<0.05$) between treatments where similar FI of 70.99, 70.56 and 69.02 g/day and weight gains of 12.91, 12.15 and 11.66 g/day were recorded in 0, 10 and 20% levels respectively while 30% recorded lower values at 61.31 and 9.08g/day for FI and weight gain respectively in pullets. In cockerels, treatments showed significant differences ($p<0.05$) with 0, 10 and 20% levels in the diets having similar FI of 94.24, 92.67 and 87.64g respectively but lower than diet with 30% level with 79.46g. Weight gain was similar in diets with 0, 10 and 20% substitution level with 20.65, 19.37 and 18.83g respectively but lower than in diet with 30% prosopis pods with 15.95g. Diet with 30% had higher values that diets with 0 and 20% level. In pullets, diet with 20% level had significantly lower ($p<0.05$) BW of 225.40g than all the other treatments. All treatments produced meat with similar ($p>0.05$) breast and drumstick pH apart from diet with 20% level which had higher pH values of 5.97 than diet with 30%. In pullet breast, diet with 0% level had higher appearance values than other treatments with 79.60. The study concluded that diets with 20% of prosopis pods could substitute improved grower indigenous chicken diet and the maize portion in experiment 1 and 2 respectively. The inclusion of mature pods in the chicken diet can contribute to sustainable and reliable supply of a feed ingredient and reduce overreliance on conventional livestock feed ingredients.

Keywords: *indigenous chicken, meat quality, prosopis juliflora,* sensory evaluation

3.2 Introduction

The demand for poultry and their products in Kenya is on the increase from 54.8 thousand metric tonnes in 2000 to 164.6 in 2030 (Robinson and Pozzi, 2011). However, poultry production is constrained by many factors among them feed quality and quantity (Kingori *et al.,* 2010a). There is therefore need to evaluate locally available, affordable and sustainable feed materials that can be used as alternative feed ingredients. The feed material identified should improve or maintain poultry production cost effectively (Meseret *et al*., 2011a). Prosopis pods can supply energy, protein, minerals and vitamins (Choge *et al.*, 2007) as various studies in layers (Manhique *et al.*, 2017) and broilers (Meseret *et al*., 2011a; Odero-Waitituh *et al.,* 2016) have reported. Nutritional studies have been done on IC in Kenya and nutritional requirements of certain categories have also been determined. Studies by King'ori *et al.* (2003), Birech (2002) and Chemjor (1998) reported that both quality and quantity of feed is a major factor limiting the attainment of full productivity potential of IC in Kenya. This is caused by high feed cost due to inadequacy and high cost of ingredients to formulate the feeds.

Feed accounts for 60-80% of the total cost of poultry production (Mukhtar, 2012), therefore, for continued poultry productivity, sustainable feed supply is paramount (Meseret *et al.,* 2012). This can be possible by embracing the use of non-conventional feedstuffs like Prosopis pods that are largely underutilized (Sawe *et al*., 1997; Kingori *et al*., 2011) in Kenya. In studies involving prosopis pods by Manhique *et al.* (2017) and Meseret *et al.* (2011b) they recommended 10 and 20% mature GPJP in laying diets respectively. Odero-Waitituh *et al*. (2016) and Meseret *et al.* (2011a) reported remarkable performance when 20% of GPJP was incorporated in broiler diet. Indigenous chickens produce meat with unique taste and texture which is preferred by a large number of consumers (Kingo'ri *et al.,* 2010a). Nutrition plays a major role in the quality and quantity of chicken meat. This study determined the performance of KIIC offered diets with varying inclusion levels of GPJP to determine the optimum inclusion for feed intake, growth, FCR and meat quality.

3.3 Materials and methods

3.3.1 Study site

The on-station feeding trial was conducted at Kenya Agricultural and Livestock Research Organization (KALRO) Non-Ruminant Institute (NRI) at Naivasha. The station is 100 km west of Nairobi at an altitude of 1900 m above sea level (asl) and has a bimodal rainfall pattern characterised by long rains from April to June and short showers from October to December, with an annual mean of 620 mm. The average day and night temperatures are 26°C and 8°C respectively and a relative humidity range between 60 and 75%. The natural vegetation is predominantly star grass (*Cynodon plectostachyus*) with scattered tall Acacia trees (*Acacia xanthophloea*). Soil is volcanic in origin, alkaline (p H 7.4), dark, sodic and deep (Herrero *et al*., 2010).

3.3.2 Experimental chicken

The study used 96, 8 weeks-old grower KIIC that were randomly allocated to four diets with each treatment having 8 birds (4 pullets and 4 cockerels) replicated 3 times. Pullets and cockerels were put is separate cages. The experimental birds were put in single-tier cages placed on the floor with wood shavings litter. This improved indigenous chicken has been bred from a range of IC in Kenya by KALRO. The chicks were hatched from the Non-Ruminant Research (NRI) and experimental birds selected from this flock at eight weeks old. A routine vaccination program to control diseases was adopted for the study as shown in Appendix I. Before commencement of the experiment, the experimental pens, waterers and feeders were thoroughly cleaned, disinfected and sprayed against external parasites.

3.3.3 Ingredients used in ration formulation

Ingredients used in diet formulation and their chemical composition are presented in Table 3.1.

Table 3.1 Chemical composition of ingredients used in ration formulation

Parameters(g/Kg)	GPJP	Maize	Fish meal	Soybean
DM	893.00	899.00	922.40	900.00
CP	138.90	114.70	540.40	422.00
EE	63.80	61.30	141.70	191.10
CF	181.40	23.60	13.60	118.90
Ash	64.00	35.00	216.00	128.60
Ca	3.70	0.70	43.00	3.20
P	1.70	0.30	26.90	6.80

DM = Dry Matter; CP = Crude Protein; EE = Ether Extract; CF = Crude Fibre; Ca = Calcium; P = Phosphorus; GPJP = Ground *Prosopis juliflora* pod

Dry mature prosopis pods were obtained from Marigat Sub County in Baringo County in the dry month of February. Marigat is located at latitude 0^0 20’N and longitude 35^0 57’E Kenya (FAO, 1992). It is about 1500m above sea level with a mean annual rainfall of 600-800mm with weak bimodal peaks recorded from March- May and June-August. Soils are mainly clay loams with alluvial deposits and contain high levels of P, K, Ca and Mg and low levels of N and C. They range from acidic to slightly alkaline (Mwangi and Swallow, 2008).

The pods were collected from the ground after the trees were shaken for the pods to drop. Spoilt and mouldy pods were discarded and clean pods were put in gunny bags and transported to Josiche Feed Millers in Nakuru town where they were milled to pass through a 5mm sieve according to the procedure by (Choge *et al.*, 2006). The mature GPJP were then used in the formulation of the experimental diets fed at different inclusion levels in the feeding trial. The other ingredients were sourced from the market, ground and a mixer used to mix the various ingredients.

3.3.4 Dietary treatments

Dietary treatments T_2, T_3 and T_4 were formulated to contain 100, 200 and 300g of mature GPJP respectively for a kilogram of T_1 (control diet) (Table 3.2). The treatments were iso-nitrogenous and iso-caloric. Metabolizable energy (ME) was determined indirectly according to the method of Wiseman (1987) as follows

ME (Kcal/kg DM) = 3951 + 54.4 EE - 88.7 CF - 40.8 Ash

3.3.5 Chemical feed analyses

Chemical analysis results of the diets used in the feeding trial are represented in Table 3.2. Feed samples were dried and ground to pass through a 1mm screen using a Wiley mill. The samples were then analyzed for proximate composition (DM, CP, EE, CF and ash) while calcium and phosphorus were analyzed using atomic absorption spectrophotometry using the methods of AOAC (1990). Nitrogen Free Extract (NFE) was determined as 100 – (% moisture +% CP +% EE +% CF +% ash).

Table 3.2 Ingredients and chemical composition of the experiment one diets

Ration composition, g/Kg	Treatments			
	T_1	T_2	T_3	T_4
GPJP	0.00	100.00	200.00	300.00
Maize	640.00	576.0	512.00	448.00
Fish meal	75.00	67.50	60.00	52.50
Soy bean meal	245.00	220.50	196.00	171.50
Vegetable oil	25.00	22.50	20.00	17.50
DCP	6.50	5.90	5.20	4.60
Iodized salt	5.00	4.50	4.00	3.50
Vitamin premix*	3.50	3.20	2.80	2.50
Total	1000.00	1000.00	1000.00	1000.00
Chemical composition, g/Kg				
DM	894.00	901.00	902.00	896.00
CP	234.00	230.7	230.50	229.00
EE	86.10	72.10	69.80	65.80
CF	45.90	55.60	65.00	77.10
Ash	78.00	82.20	83.50	83.60
NFE	453.60	454.10	448.50	440.40
Ca	10.00	9.80	10.30	10.10
P	4.50	4.60	4.40	4.90
ME (MJ/kg DM)	13.70	13.42	13.37	13.01

T_1 = diet containing 0g GPJP per kg of diet; T_2 = diet containing 100g GPJP per kg of diet; T_3 = diet containing 200g GPJP per kg of diet; T_4 = diet containing 300g GPJP per kg of diet; GPJP = ground P*rosopis juliflora* pods; DCP = dicalcium phosphate; CP = crude protein; EE = ether extracts; CF = crude fibre; NFE = nitrogen free extracts; ME = metabolizable energy. *Vitamin premix to provide the following per kg of diet: Vitamin A, 10,000 IU; Vitamin D_3, 2000 IU, Vitamin E, 5 mg; Vitamin K, 2 mg; Riboflavin, 4.2 mg; Nicotinic acid, 20 mg; Vitamin B_{12}, 0.01mg; Pantothenic acid, 5 mg; Folic acid, 0.5 mg; Choline, 3 mg; Mg, 56 mg; Fe, 20 mg; Cu, 10 mg; Zn, 50 mg; Co, 125 mg; Iodine, 0.08 mg.

3.3.6 Feeding trial

A completely randomized design (CRD) was used with 8 growers per treatment (4 pullets and 4 cockerels put in separate pens) replicated 3 times. Free access to feed and clean water was allowed throughout the experimental period. The birds were fed on grower feeds before commencement of the experiment. All experimental birds were given a one-week adaptation period to the diets, after which daily feed intake (feed offered minus feed refusals from 0700-

1800 hrs) was measured and recorded. A feed sample was preserved for chemical analyses in the laboratory. Mean live weight gain for each experimental unit was calculated using the mean pen live weight for a given period of time. Weight gain was monitored by weighing the birds weekly at 0900 hours before morning feed from the 10^{th} to 20^{th} week of age. Weekly feed conversion ratio (FCR) per bird was calculated as the ratio of feed consumed to a unit body weight gain in a week.

3.3.7 Carcass evaluation

In the 20^{th} week of feeding trial, two cockerels and two pullets from each pen were randomly selected and fasted for 12 hours but with free access to water. They were weighed and slaughtered following the standard procedure before manual de-feathering after scalding at 60-70 ^{o} C and dissection into various cuts. Carcass measurements recorded included pre-slaughter live weight after fasting for 12hrs, cold dressed weight (CDW) and prime cuts which included breasts and legs (drumstick and thigh) were recorded. Dressing percentage was calculated as a ratio of carcass weight to pre-slaughter live weight.

3.3.8 Meat quality traits (pH and water holding capacity)

pH was measured 24 hours post slaughter using a pH meter calibrated using certified standard buffer pH 7.0, pH 4.0 and pH 9.2. Meat representative samples (10 g) were cut from the breast (*pectoralis*) and leg muscles (*peroneuslongus*) and blended with 50 mls of distilled water (1:5 ratio) in a clean blender. pH measurements were recorded at 20-25°C. Water holding capacity was estimated by measuring drip loss of the breast muscle samples at 2, 7 and 14 days post slaughter when stored at 4°C using the bag method (Honikel, 1998).

3.3.9 Meat sensory test

Sensory analysis was conducted three days post-slaughter on breast and thigh meat at the sensory evaluation facility at the Department of Dairy, Food Science and Technology, Egerton University. Samples were thawed overnight and cooked by boiling in a 0.62% NaCl solution to an internal temperature of 75°C (at a weight ratio of solution: meat of 2:1). Meat was cut into 1.9 cm, bite-size cubes and served skinless.

Panelists used questionnaires to evaluate sensory characteristics of the two meat samples in appearance, juiciness, taste, texture and overall acceptability. Attribute profiling was done using a scale of 10 cm long with anchored words such as too light and too soft, for the extreme left-hand side of the scale to too dark and too hard; at the extreme right and neither light nor dark, or neither soft nor hard at the center as presented in Appendix 3. The scale enabled continuous data to be recorded. The values were transformed as percentages for ease of use. A seven-point descriptive Hedonic Scale (7- Like extremely, 6- Like very much, 5- Like moderately, 4- Neither like nor dislike, 3- Dislike moderately, 2- Dislike very much, 1- Dislike extremely) was also used to determine general acceptability (Appendix III). A total of 30 panel members was constituted from lecturers, technicians and final year Bachelor of Science students at the Department of Dairy, Food Science and Technology at Egerton University, Kenya (Appendix 4). The panel members were not given any information about the meat or the experimental treatments and procedures.

Panelists were randomly presented with samples from all treatment groups in duplicate in partitioned booths equipped with yellow bulb light (Appendix 4). Between each sample, panelists were instructed to rinse their mouth with distilled water. A 15-minutes break period was allocated to the panelists halfway through the session.

3.3.10 Cost and benefit analysis of feeding

The cost of feeding diets containing mature GPJP was calculated from total feed intake in kilograms, feed cost per kilogram in Kenya shillings (KES) and total live weight change in kilograms for the entire 77 days experimental period. Cost of GPJP was based on collection fee paid, transportation fee from Marigat, Baringo County to Nakuru, milling and cost of mixing with other ingredients.

3.3.11 Data analyses

All data were subjected to analysis of variance (ANOVA) using the PROC GLM (SAS, 2002) and means separated by Tukey's test (at 5% probability level). Chi-square test was used to analyze the general acceptability non-parametric data. The following statistical model for feed intake, daily gain, feed conversion ratio, carcass weight, pH and water holding capacity was adopted.

$Y_{ij} = \mu + T_i + E_i$;

where;

Y_{ij} - is the observation of the i^{th} treatment

μ - is the overall population mean (for cockerels and pullets)

T_i -is the i^{th} treatment factor ($i = 1…4$)

E_{ij} - is the random error effect

3.4 Results

3.4.1 Nutrient composition of the diets

The amount of CF in the diets increased as the level of mature GPJP increased from T_1 to T_4 (Table 3.2), which is a similar trend to what Meseret *et al.* (2011a) reported. Diets were formulated by inclusion of 10, 20 and 30% GPJP of the control diet (Table 3.2). Crude protein content was above 160 g/Kg DM which is a recommended standard requirement for IC growers (Kingori *et al*., 2003).

Diets were formulated to be iso-nitrogenous and iso-caloric with CP 229.0-237.0 g/Kg DM and ME 13.01-13.70 MJ/Kg. The DM content 893g/Kg DM of GPJP is similar to 891.5g/Kg DM reported by Meseret *et al*. (2011a), and 903g/Kg DM by Odero-Waitituh (2015). Odero-Waitituh *et al.* (2015) and Meseret *et al*. (2011a) reported a mean CP of GPJP as 114.0 and 154.3 g/Kg respectively similar to 13.89g/Kg in the current study. The GPJP Crude Protein values reported by Abdulrazak *et al*. (1999), Choge *et al*. (2007), Koech *et al.* (2010) and Meseret *et al.* (2011a) were 163.0, 162.0, 185.0 and 154.3 g/Kg, respectively which are higher than in this study. These differences may be attributed to differences in location and time of harvesting the pods as reported by Choge *et al*. (2007). The CP content of GPJP as an ingredient was lower (138.9 g/Kg) than the requirements for IC growers (160.0g/Kg) determined by King'ori *et al.* (2003). This therefore suggests that GPJP requires supplementation with a protein source when formulating grower diets.

The GPJP EE content (6.38%) was similar to 6.01% by Meseret *et al.* (2011a) but higher than 2.80 and 2.18% reported by Odero-Waitituh (2015) and Choge *et al.* (2007) respectively. This could explain the high metabolizable energy values that ranged from 13.01-13.70 MJ/Kg DM in formulated experimental diets.

3.4.2 Effect of substituting prosopis pods on performance of pullets

Feed intake, daily weight gain, feed conversion ratio, final live weight and live weight change results are presented in Table 3.3. There was a lower feed intake ($p<0.05$) in the pullets offered T_4 than all the other treatments. The daily weight gain in pullets offered T_4 was lower ($p<0.05$) than T_1 to T_3. Pullets offered T_4 had higher FCR ($p<0.05$) than T_1-T_3. Pullets offered T_4 had significantly ($p<0.05$) lower final live weight (FLW) and live weight change (LWC) as compared to all the other treatments.

Table 3.3 Effect of substituting growers' diet with prosopis pods in pullets

Parameters	Treatments				SEM
	T_1	T_2	T_3	T_4	
Initial live weight (g)	685.42	686.67	687.92	642.92	17.01
Average feed intake (g/day)	70.99[a]	70.56[a]	69.02[a]	61.31[b]	1.37
Average daily gain (g/day)	12.91[a]	12.15[a]	11.66[a]	9.08[b]	1.18
FCR (g feed/g weight gain)	5.50[b]	5.80[b]	5.92[b]	6.81[a]	0.16
Final live weight (g/bird)	1679.52[a]	1622.55[a]	1585.88[a]	1342.12[b]	43.5
Live weight change (g/bird)	994.10[a]	935.88[a]	897.96[a]	699.20[b]	27.2

[abc] means within a row with different superscripts differ significantly ($p<0.05$); T_1 = diet containing 0g GPJP per kg of diet; T_2 = diet containing 100g GPJP per kg of diet; T_3 = diet containing 200g GPJP per kg of diet; T_4 = diet containing 300g GPJP per kg of diet.

3.4.3 Effect of substituting prosopis pods on performance of cockerels

Feed intake, daily weight gain, feed conversion ratio, final live weight and live weight change results in cockerels are presented in Table 3.4. There was a lower feed intake ($p<0.05$) in cockerels offered T_4 as compared to all the other treatments in cockerels. The daily weight gain in cockerels offered T_4 was lower ($p<0.05$) than in T_1 while FCR was similar across all treatments. Cockerels offered T_4 had significantly ($p<0.05$) lower FLW and LWC compared to all the other treatments.

Table 3.4 Effect of substituting growers' diet with prosopis pods in cockerels

Parameters	Treatments				SEM
	T_1	T_2	T_3	T_4	
Initial live weight (g)	796.67	798.33	821.25	795.83	18.96
Average feed intake (g/day)	94.24[a]	92.67[a]	87.64[a]	79.46[b]	1.92
Average daily gain (g/day)	20.65[a]	18.83[ab]	19.37[a]	15.95[b]	1.25
FCR (g feed/g weight gain)	4.57	4.78	4.67	4.99	0.14
Final live weight (g/bird)	2386.75[a]	2289.70[a]	2271.17[a]	2024.01[b]	75.32
Live weight change (g/bird)	1590.08[a]	1491.37[a]	1449.92[a]	1228.18[b]	36.44

[abc] means within a row with different superscripts differ significantly ($p<0.05$); T_1 = diet containing 0g GPJP per kg of diet; T_2 = diet containing 100g GPJP per kg of diet; T_3 = diet containing 200g GPJP per kg of diet; T_4 = diet containing 300g GPJP per kg of diet;

3.4.4 Carcass evaluation

Yields of carcass and carcass parts of pullets and cockerels are presented in Table 3.5. Diet T_4 had significantly lower ($p<0.05$) DCW, eviscerated weight (EW), breast weight (W) and leg W than T_1 in cockerels and leg W in pullets. Diet T_3 had significantly lower DCW, EW and breast W than T_1 in pullets.

Table 3.5 Effect of substituting grower diet with prosopis pods on carcass performance

	Treatments				SEM
Cockerel	**T_1**	**T_2**	**T_3**	**T_4**	
Pre-slaughter weight (g)	2150.00	2147.00	2148.00	2150.52	72.34
Dressed cold weight (g)	1915.65^a	1902.99^b	1890.32^c	1899.34^b	54.44
Dressing %	89.10	88.60	88.10	88.30	2.75
Eviscerated weight (g)	1816.46^a	1782.38^b	1782.04^b	1777.43^c	66.73
Eviscerated %	84.40	82.90	82.90	82.60	0.33
Breast weight (g)	321.66^a	290.31^b	311.85^a	287.84^c	5.39
Leg weight (g)	522.85^a	493.24^b	508.27^{ab}	489.81^c	7.81
Pullet					
Pre-slaughter weight (g)	1580.39	1579.99	1579.90	1579.22	63.54
Dressed cold weight (g)	1401.02^a	1399.08^{ab}	1388.26^b	1389.40^{ab}	36.10
Dressing %	88.65	88.55	87.87	87.98	5.09
Eviscerated weight (g)	1307.89^a	1291.52^{ab}	1264.97^b	1299.21^{ab}	14.5
Eviscerated %	82.69	81.72	80.05	82.30	0.90
Breast weight (g)	247.06^a	232.32^{ab}	225.40^c	260.21^a	8.21
Leg weight (g)	339.65^a	334.74^{ab}	318.45^b	323.00^b	9.70

^{abc} means within a row with different superscripts differ significantly ($P<0.05$); T_1 = diet containing 0g GPJP per kg of diet; T_2 = diet containing 100g GPJP per kg of diet; T_3 = diet containing 200g GPJP per kg of diet; T_4 = diet containing 300g GPJP per kg of diet

3.4.5 Meat quality traits (pH and water holding capacity)

Ultimate pH and water holding capacity for meat from pullets and cockerels offered diets containing mature GPJP and slaughtered at 20 weeks are presented in Table 3.6. Breast sample from pullet offered T_4 had similar ($p>0.05$) ultimate pH values as T_1 and T_2 but lower

($p<0.05$) than T_3. All diets had no significant ($p>0.05$) effect on cockerel breast ultimate pH. All diets had no effect on drumstick ultimate pH for both cockerels and pullets.

Two days after slaughter, pullet breast for T_1 lost more ($p<0.05$) water as compared to cockerel breast from T4. Drip loss was similar 7 days after slaughter. Fourteen days after slaughter, pullet breast from T_1 had lost more ($p<0.05$) water than from other diets in cockerels and pullets apart from cockerels receiving the same diet (T_1).

Table 3.6 Effect of substituting complete grower diets with prosopis on meat ultimate pH and water holding capacity

Parameter	Cockerel				Pullet				
	T_1	**T_2**	**T_3**	**T_4**	**T_1**	**T_2**	**T_3**	**T_4**	**SEM**
Breast pH	5.73^{b}	5.72^{b}	5.88^{ab}	5.95^{ab}	5.88^{ab}	5.81^{ab}	5.97^{a}	5.72^{b}	0.04
Drumstick pH	6.10	6.03	6.13	6.24	6.11	6.13	6.04	6.03	0.73
Drip Loss									
After 2 days	2.17^{ab}	2.10^{ab}	2.09^{ab}	2.03^{b}	2.23^{a}	2.11^{ab}	2.08^{ab}	2.08^{ab}	0.34
After 7 days	4.19	4.14	4.09	4.10	4.18	4.15	4.13	4.61	0.15
After 14 days	6.70^{ab}	6.52^{bc}	6.42^{bc}	6.41^{c}	7.00^{a}	6.58^{bc}	6.62^{bc}	6.48^{bc}	0.05

^{abcd} means within a row with different superscripts differ significantly ($P<0.05$); T_1 = diet containing 0g GPJP per kg of diet; T_2 = diet containing 100g GPJP per kg of diet; T_3 = diet containing 200g GPJP per kg of diet; T_4 = diet containing 300g GPJP per kg of diet; GPJP=ground *Prosopis juliflora* pods

3.4.6 Meat sensory evaluation

The mean percentage sensory values of various boiled meat samples from pullets and cockerels offered diets containing graded levels of GPJP are presented in Table 3.7. Treatments had no effect ($p>0.05$) on the cockerel thigh meat in terms of appearance, juiciness, taste and texture. Pullet thigh meat from T_1 had higher ($p<0.05$) scores for appearance, juiciness and taste as compared to all other treatments while T_3 had softer ($p<0.05$) meat texture as compared to T_2.

All treatments did not affect ($p>0.05$) appearance, juiciness, taste and texture in cockerel breast meat. In pullet breasts, T_1 had significantly ($p<0.05$) lighter appearance than breast meat from all the other treatments, juicier breast meat than T_3 and tastier breast meat than $T_{4.}$ All treatments had similar effect ($p>0.05$) on softness of pullet breast meat.

Chi-square test results indicated that T_1 and T_2 had high acceptance than T_4 in cockerel thigh while in pullets' breast, T_1 had high acceptance than $T_{4.}$

Table 3.7 Meat percentage sensory values and general acceptability results for different levels of prosopis pods-based diets

	Treatments					Hedonic Scale				
	T_1	T_2	T_3	T_4	**SEM**	**Cockerel thigh**				
Cockerel thigh							χ^2	**df**	***p***	**%**
Appearance	50.37	51.90	54.73	48.37	3.14	GA	8.22	119	.042*	6.91
Juiciness	50.43	57.43	57.50	49.80	3.01	0vs30	5.05	59	.025*	8.56
Taste	54.50	62.23	58.27	59.77	3.15	10vs30	6.52	59	.011*	11.1
Texture	56.23	57.90	64.77	59.17	3.51					
Pullet thigh						**Pullet thigh**	χ^2	**df**	***p***	**%**
Appearance	85.57^{a}	65.83^{b}	71.53^{b}	64.33^{b}	3.14	GA	1.22	119	.709	1.02
Juiciness	73.33^{a}	46.23^{b}	55.50^{b}	48.97^{b}	4.02					
Taste	82.83^{a}	62.43^{b}	62.67^{b}	59.27^{b}	3.56					
Texture	64.33^{ab}	57.50^{b}	68.40^{a}	66.80^{ab}	2.91					
Cockerel breast						**Cockerel breast**	χ^2	**df**	***p***	**%**
Appearance	59.43	59.83	63.73	67.57	3.29	GA	1.90	119	.593	1.59
Juiciness	41.07	42.34	43.50	45.37	3.99					
Taste	52.87	52.81	56.40	57.87	4.24					
Texture	47.93	52.37	52.67	55.40	4.26					
Pullet breast						**Pullet breast**	χ^2	**df**	***p***	**%**
Appearance	79.60^{a}	50.83^{b}	50.37^{b}	50.57^{b}	3.11	GA	14.7	119	.002*	12.3
Juiciness	65.27^{a}	56.70^{ab}	48.23^{b}	57.03^{ab}	3.03	0vs10	10.5	59	.001*	17.7
Taste	72.73^{a}	59.97^{ab}	62.73^{ab}	58.27^{b}	3.03	10vs20	11.9	59	.001*	20.4
Texture	63.63	61.87	56.67	57.00	3.46	10vs30	7.97	59	.005*	13.5

^{ab} means within a row with different superscripts differ significantly (P<0.05); T_1 = diet containing 0g GPJP per kg of diet; T_2 = diet containing 100g GPJP per kg of diet; T_3 = diet containing 200g GPJP per kg of diet; T_4 = diet containing 300g GPJP per kg of diet; GPJP = ground *Prosopis juliflora* pods; GA = general acceptability; * p<0.05; % = percentage of effect contributed by diets;; χ^2 = chi square

3.4.7 Cost of substituting prosopis pods in grower diet on improved indigenous chicken

The cost of feeding per unit of weight gain was determined from total feed consumed and the weight gain produced from that amount of feed for both pullets and cockerels as shown in Table 3.8 and 3.9 respectively. Inclusion of 200 g of GPJP per kg of diet (T_3) in pullets' diet was the least cost diet (KES 344) while in cockerels, 300 g of GPJP per kg of diet (T_4) was the least cost diet (KES 262) per kg gained.

Table 3.8. Effect of substituting grower diets with prosopis pods on cost per kilogram gained in pullets

Parameters	Treatments			
	T_1	T_2	T_3	T_4
a) Total feed intake, kg/bird	5.47	5.43	5.32	4.72
b) Cost/kg of feed, KES	67.81	62.74	57.65	52.59
c) Total feed cost (a×b), KES	370.67	340.87	306.38	248.27
d) Weight gained, kgs	0.99	0.94	0.89	0.69
e) FCR (a/d)	5.50	5.80	5.92	6.81
f) Feed cost/kg of weight gain (c/d), KES/Kg	374.41	362.63	344.25	359.81

KES = Kenya shillings; T_1 = diet containing 0g GPJP per kg of diet; T_2 = diet containing 100g GPJP per kg of diet; T_3 = diet containing 200g GPJP per kg of diet; T_4 = diet containing 300g GPJP per kg of diet

Table 3.9 Effect of substituting grower diets with prosopis pods on cost per kilogram gained in cockerels

Parameters	Treatments			
	T_1	T_2	T_3	T_4
a) Total feed intake, kg/bird	7.26	7.14	6.75	6.12
b) Cost/kg of feed, KES	67.81	62.74	57.65	52.59
c) Total feed cost (a×b), KES	492.06	447.69	389.04	321.77
d) Weight gained, kgs	1.59	1.49	1.45	1.23
e) FCR (a/d)	4.57	4.78	4.67	4.99
f) Feed cost/kg of weight gain (c/d), KES/kg	309.43	300.16	268.32	261.99

KES = Kenya shillings; T_1 = diet containing 0g GPJP per kg of diet; T_2 = diet containing 100g GPJP per kg of diet; T_3 = diet containing 200g GPJP per kg of diet; T_4 = diet containing 300g GPJP per kg of diet

3.5 Discussion

3.5.1 Feed intake

There was an apparent depressed feed intake in pullets (Table 3.3) and cockerels (Table 3.4) offered T_4. Meseret *et al*. (2011a; 2011b), reported similar trends of depressed feed intake when 300g of GPJP was included per kg of broiler and layers' diets respectively. The results are however at variance with Manhique *et al.* (2017) who reported similar feed intake in diets with 0 to 300g of GPJP per kg of feed in KIIC layers due to their well-developed GIT. The depressed feed intake could be attributed to the high fibre with GPJP which has been reported to negatively affect nutrient digestibility, leading to increased heat production (Varastegani and Dahlan, 2014). The effect of inclusion of 300 g per kg of feed on feed intake may also be due to gut fill resulting from consumption of increased amounts of CF (Thorne *et al*., 1992). The reduced feed intake could also be due to the presence of anti-nutritive factors such as trypsin inhibitor (Del Valle *et al*., 1983). Higher levels of insoluble fibre resulted in lower digestibility and lower passage of digesta through the gut (Hetland *et al.*, 2007) which reduces feed intake.

Feed intake at 20% GPJP inclusion suggests that the birds are able to handle relatively high amount of fibre in the diet and have a similar performance as chicken receiving control diet. This observation is in agreement with Omar (2000), Gonzalez-Alvaro *et al*. (2007) and Mateos *et al*. (2012) who reported that moderate dietary fibre improved feed intake and facilitated development of gastro-intestinal tract in day-old broilers.

3.5.2 Weight gain

Growth in chicken is influenced by nutrition, environment, health, sex and genotype. Among these factors, nutrition plays the most significant role (Khobondo *et al*., 2015). In this study, diets were formulated to be iso-caloric and iso-nitrogenous to ensure that all the nutritional requirements were met. It was also observed during the whole experimental period, inclusion of 300g/Kg GPJP in diets (T_4) lowered the weight gain in both pullets and cockerels. The results of this study are in agreement with the findings of Meseret *et al.* (2011a), Yusuf *et al.* (2008) and Choudhary *et al.* (2005) who reported lower daily weight gain at 30% GPJP inclusion, 50% decorticated prosopis and 30% enzyme-supplemented levels in broiler diets respectively. This is probably because prosopis pods have anti-nutritive factors such as tannins, trypsin, hemagglutinins, prosopine (Abdul-razak *et al*., 1999; Ausol and Mukhtar, 2011) and also the increased fibre with increasing level of GPJP that lowers nutrient utilization (Jiménez-Moreno *et al*., 2009; AL-Mazooqi *et al.*, 2015) resulting in reduced daily gain.

3.5.3 Live weight changes and final live weight

Diet T_4 lowered ($p<0.05$) FLW weight in pullets and cockerels. Meseret *et al.* (2011b; 2011a) reported similar results and concluded that 20% GPJP can be substituted in layer and broiler diets respectively without adverse effects on performance.

Final live weight is a function of daily weight gain. Effect of diets on LWC and FLW were similar to daily weight gain. The results are also similar to the findings of Meseret *et al*. (2011a).

3.5.4 Feed conversion ratio

Pullets offered T_4 had higher ($p<0.05$) FCR compared to those offered T_1-T_3 (Table 10). In cockerels, FCR was similar across all treatments, which is similar to the findings by Manhique *et al.* (2017) and Meseret *et al*. (2011b) in KIIC and commercial layers respectively. This may be due to well-developed GIT that made the diet with high level of mature GPJP to be utilized efficiently. The findings in pullets are also similar to the findings by Meseret *et al*. (2011a) who reported that 300 g/Kg of GPJP inclusion in broiler diets had lowest feed conversion efficiency as compared to 0-200g/Kg levels of inclusion. This could be as a result of negative effects of high non-starch polysaccharides (fibre) in the pods on nutrient digestibility as reported by Manhique *et al.* (2017) that led to reduced feed efficiency. It is also observed that in cockerels, FCR was lower as compared to pullets. The observation by Manhique e*t al.* (2017) that improved IC have better adaptation to fibre intake and consequently better nutrient utilization was well manifested in cockerels. It is also notable that pullets were undergoing reproductive physiological development during the same period as cockerels, which could have served as a stressor and affected their response to the dietary treatments.

3.5.5 Carcass evaluation

Diets T_4 lowered DCW, EW, BW and LW than T_1 in both pullets and cockerels. Meseret *et al.* (2011a) reported that broilers offered diets with 10% GPJP inclusion yielded heavier drumstick compared to 30%. Carcass yield recorded in this study gave contradicting results compared to the findings of Meseret *et al.* (2011a) and Abdullah *et al.* (2010) who reported no effect in dressing percentages, carcass cut and organ weight in chicken offered different levels of prosopis in the diets. A similar trend was observed in dressing percentages, carcass cut and organ weight in cockerels and EW, BW and LW in pullets.

The results for CDW yields were lower than observation by Meseret *et al*. (2011a), but higher than observation by Kingori *et al.* (2010a). The yields of different carcass parts are directly linked to the effect of diets on feed intake and weight gain. The observation made for different carcass parts could be due to effects of feed on dry matter intake, FCR and weight gain. T_4 apparently lowered feed intake and weight gain as compared to lower levels of GPJP inclusion.

3.5.6 Ultimate pH and water holding capacity

There was no effect of diets on cockerel breast meat with the Ultimate pH (pHu) values ranging between 5.7 to 6.1 that was similar to 5.8 to 5.9 for broiler breast meat reported by Qiao *et al*. (2001). T_1 to T_4 had no effect on drumstick meat ultimate pH for both cockerels and pullets. These results are similar to the pHu values of 5.53 to 5.55 reported by Al-Marzooqi *et al*. (2015) where inclusion of Prosopis pods at 0-15% had no effects on pH in broiler meat. In chicken pHu has been determined by the amount of glycogen stored in the muscles after slaughter (Le Bihan-Duval *et al.*, 2008). Since the highest glycogen content produces meat with the lowest pH values (Guardia *et al.*, 2014), the results from this study indicate that carbohydrate metabolism across the diets were similar. Water holding capacity (WHC) is one of the factors that consumers use to judge the quality of meat (Tougan *et al*., 2013) and is also used to describe the ability of meat to maintain water within the fibers (Fennema, 1990). Cockerel and pullet meat lost similar ($P>0.05$) amount of water on the 2^{nd} and 7^{th} day except T_4 in cockerels at the 2^{nd} day that lost less water compared to the other treatments. On the 14^{th} day, T_4 lost more than T_1 in both cockerels and pullets. Water holding capacity is affected by the protein and amino acid profile in the diet (Marta *et al*., 2016) which is associated with binding water molecules (Young *et al*., 2004) and thereby enhancing the WHC in the meat. The diets had relatively similar CP ranging about 22.09-23.04 (Table 4) and probably the protein in the diet was available across all the treatments for the birds and therefore may be associated with the similar WHC of meat. Qiaofen and Da-Wen (2008) reported that the protein and amino acid profile in the meat has major influence on WHC.

3.5.7 Meat sensory evaluation

Diets had no effect on the cockerel thigh meat sample juiciness, taste and texture. The results are similar with the finding of Meseret *et al*. (2012) where broiler meat had similar juiciness, tenderness, flavor and overall acceptance when similar levels of GPJP were included in the diet. Similar results were reported by Al-Marzooqi *et al*. (2015) with up to 15% levels of Prosopis pods in the diet. According to Baracho *et al*. (2006), consumers expect meat to be soft, tasty and with an appealing colour. The findings of this study show that increasing the proportion of GPJP up to 30% in the diets has no effect on sensory attributes considered by consumers. In the study by Meseret *et al*. (2012), broiler meat had similar chemical composition across the treatments. This suggests that levels of GPJP in this study had similar effect on growth and muscle formation. Results indicate there was a difference in general acceptability (GA) of cockerel thigh samples with diets accounting for a 6.9% difference on GA. Meat from birds offered T_4 were less accepted at 8.56% and 11.07% when compared with T_1 (0%) and T2 (10%) respectively. This may be attributed to appearance and juiciness.

Pullet thigh meat from T_1 had higher percentage values for appearance, juiciness, taste and texture values than samples from the other dietary treatments. The results are contrary to the findings by Meseret *et al*. (2012) who reported that the inclusion of prosopis pods in diets of broilers at similar levels as in this study had no effect on meat quality. This may be due to better-feed conversion efficiency of birds that were offered T_1 as reported in section 3.5.4 and also due to different types of bird used. This indicates that as the percentage of GPJP inclusion increased, consumers tended to have a lower preference because of the appearance, juiciness, taste, and texture differences. This can be attributed to the high CF and anti-nutritive factors resulting from increasing percentage of inclusion of prosopis pods in the diet. The high fibre could be associated with inefficient feed conversion that consequently affected the available nutrients like fatty acids and protein. These nutrients are important in improving the chemical composition of meat (Meseret *et al.*, 2012). Anti-nutritive factors at high levels of GPJP inclusion could also lead to inaccessibility of nutrients by reducing the action of enzymes. Also, as the levels of GPJP increased, lower values of pH were observed (Table 3.5) whose effect on meat colour, and dryness is not in congruence to what was reported in broiler meat (Alnahhas *et al.*, 2014), an indication that the variation could be as a result of factors contributed by prosopis pods in the diet. The high CF in T_4 maybe the reason for low carbohydrate metabolism that was reported to be associated with darker meat in poultry (Marta *et al.*, 2016). Also, this may be due to the fact that pullets' thigh had a lower ultimate pH (section 3.5.6.) that reduced the WHC and consequently affected the meat characteristics desired by the consumers.

Samples from birds offered T_1 had higher scores in terms of appearance, juiciness and taste, however, there was no difference in the GA of the pullet thigh meat. This could be attributed to tenderness, which was similar in both T_1 and $T_{2.}$ Increasing level of Prosopis pods in the diet had similar effects on appearance, juiciness, taste and texture in breast meat from cockerels. The results for breast meat and thigh meat were similar, which are in agreement with the findings of Meseret *et al*. (2011a) and Al-Marzooqi *et al*. (2015). The pH values were also within the range (5.7 - 6.1) reported in broiler breast meat by Alnahhas *et al*. (2014) when offered GPJP which may explain the similarity in appearance, juiciness, taste and texture. The results for general acceptability were similar in all treatments in cockerels' breast meat.

3.5.8 Cost of feeding

Diets T_3 and T_4 had the least feeding cost per weight gain in pullets and cockerels respectively. Among the two diets the inclusion of 20% GPJP gave the least cost feed and did not affect biological performance in terms of feed intake and weight gain for both pullets and cockerels which is similar to findings on broilers when fed on 20% GPJP (Meseret *et al.,* 2011a). The results for pullets are at variance with the observation in cockerels where T_4 pullets had the least cost than T_1-$T_{3.}$ These results are in agreement with the effect that T_4 had lower feed intake, FCR and weight gain than T_{1}-T_3.

The observation maybe as a result of dietary fibre which was relatively higher as compared to the study on substitution of maize with GPJP (Chapter 4) and this was an indication of lower cost of the feed ingredient that supplied energy and protein for growth and higher levels of GPJP resulting in higher fibre in the diets.

3.5.9 Conclusions

i. Replacing grower diet with up to 20% prosopis pods improved feed intake and weight gain in both cockerel and pullets and feed conversion ratio in pullets.
ii. Replacing grower diet with 20% prosopis pods had similar breast and leg weights as in diet without prosopis pods in cockerels, while 30 and 10% had similar breast and leg weights as in control diet in pullets

iii. Replacing grower diet with 30% prosopis pods resulted in meat with lower drip loss at 14^{th} day as compared to control diet while replacing a grower diet with 0 to 30% prosopis pods resulted in similar sensorial scores in cockerel thigh and breast in all sensory attributes.

iv. Replacing grower diet at 20 and 30% with prosopis pods was the least cost diet for pullets and cockerels respectively.

CHAPTER FOUR

EFFECT OF SUBSTITUTION OF MAIZE WITH VARYING LEVELS OF PROSOPIS PODS IN GROWERS DIETS ON PERFORMANCE OF IMPROVED INDIGENOUS CHICKEN

4.1 Abstract

Maize as an energy source in non-ruminant feeding faces a number of challenges. The use of maize is unreliable due to competion for food and biofuel production. Prosopis pods as an emerging livestock feed ingredient.that can substitute maize as an energy source in improved grower indigenous chickens diets in kenya. The objectives were to determine the effects of different substitution levels of maize with prosopis pods in improved indigenous chicken grower diets on performance and carcass quality. A feeding trial was run for a period of 11 weeks using 8 weeks old, 96 improved indigenous chickens. Experimental diets were formulated by replacing maize in the diet with prosopis pods at 0% (T_1), 10% (T_2), 20% (T_3) and 30% (T_4). A completely randomized design (CRD) was used with four cockerels and four pullets per treatment in separate cages replicated three times. Feed intake and weight gains were monitored for eleven weeks and used to calculate feed conversion ratio (FCR). Two birds from each pen were slaughtered for carcass evaluation. Results showed that feed intake, weight gain and final live weight (FLW) were similar for diets diet with 0 to 20% level in cockerels. In pullets, diets with 10% to 30% levels had similar effect on feed intake but diet with 0 to 30% levels had similar effects on weight gain and LWC. Pullets offered diet with 30% level had significantly lower ($p<0.05$) FLW (1.49 kg) than in diet with 0 to 20% levels, Feed conversion ratio was similar across all treatments in both pullets and cockerels. Results for diets with 0 to 20% levels and diets with 0 to 10% levels were similar but significantly higher than diet with 30% level and 20 to 30% levels for BW and LW respectively in cockerels. diet with 10% level was the least cost feeds per unit of weight gain at Kenya Shillings (KES) 354.02 and KES 294.28 in pullets and cockerels respectively. The study recommended that 20% of prosopis pods could substitute maize ingredient in improved IC grower diets to achieve similar FI, weight and FCR to diets without prosopis pods at a lower cost. The pods can enable sustainable and reliable supply of an energy feed ingredient for improved grower IC and reduce overreliance on conventional livestock feed ingredients thereby reducing of feed costs.

Key words: indigenous chicken, carcass quality, *Prosopis juliflora*

4.2 Introduction

Poultry production in Kenya is constrained by many factors, feed being the major challenge (King'ori *et al.,* 2010a; Meseret *et al.,* 2011). The main source of energy in poultry diets is cereals (AL-Marzooqi *et al.,* 2015) of which maize is the most commonly used in Kenya. There are challenges faced in maize production and utilization. There is diminishing land size through subdivision and conversion of agricultural land into real estate development. The climatic change and emerging pests and diseases such as African army worm and necrotic disease continues to reduce maize production per unit of land and further leads to farmers diversifying to others crops and farming activities. The staple food for Kenyans is maize thus creating competition between humans and poultry which eventually lead to exorbitant feed prices (Yusuf *et al.,* 2016). All these challenges reduce the available grains for chicken and other non-ruminants. It is therefore important to look for alternative energy sources to address the current trend. Feed accounts for 60-80% of the total cost of poultry production (Mukhtar, 2012) therefore for continued poultry production, sustainable and affordable supply of feed is paramount. This may be possible by using locally available feedstuffs like mature Prosopis pods that are currently underutilized (Sawe *et al*., 1997).

Meseret *et al*. (2011a), AL-Marzooqi *et al*. (2015), Odero-Waitituh *et al.* (2016) and Yusuf *et al.* (2016) incorporated prosopis pods in broiler diets at 20% with positive effects on growth rate. Meseret *et al.* (2011b) reported good performance in layers, Manhique *et al*. (2017) reported that 10% of GPJP in layers diet improved egg quality while Haščík *et al.* (2011) reported improved sensorial attributes in meat from broilers fed on prosopis pods-based diets. Prosopis pods can be used to supply both crude protein and energy in compounding feeds for poultry. This study was therefore conducted to determine the effects of partial replacement of maize with GPJP in KIIC grower diet on performance of pullets and cockerels.

4.3 Materials and methods

4.3.1 Study site

The study was conducted at Kenya Agricultural and Livestock Research Organization (KALRO) Non-Ruminant Institute (NRI), Naivasha. The station is 100 km west of Nairobi at an altitude of 1900 m above sea level (asl) and has a bimodal rainfall pattern characterised by long rains from April to June and short showers from October to December, with an annual mean of 620 mm. The average day and night temperatures are 26°C and 8°C respectively and a relative humidity range between 60 and 75%. The natural vegetation is predominantly star grass (*Cynodon plectostachyus*) with scattered tall Acacia trees (*Acacia xanthophloea*). Soil is volcanic in origin, alkaline (p H 7.4), dark, sodic and deep (Herrero *et al.*, 2010).

4.3.2 Experimental chicken

The study used 96, 8 weeks-old grower KIIC that were randomly allocated to four diets with each treatment having 8 birds (4 pullets and 4 cockerels) replicated 3 times. Pullets and cockerels were put is separate cages. The experimental birds were put in single-tier cages placed on the floor with wood shavings litter. This improved indigenous chicken has been bred from a range of IC in Kenya by KALRO. The chicks were hatched from the Non-Ruminant Research (NRI) and experimental birds selected from this flock at eight weeks old. A routine vaccination program to control diseases was adopted for the study as shown in Appendix I. Before commencing feeding trials, experimental pens, waterers and feeders were thoroughly cleaned, disinfected and sprayed against external parasites.

4.3.3 Ingredients used in ration formulation

Ingredients used in ration formulation and their chemical composition are presented in Table 4.1. Dry mature prosopis pods were obtained from Marigat Sub County in Baringo County in the dry month of February. Marigat is located at latitude 0^0 20’N and longitude 35^0 57’E Kenya (FAO, 1992). It is about 1500m above sea level with a mean annual rainfall of 600-800mm with weak bimodal peaks recorded from March to May and June to August. Soils are mainly clay loams with alluvial deposits and contain high levels of P, K, Ca and Mg and low levels of N and C. They range from acidic to slightly alkaline (Mwangi and Swallow, 2008). The pods were collected from the ground after the trees were shaken for the pods to drop. Spoilt and mouldy pods were discarded and clean pods were put in gunny bags and transported to Josiche Feed Millers in Nakuru town where they were milled to pass through a 5mm sieve according to the procedure by (Choge *et al.*, 2006). The mature GPJP were then used in the formulation of the experimental diets fed at different inclusion levels in the feeding trial. The other ingredients were sourced from the market, ground and a mixer used to mix the various ingredients.

4.3.4 Dietary treatments

Dietary treatments were formulated to contain 0, 100, 200 and 300g mature GPJP for a kilogram of T_1, T_2, T_3 and T_4 respectively (Table 4.1). The treatments were iso-nitrogenous and iso-caloric. Metabolizable energy (ME) was determined indirectly according to the method of Wiseman (1987) as follows

ME (Kcal/kg DM) = 3951 + 54.4 EE - 88.7 CF - 40.8 Ash

4.3.5 Chemical analyses of ingredients

Feed samples were dried and ground to pass through a 1mm screen using a Wiley mill. The samples were then analyzed for DM, CP, EE, CF and ash while calcium and phosphorus were analyzed using atomic absorption spectrophotometry using the methods of AOAC (1990). nitrogen free extract (NFE) was determined as 100 – (% moisture +% CP +% EE +% CF +% ash).

4.3.6 Feeding trial

A completely randomized design (CRD) was used with 8 growers per treatment (4 pullets and 4 cockerels put in separate pens) replicated 3 times. Free access to feed and clean water was allowed throughout the experimental period.

The birds were fed on commercial indigenous feeds from day old to before commencement of the experiment. All experimental birds were given a one-week adaptation period to the diets before data collection, after which daily feed intake (feed offered minus feed refusals from 0700-1800 hrs) was measured and recorded. A feed sample was preserved for chemical analyses in the laboratory. Mean live weight gain for each experimental unit was measured using the mean pen live weight for a given period of time. Weight gain was monitored by weighing the birds weekly at 0900 hours before morning feed from the 10^{th} to 20^{th} week of age. Weekly feed conversion ratio (FCR) per bird was calculated as the ratio of feed consumed to the body weight gain.

4.3.7 Carcass evaluation

During the 20^{th} week, two birds from each pen were randomly selected and fasted for 12 hours with access to drinking water. They were weighed and slaughtered by cutting individual bird’s neck at the throat and bleeding for 3 minutes, before manual de-feathering after scalding at 60-70^{o}C and dissected into various cuts. Carcass measurements included pre-slaughter live weight, cold dressed weight and prime cuts (breast, legs (drumstick and thigh) were recorded. Dressing percentage was calculated as a ratio of carcass weight to pre-slaughter live weight.

Table 4.1 Ingredients and chemical composition of the experiment two diets

	Treatments			
Ingredients, g/Kg	**T_1**	**T_2**	**T_3**	**T_4**
GPJP	0.00	64.00	115.20	157.40
Maize	640.00	576.00	524.80	482.60
Fish meal	75.00	75.00	75.00	75.00
Soy bean	245.00	245.0	245.00	245.00
Vegetable oil	25.00	25.00	25.00	25.00
DCP	6.50	6.50	6.50	6.50
Iodized salt	5.00	5.00	5.00	5.00
Vitamin premix*	3.50	3.50	3.50	3.50
Total	1000.00	1000.00	1000.00	1000.00
Chemical composition, g/Kg				
DM	894.00	898.00	909.00	906.00
CP	234.00	233.90	233.40	229.70
EE	86.10	81.30	78.10	70.60
CF	45.90	53.60	55.90	65.40
Ash	78.00	81.00	82.00	82.50
NFE	453.60	447.00	456.30	456.70
Ca	10.10	9.70	9.90	9.60
P	4.50	4.60	4.40	4.90
ME (MJ/Kg DM)	13.70	13.47	13.41	13.07

T_1 = diet containing 0% GPJP substituting maize in grower diet; T_2 = diet containing 10% GPJP substituting maize in grower diet; T_3 = diet containing 30% GPJP substituting maize in grower diet; T_4 = diet containing 30% GPJP substituting maize in grower diet; GPJP = ground *prosopis juliflora* pods; DCP-dicalcium phosphate; CP-crude protein; ME-metabolizable energy; CF- crude fibre.

*Vitamin premix to provide the following per kg of diet: Vitamin A, 10,000 IU; Vitamin D_3, 2000 IU, Vitamin E, 5 mg; Vitamin K, 2 mg; Riboflavin, 4.2 mg; Nicotinic acid, 20 mg; Vitamin B_{12}, 0.01mg; Pantothenic acid, 5 mg; Folic acid, 0.5 mg; Choline, 3 mg; Mg, 56 mg; Fe, 20 mg; Cu, 10 mg; Zn, 50 mg; Co, 125 mg; Iodine, 0.08 mg.

4.3.8 Cost of feeding

Cost of feeding per unit of weight gain in diets containing GPJP was calculated from total feed intake in kilograms, feed cost per kilogram in Kenya shillings (KES) and total live weight change in kilograms for the entire 77 days experimental period. GPJP was costed based on collection and, transportation fee from Marigat, Baringo County to Nakuru and costs for milling.

4.3.9 Statistical model and data analyses

All data were subjected to analysis of variance (ANOVA) using the PROC GLM (SAS, 2002) and means separated by Tukey's test.

The following statistical model for feed intake, daily gain, feed conversion ratio and carcass weight was adopted. The birds were randomly assigned to the four dietary treatments. Each treatment was replicated three times with four pullets and four cockerels per treatment. Initial live weight was used as covariate in the analysis.

$Y_{ij} = \mu + T_i + E_i$;

where;

Y_{ij} - is the observation of the i^{th} treatment

μ - is the overall population mean (for cockerels and pullets)

T_i -is the i^{th} treatment factor (i = 1…4)

E_{ij} - is the random error effect

4.4 Results

4.4.1 Effect of replacing maize with prosopis pods in pullets

Feed intake, weight gain, feed conversion ratio, final live weight and live weight changes in pullets are presented in Table 4.2. Feed intake was significantly ($p<0.05$) reduced in pullets offered T_2 and T_4 compared to T_1. There was no difference ($p>0.05$) in body weight gain, LWC and FCR in pullets. Pullets offered T_4 had lower FLW as compared to other treatments.

Table 4.2 Effect of replacing maize with prosopis pods in grower diets in pullets

Parameters	Treatments				SEM
	T_1	T_2	T_3	T_4	
Initial live weight (g/bird)	668.75	658.75	664.17	690.83	17.24
Average feed intake (g/day)	65.66^a	61.22^b	62.96^{ab}	60.13^b	1.08
Average daily gain (g/day)	11.89	11.50	11.93	10.41	0.52
FCR (g feed/g weight gain)	5.49	5.24	5.39	5.91	0.51
FLW (g/bird)	1584.15^a	1544.52^a	1583.04^a	1492.37^b	24.41
LWC (g/bird)	915.40	885.77	918.87	801.54	23.66

^{abc} means within a row with different superscripts differ significantly ($P<0.05$); GPJP = Ground *Prosopis juliflora* pod; T_1 = diet containing 0% GPJP substituting maize in grower diet; T_2 = diet containing 10% GPJP substituting maize in grower diet; T_3 = diet containing 30% GPJP substituting maize in grower diet; T_4 = diet containing 30% GPJP substituting maize in grower diet

4.4.2 Effect of replacing maize with prosopis pods in cockerels

Feed intake, weight gain, feed conversion ratio, final live weight and live weight changes in cockerels are presented in Table 4.3. There was a lower feed intake, daily weight gain, LWC and FLW ($p<0.05$) in cockerels offered T_4 than those on T_1 and T_2 diets though this did not affect the FCR which was similar across the treatments.

Table 4.3 Effect of replacing maize with prosopis pods in grower diets in cockerels

Parameters	Treatments				SEM
	T_1	T_2	T_3	T_4	
Initial Live weight (g)	792.92	773.75	823.75	851.67	19.59
Average feed intake (g/day)	87.85^{a}	87.50^{a}	86.40^{ab}	82.55^{b}	1.36
Average daily gain (g/day)	19.75^{a}	19.77^{a}	19.08^{ab}	17.45^{b}	0.66
FCR (g feed/g weight gain)	4.27	4.19	4.58	5.22	0.71
FLW (g/bird)	2313.93^{a}	2296.72^{a}	2293.56^{ab}	2195.47^{b}	39.01
LWC (g/bird)	1521.01^{a}	1522.97^{a}	1469.81^{ab}	1343.80^{b}	34.66

^{abc} means within a row with different superscripts differ significantly (P<0.05); GPJP = Ground *Prosopis juliflora* pod; T_1 = diet containing 0% GPJP substituting maize in grower diet; T_2 = diet containing 10% GPJP substituting maize in grower diet; T_3 = diet containing 30% GPJP substituting maize in grower diet; T_4 = diet containing 30% GPJP substituting maize in grower diet

4.4.3 Carcass evaluation

Carcass weight for pullets and cockerels are presented in Table 4.4. Cockerels offered T4 had the lowest (p<0.05) yields of DCW, EW and BW compared to yields form in T_1-T_3. Diets T_1 and T_2 had similar leg weight. In pullets, diets T_4 had significantly (p<0.05) lower DCW, EW and BW yields than T_1. All treatments had similar effects on leg weight in pullets.

Table 4.4 Effect of replacing maize with prosopis pods in grower diets on carcass weights in pullets and cockerels

	Treatments				SEM
Cockerel	T_1	T_2	T_3	T_4	
PSW (g)	2236.19	2234.69	2237.87	2256.94	72.34
DCW(g)	2025.29^{a}	2002.23^{a}	1993.63^{b}	1984.56^{c}	10.18
Dressing%	90.61	89.58	89.12	88.71	0.46
EW (g)	1900.09^{a}	1878.26^{a}	1857.88^{b}	1851.14^{c}	12.96
Eviscerated%	84.97	84.05	83.02	82.02	0.57
BW (g)	318.77^{a}	313.14^{a}	309.17^{ab}	307.26^{b}	7.52
LW (g)	540.68^{a}	558.84^{a}	521.56^{b}	535.59^{b}	8.41
Pullet					
PSW (g)	1469.52	1469.13	1469.55	1467.71	63.54
DCW(g)	1320.17^{a}	1318.58^{b}	1302.34^{b}	1297.70^{c}	8.32
Dressing%	89.80	89.75	88.61	88.28	0.57
EW (g)	1208.97^{a}	1232.89^{ab}	1199.15^{bc}	1200.29^{c}	11.11
Eviscerated%	82.27	83.92	81.60	81.78	0.77
BW (g)	244.20^{a}	240.13^{ab}	237.34^{ab}	227.99^{b}	6.02
LW (g)	288.96	306.11	306.36	312.72	7.77

^{abc} means within a row with different superscripts differ significantly (P<0.05); T_1 = diet containing 0% GPJP substituting maize in grower diet; T_2 = diet containing 10% GPJP substituting maize in grower diet; T_3 = diet containing 30% GPJP substituting maize in grower diet; T_4 = diet containing 30% GPJP substituting maize in grower diet; GPJP = ground *prosopis juliflora* pods

4.4.4 Effect of substituting maize with prosopis pods on feeding cost per weight gain

The cost of feeding per unit of weight gain was determined from total feed consumed and weight gained for both pullets and cockerels as presented in Table 4.5 and 4.6 respectively. Substitution of 100g/Kg GPJP with maize (T_2) in both pullets and cockerels offered the least cost per weight gain.

Table 4.5 Effect of substituting maize with prosopis pods in grower diets on cost of feeding in pullets

Parameters	Treatments			
	T_1	T_2	T_3	T_4
a) Total feed intake kg/bird	5.05	4.71	5.08	4.63
b) Cost/kg of feed KES	67.81	66.52	65.50	64.66
c) Total feed cost (a×b), KES	342.83	313.57	332.67	299.37
d) Weight gained (kg)	0.92	0.89	0.92	0.80
e) FCR (a/d)	5.49	5.24	5.39	5.91
f) Feed cost/kg of weight gain (c/d), KES/kg	374.52	354.02	362.04	373.50

KES = Kenya shillings; T_1 = diet containing 0% GPJP substituting maize in grower diet; T_2 = diet containing 10% GPJP substituting maize in grower diet; T_3 = diet containing 30% GPJP substituting maize in grower diet; T_4 = diet containing 30% GPJP substituting maize in grower diet; GPJP = ground *prosopis juliflora* pods

Table 4.6 Effect of substituting maize with prosopis pods in grower diets on cost of feeding in cockerels

Parameters	Treatments			
	T_1	T_2	T_3	T_4
a) Total feed intake kg/bird	6.76	6.74	6.65	6.36
b) Cost/kg of feed KES	67.81	66.52	65.50	64.66
c) Total feed cost (a×b), KES	458.69	448.18	435.76	411.01
d) Weight gained (kg)	1.58	1.61	1.45	1.22
e) FCR (a/d)	4.27	4.19	4.58	5.22
f) Feed cost/kg of weight gain (c/d), KES/kg	301.57	294.28	296.47	305.85

KES = Kenya shillings; T_1 = diet containing 0% GPJP substituting maize in grower diet; T_2 = diet containing 10% GPJP substituting maize in grower diet; T_3 = diet containing 30% GPJP substituting maize in grower diet; T_4 = diet containing 30% GPJP substituting maize in grower diet; GPJP = ground *prosopis juliflora* pods

4.5 Discussion

4.5.1 Feed intake

Feed intake results in grower KIIC are in agreement with AL-Beitawi (2010) who reported that maize could be replaced at 20% with prosopis pods in broiler diets but Odero-Waitituh *et al.* (2016) reported a lower level at 10% in broiler diets. Inclusion of enzymes in broiler diets resulted in maize replacement up to 20% (Choudhary *et al.*, 2005), but this is the optimum level found in this study without the use of enzymes. This is probably because the improved ICs are able to utilize non-starch polysaccharide (fibre) better than broilers (Manhique *et al.*, 2017) and also may be due to the fact that broiler GIT is less developed than that of KIIC. The amount of mature GPJP in the diets was relatively lower in this experiment as compared to the previous study (in Chapter 3), thereby causing relatively higher feed intake. Omar (2000), reported an improved feed intake with increased fibre in the diet and this is because dietary fibre is important in proper development and physiology of GIT (Mateos *et al*., 2012). The birds were also in the growth phase that required supply of nutrients for both growth and maintenance requirements.

Feed intake was significantly ($p<0.05$) reduced by T_2 and T_4 diets compared to T_1 in pullets while in cockerels, T_4 significantly ($p<0.05$) depressed feed intake compared to T_1 and $T_{2.}$ These results are similar to the effects of feeding chicken complete diet when replaced with graded levels of GPJP (Chapter 3). The results of feed intake for pullets and cockerels are in agreement with findings of Odero-Waitituh *et al.* (2016), Meseret *et al*. (2011a) and AL-Beitawi *et al*. (2010) who reported that up to 20% GPJP inclusion level in broiler diets did not reduce the feed intake. Meseret *et al*. (2011b) also reported similar effect of reduced feed intake as GPJP levels increased in commercial layers diets. Diet T_4 had lower ($p<0.05$) feed intake as compared to T_1 and T_2 but similar to $T_{3.}$

4.5.2 Weight gain, final live weight change and live weight change

Weight gain in pullets was not affected by GPJP inclusion in the diet while in cockerels, T_4 significantly lowered ($p<0.05$) weight gain compared to T_1 and $T_{2.}$ Diets T_1–T_3 had similar effect on weight gain and FLW which is in agreement with the findings of Odero-Waitituh (2015) who reported similar results in broilers fed on diets with similar substitution levels of maize with GPJP. However, in this study, weight gain and FLW of birds offered T_3 and T_4 were similar. This is at variance with the results of Odero-Waitituh (2015) who reported that in broilers on 30% level of substitution had significantly ($P<0.05$) reduced weight gain and

FLW as compared to T_3. At 20% maize substitution with GPJP, AL-Beitawi *et al*. (2010) reported that broilers had the highest weight gain and FLW. This suggests that the mature GIT of improved IC may utilize nutrients available in diets with relatively higher levels of GPJP to attain better weight gain than broilers that take a shorter time to reach maturity.

The findings on substitution of grower diet with graded levels of GPJP (Chapter 3) and replacing maize with graded levels of GPJP (Chapter 4) indicate similar effects on FLW in both pullets and cockerels offered T_1-T_3 while T_4 significantly ($p<0.05$) reduced FLW. This suggests that IC are able to tolerate increased levels of CF and tannins compared to broilers. Indigenous chickens also had better performance at increased levels of prosopis pods in the diets at 20% inclusion level (Meseret *et al*., 2011a).

Diets T_1 to T_4 had similar effect ($p>0.05$) on live weight change and weight gain in pullets despite T_4 having significantly less ($p<0.05$) feed intake as compare to T_1-T_3. This suggests that pullets had better nutrient utilization of the nutrients consumed. The findings in pullets are at a variance to those in cockerels where T_4 depressed both feed intake and weight gain. This may be due to higher feed intake in cockerels compared to pullets, which may have negatively influenced intake due to higher fibre intake and consequently lowering the weight gain.

4.5.3 Effect on feed conversion ratio

Diet T_1 to T_4 had similar FCR in pullets and cockerels. Results of the study by Odero-Waitituh (2015) also reported similarities in broilers' FCR when maize was replaced at the same levels as in this study. However, AL-Beitawi *et al*. (2010) reported that broilers receiving 20% of prosopis pods diet had the lowest FCR. These results are in agreement with findings on feed intake and weight gain that may probably be attributed to adaptation of improved IC as reported by Manhique *et al*. (2017) and also the increased fibre in the diet had been reported to improve feed intake (Omar, 2000) due to the positive effect of fibre on development on GIT.

4.5.4 Carcass evaluation

The cockerels that were offered T_4 had the lowest ($p<0.05$) yields for DCW, EW and BW compared to yields from the other treatments. Diets T_1 and T_2 had similar weights for DCW and EW while T_1 to T_3 had similar effects on BW. In pullets, T_4 significantly lowered ($p<0.05$) DCW and EW yields, but T_2 and T_3 had similar yields. The birds on diets T_1 to T_3

had similar BW but T_4 lowered ($p<0.05$) BW. However, treatments had no effect on LW. These findings are not in congruence with the observation by Yusuf *et al*. (2008), AL-Beitawi *et al.* (2010), Meseret *et al.* (2011a) Odero-Waitituh (2015) who reported that 30% prosopis pods inclusion level in broilers diets had no effect on in dressing percentage. This could be attributed to the differences in deposition of weight and fat in different carcass parts between broilers and indigenous chicken.

4.5.5 Cost and benefit of feeding Prosopis pods

Diets T_1-T_3 had similar effect on feed intake, weight gain, FCR and FLW (Table 4.3 and 4.4) but T_2 resulted in lowest feeding costs per weight gain in both pullets (Table 4.6) and cockerels (Table 4.7). This suggests that T_3 had similar biological performance as compared to T_1 but provided a cheaper alternative for the same biological performance in both pullets and cockerels. This is at variance with a study by Meseret *et al*. (2011a) involving inclusion of GPJP in broiler diets at similar levels as this study where up to 20% level, broilers did not perform better as compared to 0%, but the cost of feeding per weight gain was lower. Further findings report that inclusion of GPJP in improved IC diets at 20 and 30% (Chapter 3) had the lowest feeding cost per weight gain in pullets and cockerels respectively but 30% had similar performance in terms of feed intake and weight gain as in broiler study (Meseret *et al.,* 2011a).

The observation made is that as a result of the relatively lower amount of fibre in the diet in mature pods replacing maize in the complete diet as compared to mature pods replacing complete diets there was higher cost of feed ingredients in this experiment.

4.5.6 Conclusions

i. Substituting maize up to 20% with prosopis pods improved feed intake and final live weight in both pullets and cockerels and weight gain in cockerels. Substituting maize in grower diets with 10% prosopis pods resulted in similar dressed cold weight, eviscerated weight and leg weight in pullets and up to 20% level for breast weight in cockerels
ii. Substituting maize at 10% with prosopis pods had the lowest feeding cost per unit of weight gain in both pullets and cockerels

CHAPTER FIVE

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 General discussion

Prosopis tree grows freely in Kenya in the semi-arid and arid areas. Uncontrolled feeding has brought negative impact in livestock production whereas research on incorporation of the pods in livestock feed has reported many beneficial effects of prosopis pods. In experiment involving substitution of grower diet with prosopis pods, it is apparent that 20% level did not interfere with feed intake and weight gain. Similarly, FCR was not affected from 0 to 20% level of inclusion. These findings are similar to Meseret *et al*. (2011a) where broilers had similar performance at 0 to 20 % level. Breast and leg weight were also not affected at 20 and 10% levels in pullets and cockerels respectively. Water holding capacity and pH are important in determining the keeping quality of meat. The was no effect on pH at all levels of prosopis pods substitution in pullets and cockerels. Diets T_1 (0%) had the highest water loss than T_4 in both pullets and cockerels. The findings for both pH and WHC indicate the absence of interference in keeping quality of meat in both pullets and cockerels. Sensory analysis results indicated that there was similar performance on cockerel thigh and breast meat receiving pods from 10 to 30% as compared to the control diet. In pullet thigh, texture and general acceptability were similar across all treatments. The use of prosopis pods as an alternative feed ingredient is viable in terms of performance and meat quality. The findings in cost of feeding corroborated the finding in performance where the least cost was KES 344.25 and KES 268.32 in cockerels and pullets respectively at 20% level of substitution.

Maize is the main source of energy in poultry diets. Experiment two was aimed at substituting maize with prosopis pods to determine at what level the birds would perform well at least cost per unit of weight gain. At 20% level, feed intake was similar to control diet while weight gain was similar across all treatments in pullets. In cockerels, 0 to 20% substitution level of maize with prosopis pods had similar performance. This indicated that prosopis pods could substitute maize at 20% without any processing. In carcass weight, up to 20% prosopis pods did not reduce breast weight in pullets and cockerels and also 10% prosopis pods in leg weight in pullets. The cost of feeding per unit of weight gain was lowest in T_2 in both cockerels (KES 294.28) and pullets (KES 354.02). This indicate that maize can be substituted as a viable alternation to provision of energy at 20%.

Studies by Manhique *et al.* (2017) and Meseret *et al*. (2011b) reported that egg quality was improved at 10% inclusion levels of GPJP in layer diets. This study focused on the grower phase of KIIC, which is the foundation stock for layers. From the results, it is concluded that 20% prosopis pods feed may be included in improved grower IC without negatively interfering with performance. Results of the present study demonstrated that cockerel diets may contain up to 20% GPJP.

5.2 Conclusions

This study focused on feeding of grower phase

of KIIC, which has gained popularity in Kenya as chicken of choice for many poultry keepers.:-

i. Prosopis can substitute grower diets and can also substitute maize portion in grower diets up to 20% level without negatively affecting feed intake, weight gain and FCR.
ii. Substituting grower diet and maize ingredient in grower diet at 20% level improved the carcass quality and consumers meat sensory evaluation.
iii. Grower feeds substituted with prosopis pods at 20% have lowest cost per unit of weight gain in both cockerels and pullets. Substituting maize with pods at 20% level also is the lowest cost per unit of weight gain in both cockerels and pullets

This shows that there is potential that can be commercially exploited in prosopis pods as a feed resource to reduce overreliance on grains, cut on production cost and ensure a sustainable feed supply. The use of the prosopis pods will also help improve the feeding of grower indigenous chicken and also reduce on the cost of production in terms of feed costs and also control invasion by reducing the seeds through their utilization as chicken feed.

5.3 Recommendations

From the findings of this study, it is recommended that: -

i. Further studies on handling and processing of pods are recommended. The benefits of such diets maybe further exploited using cheaper methods of treating GPJP such soaking and incorporating enzymes in the diets so as to enhance nutrients bioavailability and reduce feeding costs as well as improve performance of IC.
ii. This and previous studies have clearly reported that feeding chicken with 20% prosopis pods does not interfere with performance on meat attributes. It is recommended that chemical analysis of meat be performed to establish the effect of

prosopis pods-based diets on the chemical analysis of the meat such as amino acid profile.

iii. A study is recommended to determine of effects inclusion of mature ground prosopis pods in grower diets on GIT development and pathological changes.

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APPENDICES

Appendix 1. Indigenous chicken vaccination program

AGE	VACCINE	Mode of administration	Remarks
Day old	Marek's	Subcutaneous	Mainly for commercial hatcheries
Day 10	Gumboro (1st dose)	Drinking water	
Day 18	Gumboro (2nd dose)	Drinking water	
3 weeks	Newcastle disease (1st dose)	Eye drop or drinking water	
3 weeks (in hot spot areas) 6weeks (other areas)	Fowl pox	Wing web stab	
8 weeks	Newcastle disease (2nd dose)	Eye drop or drinking water	
	Fowl typhoid	Intramuscular injection	
18 weeks	Newcastle disease (3rd dose at the point of lay)	Eye drop or drinking water	Repeat after 3 months
19 weeks	De-worming	Drinking water	Repeat after 3 months

Adopted from KALRO Indigenous Chicken Vaccination Program

Appendix 2. Questionnaire for sensory analysis

Sample Number……………………………………………………Name (Optional)…………………………………………………...

Please open the wrapped sample, observe then chew it and rank the sample in the table below with a tick for appearance, juiciness, taste, texture and overall general acceptability.

There are ______samples before you. Kindly evaluate them on the scale given on Appearance, Juiciness, Taste, Texture and General acceptability.

Sample number: ______

Appearance	Too light	|———————|———————|	Too dark
Juiciness	Too dry	|———————|———————|	Very juicy
Taste	Extremely tasteless	|———————|———————|	Extremely tasty
Texture	Extremely soft	|———————|———————|	Extremely tough

10 cm

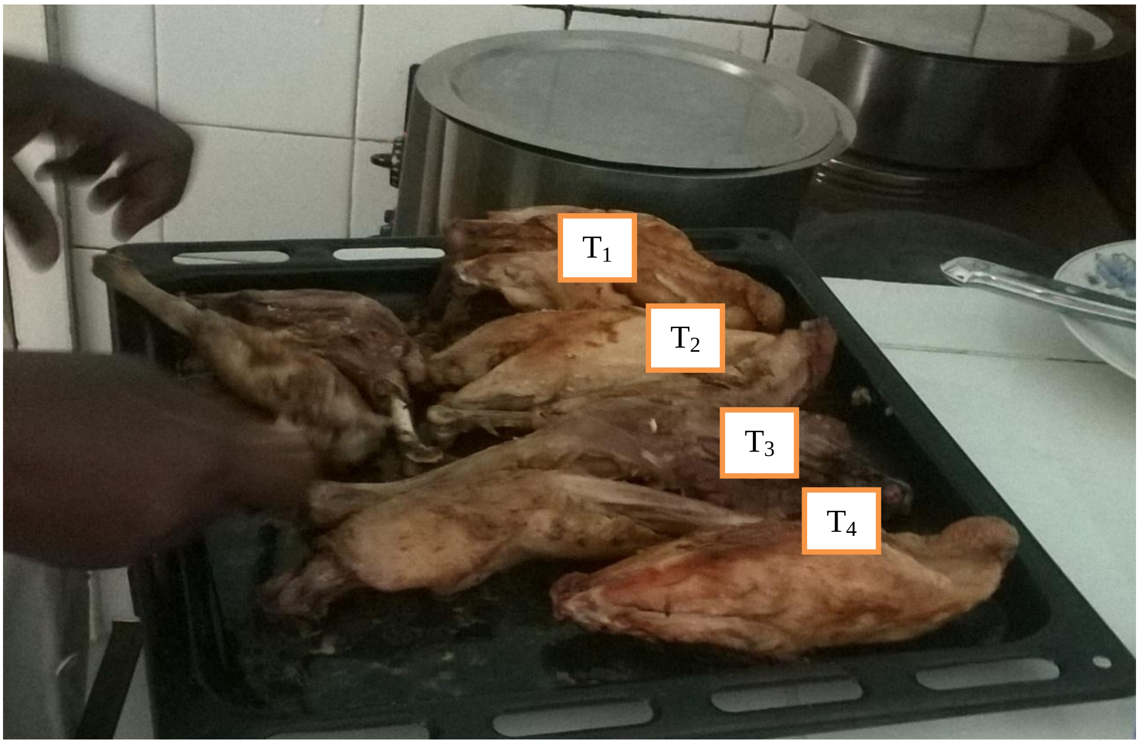
	Like extremely (7)	Like very much (6)	Like moderately (5)	Neither like nor dislike (4)	Dislike moderately (3)	Dislike very much (2)	Dislike extremely (1)
General Acceptability							

Appendix 3. Plate indicating prosopis tree branch with ripe and green pods

Appendix 4. Plate of sensory evaluation facilities at Egerton University

Appendix 5. Plate showing panelists evaluating meat samples

Appendix 6. Plate showing thigh meat samples from across treatments



Appendix 7. Analysis of variance table for feed intake in experiment one pullets

The GLM Procedure

Class Level Information

Class	Levels	Values
DIET	4	1 2 3 4

Number of observations 132

Dependent Variable: AFI

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	5355.340258	765.048608	21.05	<.0001
Error	124	4507.668749	36.352167		
Corrected Total	131	9863.009006			

R-Square	Coeff Var	Root MSE	AFI Mean
0.542972	8.433590	6.029276	67.97306

Source	DF	Type I SS	Mean Square	F Value	Pr > F
DIET	3	755.490394	251.830131	6.93	0.0002
ILW	1	0.257469	0.257469	0.01	0.9331
FLW	1	4374.636934	4374.636934	120.34	<.0001
ADG	1	18.978117	18.978117	0.52	0.4713
FCR	1	205.977344	205.977344	5.67	0.0188

Least Squares Means

DIET	AFI LSMEAN	Standard Error	Pr > |t|
1	70.99017988	1.3104383	<.0001
2	70.56392496	1.3204307	<.0001
3	69.02752301	1.3210872	<.0001
4	61.31062771	1.51298814	<.0001

Tukey's Studentized Range (HSD) Test for AFI

Alpha	0.05
Error Degrees of Freedom	124
Error Mean Square	36.35217
Critical Value of Studentized Range	3.68292
Minimum Significant Difference	3.8655

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	DIET
A	70.990	33	1
A	70.563	33	2
A	69.027	33	3
B	61.310	33	4

Appendix 8. Analysis of variance table for weight gain in experiment one pullets

The GLM Procedure

Class Level Information

Class	Levels	Values
DIET	4	1 2 3 4

Number of observations 132

Dependent Variable: ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	3756.317856	536.616837	60.72	<.0001
Error	124	1095.865837	8.837628		
Corrected Total	131	4852.183693			

R-Square	Coeff Var	Root MSE	ADG Mean
0.774150	24.80399	2.972815	11.45148

Source	DF	Type I SS	Mean Square	F Value	Pr > F
DIET	3	54.008851	18.002950	2.04	0.1121
ILW	1	1.570881	1.570881	0.18	0.6740
FLW	1	2983.785637	2983.785637	337.62	<.0001
AFI	1	7.269514	7.269514	0.82	0.3662
FCR	1	709.682973	709.682973	80.30	<.0001

Least Squares Means

DIET	ADG LSMEAN	Standard Error	Pr > |t|
1	12.9110498	1.1156315	<.0001
2	12.1461683	1.12429662	<.0001
3	11.6634083	1.2244347	<.0001
4	9.0852827	1.2821072	<.0001

Tukey's Studentized Range (HSD) Test for ADG

Alpha	0.05
Error Degrees of Freedom	124
Error Mean Square	8.837628
Critical Value of Studentized Range	3.68292
Minimum Significant Difference	1.9059

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	DIET
A	12.9103	33	1
A	12.1461	33	2
A	11.6634	33	3
B	9.0852	33	4

Appendix 9. Analysis of variance table for feed conversion ratio in experiment one pullets

The GLM Procedure

Class Level Information

Class	Levels	Values
DIET	4	1 2 3 4

Dependent Variable: FCR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	2752.225000	393.175000	33.47	<.0001
Error	124	1456.608099	11.746840		
Corrected Total	131	4208.833099			

R-Square	Coeff Var	Root MSE	FCR Mean
0.653916	41.83155	3.427366	6.010959

Source	DF	Type I SS	Mean Square	F Value	Pr > F
DIET	3	179.435627	59.811876	5.09	0.0023
ILW	1	5.633002	5.633002	0.48	0.4899
FLW	1	1585.093753	1585.093753	134.94	<.0001
DFI	1	38.762872	38.762872	3.30	0.0717
DWG	1	943.299746	943.299746	80.30	<.0001

Least Squares Means

DIET	FCR LSMEAN	Standard Error	Pr > |t|
1	5.50186659	0.15220632	<.0001
2	5.80389085	0.16938068	<.0001
3	5.92387513	0.16159995	<.0001
4	6.81420262	0.18330729	<.0001

Tukey's Studentized Range (HSD) Test for FCR

Alpha	0.05
Error Degrees of Freedom	124
Error Mean Square	11.74684
Critical Value of Studentized Range	3.68292
Minimum Significant Difference	2.1973

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	DIET
A	6.8142	33	4
B	5.9238	33	3
B	5.8038	33	2
B	5.5018	33	1

Appendix 10. Analysis of variance table for breast meat in experiment one pullet

The GLM Procedure

Class Level Information

Class	Levels	Values
DIET	4	1 2 3 4

Number of observations 24

Dependent Variable: BREAST

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	17354.27188	2479.18170	14.38	<.0001
Error	16	2758.22812	172.38926		
Corrected Total	23	20112.50000			

R-Square	Coeff Var	Root MSE	BREAST Mean
0.862860	5.442366	13.12971	241.251

Source	DF	Type I SS	Mean Square	F Value	Pr > F
DIET	3	5945.833333	1981.944444	11.50	0.0003
REP	1	6.250000	6.250000	0.04	0.8514
PSW	1	8463.409449	8463.409449	49.09	<.0001
DW	1	2469.241176	2469.241176	14.32	0.0016
EW	1	469.537919	469.537919	2.72	0.1184

Least Squares Means

DIET	BREASTLSMEAN	Standard Error	Pr > |t|
1	247.061622	7.891200	<.0001
2	232.324994	7.442459	<.0001
3	225.403414	7.374298	<.000
4	260.213789	10.120676	<.0001

Tukey's Studentized Range (HSD) Test for BREAST

Alpha	0.05
Error Degrees of Freedom	16
Error Mean Square	172.3893
Critical Value of Studentized Range	4.04609
Minimum Significant Difference	21.688

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	DIET
A	260.213	6	4
A	247.213	6	1
A B	232.324	6	2
C	225.403	6	3

Appendix 11. Analysis of variance table for feed intake in experiment one cockerels

The GLM Procedure

Class Level Information

Class	Levels	Values
DIET	4	1 2 3 4

Number of observations 132

Dependent Variable: AFI

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	7321.61178	1045.94454	12.32	<.0001
Error	124	10528.55878	84.90773		
Corrected Total	131	17850.17055			

R-Square	Coeff Var	Root MSE	AFI Mean
0.410170	10.01138	9.214539	88.50489

Source	DF	Type I SS	Mean Square	F Value	Pr > F
DIET	3	393.031897	131.010632	1.54	0.2068
ILW	1	20.537270	20.537270	0.24	0.6237
FLW	1	6881.277959	6881.277959	81.04	<.0001
FCR	1	19.056451	19.056451	0.22	0.6365
DWG	1	7.708199	7.708199	0.09	0.7637

Least Squares Means

DIET	AFI LSMEAN	Standard Error	Pr > |t|
1	94.241264	1.8433728	<.0001
2	92.670995	1.8258131	<.0001
3	87.643498	2.1517379	<.0001
4	79.463822	1.8675234	<.0001

Tukey's Studentized Range (HSD) Test for DFI

Alpha	0.05
Error Degrees of Freedom	124
Error Mean Square	84.90773
Critical Value of Studentized Range	3.68292
Minimum Significant Difference	5.9076

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	DIET
A		94.244	33	1
A		92.674	33	2
A		87.643	33	3
	B	79.462	33	4

Appendix 12. Analysis of variance table for weight gain in experiment one cockerels

The GLM Procedure
Class Level Information

Class	Levels	Values
DIET	4	1 2 3 4

Number of observations 132
Dependent Variable: ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	3785.515906	540.787987	23.43	<.0001
Error	124	2861.780782	23.078877		
Corrected Total	131	6647.296688			

R-Square	Coeff Var	Root MSE	ADG Mean
0.569482	25.88663	4.804048	18.70228

Source	DF	Type I SS	Mean Square	F Value	Pr > F
DIET	3	229.138991	76.379664	3.31	0.0224
ILW	1	5.223461	5.223461	0.23	0.6351
FLW	1	2916.320989	2916.320989	126.36	<.0001
AFI	1	6.325054	6.325054	0.27	0.6016
FCR	1	628.507411	628.507411	27.23	<.0001

Least Squares Means

DIET	ADG LSMEAN	Standard Error	Pr > |t|
1	20.6535426	1.2014163	<.0001
2	18.8343965	1.1959914	<.0001
3	19.3706814	1.4075058	<.0001
4	15.9505007	1.2199415	<.0001

Tukey's Studentized Range (HSD) Test for DWG

Alpha	0.05
Error Degrees of Freedom	124
Error Mean Square	23.07888
Critical Value of Studentized Range	3.68292
Minimum Significant Difference	3.0799

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	DIET
A	20.653	33	1
A	19.371	33	3
A B	18.834	33	2
B	15.950	33	4

Appendix 13. Analysis of variance table for feed conversion ratio in experiment one cockerels

The GLM Procedure

Class Level Information

Class	Levels	Values
FEED	4	1 2 3 4

Number of observations 132

Dependent Variable: FCR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	1733.161290	247.594470	3.91	0.0007
Error	124	7861.406409	63.398439		
Corrected Total	131	9594.567699			

R-Square	Coeff Var	Root MSE	FCR Mean
0.180640	123.0983	7.962314	4.756629

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FEED	3	134.110893	44.703631	0.71	0.5507
FLW	1	1342.480058	1342.480058	21.18	<.0001
ILW	1	0.491617	0.491617	0.01	0.9300
DFI	1	68.676131	68.676131	1.08	0.3000
ADG	1	187.402590	187.402590	2.96	0.0881

Least Squares Means

FEED	FCR LSMEAN	Standard Error	Pr > |t|
1	4.57435003	1.52479408	0.0002
2	4.78194086	1.55474278	0.0002
3	4.67543538	1.43223831	<.0001
4	4.9947906	1.66814965	0.0009

Tukey's Studentized Range (HSD) Test for FCR

Alpha	0.05
Error Degrees of Freedom	124
Error Mean Square	63.39844
Critical Value of Studentized Range	3.68292
Minimum Significant Difference	5.1048

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	FEED
A	4. 994	33	4
A	4.781	33	2
A	4.675	33	3
A	4. 574	33	1

Appendix 14. Analysis of variance table for breast sample in experiment one cockerels

The GLM Procedure

Class Level Information

Class	Levels	Values
DIET	4	1 2 3 4

Number of observations 24

Dependent Variable: BREAST

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	32039.32050	4577.04579	23.96	<.0001
Error	16	3056.51284	191.03205		
Corrected Total	23	35095.83333			

R-Square	Coeff Var	Root MSE	BREAST Mean
0.912910	4.562784	13.82143	302.9183

Source	DF	Type I SS	Mean Square	F Value	Pr > F
DIET	3	21154.16667	7051.38889	36.91	<.0001
REP	1	976.56250	976.56250	5.11	0.0380
PSW	1	9301.66975	9301.66975	48.69	<.0001
EW	1	576.29123	576.29123	3.02	0.1016
DCW	1	30.63035	30.63035	0.16	0.6941

Least Squares Means

DIET	BREAST LSMEAN	Standard Error	Pr > |t|
1	321.664970	5.371604	<.0001
2	290.312463	4.934552	<.0001
3	311.857868	5.060529	<.0001
4	287.838194	6.067240	<.0001

Tukey's Studentized Range (HSD) Test for BREAST

Alpha	0.05
Error Degrees of Freedom	16
Error Mean Square	191.0321
Critical Value of Studentized Range	4.04609
Minimum Significant Difference	22.83

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	DIET
A	321.664	6	1
A	311.857	6	3
B	290.312	6	2
C	287.838	6	4

Appendix 15. Analysis of variance table for feed intake in experiment two pullets

The GLM Procedure

Class Level Information

Class	Levels	Values
DIET	4	1 2 3 4

Number of observations 132

Dependent Variable: AFI

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	5355.340258	765.048608	21.05	<.0001
Error	124	4507.668749	36.352167		
Corrected Total	131	9863.009006			

R-Square	Coeff Var	Root MSE	AFI Mean
0.542972	8.433590	6.029276	62.49457

Source	DF	Type I SS	Mean Square	F Value	Pr > F
DIET	3	755.490394	251.830131	6.93	0.0002
ILW	1	0.257469	0.257469	0.01	0.9331
FLW	1	4374.636934	4374.636934	120.34	<.0001
DWG	1	18.978117	18.978117	0.52	0.4713
FCR	1	205.977344	205.977344	5.67	0.0188

Least Squares Means

DIET	AFILSMEAN	Standard Error	Pr > |t|
1	65.66017988	1.0804383	<.0001
2	61.22392496	1.0804307	<.0001
3	62.96312301	1.0810872	<.0001
4	60.13106277	1.08298814	<.0001

Tukey's Studentized Range (HSD) Test for AFI

Alpha	0.05
Error Degrees of Freedom	124
Error Mean Square	36.35217
Critical Value of Studentized Range	3.68292
Minimum Significant Difference	3.8655

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	DIET
A		65.660	33	1
A	B	62.963	33	3
	B	61.223	33	2
	B	60.131	33	4

Appendix 16. Analysis of variance table for weight gain in experiment two pullets

The GLM Procedure

Class Level Information

Class	Levels	Values
FEED	4	1 2 3 4

Number of observations 132

Dependent Variable: ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	4419.127497	631.303928	61.78	<.0001
Error	124	1267.195728	10.219320		
Corrected Total	131	5686.323224			

R-Square	Coeff Var	Root MSE	ADG Mean
0.777150	28.10532	3.196767	11.43799

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FEED	3	55.500285	18.500095	1.81	0.1487
IW	1	6.303639	6.303639	0.62	0.4337
FCR	1	2584.039854	2584.039854	252.86	<.0001
FLW	1	1771.344444	1771.344444	173.33	<.0001
AFI	1	1.939275	1.939275	0.19	0.6639

Least Squares Means

FEED	ADGLSMEAN	Standard Error	Pr > |t|
1	11.8939705	0.5224906	<.0001
2	11.5086824	0.5142694	<.0001
3	11.9345021	0.5234202	<.0001
4	10.4148146	0.5268403	<.0001

Tukey's Studentized Range (HSD) Test for DWG

Alpha	0.05
Error Degrees of Freedom	124
Error Mean Square	10.21932
Critical Value of Studentized Range	3.68292
Minimum Significant Difference	2.0495

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	FEED
A	11.9345	33	3
A	11.8939	33	1
A	11.5086	33	2
A	10.4148	33	4

Appendix 17. Analysis of variance table for feed conversion ratio in experiment two pullets

The GLM Procedure

Class Level Information

Class	Levels	Values
FEED	4	1 2 3 4

Number of observations 132

Dependent Variable: FCR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	4352.501090	621.785870	16.64	<.0001
Error	124	4634.664149	37.376324		
Corrected Total	131	8987.165239			

R-Square	Coeff Var	Root MSE	FCR Mean
0.484302	65.63677	6.113618	5.511818

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FEED	3	250.967590	83.655863	2.24	0.0871
IW	1	34.606825	34.606825	0.93	0.3378
FLW	1	2882.874066	2882.874066	77.13	<.0001
ADG	1	1114.846992	1114.846992	29.83	<.0001
AFI	1	69.205616	69.205616	1.85	0.1761

Least Squares Means

FEED	FCR LSMEAN	Standard Error	Pr > |t|
1	5.4942968	0.5130281	<.0001
2	5.2444606	0.5181148	<.0001
3	5.3949349	0.5102501	<.0001
4	5.9135804	0.5168354	<.0001

Tukey's Studentized Range (HSD) Test for FCR

Alpha	0.05
Error Degrees of Freedom	124
Error Mean Square	37.37632
Critical Value of Studentized Range	3.68292
Minimum Significant Difference	3.9195

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	FEED
A	5.913	33	4
A	5.494	33	1
A	5.394	33	3
A	5.244	33	2

Appendix 18. Analysis of variance table for breast meat in experiment two pullets

The GLM Procedure

Class Level Information

Class	Levels	Values
FEED	4	1 2 3 4

Number of observations 24

Dependent Variable: BREAST

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	6054.971449	864.995921	4.57	0.0057
Error	16	3028.361885	189.272618		
Corrected Total	23	9083.333333			

R-Square	Coeff Var	Root MSE	BREAST Mean
0.666602	5.813087	13.75764	237.4186

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FEED	3	2458.333333	819.444444	4.33	0.0205
REP	1	689.062500	689.062500	3.64	0.0745
PSW	1	2513.632920	2513.632920	13.28	0.0022
EW	1	317.095454	317.095454	1.68	0.2139
DW	1	76.847241	76.847241	0.41	0.5330

Least Squares Means

FEED	BREAST LSMEAN	Standard Error	Pr > |t|
1	244.208357	6.485908	<.0001
2	240.131907	5.730943	<.0001
3	237.343242	5.741466	<.0001
4	227.990861	6.132847	<.0001

Tukey's Studentized Range (HSD) Test for BREAST

Alpha	0.05
Error Degrees of Freedom	16
Error Mean Square	189.2726
Critical Value of Studentized Range	4.04609
Minimum Significant Difference	22.725

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	FEED
A		244.208	6	1
A	B	240.131	6	2
A	B	237.343	6	3
	B	227.990	6	4

Appendix 19. Analysis of variance table for feed intake in experiment two cockerels

The GLM Procedure

Class Level Information

Class	Levels	Values
FEED	4	1 2 3 4

Number of observations

Dependent Variable: AFI

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	9064.69848	1294.95693	23.26	<.0001
Error	124	6904.11193	55.67832		
Corrected Total	131	15968.81041			

R-Square	Coeff Var	Root MSE	AFI Mean
0.567650	7.974200	7.461791	86.07767

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FEED	3	1609.351717	536.450572	9.63	<.0001
FLW	1	6962.686627	6962.686627	125.05	<.0001
ILW	1	254.777824	254.777824	4.58	0.0344
ADG	1	208.041674	208.041674	3.74	0.0555
FCR	1	29.840633	29.840633	0.54	0.4655

Least Squares Means

FEED	AFI LSMEAN	Standard Error	Pr > |t|
1	87.8549960	1.3607848	<.0001
2	87.5032064	1.3606823	<.0001
3	86.4014357	1.3511890	<.0001
4	82.5510287	1.3649359	<.0001

Tukey's Studentized Range (HSD) Test for DFI

Alpha	0.05
Error Degrees of Freedom	124
Error Mean Square	55.67832
Critical Value of Studentized Range	3.68292
Minimum Significant Difference	4.7839

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	FEED
A		87.854	33	1
A		87.503	33	2
A	B	86.401	33	3
	B	82.551	33	4

Appendix 20. Analysis of variance table for weight gain in experiment two cockerels

The GLM Procedure

Class Level Information

Class	Levels	Values
FEED	4	1 2 3 4

Number of observations 132

Dependent Variable: ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	5724.060541	817.722934	26.20	<.0001
Error	124	3869.568131	31.206195		
Corrected Total	131	9593.628673			

R-Square	Coeff Var	Root MSE	ADG Mean
0.596652	29.92829	5.586250	19.01545

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FEED	3	237.261497	79.087166	2.53	0.0600
FLW	1	5221.608532	5221.608532	167.33	<.0001
IW	1	54.079015	54.079015	1.73	0.1905
DFI	1	118.867559	118.867559	3.81	0.0532
FCR	1	92.243939	92.243939	2.96	0.0881

Least Squares Means

FEED	ADGLSMEAN	Standard Error	Pr > |t|
1	19.7510570	0.660509	<.0001
2	19.7722920	0.6638713	<.0001
3	19.0884148	0.6607718	<.0001
4	17.4500545	0.6624489	<.0001

Tukey's Studentized Range (HSD) Test for DWG

Alpha	0.05
Error Degrees of Freedom	124
Error Mean Square	31.20619
Critical Value of Studentized Range	3.68292
Minimum Significant Difference	3.5814

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	FEED
A		19.772	33	2
A		19.751	33	1
A	B	19.088	33	3
	B	17.450	33	4

Appendix 21. Analysis of variance table for feed conversion ratio in experiment two cockerels

The GLM Procedure

Class Level Information

Class	Levels	Values
FEED	4	1 2 3 4

Number of observations 132

Dependent Variable: FCR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	1733.161290	247.594470	3.91	0.0007
Error	124	7861.406409	63.398439		
Corrected Total	131	9594.567699			

R-Square	Coeff Var	Root MSE	FCR Mean
0.180640	123.0983	7.962314	4.756629

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FEED	3	134.110893	44.703631	0.71	0.5507
FLW	1	1342.480058	1342.480058	21.18	<.0001
ILW	1	0.491617	0.491617	0.01	0.9300
AFI	1	68.676131	68.676131	1.08	0.3000
ADG	1	187.402590	187.402590	2.96	0.0881

Least Squares Means

FEED	FCR LSMEAN	Standard Error	Pr > |t|
1	4.57435003	1.52479408	0.0002
2	4.78194086	1.55474278	0.0002
3	4.67543538	1.43223831	<.0001
4	4.9947906	1.66814965	0.0009

Tukey's Studentized Range (HSD) Test for FCR

Alpha	0.05
Error Degrees of Freedom	124
Error Mean Square	63.39844
Critical Value of Studentized Range	3.68292
Minimum Significant Difference	5.1048

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	FEED
A	4. 994	33	4
A	4.781	33	2
A	4.675	33	3
A	4. 574	33	1

Appendix 22. Analysis of variance table for breast meat in experiment two cockerels

The GLM Procedure

Class Level Information

Class	Levels	Values
FEED	4	1 2 3 4

Number of observations 24

Dependent Variable: BREAST

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	24279.96055	3468.56579	7.85	0.0003
Error	16	7065.87279	441.61705		
Corrected Total	23	31345.83333			

R-Square	Coeff Var	Root MSE	BREAST Mean
0.774583	6.788055	21.01469	312.0903

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FEED	3	5270.83333	1756.94444	3.98	0.0270
REP	1	306.25000	306.25000	0.69	0.4172
PSW	1	18563.21180	18563.21180	42.03	<.0001
DW	1	5.13943	5.13943	0.01	0.9154
EW	1	134.52598	134.52598	0.30	0.5886

Least Squares Means

FEED	BREAST LSMEAN	Standard Error	Pr > |t|
1	318.773312	7.402754	<.0001
2	313.144451	7.6039675	<.0001
3	309.173575	7.3274166	<.0001
4	307.26969	7.762276	<.0001

Tukey's Studentized Range (HSD) Test for BREAST

Alpha	0.05
Error Degrees of Freedom	16
Error Mean Square	441.617
Critical Value of Studentized Range	4.04609
Minimum Significant Difference	34.712

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	FEED
A	318.773	6	1
A	313.144	6	2
A B	309.173	6	3
B	307.270	6	4

Appendix 23. Published papers

D M Wanjohi, A M King'ori, A Y Guliye and A M Wachira. 2018: Effect of substituting maize in the grower diet with ground *Prosopis juliflora* pods on performance of indigenous chicken in Kenya. http://www.lrrd.org/lrrd30/4/dunc30063.html

Wanjohi D M, King'ori A M, Wachira A M and Guliye A Y 2017: Effect of replacing complete grower diet with ground *Prosopis juliflora* pods on performance of improved indigenous chicken in Kenya. http://www.lrrd.org/lrrd29/8/dunc29157.html

Duncan Maina Wanjohi. 2017. Anthony Macharia King'ori, Ann Mumbi Wachira, Abdi Yakub Guliye and Peninah Njiraine Ngoda. Sensory attributes and quality of meat in improved indigenous chicken fed on *Prosopis juliflora* pods in Kenya. http://interesjournals.org/ajfst/november-2017-vol-8-issue-8