EFFECT OF INCLUSION OF GROUND PROSOPIS (*Prosopis juliflora)* PODS ON PERFORMANCE OF LAYING IMPROVED INDIGENOUS CHICKENS IN KENYA

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EGERTON UNIVERSITY

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DECLARATION AND RECOMMENDATION

DECLARATION

This thesis is my original work and has not been presented in this University or any other known to me for the award of a degree

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KM11/13525/14

RECOMMENDATION

This thesis has been prepared with our supervision and submitted for examination with our approval and recommendation as the University supervisors.

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DEDICATION

This thesis is dedicated to my daughter, Sheron António Manhique who has been a source of love and motivation during hard times. To my Sisters, Teresa and Adelícia, my brothers Salomão and Bernardino for their prayers and motivation, who never left my side even in hard moments.

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ABSTRACT

Indigenous chicken contribute significantly as a source of animal protein but productivity in Kenya is low due to inadequate feed supply and high cost of commercial feed. *Prosopis juliflora* pods is an alternative local and nutritive feed resource that can be used as a feed ingredient in poultry to increase productivity. Therefore, the aim of this study was to assess performance of laying improved Indigenous Chicken (IC) fed on diets containing ground mature *Prosopis juliflora* pods (GPJP) for a period of eight weeks. Samples of pods were collected from Baringo, Kajiado and Garissa Counties. Proximate analysis showed high CP and CF in samples from Garissa, 148.7 and 339.1 g/kg respectively while samples from Baringo County had higher gross energy, 17.31 MJ/kg. Experiment I assessed metabolizable energy (ME) of pods from Baringo *in vivo* using improved IC roosters force-fed with 40 g of GPJP and 40 ml glucose as the trial and control treatments respectively. The result showed that the pods had 7.6 MJ/Kg ME. In experiment II a Completely Randomized Design (CRD) with four (4) dietary treatments including GPJP in total ration at T1-0%, T2- 10%, T3- 20% and T4- 30% were used. Sixteen hens per treatment weighing 1.87$\pm$0.49 kg live weight were each allocated to battery cages. The diets were iso -nitrogenous, 16 % CP and iso-caloric, 12.8 KJ/Kg ME. Data on feed Intake (FI), Egg Production (EP) were recorded daily and egg quality parameters were analyzed ($P<0.05$) twice per week on 6 eggs randomly picked per treatment. Inclusion of prosopis pods had no effect on feed intake but depressed body weight. Egg production was similar ($P >0.05$) for hens offered T1, 74.55%, and T2, 75.22% but was higher ($P <0.05$) than in hens offered T3, 62.72%, and T4, 68.30%. Egg weight was similar ($P >0.05$) for hens offered T1, 63.54 and T4, 63.00 g but was higher ($P <0.05$) than for hens offered T2, 61.72 g, and T3, 61.08 g. All parameters of egg quality were not influenced ($P >0.05$) by inclusion of GPJP in all the treatments except shell thickness which was greater in hen on T4. Yolk colour was deep yellow in hens on T4, graded at 10.92 on the yolk fan followed by hens on T3, 10.25 while hens on T1 and T2 graded at 9.23 and 9.25 respectively. The Cost Benefit Ratio and Return on Investment analyses were 1.27 and 26.71% respectively for T2 which was higher than all other treatments. It was concluded that the inclusion of GPJP at 10% of the diet improved egg production without affecting egg quality and increased the profit margin of egg production. However, further research is recommended with the inclusion of feed additives that enhance digestibility and bind tannins to assess their effect on the utilization of the GPJP pods.

Key word: **Egg production, egg quality, feed formulation, pods**

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ABBREVIATIONS

ADG	Average Daily Gain
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
ASALs	Arid and Semi-arid Lands
Ca	Calcium
CP	Crude Protein
CF	Crude Fibre
CRD	Completely Randomized Design
DE	Digestible Energy
DM	Dry Matter
EE	Ether Extract
EG	Egg Weight
EP	Egg Production
EQ	Egg Quality
FCR	Feed Conversion Ratio
FE	Feed Efficiency
FI	Feed Intake
GLM	General Linear Model
GMPP	Ground Mature *Prosopis* Pods
GPJP	Ground *Prosopis Juliflora* Pods
HHEP	Hen-Housed for Egg Production
HW	Hen Weight
IC	Indigenous Chicken
Kcal	Kilocalorie
Kg	Kilogram
KJ	Kilo-joule
KALRO	Kenya Agricultural and Livestock Research Organization
ME	Metabolized Energy
MJ	Mega-joule
NE	Net Energy

NRC	National Research Council
NRI	Non-Ruminant Institute
P	Phosphorus
SAS	Statistical Analysis System

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Generally, the demand for food increases as human population increases. Consequently, there are efforts geared towards increasing animal production, especially poultry in order to meet the critical animal protein needed by Africa's growing human population (Gueye, 2000). Indigenous chicken (IC) (*Gallus domesticus*) contributes a significant amount of protein to the livelihood of rural and urban communities. Indigenous chicken are about 75% of the poultry population in Kenya (MoLDF, 2004) and contribute about 46 and 58% of eggs and meat from poultry respectively (Mukherjee, 1992; Kingori *et al.,* 2010). IC are reared under the extensive system, which is a low input system compared to the intensive one. However, the productivity of IC under this system is low due to among others, inadequate supply of feeds all year round. The feeds are limited during the dry season, consequently decreasing the productivity of IC.

One way of improving productivity of IC is by providing adequate (quality and quantity) feed throughout the year. This can be accomplished by using feed resources that are locally available and affordable such as prosopis (*Prosopis juliflora*) pods. *Prosopis* is a leguminous tree native to the South and Central Americas and distributed around the dry regions of the world over the past 200 years (Choge *et al.,* 2007). In Kenya, the first documented introduction of *Prosopis*, from Brazil and Hawaii was in 1973 for rehabilitation of quarries near Mombasa and has since become the most common naturalized species in the country. It has spread widely outside the designated plantation areas. According to Sawal *et al.* (2004) and Mahgoub *et al.*(2005) the tree is drought resistant, evergreen, spiny with drooping branches and a deep laterally spreading root system. It grows in semi-arid and arid tracts of tropical and sub-tropical regions of the world and is spreading because the leaves are unpalatable to animals and the seeds are indigestible. *Prosopis* produces pods over the year with variation effect according to the environment. The pods which are high in sugars, carbohydrates and protein have been used as a human source of food and feed for livestock in Africa (Choge *et al.,* 2007).

In this study, *Prosopis juliflora* pods were used for comparative proximate analysis according to the origin, determination of metabolizable energy (ME) and as a feed ingredient to formulate diets to evaluate the performance of laying improved indigenous chickens.

1.2 Statement of the Problem

Poultry production contributes considerably to household nutrition and income in the rural areas of Kenya. Indigenous chicken account for about 75% of poultry population and contribute 46 and 58% of egg and poultry meat produced, respectively. This is a low productivity that can be attributed to their genetics and inadequate feed. Poultry feeds are mainly manufactured from feed resources that are also utilized as human food, thus leading to competition. Consequently, the feeds are expensive and sometimes unavailable leading to poor nutrition. Therefore, alternative locally available and affordable feed resources are being explored. However, their nutritive value as a feed resource for indigenous chicken has not been evaluated. Therefore, this study, evaluated the optimum inclusion level of Ground mature *Prosopis juliflora* Pods (GPJP) on performance of laying improved indigenous chicken layers.

1.3 Objectives

1.3.1. Broad objective

The overall objective was to contribute to increase laying improved indigenous chicken productivity through the utilization of mature *Prosopis juliflora* pods as a feed resource.

1.3.2 Specific objectives

i. To determine the nutritional composition content of ground mature *Prosopis juliflora* pods (GPJP) from Baringo, Kajiado and Garissa Counties of Kenya;
ii. To determine metabolizable energy (ME) of ground mature *Prosopis* pods (GPJP)
iii. To determine optimum inclusion level of ground mature *Prosopis* pods (GPJP) of laying improved indigenous chicken diets;
iv. To determine the effects of including GPJP on performance of laying improved indigenous chicken;
v. To determine the effect of inclusion of GPJP of laying improved indigenous chicken diets on egg characteristics (external and internal quality);

vi. To calculate the effects of including GPJP of laying improved indigenous chicken diets on the economics of egg production.

1.4 Hypotheses

The following null (H_0) hypotheses were postulated for this study

I. Different environments does not influence nutritive composition of GPJP;
II. Metabolizable energy (ME) of prosopis pods from Baringo county is similar to the reported in the literature;
III. Inclusion of GPJP on diet of laying improved indigenous chicken has no effect on feed intake and hen weight;
IV. Inclusion of GPJP on diet of laying improved indigenous chicken has no effect on egg production.
V. Inclusion of GPJP on diet of laying improved indigenous chicken has no effect on egg characteristics (external and internal);
VI. Inclusion of GPJP on diets of laying improved indigenous chicken has no effect on the economics of egg production.

1.5 Justification

Propsopis juliflora grows in arid and semi-arid regions (about 75% of Kenya land mass) because of its resistance to drought and has many potential uses. It produces pods throughout the year. *Prosopis* pods have high palatability and nutritive value with 16% CP and soluble sugar which comprises of 75% sucrose, 12 fructose, 5% glucose and 1% raffinose (Marangoni and Alli, 1988). They have a high content of calcium and phosphorus that varies depending upon season, soil type, year, etc. Using *Prosopis* pods as a feed resource will reduce cost of feed for chicken, minimize the competition between humans and chicken for conventional food/feed resources and minimize the rapid spread of this tree (management by utilization) in the ASALs by utilization. This study evaluated the performance of laying improved indigenous chicken hens offered compounded layer diets with varying levels of ground mature *Prosopis* pods to increase productivity

CHAPTER TWO

LITERATURE

2.1 *Prosopis* origin

Prosopis juliflora is a drought resistant, evergreen, spiny tree with drooping branches and a deep laterally spreading root system, native to northern South America, Central America and the Caribbean. It is fast growing, nitrogen-fixing and tolerant of arid conditions and saline soils. *Prosopis juliflora* has a large crown and an open canopy and can grow to a height of 14 meters. Its stem is green-brown, sinuous and twisted with axial and strong thorns (Andersson, 2005).

In the hot dry parts of the Americas, *Prosopis* is common, and important for people by providing resources such as wood (as an excellent fuel and timber, hard and comparable to the finest hardwoods). The sweet nutritious pods are relished by all livestock and are made into different foods and drinks (HDRA, 2005). Honey from the flowers is high quality, the gum is similar to gum Arabic, bark and roots are rich in tannin, leaves can be used as mulch, reducing pests and weeds (HDRA, 2005).

Pasiecznik *et al.* (2012) reported that, *Prosopis* trees cover at least 10 million hectares across Africa. There are an estimated 1.2 million hectares of *Prosopis juliflora* in Kenya alone, a million hectares in Ethiopia, at least half a million in Sudan, and large but unsurveyed areas in every other country from Senegal to Somalia. In southern Africa, other species of *Prosopis* are more common and there are more than two million hectares in South Africa and known invasions in all neighboring countries. *Prosopis juliflora* is considered to be the most common and widespread tree in dry land and is very common in many countries.

P.juliflora flowers throughout the year with yellow flowers hanging from the branches. Its fruits are pods, which are green when immature and turn yellow when they mature (Masilamani and Vadivelu, 1997). The pods contain a high level of sugar (20-25% of saccharose) and are palatable to livestock when ripe. A mature *P. juliflora* tree can produce 40 kg of pods per year (Talpada & Shukla 1988 and Andersson, 2005).

In Kenya *P. juliflora* was first planted in the early of the 1970s from Brazil and Hawaii to rehabilitate a quarry in Bamburi near Mombasa (Choge *et al.,* 2007 and Sirmah *et al.,* 2008). In

1980s the plant was introduced in the Lake Baringo area through the Fuelwood Afforestation Extension Project. The major objectives of the project were to involve the local people in tree planting to overcome problems such as lack of firewood and overgrazing. The project was implemented in two phases, from 1983 to 1985 and from 1987 to 1990 (Choge *et al.*,2007). Choge *et al.* (2002), currently, the counties with the greatest *Prosopis* populations are Garissa, Wajir, Mandera, Baringo, Turkana, Taita Taveta and Tana River. This plant has a high potential for providing quality forage to livestock in the semi-arid areas of Kenya owing to its high nutritive value of the pods and leaves all the year round. *Prosopis juliflora* was tried and found to be suitable for the lake Baringo area together with other exotic tree species

2.2 Fruit (pod) products

2.2.1 Pod composition

The fruits of the *P. juliflora* and *P. pallida* complex are indehiscent pods, generally pale yellow in colour. Pods of *P. pallida* in Peru are 10-25 cm long, 1.5 cm wide and 0.8 cm thick with an average weight of 12 g. A pod consists of three separable components: exo- and mesocarp (pulp), endocarp (fibrous hulls) and seeds. The seeds are enclosed in the endocarp, which can be opened by hand only with difficulty. There is an average of 25 seeds per pod (Solano, 1989). The seeds are small and very hard, approximately 5 mm in diameter, ovoid in shape and weigh about 40 mg. Seeds are made up of three parts, an episperm being the thin, brown seed coat, the endosperm which is adhered to the seed coat, and the cotyledon. Figure 1 shows the structure of a *Prosopis* pod and seed, with percentages of each component (Pasiecznik *et al.*, 2001).

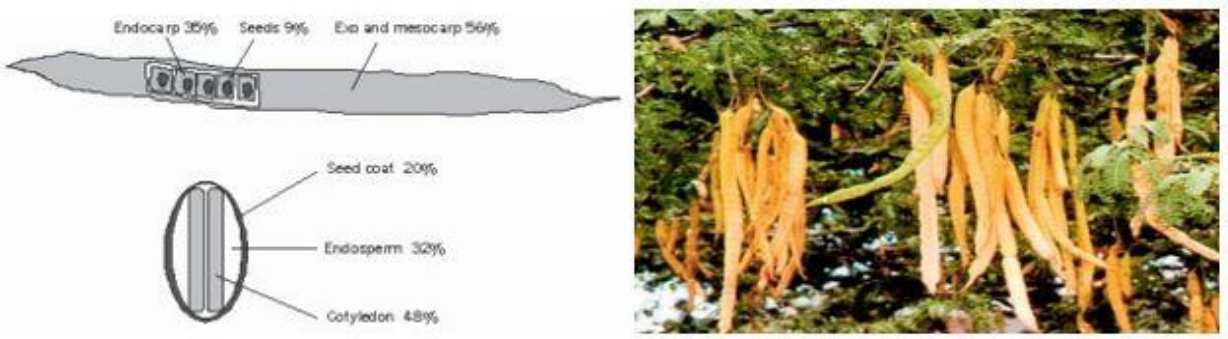


Figure 1: Structure of pod and seed of *Prosopis juliflora*. **Source: Alcedo (1999)**

The term 'pod' is predominantly applied as a descriptor for the whole fruit but in some cases it refers to the pericarp (pod without seeds). The term 'pulp' describes the sum of exo and mesocarp only, which represent the sweet portion of the fruit, while the term pod refers to the whole fruit with seeds (Pasiecznik *et al.,* 2001).

Dry matter content of mature pod is approximately 90% while crude protein varies between 7 and 17%. King'ori *et al.* (2011) reported in common *algorabas genus* (*Prosopis spp*) 7-22% protein but fruits of *P. juliflora* contain 15.95% CP, 30-75% carbohydrates, 11-35% crude fibre, 1-6% fat and 3-6% ash. This variation may be because of genetic differences in pod composition or differences in methods used to analyze, location and age of harvesting. Crude fiber and nitrogen free extract also vary widely, from 12 to 32%, and 40 to 75%, respectively, which may again be caused by differences in methods used for chemical analysis (Pasiecznik *et al.,* 2001).

Study published by Sawal *et al.* (2004), characterizing *P. Juliflora* as feed resource for livestock described pods as whole and the pericarp meal containing 68.8 and 65.6% digestible Dry Matter (DM); 5.6 and 2.6% digestible protein; 2,880 and 2,675 kcal/kg digestible energy; 2682 and 2,466 kcal/kg metabolizable energy; 2,642 and 2,432 kcal/kg nitrogen corrected metabolizable energy respectively. Silva *et al.* (1990) reported that whole pod and pericarp contained 4,340 and 4,291 kcal/kg gross energy respectively.

2.2.2 Pods as an animal feed

The prosopis fruit is sweet, nutritious, has low concentrations of tannins and other unpalatable chemicals while it has moderate to high digestibility. Natural selection favoured these characters as they are attractive to foraging animals and thus help in dispersal of seed. *Prosopis* pods and seeds are consumed by a wide variety of animals, both in their native range and where introduced, and are often an important part of mammalian diets when trees are present in large numbers. Insects, reptiles and birds are minor disseminators of seed, but pods may play an important role as a source of nutrition of such animals (Mooney *et al.,* 1977).

P. juliflora pods are used as a feed mainly for cattle but also for sheep, goats, camels, pigs and poultry. Pods are mainly used as forage, browsed directly from the tree or the ground below, rather than as a fodder, where the pods are collected and fed to stalled stock. As a part of extensive grazing systems, livestock was introduced into native *Prosopis* woodlands in the Americas and still browse in natural woodland today. Many introductions of *P. juliflora* is made in arid and semi-arid zones around the world primarily because of a perceived need for additional sources of forage. Livestock is often allowed access to naturalized stands and plantations of *P. juliflora* and *P. pallida* where introduced. These species are especially suitable for extensive grazing systems as the leaves are unpalatable and pods are produced either towards the end of the dry season are easily stored until then, coinciding with the period when alternative sources of forage are lacking (Pasiecznik *et al.,* 2001).

Processing pods involves the pounding, grinding or milling, either as a single process producing a whole pod extract, or with some separation of pod parts and further processing of each fraction. Processing usually involves milling of whole pods into a homogeneous, coarse flour, although in some cases exo-carp and meso-carp (pulp) are separated from the endocarp and seed. Pods must be ground or milled to secure the full nutritive value as most of the protein rich seeds would otherwise pass undigested through the digestive tract of livestock. Whole pods *P. juliflora* were found to provide 7% digestible crude protein and 75% total digestible nutrients on a dry matter basis. The digestibility of crude protein from *P. juliflora* pods was 50-60%, with the average digestibility of ether extract being 70%, crude fiber 80%, nitrogen free extract 79% and organic matter 74%. The *in vitro* digestibility of *P. pallida* pulp protein has been determined to be 73%,

similar to the value for *P. juliflora* pulp from Ecuador. These figures are comparable with other results for *P. juliflora, P. pallida* and other *Prosopis* species (Pasiecznik *et al.*, 2012).

Nitrogen and calcium balances were positive in poultry, but the phosphorus balance was negative suggesting that pods should be fed with a phosphorus rich feed supplement. Levels of anti-nutritional chemicals are not significant in pods of *Prosopis* species, and the tannin content of pods is low (0.72%). Speedy (1991) recommended storage of pods protected from the rain. Pods are prone to insect attack, requiring fumigation of the storage houses with bi-sulphide or phosgene and in these conditions can be stored for several years. Stock poisonings have been recorded from pods eaten after exposure to rain. Only ripe pods should be fed, as the green pods are bitter and have little feed value. The foliage is good-quality fodder but its use is not widespread; direct browsing of the foliage has been used but may limit tree development and it is not particularly palatable (Pasiecznik *et al.*, 2012).

2.2.3 *Prosopis* Pods as feed resource on Poultry

Prosopis pods have been used in feeding poultry as an alternative feed, rich in nutrients but cheaper than conventional feed. A Study conducted by Odero-Waitituh *et al.* (2015) to determine the effect of replacing maize in broiler finisher diets with milled mature *Prosopis* pods (GPJP) reported that levels up to 20% of *Prosopis* pod meal could be included in broilers diets with no negative effect on performance. Girma *et al.* (2011a) reported that *P. juliflora* can be included up to 20% in broiler diets with no effect on performance and reduce feed costs.

Girma *et al.* (2011a) reported better ($P<0.05$) and economical performance in diet containing up to 20% of *Prosopis* pods in layer diets. A 30% inclusion of pods improved yolk colour and was recommended if yolk colour is the preference of consumers according to the prices offered. In Peru, trial carried out by Speedy (1991) using *P.Juliflora* flour replacing up to 100% of wheat bran in rations for chickens reported no effect on feed intake, FCR or egg weight.

Experiments conducted by Kondra *et al.* (1974), to determine the effect of feeding a high (19.6%) or low (7.7%) fiber diet to meat- and egg-type in mature chickens over 6 weeks reported a significant increase in weight, size and number of various components of the digestive system. The study revealed that an addition of fibre to feed resulted in a relative increase in the weight of

the alimentary canal, the crop, proventriculus, gizzard, length of the small and large intestines, caeca and total number and length of villi. Increase in size of various organs is considered to be an attempt to hold and process a relatively large volume of feed and extract the nutrients more efficiently the diet.

Ngeno *et al.* (2014) based on this study concluded that chickens anatomical and physiological adaptation increase volume of feed of low nutrient density, so that required nutrients can be obtained. This adaptation can maximize nutrients utilisation on the diets of low and variable quality and it could be more advanced and complex in IC.

2.2.4 Metabolizable Energy (ME) in Poultry

Energy is not a nutrient but a property of energy-yielding nutrients when they are oxidized during metabolism (Livesey, 1995). National Research Council (1994), energy value of a feed ingredient or of a diet can be expressed in several ways as shown below. The units of energy are calorie (Cal) and Joule (J) where 1 cal is equivalent more precisely to 4.184 joules. National Research Council (1994) defined a calorie (cal) as the heat required to raise the temperature of 1 g of water from 16.5° to 17.5° C.

Gross energy (E) is the energy released as heat when a substance is completely oxidized to carbon dioxide and water. Gross energy is also referred to as the heat of combustion. It is generally measured using 25 to 30 atmospheres of oxygen in a bomb calorimeter (NRC, 1994).

Apparent digestible energy (DE) is the gross energy of the feed consumed minus the gross energy of the faeces. (DE = [E of food per unit dry weight × dry weight of food] - [E of faeces per unit dry weight × dry weight of faeces]). Birds excrete faeces and urine together via a cloaca, and it is difficult to separate the faeces and measure digestibility. According to the same author, for poultry the gaseous products are usually negligible, so *ME* represents the gross energy of the feed minus the gross energy of the excreta. A correction for nitrogen retained in the body is usually applied to yield a nitrogen-corrected ME *(*ME_n*)* value. ME_n, as determined using the method described by Anderson *et al.* (1958)**,** or slight modifications therefore, is the most common measure of available energy used in formulation of poultry feeds.

Metabolised Energy intake is partitioned into energy retained in body tissues (mainly as fat and protein) and as heat production (Lopez & Leeson, 2008) or can be accurately determined from the difference between the gross energy of the feed and the gross energy of the excreta (excreta= faeces and urine in poultry) derived from such feed (NRC, 1994).

The relative amounts of the metabolizable and net energy depend on composition of the feedstuffs in the diet. Other factors, such as the species, genetic makeup, and age of poultry, as well as the environmental conditions, also influence the precise distribution of dietary energy into the various compartments (NRC, 1994).

2.3 Improved Indigenous Chicken

Indigenous chickens play an important role in the livelihoods of rural families in Eastern Africa. The improvement of IC in Kenya came up with "Kienyeji" to offer better yield where Kenya Agriculture and Livestock Research Organization (KALRO)- Naivasha developed through years of intensive research under the Nation Poultry Development Programme. Improved IC are easy to establish for low-income families, develops faster, is highly resistant to diseases and has high productivity compare to the pure indigenous chicken (KALRO, 2013) and high commercial hybrid (Hassan *et al.*, 2004). This organization (KALRO) took 10 years to develop the bird after studying the strengths and weakness of the different breeds of IC across the country.

The chicken is easy to maintain, are suitable for free range and can be utilized as a dual purpose breed by among small scale farmers. They are less fatty, and tastier compared to the hybrid chicken, lay more eggs than the local chicken and have softer meat associated with improved growth (KALRO, 2013). They can be fed on either commercial feed or others like greens, maize, termites, insects, and kitchen leftover. When offered quality feeds, a hen can achieve 1.5 Kg in about 5 months and a cock 2.1 Kg. At this age, the rest of the indigenous ecotypes take up to seven months or more. The hen can produce between 220 to 280 eggs per year (KALRO, 2013).

2.4 Factors affecting Egg Production

The cycle of egg production in hens is over the year, 52-56 weeks. The egg production and quality during this period is affected by many factors. Koelkebeck (2006), defined food quality as

"the sum of characteristics of food which influence the acceptability or preference for food by the consumer". According to Gerber (2005) egg quality means different things to different people or the consumer's perception of quality depend on consumers' preferences in certain place or region. The major important parameters on egg quality for industry worldwide are: egg shell quality and egg internal quality. Ahmadi & Rahimi (2011), quality characteristics are affected by many factors such as: strain and age of hen; nutritional factors such as calcium, phosphorus, vitamins, water quality, non-starch polysaccharides, enzymes, contamination of feed; heat stress; disease, production system, or addition of proprietary products to the diets.

2.4.1 Age and Bird Strain

Different strains of laying hen vary significantly in egg shell quality, egg size and production. With advancement in age, egg production increases, gets to a peak and then declines but there are different trends with the advancement of age in different egg quality traits (Gerber, 2005; Usman & Rehman, 2011). Older hens tend to lay bigger eggs and have a higher egg output, which impacts on shell strength and very young hens with immature shell glands may produce shell-less eggs with very thin shell. The production increases with both hen weight and egg size (Joly, 2009).

According to different studies, egg shell quality decreases as hens grow older, also the pigment decreases. Gerber (2005) reported that egg size increases with increasing hen age and at the same time shell weight increases or remains the same. Either way, the increase in egg weight is not accompanied by a proportional increase in shell weight, so that the ratio of shell weight to egg weight decreases.

The inability of the hen to produce an increased amount of egg shell is related to the activity of 25-hydroxy-cholecalciferol-1-hydroxylase – an enzyme involved in calcium homeostasis. Dietary manipulations that decrease egg size may improve egg shell effective in improving egg shell quality in aging hen (De Ketelaere *et al.,* 2002; Gerber, 2005).

2.4.2 Nutritional factors (minerals and vitamin concentrations in the diet)

Feed intake has a direct impact on the hens' intake of nutrients and the size of eggs that they produce. Any factor that limits feed consumption, such as crowding, heat stress or inadequate

water supply, will reduce egg production and size (Applegate, 2012). Similar factors affect the rate of movement of the food through the digestive system with a meal of normal food taking approximately 4 hours to pass through in the case of young stock, 8 hours in the case of laying hens and 12 hours for broody hens. Intact, hard grains take longer to digest than the cracked grain and, quite often some whole grain will pass through unchanged (Dublecz, 2011).

2.4.2.1 Energy Content in feed

Experiment carried out by Grobas *et al.* (1999) with Isa -brown chicken fed a diet containing 2 810 Kcal/kg reported 88.9 %, 64 g, 57.3 g and 218 g on egg production, egg weight, egg mass and weight gain respectively. Frikha *et al.* (2009) reported improvement of productive performance of layers with increasing energy in the diet, therefore the level of energy has positive correlation with layers performance during laying period.

2.4.2.2 Protein level in the feed

Protein level has an influence on egg size at different stages of production. In the first months of egg production, feeding a high (18% to 20%) protein layer ration will increase egg size. After the flock has reached maximum egg production, high protein diets no longer promote large increases in egg size. It has been reported that at the onset (first days of laying) production, dietary protein is the main factor influencing feed intake, and after 23 weeks of the age, feed energy becomes the main factor determining feed intake. After 36 weeks of age, feeding rations with 15-17% protein will help to slow increases in egg size (Valkonen, 2010).

Low protein in diet, methionine or other essential amino acids reduces egg weight. Fat in hens' diet, both level and composition has influence on egg weight. For early egg weight gain can be stimulated by adding extra fat to the diet, especially vegetable oils rich in unsaturated fatty acids and linoleic acid have positive effects on egg weight. In older birds feeding more saturated fat (palm oil) and limiting the unsaturated fatty acids and linoleic acid can control the increase of egg weight occurring later in period of lay. Albumen quality (Haugh Units) decreases with increasing dietary lysine concentration and increases with vitamin C or E supplementation (Niekerk, 2014).

2.4.2.3 Minerals and Vitamins

More than 70% in body ashes of animal consist of Ca and P with about 99 and 80% in bones respectively. The provision of adequate dietary minerals and vitamins is essential for good eggshell quality (Hunton, 2005; Pelicia *et al.,* 2009). While hens get older the egg size increases and the percentage eggshell decreases. Therefore, eggs are bigger but with a lower eggshell percentage but total calcium exported through the egg increase. This leads mechanically to higher calcium requirement for older hens. Calcium deficiency will lead to weaker eggshell with a decrease of eggshell weight and eggshell strength (Ahmadi & Rahimi, 2011; Bar *et al.,* 2002).

Also vitamins are required in many metabolic processes. Vitamin D is required for Ca metabolism and it must be provided in the diet. The vitamin D metabolite 25-hydroxyvitamin D_3, converted into the biologically active to form available D_3. Also vitamin C is necessary for good health and may also help to alleviate the effect of stress including vitamin E. Water with high concentration of electrolytes (saline water or with high concentration of Chlorine) may influence egg shell quality because it interfere with minerals absorption, Ca and P (Ahmadi & Rahimi, 2011; Sasongko *et al.,* 2012; Niekerk, 2014).

Additional artificial enzyme has been reported in improvement on performance of the birds. Phytase supplementation has been shown to improve egg shell quality. The effect is due to improvement of availability and absorption of P in gastro-intestinal tract therefore, reducing environmental pollution (Pelicia *et al.,* 2009 ; Ahmadi & Rahimi, 2011).

2.4.3 Heat stress

Temperature is one of the key factors affecting egg weight. Generally temperature above 30^{o}C can result in smaller eggs and reduced shell quality through physiological processes occurring within the animal. Egg weight falls by about 0.4% per 1^{o}C between 23 to 27^{o}C; above 27^{o}C the reduction is about 0.8%. Growth at start of lay is reduced above 24^{o}C and is extremely low above 28^{o}C. The FCR is minimum at a temperature around 28^{o}C and above it increases due to the lowering of production (Joly, 2009). Pesti (1995); Zollitsch *et al.* (1999) reported that when temperature increases from 19 to 27.7 ^{o}C, energy intake reduces by between 24 to 26 Kcal/day in diets with a content of 2645 to 2975 Kcal/kg respectively. Energy intake, egg weight and egg mass

are extremely affected by temperatures between 30.5 to 35^{o}C where energy intake reduces by 69 to 84 Kcal and consequently affect egg weight by 5.43 to 5.74 g and egg mass by 9.1 to 10. 3 g/day.

Koelkebeck (2006) reported temperature above 25^{o}C affect feed intake and consequently calcium resulting in a decreased availability of calcium for shell deposition. As well as decreasing feed intake, laying hens will try to overcome heat stress through panting. This is a physiological mechanism to overcome heat stress causing a decrease in the amount of carbon dioxide in the hens' blood, a condition known as respiratory alkalosis. As egg shells are made up of 95 % calcium carbonate (Ca_2CO_3), this decrease in blood CO_2 levels, combined with an increase in blood pH and a subsequent decrease in Ca^{2+} for shell formation leads to an increase in the number of thin or soft shelled eggs produced. This process occurs due to reducing the activity of carbonic anhydrase, an enzyme which results in the formation of bicarbonate which contributes the carbonate to the egg shell. Ahmadi & Rahimi (2011) recommends that feed formulation in hot environment should consider sources of energy which minimize heat increment in metabolic processes such as additional fat to the diet.

Radu-rusu *et al.* (2008) reported that "temperatures exceeding 28°C trigger heat stress, manifested by decreased egg weight and changes in the proportion of eggs components. The albumen / yolk ratio is less affected, but significantly decreases the proportion of mineral shell. When birds are exposed for a long period of time to temperatures exceeding 28°C, egg white/yolk ratio changes, involving reduction of the yolk weight comparing to the albumen. Provision of cool drinking water can alleviate the effects of heat stress.

2.4.4 Diseases

Any disease that compromises the health of the hen may result in defective egg production and quality. Trematode and *Prosthogonimus* spp can inflame the oviduct resulting in the formation eggs with soft shells or lacking a shell. Any pathogenic agent that grows in the tissues of the reproductive tract can cause problems with egg shell formation. Infectious bronchitis has been reported to cause egg shells to be paler in colour and sometimes wrinkled in appearance. Egg drop syndrome (caused by adenovirus), as well as causing drops in production may also result in paler coloured egg shells and other deformities such as soft-shelled eggs or rough shell. Newcastle

disease, avian influenza, avian encephalomyelitis and *Mycoplasma gallisepticum* can cause drop in the production (Ahmadi & Rahimi, 2011).

2.4.5 Housing on Egg Quality

Cages and non-cage a hen has a great influence on egg size and contamination. Hens in non-cage systems spend more energy on movement, which can result in either smaller eggs or reduced yolk content. Contamination of shell with microorganisms is higher in non-cage systems since more eggs tend to be laid outside nest boxes and the interactions between active hen and bedding material increases dust in the atmosphere which is a carrier of microbes and thus contamination (Niekerk, 2014).

2.4.6 Lighting program

Photoperiod ratio (light: dark) influences egg size by accelerating or delaying the age at which hens start to lay eggs (Sujatha *et al*., 2014; Narinc *et al*., 2013). The younger a hen is when egg production starts, the smaller eggs will be during the first year of life. The start of egg production can be delayed by providing 10 hours or less of light each day up to 19 weeks of age. Decreasing the daily hours of light at any time after 10 weeks of age will also delay the start of egg production (Joly, 2009). Ebraheem *et al.* (2012) recommended that the length of light between 16 to 17 hours will ensure constant and maximize egg production.

2.5 Egg formation

The hen's egg consists basically of the yolk, 30-33%, albumen, approximately, 60% and the shell 9-12% (Warren and Scott, 1935; Ahmadi & Rahimi, 2011; Roberts, 2014) (Fig. 2). Egg albumen is about 12% protein of which the main ones are ovalbumin (54%), ovotransferrin (13%), ovomucoid (11%), alpha and beta ovomucin (1.5-3%) and lysozyme (3.5%) (Johnson, 2015).

Egg formation is a complex process that occurs in the female reproductive system of the hen. The ovulation of the yolk occurs from the left ovary into oviduct whereas the right ovary and oviduct do not develop in the commercial hen (Roberts, 2004).

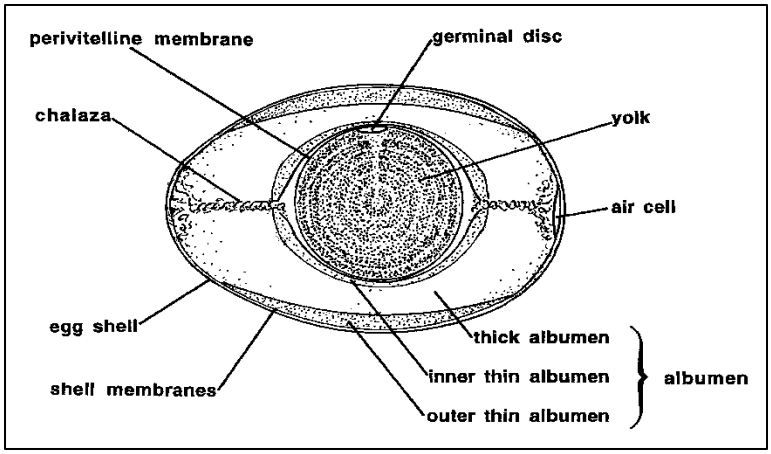


Figure 2. Structure of the egg **Source**: Roberts (2004)

The yolk is deposited to the infundibulum where development perivitelline membrane and chalazae occurs. The process takes 15 minutes. In breeder birds, the fertilization occurs in this region of the oviduct. The egg moves to magnum where the albumen formation (proteins) takes place for about 3 hours (Roberts, 2014). The layer of proteins (albumen) provides mechanical and bacterial protection for the yolk as well as creating a template for the later formation of the shell membrane and egg shell. Next the developing egg passes into the isthmus which over about one hour, produces the fibres that make up the inner and outer shell membranes (Roberts, (2014). The egg then enters the tubular shell gland where water and electrolytes enter the albumen in process called "plumping" and the formation of the mammillary cores commences, over a period of approximately 5 hours. The longest time during egg formation is spent in the shell gland pouch (at least 15 hours) and it is here that the egg shell is formed and the process of "plumping "is completed (Roberts, 2004; Johnson, 2015).

The organic matrix of the egg shell consists of the shell membranes, the mammillary cores, the shell matrix and the cuticle. The inorganic portion of the egg shell consists of calcium carbonate (Roberts, 2014).

Calcium availability and particle size is probably the most important parameter which affects eggshell quality. Most of calcium particle below 2 mm are found in the manure, unlike particle above 2mm which are retained in the gizzard. Calcium particle store in the gizzard will slowly solubilise, delaying the calcium assimilation. Eggshell formation takes 12 to 15 hours and occurs

mainly during the night period. Most of the calcium required for eggshell formation is during the night. Bones are the calcium storage organs and more precisely medullary bone. Several trials have shown eggshell is stronger if the calcium is coming from the feed instead of the bone (Galea, 2009).

Phosphorus is an important nutrient for eggshell quality. Phosphorus has a strong effect on bone strength. Calcium and phosphorus are combined in the hydroxyapatite crystal, storage form of calcium and phosphorus in the bones. If calcium provided from the feed is not enough to support the calcium requirement for the eggshell formation, calcium is mobilized from the bone. But this calcium mobilisation is linked with a phosphorus release in the blood. A high phosphorus level in the blood inhibits the calcium mobilisation from the bones. Several trials have shown a negative correlation between the phosphorus content of the diets and the eggshell quality (Pelicia *et al*., 2009). A high phosphorus intake leads to increase the phosphorus content of the blood, which inhibits the bone calcium mobilization, then eggshell quality is depressed. Phosphorus is required for strong bones but high levels depress eggshell quality. Vitamin D is necessary for calcium metabolism (Çelebi *et al.*, 2005; Roberts, 2014). According to Çelebi *et al.* (2005), vitamin D deficiency leads to poor eggshell quality, mainly due to a decrease of the eggshell weight.

Trace elements like zinc, copper and manganese have been shown to have an effect on eggshell quality. They influence calcite crystal growth during the eggshell formation and influence mechanical propriety of eggshell (Galea, 2011).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experiment location

The experiments were carried out at the Poultry Unit, Non-Ruminant Research Institute (NRI) at Kenya Agricultural and Livestock Research Organization (KALRO), Naivasha. The Institute is located at Naivasha sub- county, Nakuru County. It is about 100 km west of Nairobi along the Nairobi-Nakuru highway. The Research Centre is about 1,700 m above sea level and has average annual rainfall is 1100 mm with bimodal peaks recorded from March to May and October to December. Minimum temperature is 8° C in July and August, the maximum temperature is 25° C in January and February (Herrero *et al.,* 2010).

3.2 Experiment I: Determination of Metabolizable Energy

Metabolized energy was determined using procedure developed by Sibbald (1978) during 3 days of the trial. *Prosopis juliflora* pods were collected from Baringo County, Kenya using procedure described by Choge *et al*. (2006). Samples were dried at 60^{o}C over 24 hours in the oven ground into 1mm of size. Proximate analysis was done in triplicate t the department of Animal Sciences, at Egerton University-Kenya according to the procedures described on Chemical analysis.

Sixteen roosters aged 35 weeks old of the improved Indigenous chicken were used in this study. Average live body weight was 2.75 ±0.40 kg. The roosters were housed in individual wire battery cages measuring 40x45x40 cm and offered access to clean water (Figure 3B). All birds were selected from the same flock according to the age and weight. Alternate cages were left vacant to prevent feed mixing during adaptation and assay period. The birds were divided into two treatment groups, T1- fed with 40 ml of saturated glucose as a control diet and T2- fed with 40 grams of ground pods. All treatments were replicated 4 times with 2 roosters each. During the adaptation period, the feed ingredient (ground pods) under study was offered gradually 15, 30 and 40 grams per day. At the start of the experiment, the birds were weighed, fasted for 24 hours to empty their digestive tracts and force-fed with GPJP using a transparent polyvinyl tube (8 mm of

diameter) connected to a plastic funnel fused in one end of the tube to facilitate the flow of feed into the crop via the oesophagus). After force-feeding, the time of day was recorded and the birds were returned to their cages. A metal tray covered with a plastic sheet on the top was placed under each cage to collect the excreta after disinfection (Figure 3A). The excreta of each bird was collected three days after 24, 48 and 72 hours, feathers cleaned off, sealed in a sample bag, labelled, and frozen (with help of freeze drier, dried to reach equilibrium with atmospheric moisture). The excreta of each bird was ground and gross energy (GE) determined with bomb-calorimeter. The control group (8 birds) were force fed a saturated glucose solution, 40 ml once in 24 hours and faeces collected for analysis of endogenous energy from catabolism. The ground samples of excreta were analysed for gross energy using a bomb calorimeter and metabolizable energy calculated according to the procedure described by Sibbald, (1975b) using the following formula:

$$\mathrm{ME(MJ/Kg)} = \frac{(\mathrm{GEf} * \mathrm{Fi}) - (\mathrm{GEe} - \mathrm{GEuf})}{\mathrm{Fi}}$$

Where:

ME- Metabolizable Energy; GEf- Gross energy content in feed;

Fi- Feed intake (grams); GE e- Gross energy content in excreta;

GEuf- Gross energy from excreta of unfed birds

Figure 3. Disinfection of the metal trays (A) roosters housed in cages (B)

3.2.1 Excreta collection

After force-feeding (Figure 4A), collection trays were removed after 24 hours, cleaned of feathers and excreta collected (Figure 4B). The excreta were frozen (-28 ^{o} C) and freeze dried. At the end of the experiment, 2 grams of the excreta per sample were combusted in a bomb calorimeter for gross energy determination at the Animal Nutrition Laboratory, Egerton University. Thereafter, the ME was calculated.

Figure 4. Force-feeding (A) and excreta collection (B)

3.3 Experiment II. Effect of Inclusion of Ground mature *P. juliflora* in diet of IC layers on Egg Production

Sixty four hens (KALRO-improved indigenous chickens) aged 43 weeks, weighing 1.87±0.49 kg live weight (average per treatment) were assigned to four treatments in a Completely Randomized Design (CRD), (Appendix I). Each treatment was replicated four times with four hens each. Environmental temperature and relative humidity were 17-25^{o}C and 60-85% respectively.

The hens were weighed and housed individually in battery cages after disinfection with hy-protectol (Figure 5A and 5B) (45x45x40 cm) and separated by an empty cage between the treatments. The battery house received natural light (whole day). The cages were equipped with metal feeders fixed along the front length of the cages with the drinking trough located at the back of the cage.

Figure 5.Disinfection of the battery cages (A) and Hens housed in cages (B)

3.3.1 Experimental diets

Dietary ingredients for the study included ground white maize, pollard, soybean meal, ground fish meal (omena), sunflower meal, bone meal and Ground mature *Prosospis juliflora* Pods (GPJP) collected from Baringo County which was collected and processed according to Choge *et al*. (2002). Table 1 shows the treatments (diets) which were formulated to meet the nutrient requirement for IC (Kingori *et al.,* 2014) which minimum required is 1185 kJ/kg ME, 120 g/kg CP. Hens were offered feed and water *ad libitum* throughout the experimental period (43 to 51 weeks of age). The hens were given a 7 days adaptation period to the diets followed by the feeding trial to evaluate the performance and economics. GPJP was included at 0, 10, 20 and 30% levels of total diet ingredients as follows:

Treatment 1- diet formulated as a standard layer feed without GPJP (T1-0%);

Treatment 2- diet formulated as a standard layer feed with 10% of GPJP (T2-10%);

Treatment 3- diet formulated as a standard layer feed with 20% of GPJP (T3-20%);

Treatment 4- diet formulated as a standard layer feed with 30% of GPJP (T4-30%).

Proximate analysis and minerals (dry matter, crude protein, fat, fibre, ash, calcium and phosphorus) of the diets were done according to the procedure of Association of Official Analytical Chemists (AOAC, 1990). Methionine and lysine were included in the feed according to their manufacturer's recommendations (0.25% of total diet). Gross energy was determined using bomb calorimeter.

Table 1: Composition of the experimental diets containing different levels of GPJP

Ingredients	T1-0%	T2-10%	T3-20%	T4-30%
• **Ground *Prosopis* Pods**	**0.00**	**10.00**	**20.00**	**30.00**
• Maize meal	46.30	40.40	35.10	31.50
• Pollard	17.30	15.10	13.20	12.00
• Cotton seed cake	6.30	7.4	6.70	6.00
• Fish meal	5.30	4.40	3.70	2.50
• Ground Sunflower seed	3.30	3.40	3.70	4.00
• Soybean meal	14.00	11.70	9.70	6.10
• Bone meal	1.30	1.40	1.70	1.70
• Premix*	0.10	0.10	0.10	0.10
• DCP	0.40	0.40	0.40	0.40
• Limestone	5.00	5.00	5.00	5.00
• Salt	0.20	0.20	0.20	0.20
• Lysine	0.25	0.25	0.25	0.25
• Methionine	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00

*Commercial layers vitamins and minerals containing (mg/100g)= Vitamins: A-4500 I.u, D3- 900 IU, E- 8 IU, k3-1 mg, B1-0.7 mg, B2-1.75 mg, B6 - 1.5 mg, B12 - 0.048 mg, Vitamin C- 40.0 mg, Nicotinic acid - 17.5 mg, Pantothenic acid - 4.0 mg, Biotin -0.02 mg, Folic acid - 0.4 mg, Choline Chloride - 140 mg, Caropyll (R+Y) - 13 mg, Minerals: Mn - 48 mg, Fe - 12.8 mg, Zn 14.4 Cu - 1.6 mg, Co - 0.064 mg, Iodine - 0.448 mg, Se-0.04 mg.

3.3. 2 Production performance

The production performance data (egg production and egg quality) was collected daily and evaluated weekly except for the hen weight gain, which was evaluated twice throughout the experiment (8 weeks). Weight gain per hen was calculated as a difference between the final and initial weight of the hens using an electronic weighing balance (0.5 g accuracy) (Figure 6A); Feed intake was calculated as the difference between feed offered and leftover (refusal) after 24 hours. Feed conversion ratio (FCR) was calculated as average feed intake (g) divided by average egg weight (g) during each week). Egg production (eggs collected twice per day) was calculated by dividing the average number of eggs laid per treatment per week by number of hens multiplied by 100. External egg quality (egg weight, shell weight, egg height, egg width, shell thickness, yo1k colour, and Haugh unit) was assessed using six eggs randomly sampled (three eggs twice per week) from each treatment. Eggs were weighed weekly during the 8 weeks experimental period. Egg mass was calculated as the average of number of eggs/day multiplied by egg weight per number of hen in each treatment. Eggs were weighed using an electronic balance (0.01g weight graduation) (Figure 6B). The formulae (1, 2, 3, 4 and 5) show the equations used to calculate the production performance:

(1) Average weight gain (AWG) per hen (g) = Final body weight (g) – Initial body weight (g)

$$(2)\quad \text{Feed Intake (FI) per hen (g)} = \frac{\text{Feed offered (g)- Feed remain (g)}}{\text{Number of hens/treatment}}$$

$$(3)\quad \text{Feed conversion ratio (FCR)} = \frac{\text{Feed consumed per hen (g)}}{\text{Average egg weight (g)}}$$

$$(4)\quad \text{Egg production (\%)} = \frac{\text{Average number of eggs laid/week}}{\text{Number of hens per treatment}} \times 100$$

$$(5)\quad \text{Egg mass} = \frac{\text{Average number of eggs/week* Average egg weight (g)}}{\text{Number of hen per treatment}}$$

Figure 6. Weighing hens (A) and eggs (B)

Egg quality (egg weight, shell weight, egg height, egg width, shell thickness, yo1k colour, and Haugh unit) was analysed using electronic weighing balance with 0.01 g accuracy and digital vernier calliper ruler with 0.01 mm accuracy and Haugh unit using formula described by Haugh (1937). Egg quality can be considered as both external egg parameters, focusing on the eggshell qualities while internal egg quality, focuses on the egg content. Egg quality is defined as the characteristics of an egg which influences the acceptability or preference for egg by the consumer. These egg characteristics (egg quality) were divided into two groups: external and internal quality.

3.3.3 External egg quality

External egg quality was determined by the egg height and width, shell weight, thickness and the shape index. Egg height and width were measured with a digital vernier calliper ruler from the bottom (pointed end) to the top (Figure 7A) and from the centre of the egg or equator (mm) (Figure 7B) respectively; shape index was calculated as a measurement of width per length multiplied by 100; eggshell weight using a weigh balance with 0.01g accuracy after the inner membrane was removed from the shell and dried in the oven for 48 hours at 55^{o}C; eggshell

thickness measured four pieces of the eggshell, two pieces from the two ends and two pieces from the width; eggshell ratio as the result of eggshell weight divided by egg weight multiplied by 100 as shown in formulae 1, 2 and 3.

$$(1) \quad \text{Shape Index (\%)} = \frac{\text{Egg width or centre (mm)}}{\text{Length (mm)}} \times 100$$

$$(2) \quad \text{Shell thickness (mm)} = \frac{\text{1 piece of the bottom+ 2 pieces of the centre + 1 piece of the top}}{4}$$

$$(3) \quad \text{Eggshell ratio (\%)} = \frac{\text{Eggshell weight (g)}}{\text{Egg weight (g)}} \times 100$$

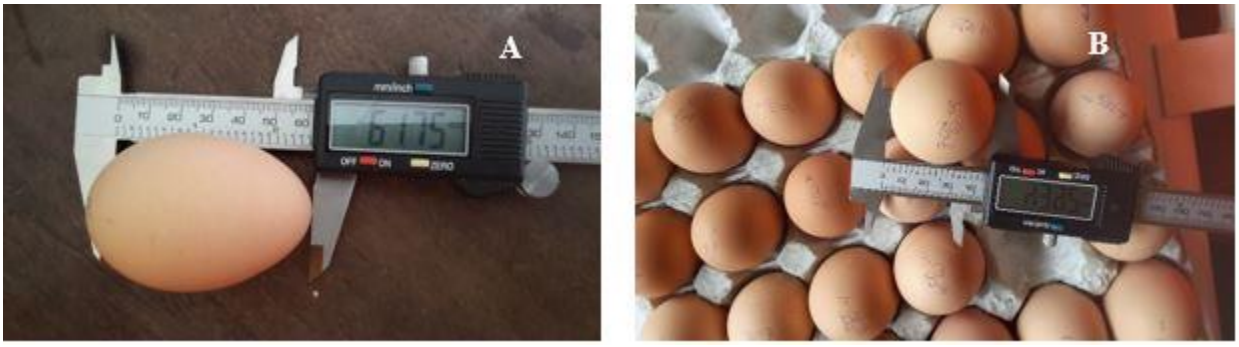


Figure 7. Egg height (A) and width (B) measurements

3.3.4 Internal egg quality

The internal quality characteristics of an egg were determined by composition, freshness of egg white (albumen) and yolk. Yolk and albumen weight were measured after separation through a funnel; yolk height, yolk diameter and albumen height using digital vernier calliper ruler to the nearest 0.01 mm (Figure 7A); albumen weight was calculated as a difference between egg weight less yolk weight plus egg shell weight; yolk ratio was calculated as yolk weight per egg weight multiplied by 100 (1); yolk index as yolk height per yolk diameter multiplied by 100 (2); yolk: albumen ratio as a yolk weight per albumen weight multiplied by 100; Haugh unit for freshness or

viscosity measurement was calculated by albumen height and average egg weight per treatment according to the procedures described by Haugh (1937) and yolk diameter by caliper ruler (Fig 8A) colour was determined by comparing the colour of properly mixed yolk sample placed on white paper with the colour strips of Roche Yolk fan (Figures 8 B) measurement, which consisted of 1-15 strips ranging from pale to orange yellow colour (fig 9 A & B).

$$(1)\quad \text{Yolk ratio (\%)} = \frac{\text{yolk weight (g)}}{\text{egg weight (g)}} \times 100$$

$$(2)\quad \text{Yolk index (\%)} = \frac{\text{yolk height (mm)}}{\text{yolk diameter (mm)}} \times 100$$

$$(3)\quad \text{Yolk/Albumen ratio (\%)} = \frac{\text{Yolk weight (g)}}{\text{Albumen weight (g)}} \times 100$$

$$(4)\quad \text{Haugh Unit} = 100 * \log (H + 7.57 - 1.7^{W0.37})$$

Where:

HU - Haugh unit;

H - Albumen height (mm);

W - Average egg weight (g)

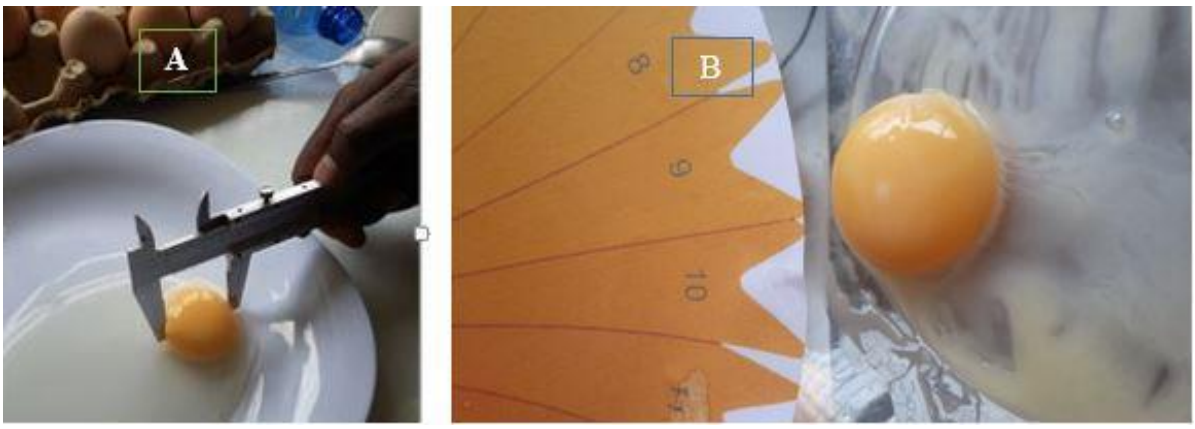


Figure 8. Yolk diameter and colour according to the treatment

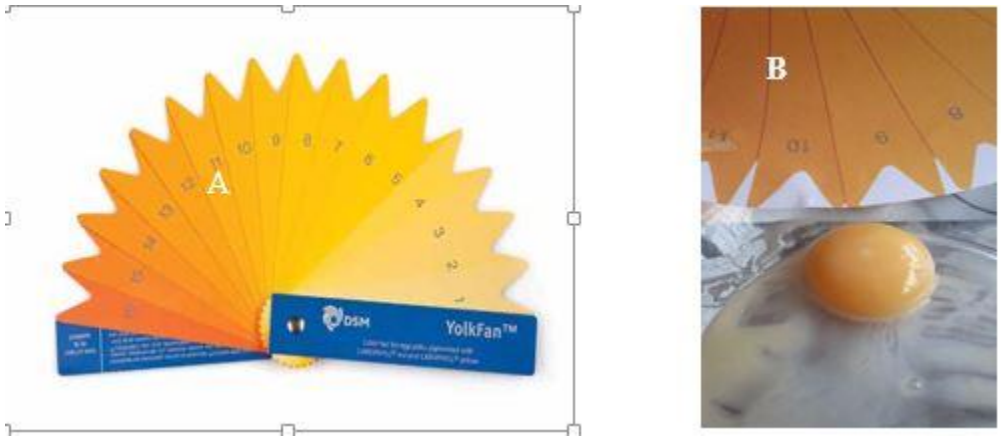


Figure 9. DSM yolk fan (A) (www.monodesign.co.uk.2016) and yolk colour measurement (B)

3.4 Economic Analysis

This study used two economics methods (1) Cost-benefit analysis- CBA and (2) Return on Investment-RoI) to compare the treatment which gave the most economical for the farmer.

3.4.1 Cost-Benefit Analysis (CBA)

CBA is a systematic process for calculating and comparing benefits, costs of a decision in a particular project. It is meant to compare if an investment is feasible verifying whether its benefits outweigh the costs, and by how much, and to compare whether Cost-benefit ratio (CBR) among the alternative project (diet) have an acceptable return (Boardman, 2011 & Alvarado, 2013). It helps decision-makers to decide the most profitable from a financial point of view.

The prevailing market prices for all ingredients for the diet, transport, disinfectant and price of eggs were considered as following: T1- 712.04, T2-668.87, T3- 657.9 and T4- 645.90 KSh. The difference between revenue generated less the cost of production gave the profit per treatment. The profit per treatment were compared to determine the most profitable one for recommendation using the formula below:

$$\text{Cost-Benefit Ratio (CBR)} = \frac{\text{Total Income}}{\text{Total Cost}}$$

If a project has a CBR greater than 1, it indicates that the net present value (NPV) of the project benefits outweigh the NPV of the costs. Therefore, the project should be considered if the value is significantly greater than 1. If the CBR is equal to 1, the ratio indicates that the NPV of expected profits equal the costs. If a project's CBR is less than 1, the project's costs outweigh the benefits and it should not be considered.

3.4.2 Return on Investment (RoI)

Haughey (2010) defined return on investment (RoI) as a measurement that investigates the amount of additional profits produced due to a certain investments. RoI is suitable in comparison of different scenarios for an investments to evaluate which would produce the greatest profit and benefit for the project. RoI involves only two values: the cost of the investment and the gain from the investment. The formula is as follows:

$$\text{RoI (\%)} = \frac{\text{Gain from Investment - Cost of Investment}}{\text{Cost of Investment}} * 100\%$$

The ratio is multiplied by 100, making it a percent to express the percentage of the investment that has been gained back after a period of the experiment or project.

3.5 Chemical analysis

All ingredients and feed samples collected were subjected to proximate analysis. Samples were ground using a 1-mm screen in a grinder for analyses according to procedure described Association of Official Analytical Chemists (AOAC, 1990): Dry Matter (DM) using an oven set at 105^{o}C for 24 hours, Crude Protein (CP) by Kjeldah method; Gross Energy (GE) was done using bomb- calorimeter and metabolizable energy determined using method described by Sibbald (1975); Ether Extract (EE) using Soxhlet extractor method, Ash - by using muffle furnace at 550^{o} C for 4 hours and Crude fiber (CF) through “Anikom 200 fiber analyzer”. Condensed tannins were analysed using the method described by Pearson (1976). Absorbance was recorded using a spectrophotometer and results were expressed as mg tannic acid equivalent per gram dry weight and converted to percentage. Minerals, Ca, P, Na, K, Fe Cu, Zn, using an atomic absorption

spectrophotometer for calcium, total phosphorus content by SP75 UV spectrophotometer, sodium, ion, cobalt, zinc and potassium by flame photometer (AOAC, 1990).

3.6 Statistical analysis

Statistical Analyses were performed using Statistical Analysis System (SAS) software version 9 in a Completely Randomized Design (CRD). Prior to analysis, data were tested for normality using the Kolmogorov–Smirnov and shapiro tests Statistical Analysis Software (SAS, version 9, 2002). With the exception of yolk colour (used Yolk colour fan), all other data were analyzed using the General Linear Model of Analysis of Variance-GLM (ANOVA) to determine differences between treatments at 5% level of significance. Mean separation was done using multi-comparison Tukey's test. The following model was used for data analysis.

Model:

$Y_{ij} = \mu + \tau_i + \varepsilon_{ij}$

Where: Y_i- Effect of treatment (feed);

i =1, 2, 3 and 4.

μ - is the overall mean;

τ_i - effect of the diet;

ε_j - error term

CHAPTER FOUR

RESULTS

4.1 Chemical Composition of Ground Mature *Prosopis* pods

The chemical composition of the *Prosopis* pods were analysed in triplicate and compared according to the county of origin. Results of the ash, CP, DM, EE, CF, neutral detergent fibre (NDF), acid detergent fibre (ADF) and condensed tannins contents are presented in Table 2.

The DM, CP, EE and ash content differed with the source of the pods. However, the energy content was similar (P>0.05) for the Baringo and Kajiado samples but different (P<0.05) from Garissa samples. Crude fibre and condensed tannins content significantly differed with the source (county) of pods. The Baringo and Kajiado samples had similar (P>0.05) NDF and ADF contents.

Table 2: Chemical composition of mature prosopis pods by county

Parameters	County			± SEM
	Baringo	Kajiado	Garissa	
DM (g/Kg)	944.0 [a]	921.6 [b]	893.3 [c]	01.8
		In DM basis		
Gross Energy(MJ/Kg)	17.31 [a]	17.15 [a]	16.22 [b]	0.25
CP (g/kg)	125.6 [c]	128.1 [b]	148.7 [a]	0.01
EE (g/kg)	18.9 [b]	28.5 [a]	16.6 [c]	0.03
Ash (g/kg)	43.7 [b]	48.5 [a]	38.7 [c]	0.09
CF (g/kg)	191.6 [c]	262.4 [b]	339.1 [a]	03.8
NDF (g/kg)	458.7 [b]	430.4 [b]	523.2 [a]	2.97
ADF (g/kg)	297.1 [b]	320.3 [b]	370.1 [a]	1.57
Cond. Tannins (g/kg)	1.09 [C]	1.19 [ab]	2.08 [a]	0.02

Means in same row with different superscripts differ significantly (P < 0.05), SEM- Standard error mean

The mineral content of the pods is presented in Table 3. The pods had a similar (P>0.05) K, Cu and Zn but differed (P<0.05) in P, Ca, Na and Fe content.

Table 3. Mineral composition of mature prosopis pods by county

Mineral (g/DM)	County			
	Baringo	Kajiado	Garissa	± SE
P	1.7 [a]	1.5 [b]	1.6 [b]	0.01
K	7.3 [a]	7.4 [a]	7.6 [a]	0.06
Ca	4.3 [a]	3.2 [b]	2.9 [c]	0.01
Na	0.2 [b]	0.4 [a]	0.1 [c]	0.01
Fe	0.4 [b]	0.4 [c]	0.5 [a]	0.01
Cu	0.1 [a]	0.1 [a]	0.1 [a]	0.01
Zn	0.3 [a]	0.3 [a]	0.3 [a]	0.01

Means in same row with different superscripts differ significantly ($P < 0.05$).

4.2 Metabolizable Energy of Pods

Farrell (1974) defined ME as a value represented as the difference between the heat of combustion of the feed consumed and the heat of combustion of faeces and urine attributed to the amount of feed eaten. Table 4 shows ME of the *Prosopis* pods which was determined to be 7.61 MJ/Kg.

Table 4. Metabolizable Energy (ME) content of prosopis pods from Baringo County

Feedstuff	N^{o} of samples	DM (%)	± SE	GE (MJ/Kg)	± SE	ME (MJ/Kg)	± SE
P.juliflora pods	9	94.41	4.59	16.57	1.73	7.61	1.55

DM- Dry matter, GE- Gross energy, ME- Metabolizable energy, SE- standard error, MJ- Mega joule.

4.3 Experimental diets

The results of the chemical composition of experimental diets is shown in Table 5. As the level of inclusion of *P. juliflora* pods (GPJP) increased, the level of crude fibre also increase due

to higher fibre content of pods (Table 5). All diets were, iso-caloric and iso-nitrogenous, 12.8MJ/kg ME and 16% Crude Protein respectively.

Table 5. Analyzed chemical composition of the diets including mature prosopis pods (GPJP)

Nutrients	Treatments			
	T1-0%	**T2-10%**	**T3-20%**	**T4-30%**
• Dry matter (%)	93.55	93.12	92.58	92.33
		In DM basis		
• ME (MJ/kg)	12.90	12.80	12.80	12.80
• CP (%)	15.89	15.86	15.91	15.85
• CF (%)	2.20	5.10	7.90	10.70
• Ca (%)	4.10	4.20	4.10	4.10
• P (%)	1.10	1.10	1.00	1.10

Source of chemical analysis of *P. juliflora pods*: Nutrition Laboratory Animal Science, Egerton University.

4.4 Production Performance of layers

The result of production performance, feed intake, weight gain, feed conversion ratio, egg production, egg weight and egg mass are presented in Table 6. Inclusion of GPJP in the diets had a negative effect on final live weight ($Y= -70.2x+2059$, $R^2=0.93$) (Table 6 and Figure 10) ($P<0.05$) but had no affect feed intake ($P>0.05$). Egg production decreased with increasing inclusion level of GPJP and was similar for hens offered T1 and T2 diets, but higher than those offered T3 and T4 which T4 was also similar to T1 (Table 6, Figure 11). Egg weight was higher for hens offered T1 ($P<0.05$) than T2, T3 and similar to T4 ($P>0.05$). Hens offered T2 and T3 diets had similar egg weights.

Table 6. Productive performance of laying IC layers offered diets containing prosopis pods

Parameters	Treatments				
	T1-0%	T2-10%	T3-20%	T4-30%	±SE
Initial body weight (g/bird)	1867.19^{a}	1845.94^{a}	1892.81^{a}	1861.88^{a}	48.78
Final body weight (g/bird)	2010.31^{a}	1884.31^{ab}	1854.38^{b}	1786.25^{b}	53.31
Body weight gain (g/bird)	143.13^{a}	38.38a^{b}	-38.44^{b}	-75.00^{b}	53.57
Egg production (nr/week)	84.63^{ab}	84.75^{a}	70.63^{c}	76.25^{bc}	2.31
Egg production (%)	74.55^{ab}	75.22^{a}	62.72^{c}	68.30^{bc}	1.99
Total egg samples (nr of eggs)	48	48	48	48	
Egg weight (g)	63.54^{a}	61.08^{b}	61.71^{b}	63.00^{ab}	0.59
Egg mass (g)	48.06^{a}	46.21^{a}	38.92^{b}	42.90^{ab}	1.38
Feed intake (g/bird)	115.73^{a}	115.23^{a}	122.88^{a}	121.56^{a}	2.47
FCR (per egg weight)	1.82^{b}	1.94^{ab}	1.99^{a}	1.93^{ab}	0.04

Means in same row that do not share a superscript letter are significantly different (at 5% level of significance). FCR- Feed Conversion Ratio (average feed intake (g)/average egg weight (g)

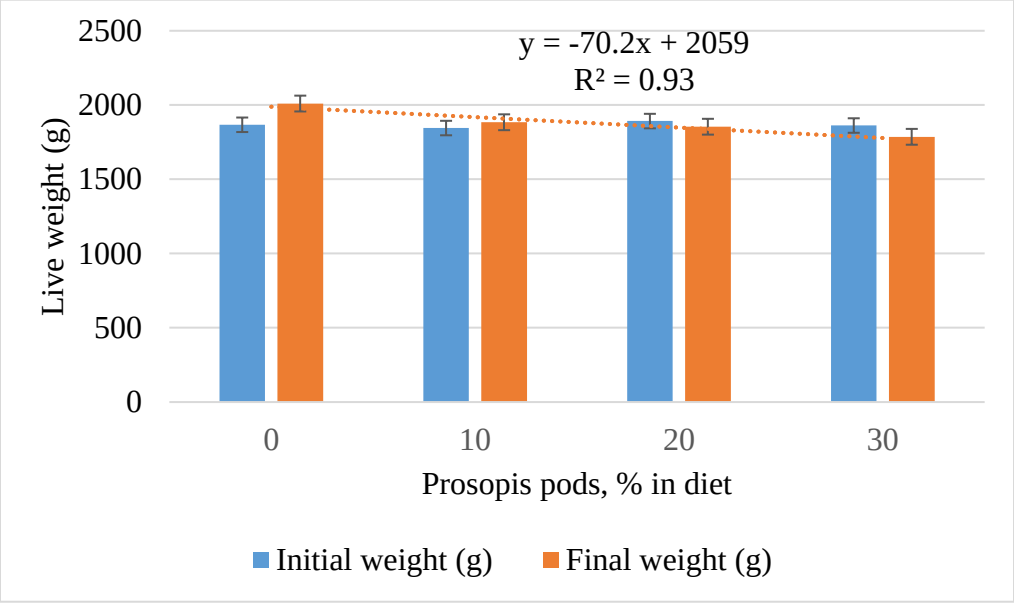


Figure 10. Effect of proportion of Prosopis pods in the diet on changes in live weight

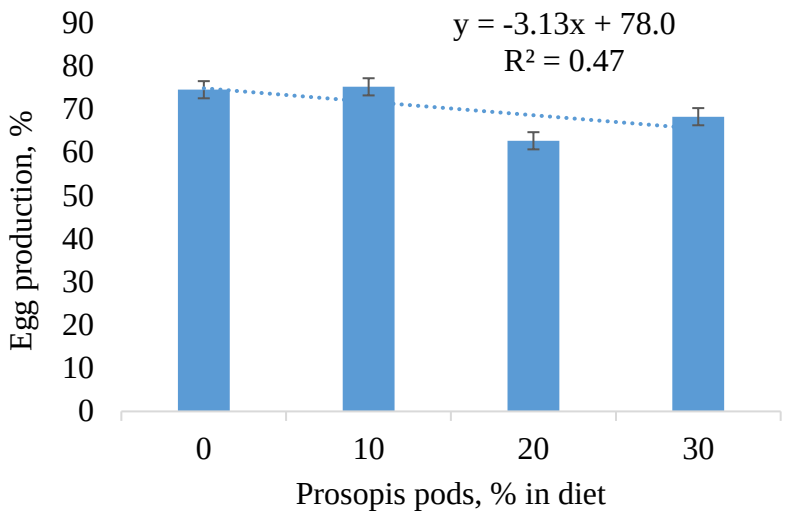


Figure 11. Effect of proportion of Prosopis pods in the diet on egg production

Egg mass was higher in hens offered T1 and T2 than those on T3 and T4 diets while hens on T1 and T2 diets had similar weight. Feed intake was similar for hens in all treatments but feed conversion ratio was different for hens offered T1 and T3 but similar for hens on T3 and T4. Hens on T1 diet were more efficient compared to those on T3and but similar to hens on T2 and T4.

4.5 External Quality

The effect of inclusion of GPJP in the layer diets on external egg quality analysis is presented on Table 7. External egg quality is related to size, shell quality and shape index which were measured using indirect methods based on egg height, width, shape index and egg eggshell weight. These parameters were similar except eggshell thickness and eggshell ratio. Shell thickness was similar in hens offered T1and T2 but higher ($P<0.05$) in those offered T3 and T4. Shell ratio as a measure of the proportion of shell weight to egg weight was similar for hens offered T2 and T4 but different from those on T1 and T3.

Table 7. External egg quality characteristics

Parameters	Treatments				
	T1-0%	T2-10%	T3-20%	T4-30%	±SE
Egg height (mm)	59.36	69.07	57.76	59.35	5.28
Egg width (mm)	43.30	42.61	42.86	43.09	0.22
Shape index (%)	73.01	67.2	74.23	72.61	2.93
Eggshell weight (g)	4.91	5.02	5.24	5.14	0.09
Shell thickness (mm)	0.34^{b}	0.34^{b}	0.36^{ab}	0.37^{a}	0.01
Eggshell ratio (%)	7.72^{b}	8.21^{ab}	8.48^{a}	8.16^{ab}	0.12

Means in same row that do not share a superscript letter are not significantly different (at 5% level of significance) ($P<0.05$)

The diets had no effect ($P>0.05$) on egg height, egg width, shape index and eggshell weight. Diets T2 and T4 had similar ($P>0.05$) effect on eggshell ratio. The diets had a different effect on shell thickness.

4.6 Internal Egg Quality

The internal quality of an egg is determined by the composition of egg white, yolk, possible enclosures (fresh, blood), and also by viscosity or freshness since egg starts to age directly after laying (Niekerk, 2014). Quality is determined by proportion of the yolk, albumen and eggshell weights compared to the average egg weight and height, diameter and colour of the yolk. Yolk weight, height, diameter, yolk index and ratio, albumen weight, height, yolk: albumen ratio, and Haugh unit were not affected by the inclusion of GPJP in all treatments except yolk colour which was evidently higher (deep yellow colour) for eggs from hens offered T4 followed by T3 while eggs from hens on diets T1 and T2 had a similar yolk colour as indicated in Table 8 and figure 12.

Table 8. Internal egg quality characteristics

Parameters	Treatments				
	T1-0%	T2-10%	T3-20%	T4-30%	±SE
Yolk weight (g)	17.65	16.78	16.86	17.29	0.27
Yolk height (mm)	16.14	14.69	14.53	14.75	0.54
Yolk diameter (mm)	39.44	38.63	39.58	39.89	0.50
Yolk index (%)	40.99	38.07	36.72	36.99	1.46
Yolk ratio (%)	27.78	27.46	27.34	27.44	0.40
Albumen weight (g)	40.99	39.29	39.62	40.57	0.50
Albumen Height (mm)	7.88	7.80	7.83	7.97	0.12
Yolk: albumen ratio	43.08	42.72	42.64	42.68	0.91
Haugh unit	87.89	88.05	87.97	88.40	0.69
Yolk colour	9.23^{c}	9.25^{c}	10.25^{b}	10.92^{a}	0.13

Means in same row that do not share a superscript letter are not significantly different (at 5% level of significance) ($P<0.05$)

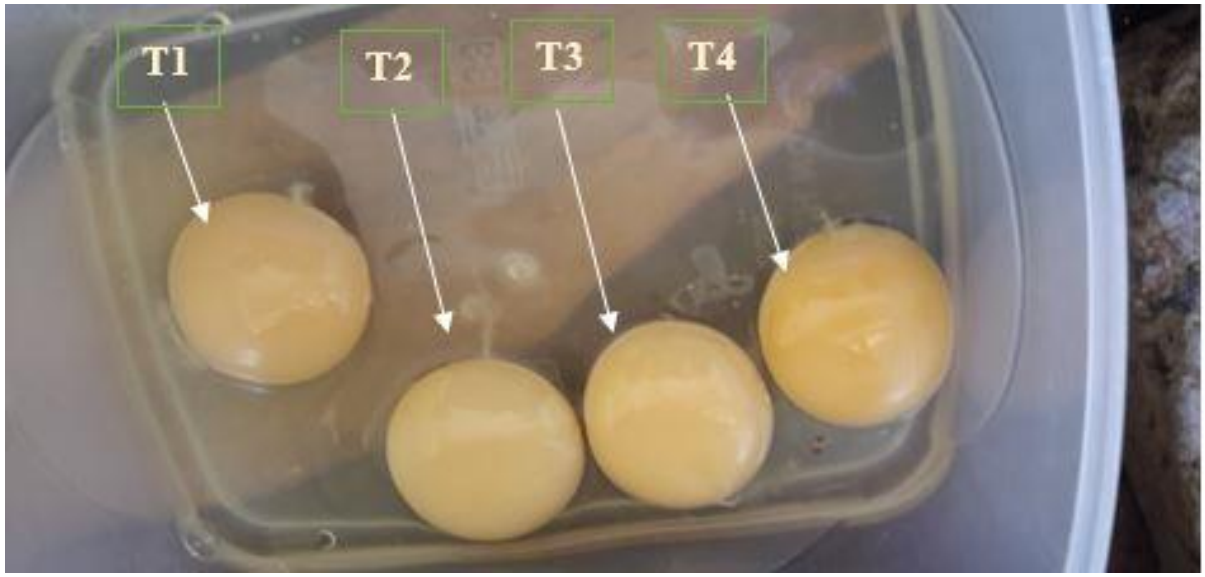


Figure 12. Yolk colour according to the treatment.

4.7 Economic Analysis

The cost benefit parameters of egg production per treatment were determined using the

method described by Boardman (2011) & Alvarado (2013) which was meant to compare suggested project based on income and cost using Cost-Benefit ratio (CBR). Another method was Return on Investment (RoI) and both suggested T2, (10%) had the greatest profit.

Costs related to the experimental diets, transport, drugs and labour were considered and income from egg production per week. The price of table eggs was KSh 10 per egg. The profit was calculated as the difference between income and cost per week in each treatment. The cost decreased as the inclusion of GPJP increased in the diet. The diet at 10% of GPJP inclusion (T2) was cheaper (KSh, 7.62) compared to all other treatments

According to the prevailing price per egg in the market, income per egg was higher from hens offered diet T2 than all other treatments followed by T1, T4 and lowest T3. The profit/week was higher in hens on T2 compared to all treatments (Table 9). The Cost benefit ratio in T2=1.27 indicates that the production benefits significantly outweigh its costs due to high egg production of hens compared to other treatments. This ratio indicated more incomes when the farmers adopt 10% of GPJP inclusion in the diet or expect KSh, 1.27 in benefits for each KSh 1 of its cost.

Return on Investment (RoI) also showed diet T2 to be the treatment with greatest profit, 26.71% compared to others. This percentage was a result of the gain from income/benefit of the eggs sold minus Cost of Investment divided by Cost of the investment multiplied by 100%.

Table 9. Economic Analysis (CBR and RoI) of inclusion of GPJP in the diet of laying IC

Parameters	Treatments			
	T1-0%	**T2-10%**	**T3-20%**	**T4-30%**
Feed cost (KSh)	422.04	378.87	367.9	355.9
Transport (KSh)	75.00	75.00	75.00	75.00
Disinfectant (KSh)	27.50	27.50	27.50	27.50
Labour (KSh)	187.50	187.50	187.50	187.50
Total cost (KSh)	712.04	668.87	657.9	645.90
Nr of egg produced	84.63	84.75	70.63	76.25
Cost per egg (KSh)	8.41	7.62	9.31	8.47
Income/benefit (KSh)	846.25	847.5	706.25	762.50
Profit (KSh)	134.21	178.63	48.35	116.60
Cost-Benefit Ratio (CBR)	1.19	1.27	1.07	1.18
RoI (%)	18.85	26.71^{B}	7.35	18.10

B- Recommended treatment KSh-Kenyan Shillings (currency)

CHAPTER FIVE

DISCUSSION

5.1 Nutritive Composition of Prosopis pods

Mahgoub *et al.* (2005) reported similar results to this study (g/kg), dry matter (930), Crude protein (120), ether extract (26), Ash (40) content. However, there were differences in crude protein content with samples from Garissa (148.7 g/kg) compare to the cited authors. This may be attributed to the analytial method used by the cited authors (Foss Tecator Kjeltec 2300 Nitrogen/Protein Analyser- method 976.05) which was different from this study which used methods described in AOAC (1990), (digestion, distillation and titration). However, ether extract and calcium from Baringo and Garissa Counties samples were all different (P <0.05), 18.9, 4.25 g and 16.6 g and 2.9 g/kg respectively except phosphorus which was higher, 1.72g (P <0.05) in Baringo and similar between Kaijado, 1.54 g and Garissa, 1.55 g Counties (P >0.05) but lower compared to values reported by previous cited authors. This variation may be atributted to differences in environmental factors between Oman and Kenya such as type of soil and fertility, pH and water availability. Samples in this study were collected from wild forests (without human management) which can bring difference in soil fertility and therefore in plant tissues nutrients content. Odero-Waitituch *et al.,* (2015) reported nutritional composition of pods from Marigat Sub-county in Baringo County, DM- 903.0 g, CP-114.0g, CF- 177.0g ash- 27g which is lower compared to all Counties in this study (Tables 2) except DM from Garissa, 893.3 g which was similar with the cited author. Choge *et al.* (2007) reported higher CP content of 160.0g in pods similar to Abdulrazak *et al.* (1999) who reported a CP of 163.0 g. The cited authors also concluded that different silvopastoral practices contribute to variation in nutritional composition of the plant tissues.

Sawal *et al.* (2004) evaluated *Prosopis juliflora* pods as a feed resource for livestock. Chemical composition reported for the whole pods, the values of CP, EE, CF and Ash in g/kg were 73.3 -165.0; 13-42.6; 169.0-307.7 and 320-71.0 respectively. Results of this experiment are within this range but higher than results reported by Girma *et al.* (2012) in CF, 146.0 g/kg and lower in EE, 60.1 g/kg where the cited authors used different method for CF analysis compared to this study (ANICOM, 200 fiber analyser) which is more accurate.

Tegegn, (2008) reported 130.0 g/kg crude protein which is similar to CP from Kajiado, 128.1 g. King'ori *et al.* (2011)- published a review paper on *Prosopis* pods from Kenya and others countries reported CP of 159.5 g/kg. Girma *et al.*(2012) studied pods as a livestock feed resource in Ethiopia and reported CP content, of 154.3 g/kg. This was higher compared to the results of this study but is within the range of African *Prosopis* pods, 70-220 g/kg reported by Oduol *et al.* (1986). However, crude fibre, 110-350 g/kg, fat 10-16.0 g/kgand ash, 30-60.0 g/kg were similar to the reported studies. Mahgoub *et al.* (2005) reported similar results to Kajiado samples for NDF, 402.0 g/kg and ADF, 317.0 g/kg but lower than samples from Garissa samples NDF, 523.0 g, and ADF, 370.0g/kg.

Tannins in this study were higher (10.93 to 20. 83 g/kg) compared to values reported by Ehsen *et al.* (2016); Kiran & Bhima, (2012) 0.5 g/kg and 1.1 g respectively but not harmful to the animal. Villalba *et al.* (2002); Frutos *et al.* (2004) reported that tannins in low doses (less than 4%) increase animal feed intake. Barry & McNabb (1999) recommended 5 to 30 g of tannins for animal feed as they improved protein digestion and productivity of grazing ruminants. Terriell *et al.* (1992) reported that tannins in high concentration in the diet bind the protein and reduces digestion and absorption and consequently essential amino acids, which depresses voluntary feed intake.

Hardikar & Pandey (2008) and Faquin, (2005) reported that salinity causes reduction in water content and water potential of plant tissues, resulting in internal water deficit due to lower osmotic potential of soil water and consequently the availability of soil water to the plant. This could be the reason for the higher dry matter content in samples from Baringo and Kajiado where the soils are moderately saline pH (5.1 -8.0) and pH (6.1- 8.1) respectively. The study also reported that increased soil salinity leads to increased Na concentration in plant tissues which was observed in samples from Kajiado saline, 0.4 g compared to Garissa, 0.1 g where soils had a neutral (pH~7). Nevertheless, N accumulation decreases in plant tissues with increasing salinity. This is due to the fact that an increase in chloride uptake and accumulation is mostly accompanied by a decrease in shoot nitrate concentration. Samples from Baringo and Kajiado were lower in CP, 125.6 g/kg and 128.1g/kg respectively which can be attributed to low N in the plant tissues as a result of increased soil salinity compared to Garissa which recorded, 148.7 g/kg CP content for the pods. Ali *et al.* (2014) reported low crude fibre in salinized soils which is similar in this study where crude fibre

of the saline soils from Baringo and Kajiado were 191.6 and 262.4 g/kg respectively compared to neutral soil of Garissa, 339.1g/kg of crude fibre.

Keogh *et al.* (1988) reported plant growth reduction at temperatures above 25^{o}C and may cease above 30-35^{o}C consequently reducing mobilization of nutrients due to heat stress even with fertile soil and water content. The temperature in Baringo, Kajiado and Garissa Counties vary according to the season ranging from 25 to 38^{o}C thus influencing plant physiology. Levitt (1980) reported that when high temperature was the primary stress, which induced a water deficit subsequently caused mineral nutrient deficiency. Therefore, the major factor influencing the composition of *Prosopis* pods nutrient composition in this study is soil pH since all counties have high temperatures.

5.2 Metabolizable Energy

Metabolizable energy was 7.6 MJ/kg which was lower than the reported by Odero-Waitituh *et al*. (2015). This can be explained by the indirect method used by the cited author compared to this study which was *in vivo* despite GE being in the range reported by Choge *et al*. (2007), 15.3 MJ/Kg DM and Odero-Waitituh *et al*. (2015), 17.5 MJ/kg DM. The stage of harvesting and storage at the airtight bags was different to the present study where the storage was in the air circulated.

Sibbald and Price (1975a) recommended adult roosters for the measurement of ME of diets since adult birds would be approximately in nitrogen balance; and they can tolerate diets which may be imbalanced, or contain large amounts of a single ingredient. Farrell, (1974); Sibbald & Price (1975a) recommended substitution of the test ingredient with the basal diet (control) no less than 10% due the variation in the result. In this study the amount of control diet (glucose) was similar to the test ingredient, *Prosopis* pods (40 g). Guillame and summers (1970) concluded that feed intake below 40 g/d can influence ME from endogenous and metabolic process. To be accurate the test ingredient fed daily should be equal to or above 40 g per rooster and weight of bird considered. This was done in the current study. Farrell (1974) concluded that total collection of excreta from the birds kept individually, fasted over 24 hours before trial period represent all excreta from the feed consumed and gives an accurate assessment of ME of the diet. These procedures were followed in this study although in the cited study, the feeding was *ad-libitum*. In this study, the roosters were force-fed once to be accurate in amount fed.

5.3 Productive performance of hens

The level of crude fibre across the treatments was different (Table 5) but did not influence feed intake. Girma *et al.* (2011a) reported lower live weight in broilers on treatments of 20 to 30% GPJP inclusion compared to control (0% of GPJP) which was similar to the present study. The tendency for reduced live weight and rate of egg production observed can be attributed to lower digestibility of prosopis pods compared the treatment T1 and T2 with high level of inclusion of ingredients such as maize, soybean and fish meal. It has reported also that hens have ability to adjust their nutrients requirement from the catabolism to sustain production when feed supplies less than required. This metabolic process (catabolism) might be the reason for live weight loss in T3 e T4 to sustain egg production, however T1 and T2 have increased the weight due to higher level of inclusion of the maize, soybean and fish meal and therefore higher digestibility.

The differences on egg weight was not clear explained among the treatments in the current study although prosopis pods could be limited in some amino acids such as lysine, methionine and cysteine (Odero-Waitituh *et al.*,2015) which were reported by Joly (2009) as factors contributing to reduction on rate of egg production, egg weight and mass. Lower digestibility of prosopis pods due to trypsin inhibitor reported by Valle *et al.* (1983) in pods compared to maize and fish meal in control group stands out to nutrients deficiency and leads to low rate of egg production.

Feed intake was similar but different in final live weight and this was in agreement with the results reported by Nigatu (2015) in evaluation of the performance of white leghorn layers fed on a diet with up to 30% of GPJP. Girma *et al.* (2012) and Silva *et al.* (2002) reported reduced feed intake as the inclusion of GPJP increased in commercial layers and Japanese quails diets above 20%. Their findings are different from the results of this study probably due to the use of improved indigenous hens in this study, which are may be better adapted to high non-starch polysaccharides (fibre) intake as scavenging chicken. This is also explained by the feed conversion ratio, which was similar for hens offered treatments T1, T2 and T4 despite higher fibre.

Experiments conducted by Kondra *et al.* (1974), to determine the effect of feeding high (19.6%) or low (7.7%) fibre diet to meat- and egg-type chickens reported a significant increase in weight, size and number of various components of the digestive system with increasing fibre in the diets. Increase in size of various organs is considered to be an attempt to hold and process a

relatively large volume of feed and extract the nutrients more efficiently from the diet despite poultry known by decreasing nutrients digestibility in diet with higher fibre level. Ngeno *et al.*, (2014) based on previous cited study concluded that chickens anatomical and physiological adaptation to increase volume of feed of low nutrient density, so that required nutrients can be obtained. This adaptation can maximize nutrients utilization on the diets of low and variable quality and it could be more advanced and complex in indigenous chickens.

Study conducted by Odero-Waitituh *et al.* (2015) to determine the effect of replacing maize in broiler finisher diets with milled mature Prosopis pods (MMPP) at 0, 10, 20 and 30% levels on performance of broilers (male and female) indicated negative performance in feed intake, FCR, weight and average daily gain when the level of GPJP increased. These authors reported that a level of up to 20% of GPJP meal could be included in diets of broilers with no loss of performance. Mirnawati *et al.* (2011) concluded that in broilers, fibre above 6% hinder protein and energy digestibility hence depresses feed intake and enzymatic activity that helps carbohydrate, protein and fat digestion. The facts observed in mentioned study differ in feed intake and FCR may be due to relative tolerance of fibre in improved indigenous chicken layers. Similar result was observed in weight gain since layers adjust the nutrients from catabolism (Joly, 2009) to maintain egg production depressing body weight up to minimum required for maintenance.

Girma *et al.* (2011b) reported higher income from commercial layers offered diets containing up to 20% prosopis pods. The same authors reported no effect (0-30% of GPJP inclusion) on body weight gain, egg weight, and FCR. Silva *et al.* (2002) using *P.Juliflora* flour (0 to 25%) in quail diet and Speedy (1991) using same flour replacing up to 100% of wheat bran in rations for chickens reported no effect on feed intake, FCR and egg weight. Similar results on feed intake were observed in this study except body weight gain decreased on T3 and T4 and egg weight was affected negatively with increasing GPJP in the diet T2 and T3. FCR was higher in hens offered T2, T3 and T4 while egg weight was higher in hens on T1, T2 and T4 compared to those on T3.

The low nutrients density in T2, T3 and T4 diets due to increasing crude fibre with increase in GPJP could be the reason for higher FCR compared to hens on diet T1 which was the control (0% of GPJP). Studies of the cited authors were replacing an ingredient (wheat bran with pods

flour) in the diet compared to the current study which was in total diet and Chee (2005) reported low crude fibre (8.7%) on wheat bran than prosopis pods (19.2%).

Studies published by Girma *et al.* (2011b), 58.0 g; Nigatu, (2015), 50.5 g. Joly (2009), reported that bigger hens produce larger eggs than smaller hens and bigger breeders produce larger eggs than smaller breeders. The increases in production with both hen weight and egg size can be also attributed to the difference in breeds (improved indigenous vs exotic) and hen weight 1.33 ±0.22 and 1.08 ±0.6 kg used by Girma *et al.* (2011b) and (Nigatu, 2015) respectively compared to this study (1.87 ± 0.49 kg). Egg mass was also higher in this experiment than by the cited authors due to lower egg production and egg weight in their studies.

5.4 Egg quality (external and internal)

Girma *et al.* (2011a) reported no influence of GPJP on egg quality parameters except yolk colour which tended to increase with increasing level of GPJP in the diet. Similar results were observed in this study where dietary GPJP of 30% (T4) resulted in eggs with a similar colour to eggs laid by hens offered diets with 20% GPJP (T3) which was a deeper colour than for eggs laid by hens on the control diets (0%) and 10% GPJP inclusion in the diets ($P>0.05$). Nigatu (2015) also reported that 30% of GPJP improved yolk yellow colour than others treatments up to 20%. Yellow yolk colour is determined by animal genetic or xanthophyll (plant pigment with beta-carotene) content in the diet. Beta-carotene in GPJP was reported also by Girma *et al.* (2011a) at 82.35 µg/100g level which was responsible for the yellow yolk colour. DSA Animal Nutrition (2016) reported that deposition of dietary carotenoids in the egg yolk depends on carotenoid molecule. As the content of carotenoid in the feed increases, their concentration in the egg yolk rises. Diets containing 20 and 30% GPJP increased yolk colour in this study. At 30% GPJP inclusion in laying chicken diet was recommended as the preferred yolk colour for the consumers.

Shell thickness was higher in eggs for hens offered T4 ($P<0.05$) compared to T1and T2 but similar to T3 ($P>0.05$). This could be as a result of anatomical and physiological adaptation Ngeno *et al.* (2014) which increased volume of GIT organs and feed of low nutrient density (higher fibre), so as to maximize nutrients utilization on the diet. Nigatu (2015) reported similar results with this study but higher than observed by Girma *et al.* (2011b) due to calcium levels in the diet which were 3.93% in total feed compared to 4.1 and 4.2% applied in this study and by Nigatu (2015)

respectively. Olgun *et al.*(2013) evaluated the effect of limestone particle size at 4% of calcium inclusion in the diet on performance of layers and quality of eggshell reported 37 mm of eggshell thickness which was also similar with this study due to the same level of calcium.

CHAPTER SIX

CONCLUSION

From the findings of this study, the following conclusions were made:

i. Gross energy of pods from Baringo County was 17.31 MJ/kg. For the samples from Garissa County, the crude protein and crude fiber content were 148.7 and 339.1 g/kg respectively. Calcium and Phosphorus content were 4.3 and 1.7 g/kg respectively in samples from Baringo County. The crude fibre of the pods was 339.1 and 191.6 g/kg in the samples from Garissa and Baringo Counties respectively.

ii. The metabolizable energy content of the pods from Baringo County was 7.61 MJ/kg.

iii. The optimum inclusion level of GPJP in laying improved indigenous chicken diet was 10% of total ration. Inclusion of GPJP at 10% of total ration of laying improved indigenous chicken resulted in a similar performance with the control diet.

iv. Inclusion of GPJP at 30% of total ration in laying improved indigenous chicken diet had no effect on egg quality except egg yolk colour.

v. Inclusion of GPJP at 10% of total ration in laying improved indigenous chicken diet had lower cost of production and higher profit margin than the control and other diets.

RECOMMENDATIONS

I. Ground *Prosopis juliflora* pods can be used in improved indigenous chicken feed formulation with up to 10% inclusion of the total ration for laying improved indigenous chicken.

II. Pods should be processed (grinding) before feed mixing.

III. A study should be conducted to assess the effect of processing method (fermentation, milling) and inclusion of feed additives (fibrolytic enzymes, tannin binder) on the level of inclusion of Prosopis pods in chicken diets.

REFERENCES

Abdulrazak, S. A., Awanol, T. I., Fujihara1, T. and Nyangaga, J., (1999) Nutritive evaluation of *Prosopis juliflora fruits* and leaves from Kenya: Chemical composition and *in vitro* gas production. In Proceeding of British Society of Animal Science, Scarborough, UK.22-24 March 1999 p. 146.

Ahmadi, F., & Rahimi, F. (2011). Factors Affecting Quality and Quantity of Egg Production in Laying Hens : A Review. *World Applied Sciences Journal* 12 (3): 372-384, 2011 ISSN 1818-4952 © IDOSI Publications, 2011, 12(3), 372–384.

Ali, A. S., Mohamed, B. F., & Dreyling, D. (2014). Salt tolerance and effects of salinity on some agricultural crops in the Sudan. *Journal of Forest Products & Industries 3*(2), 56-65.

Alcedo, G. E. C. (1999). Production and characterisation of Prosopis seed galactomannan (Doctoral dissertation, Universidad de Piura). ETH No 13153

Alvarado, E. (2013). Cost-Benefit Analysis of an Agricultural Project Involving a Smallholder Production System, (December).

Anderson, D. L & Hill, F. W. (1958). Comparison of metabolizable energy and productive energy determinations with growing chicks. *Journal of Nutrition*, *64*, 587-603.

Andersson, S. (2005). Spread of the introduced tree species Prosopis juliflora (Sw.) DC in the Lake Baringo area, Kenya, (5). Retrieved from www.researchgate.net/.../27655031

Association of Official Analytical Chemists: Official Methods of Analysis (AOAC) (1990). (Volume1), Retrieved from https://law.resource.org/.../aoac.methods.1.1990.pdf

Applegate, T. J. (2012). Factors Affecting Feed Intake. In *Arkansas Nutrition Conference*. Retrieved from www.thepoultryfederation.com/.../Applegate_Factors affectin

Bar, A, Razaphkovsky, V., & Vax, E. (2002). Re-evaluation of Calcium and Phosphorus requirements in aged laying hens. *British Poultry Science*, *43*(2), 261–269. http://doi.org/10.1080/00071660120121481

Barry, T.N. & McNabb W. C (1999), The implicationsnof Condensed tannins on nutritive value of temperate forages fed to ruminant. *British Journal for Nutrition* 81 (4): 263-27

Boardman, A.E (2011). Cost-benefit analysis: concepts and practice. Upper Saddle River, NJ Prentice Hall *Environmental Science & Policy Journal17 (1) 18-36*

Çelebi, S., Bölükbasi, S. C., & Utlu, N. (2005). The influence of dietary phosphorus level on plasma calcium and phosphorus, eggshell calcium and phosphorus. *International Journal of Poultry Science*, *4*(7), 497–499. http://doi.org/10.3923/ijps.2005.497.499

Chee, K. M., Chun, K. S., Huh, B. D., Choi, J. H., Chung, M. K., Lee, H. S. & Whang, K. Y. (2005). Comparative feeding values of soybean hulls and wheat bran for growing and finishing swine. *Asian-Aust. J. Anim. Sci., Melborne*, *18*(6), 861-867.

Choge, S. K., Pasiecznik, N. M., Harvey, M., Wright, J., Awan, S. Z., & Harris, P. J. C. (2007). Prosopis pods as human food, with special reference to Kenya. *Water SA*, *33*(3 Special ediction), 419–424. http://doi.org/10.4314/wsa.v33i3.49162

Choge, S. K., Ngunjiri F. D., Kuria, M.N., Busaka E. A & Muthondeki J. K. (2002). The status and Impact of *Prosopis spp* in Kenya. Kenya Forestry Research Institute and Forest Department.

Dublecz, K. (2011). Poultry nutrition Lecture notes for students of MSc courses of Animal Science and Nutrition and Feed Safety. Az Agrármérnöki MSc szak tananyagfejlesztése Támop-4.1.2-08/1/A-2009-0010 projekt

Dutch State Mines (DSM) (2016) Animal Nutrition "Nederlandse Staatsmijnen" DSM egg yolk pigmentation guidelines, *DSM Bright Sciences* Bright Living Retrieved May 22, 2016 from http://www.dsm.com

Ebraheem Altahat, A. A.-S., & Altarawneh, M. (2012). Factors Affecting Profitability of Layer Hens Enterprises Ebraheem Altahat , Ali AL-Sharafat and Mohammad Altarawneh Department of Agricultural Economics and Extension , Faculty of Agriculture , Jerash University , Jerash , 26150 , Jordan, *7*(1), 106–113. *American Journal of Agricultural Biological Sciences*, *7*(1), 106-113.

Ehsen, S., Qasim, M., Abideen, Z., Rizvi, R. F., Gul, B., Ansari, R., & Khan, M. A. (2016). Secondary Metabolites As Anti-Nutritional Factors In Locally Used Halophytic Forage/Fodder. *Pakistan Journal Botany*, *48* (2), 629-636

.Faquin, V. (2005). Solos E Meio Ambiente Nutrição Mineral De Plantas. *Universidade Federal De Lavras-Ufla*, *Iii* (Faepe), *Revista Caatinga* 186.

Farrell, D. J. (1974). Rapid determination of metabolisable energy of Poultry Feedstuffs. Department of Biochemistry and Nutrition, University of New England Armidale *British Poultry Science*, *19*(3), 303-308.

Frikha, M., Safaa, H. M., Jiménez-Moreno, E., Lázaro, R., & Mateos, G. G. (2009). Influence of energy concentration and feed form of the diet on growth performance and digestive traits of brown egg-laying pullets from 1 to 120 days of age. *Animal Feed Science and Technology*, *153*(3–4), 292–302. http://doi.org/10.1016/j.anifeedsci.2009.06.012

Frutos, P., Hervas, G., Giráldez, F. J., & Mantecón, A. R. (2004). Review. Tannins and ruminant nutrition. *Spanish Journal of Agricultural Research*, *2*(2), 191-202.

Galea, F. (2009). Nutrition and food management and their influence on egg quality. In *XLVIII Simposio Científico De Avicultura. Santiago de Compostela* (Vol. 5).

Gerber, N. (2005). Factors Affecting Egg Quality. Poultry Industry Association of New Zealand 96 D Carlton Gore Road, Newmarket, 1023, Auckland, 1–4. http://eggfarmers.org.nz/actors_affecting_egg_quality.pdf.

Girma, M., Tamir, B., & Dessie, T. (2012). Effects of replacing peanut seed cake with brewery dried yeast on laying performance, egg quality and carcass characteristics of rhode island red chicken. *International Journal of Poultry Sciences*, *11*, 65-72.

Girma, M., Urge, M., & Animut, G. (2011a). Ground Prosopis juliflora Pod as Feed Ingredient in Poultry Diet : Effects on Laying Performance and Egg Quality, *Pakistan Journal for Nutrition 10*(11), 879–885.

Girma, M., Urge, M., & Animut, G. (2011b). Ground prosopis juliflora pod as feed ingredient in

poultry diet: Effects on laying performance and egg quality. *International Journal of Poultry Science*, *10*(11), 879–885.

Guillaume, J., & Summers, J. D. (1970). Maintenance energy requirement of the rooster and influence of plane of nutrition on metabolizable energy. *Canadian Journal of Animal Science*, *50*(2), 363-369.

Grobas, S., Mendez, J., De Blas, C., & Mateos, G. G. (1999). Laying hen productivity as affected by energy, supplemental fat, and linoleic acid concentration of the diet. *Poultry Science*, *78*(11), 1542–1551. http://doi.org/10.1093/ps/78.11.1542

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

Guillaume, J. & Summers, J. D. (1970) Net utilization of the energy from carbohydrates and protein in the growing chicks (1 to 3 weeks of age) in Energy metabolism of farm animals, Ed M. Vermorel, pages 281-284. *Canadian Journal of Animal Sciences* 50: 363

Hardikar, S., & Pandey, A. N. (2008). Growth, water status and nutrient accumulation of seedlings of Acacia senegal (L.) Willd. in response to soil salinity. *Anales de Biología*, *30*(9), 17–28. http://doi.org/10.1080/00103624.2011.584596

Hassan, M. K., Afify, M. a., & Aly, M. M. (2004). Genetic Resistance of Egyptian Chickens to Infectious Bursal Disease and Newcastle Disease. *Tropical Animal Health and Production*, *36*, 1–9. http://doi.org/10.1023/B:TROP.0000009524.47913.d4

Haugh, R. R, (1937) The Haugh unit for measuring egg quality. US egg. *Poultry Management*, 43:522-555. 572 -573.

Haughey, T. (2010). The Return on Investment (ROI) of Data Modeling, (March), 1–17.

HDRA, T. organic organisation. (2005). Controlling the spread of Prosopis in Ethiopia by its utilisation, (1). Retrieved from www.hdra.org.uk/international programme/ip publications.htm

Herrero, M., Ringler, C., Steeg, J. Van De, Koo, J., & Notenbaert, A. (2010). Climate variability and climate change and their impacts on Kenya's agricultural sector. *ILRI, Nairobi. Kenya*, 1–56.

Hunton, P. (2005). Research on eggshell structure and quality : An historical review. *Brazilian Journal of Poultry Science*, *7*, 67–71. http://doi.org/10.1590/S1516-635X2005000200001

Jacob, J., Pescatore, T. & Cantor A (2011) Avian Digestive System. University of Kentucky-Cooperative Extension Service College of Agriculture, (2), 1-6.

Johnson, A. L. (2015). Reproduction in the female. In: Avian Physiology, 6th Ed. *Sturkie's Avian Physiology*. http://doi.org/10.1016/B978-0-12-407160-5.00028-2

Joly, B. P. (2009). Factors That Influence Egg Weight : How To Change It To Meet Market Requirements, (2000), 1–11.

Kenya Agricultural & Livestock Research Organization (KALRO) (2013) Improved Practices in Rearing Indigenous Chickens (pp.0-3) Retrieved from http:// www. kienyejichicken.co.ke

Keogh, F., City, M., White, R. S., & Haferkamp, R. (1988). Environment al Factors Affecting Plant Productivit y, (September 1987).

Ketelaere, B., Govaerts, T., Coucke, P., Dewil, E., Visscher, J., Decuypere, E., De Baerdemaeker, J. (2002). Measuring the eggshell strength of 6 different genetic strains of laying hens: techniques and comparisons. *British Poultry Science*, *43*(2), 238–244. http://doi.org/10.1080/00071660120121454

Kingo'ri A. M; Guliye, A. Y. J. A., & Odero-Waitituh. (2011). Mathenge (*Prosopis julifiora*): An Underutilized Livestock Feed Resource in Kenya. *Research Journal of Animal Science, 5, 43–51*.

King'ori, a. M., Tuitoek, J. K., Muiruri, H. K., & Wachira, a. M. (2010). Effect of dietary crude protein levels on egg production, hatchability and post-hatch offspring performance of lndigenous chickens. *International Journal of Poultry Science*, *9*(4), 324–329. http://doi.org/10.3923/ijps.2010.324.329

King'ori, a M., Wachira, a M., & Tuitoek, J. K. (2014). Influence of Energy Intake on Egg Production and Weight in Indigenous Chickens of Kenya. *International Journal of Poultry Science*, *13*(3), 151–155.

Kiran, B. Bhima, B. (2012). Detoxification Of Anti Nutrients (Tannins) Present In Fruit Extracts For Probiotic Yeast Production B . Kiran Kumar and B . Bhima * Detoxification of Tannins, *International Journal of applied Biology and Pharmaceutical Technology* vol 3 Issue 3 Sptember 2012, 275–279.

Koelkebeck k. W. (2006) What is egg quality and Conserving It? University of Illinois *American Journal for Poutry Sciences* (5) 16-19.

Kondra, P. A., Sell, J. L., & Guenter, W. (1974). Response of meat-and egg-type chickens to a high fiber diet. *Canadian Journal of Animal Science*, *54*(4), 651-658.

Latour, B. M. a, Meunier, R., Stewart, J., Timeline, E. F., Reproductive, U., & Structures, T. (2012). Department of Animal Sciences. *Journal of Baylor Health Care System*

Livesey, G., & Brown, J. C. (1995). Whole body metabolism is not restricted to D-sugars because energy metabolism of L-sugars fits a computational model in rats. *The Journal of nutrition*, *125*(12), 3020.

Levitt, J. (1980) Responses of plant to environmental Stress. Volume II. Water, Radiation, Salt and other stresses. Academic Press. New York

Lopez, G., & Leeson, S. (2008). Review: energy partitioning in broiler chickens. *Canadian journal of animal science*, *88*(2), 205-212.

Mahgoub, O., , Isam T. Kadim, N. E. F., Dawood S. Al-Ajmi, Naseeb M. Al-Saqry, A. S. A.-A., & Annamalai, K. (2005). Evaluation of Meskit (*Prosopis juliflora*) pods as a feed for goats Evaluation of Meskit (*Prosopis juliflora*) pods as a feed for goats. *Animal Feed and Science Technology*, (March 2016). http://doi.org/10.1016/j.anifeedsci.2005.01.016

Marangoni, A & Alli (1980) Composition and properties of seeds and pods of the tree legume *Prosopis juliflora* (DC). *Journal of Science Food Agriculture* 44: 99-110

Masilamani, P., & Vadivelu, K. K. (1997). Tracing the seed development and maturation in kassod tree. *Madras Agricultural Journal*, *84*, 19-21.

Ministry of Livestock and Fisheries Development (MoLFD) (2004). Indigenous chickens Production in Kenya. retrieved June , 2, 2015 from http:// www.researchgate.net

Mukherjee T. K. (1992) Usefulness of indigenous breeds and imported stock for poultry production in hot climates. *World poultry congress*. September, 1992 Amsterdam. The Netherlands.

Mooney, H. A., Simposon B. B & Solbrio O. T. (1997) Phenology, morphology, physiology pp 26-43. In Mesquite. Its Biology in two Ecosystems. Simpson Dowden, Hutchinson and Ross, Stroudsburg, Pennsylvania, USA.

Narinc, D., Karaman, E., Aksoy, T., & Firat, M. Z. (2013). Investigation of nonlinear models to describe long-term egg production in Japanese quail. *Poultry science*, *92*(6), 1676-1682.

National Research Council (NRC) (1994). Nutrient Requirements of Poultry - *Google Books*, Ninth Revised Edition, Washington, DC: The National Academies Press http://doi.org/10.17226/2114

Ngeno, K., Vander Waaij, E. H., & Kahi, a. K. (2014). Indigenous chicken genetic resources in Kenya: their unique attributes and conservation options for improved use. *World's Poultry Science Journal*, *70*(1), 173–184. http://doi.org/10.1017/S0043933914000154

Niekerk, T. Van. (2014). Egg quality. Retrieved from www.lowinputbreeds.org

Nigatu, L. G. (2015). Effects of Inclusion of Ground *Prosopis Juliflora* Pod on Growth, Egg Production, Quality, Fertility And Hatchability Of White Leghorn Hens. *Statewide Agricultural Land Use Baseline 2015*,

Odero-Waitituch J. A., King'ori, A. M, G. A. Y. (2015). Prosopis juliflora Pods as Sources of Energy , Protein , Vitamins and Minerals in Livestock Diets in Kenya. *Egerton Journal of Science & Technology*, *15*(2073), 132–140.

Oduol, P. A., Felker, P., McKINLEY, C. R., & Meier, C. E. (1986). Variation among selected Prosopis families for pod sugar and pod protein contents. *Forest Ecology and Management*, *16*(1-4), 423-431.

Olgun, O., Yildiz, A. O., & Cufadar, Y. (2013). Effects of limestone particle size and dietary available Phosphorus (AP) contents on performance, eggshell quality and mineral excretion in laying hens. *Journal of Medicine Veterinary.-Toulouse*, *164*, 464-470.

Pasiecznik, N. M., Choge, S. K., Trenchard, L. J., & Harris, P. J. C. (2012). Improving food security in famine-prone areas using invasive and underutilized prosopis trees. *Food Chain*, *2*(2), 197–206. http://doi.org/10.3362/2046-1887.2012.017

Pasiecznik, Felker, P., Cruz, G., & Cadoret, K. (2001). The Prosopis juliflora - Prosopis pallida Complex : The Prosopis juliflora - Prosopis pallida Complex : Retrieved from https://www.gardenorganic.org.uk/.../ProsopisMonographComplete.pdf

Pelicia, K., Garcia, E., Faitarone, A., Silva, A., Berto, D., Molino, A., & F, V. (2009). Calcium and Available Phosphorus Levels for Laying Hens in Second Production Cycle. *Brazilian Journal of Poultry Science*, *11*(1), 39–49. http://doi.org/10.1590/S1516-635X2009000100007

Pearson, K. G., Wong, R. K., & Fourtner, C. R. (1976). Connexions between hair-plate afferents and motoneurones in the cockroach leg. *Journal of Experimental Biology*, *64*(1), 251-266.

Pesti, G. M. (1995). *Nutrient requirements of poultry*. *Animal Feed Science and Technology* (Vol. 56). http://doi.org/10.1016/0377-8401(95)90024-1

Radu-rusu, C. G., Pop, I. M., Simeanu, D., & Albu, A. (2008). Improvement of Quantitative and Qualitative Eggs Production Issued From Laying Hens , Under Thermal Stress Conditions . a Nutritional Approach, 186–190.

Roberts, J. A (2004) Factors Affecting Egg Internal Quality and Egg Shell Quality in Laying Hens; Animal Physiology, School of Rural Sciences and Agriculture. University of New England, Armidade, NSW, 2351, Australia, Review, *Journal of Poultry Sciences*, 41: 161-1777

Roberts, J. R. (2014). Ḥ Review ˜. Animal Physiology, *School of Rural Science and Agriculture,*11.

Statistical Analysis System (SAS) (2002) Institute Inc, The SAS System for Windows, Release 9.0

Sasongko, H., Yuwanta, T., Zuprizal, Z., Supadmo, S., & Widiyono, I. (2012). The Effect Of Calcium and Phosphorus Dietary Level on Egg Production of the Bantul Local Duck. *Journal of the Indonesian Tropical Animal Agriculture*, *37*(4), 257-262.

Sawal, R. K., Ratan, R., & Yadav, S. B. S. (2004). Mesquite (Prosopis juliflora) pods as a feed resource for livestock - A review. *Asian-Australasian Journal of Animal Sciences*, *17*(5), 719–725. Retrieved from www.ajas.info/upload/pdf/17-118.pdf

Sibbald, I. R., & Kramer, J. K. G. (1978). The effect of the basal diet on the true metabolizable energy value of fat. *Poultry Science*, *57*(3), 685-691.

Sibbald, I. R. Price (1975a) Variation in Metabolizable energy values for energy poultry and some physical and chemical data describing vanadian wheats, oats and barleys. *Canadian Journal of Animal Sciences* 55: 283

Sibbald, I. R. Price (1975b) The effect of level of feed intake on metabolizable energy values measured with adult roosters. *Journal of Poultry Sciences* 54: 1990-1998

Silva, J. H. V, de Oliveira, J. N. C., da Silva, E. L., Jordao, J., & Ribeiro, M. L. G. (2002). Use of integral mesquite (Prosopis juliflora (Sw.) DC) pods meal in the Japanese quails feeding. *Revista Brasileira De Zootecnia-Brazilian Journal of Animal Science*, *31*(4), 1789–1794.

Silva, A. M., Rodrigues, M.E & Silva J. F (1990) Nutritive Value of Mesquite beans (Prosopis juliflora) in the diet rabbit, Veterinaria e Zootecnia. *Asian Journal of Animal Sciences* 2004 vol 17, No 5: 719-725

Sirmah, P., Muisu, F., Mburu, F., Dumarçay, S., & Gérardin, P. (2008). Evaluation of Prosopis juliflora properties as an alternative to wood shortage in Kenya. *Bois et forêts des tropiques, 298*(4), 25-35.

Solano, L. (1989). Physical characteristics and contents of sugar in Prosopis species "Caracteristicas fisicas y Contenidos de azucar de diversas variedadesde algarroba" BSc thesis, Universidade de Piura, Peru.

Speedy, A. W. (1991). The Development of the FAO Tropical Feeds Information System, 9–21. Retrieved from www.fao.org/livestock/agap/frg/ECONF95/PDF/PROSOPIS

Sujatha, T., Rajini, R. A., & Prabakaran, R. (2014). Efficacy of pre-lay diet. *Journal of Applied Animal Research*, *42*(1), 57-64.

Talpada, P. M., & Shukla, P. C. (1988). Influence of Feeding *Prosopis-Juliflora* Pods on Digestibility and Balances in Lactating Cows. *Indian Journal of Animal Sciences*, *58*(6), 727-730.

Tegegn, G. G. (2008). Experiences on Prosopis Management Case of Afar Region, (September). Retrieved from www.farmafrica.org/.../FARM Africa

Terriell, T., Rowan A. M., Douglas, G. B & Barry T.N (1992). determination of extractable and bound tannin concentrations in forage plants, protein concentrate meals and cereals grains, *Journal of Food Sciences and Agriculture*, 58: 321-329

Usman M. & Rehman (2011). Aged related changes in egg weight and quality Traits in Flour deifferent close breed stocks of japanese quail cells, *Animal and Therapeutics Journal openaceas Journal*

Valkonen, E. (2010). *Egg production in furnished cages*. MTT Agrifood Research Finland. Retrieved from www.mtt.fi/mtttiede/pdf/mtttiede12.pdf

Valle, N. R. D., Rosario, M., & Torres-Blasini, G. (1983). Effects of pH, temperature, aeration and carbon source on the development of the mycelial or yeast forms of Sporothrix schenckii from conidia. *Mycopathologia*, *82*(2), 83-88.

Villalba, J. J., Provenza, F. D., & Banner, R. E. (2002). Influence of macronutrients and polyethylene glycol on intake of a quebracho tannin diet by sheep and goats. *Journal of Animal Science*, *80*(12), 3154-3164.

Warren, D.C. and Scott, H. M. (1935). Physiological factors influencing the rate of egg formation

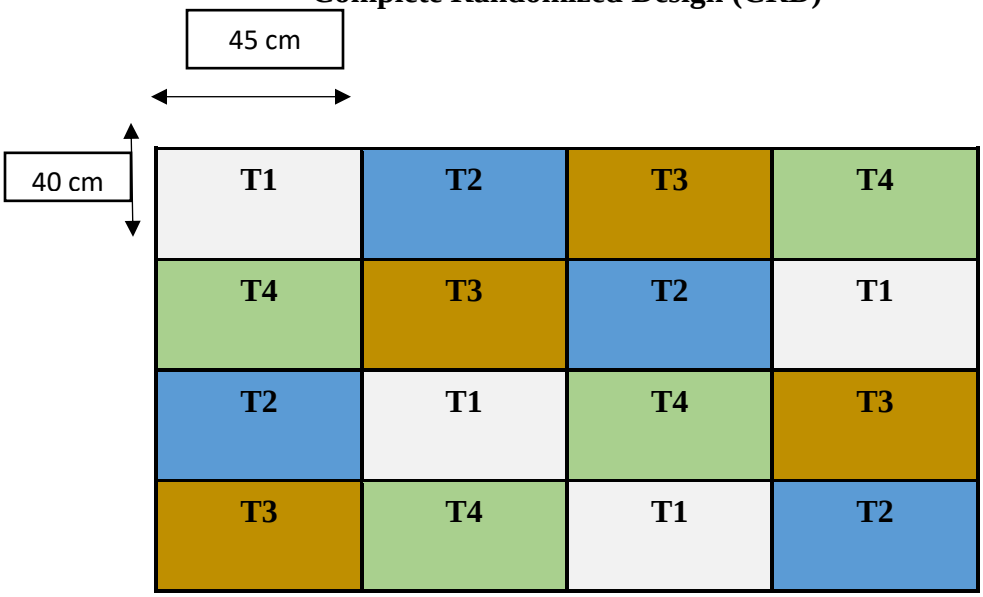
in the domestic hen. *Journal of Agricultural Research*, *51*(6), 51: 565-572. Retrieved from http://naldc.nal.usda.gov/naldc/download.xhtml

Zollitsch, W., Z. Cao, A. Peguri, B. Zhang, T. Cheng and C. Coon, (1999). Nutrient requirements of laying hens. In Simposio Internacional sobre exigencias nutricionais de avec e suinos. Editor: Horacio Santiago Rostagno.

APPENDICES

APPENDIX I: Layout of experimental design

Complete Randomized Design (CRD)



Treatment one (T1) - Control (0% of GMPP);

Treatment Two (T2) – 10% of GMPP;

Treatment Three (T3) - 20% of GMPP;

Treatment Four (T4)- 30% of GMPP.

GMPP- Ground Mature *Prosopis* Pods

APPENDIX II: Equipment used in the study

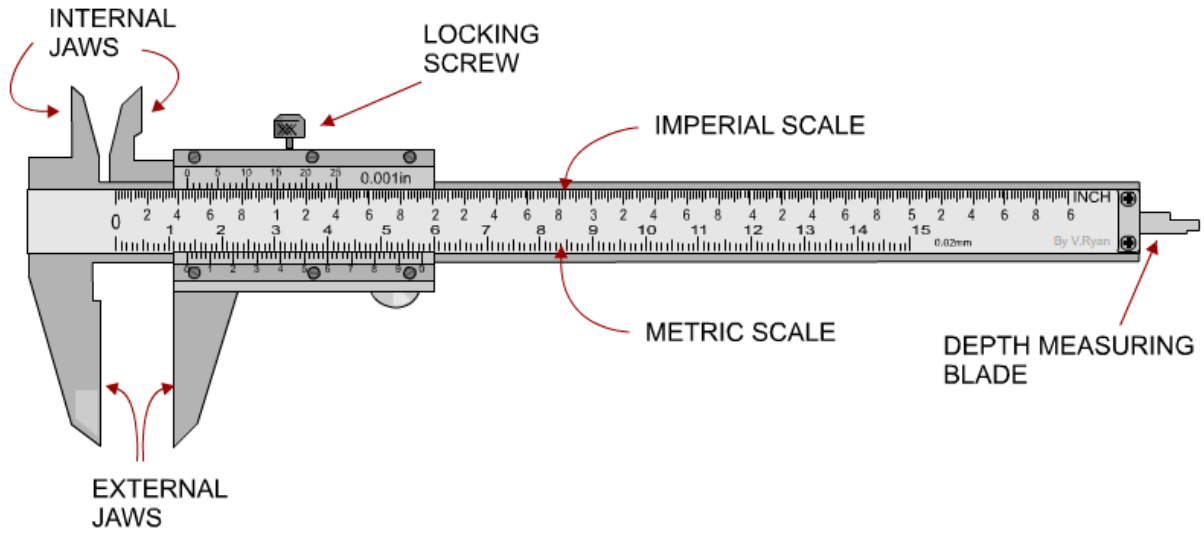


Fig 1- Caliper rule for length and width of the egg, albumen and yolk determination

Fig 2- Yolk colour fan for yolk colour determination