PERFORMANCE AND COST OF PRODUCTION OF NEW ZEALAND WHITE, CALIFORNIA WHITE RABBIT (*Oryctolagus cuniculus*) BREEDS AND THEIR CROSS UNDER TWO FEEDING REGIMES

A thesis submitted in partial fulfillment of requirements for Masters Degree of University of Nairobi (Animal Nutrition and Feed Science)

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DECLARATION

This thesis is my original work and has not been presented for award of a degree in any other University.

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DEDICATION

To my parents.

Who made me understand the importance of education at a tender age

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LIST OF ABBREVIATIONS

ADF	Acid Detergent Fiber
ANOVA	Analysis of Variance
AOAC	Association of Analytical Chemists
APD	Animal Production Department
ARBA	American Rabbit Breeders Association
CAL	California White
CRD	Completely Randomized Design
CP	Crude Protein
CPI	Crude protein Intake
CF	Crude Fiber
Z × C	Crossbreed of NZW (dam) and CAL (sire)
DE	Digestible Energy
DEI	Digestible Energy Intake
DLP	Drip loss percentage
DM	Dry Matter
EE	Ether Extract

F.A.O	Food and Agriculture Organization of the United Nations
FCR/E	Feed Conversion Ratio/Efficiency
GoK	Government of Kenya
GTZ	German International Development Agency
KLDC	Kenya Leather Development Corporation
LAB	Lactic acid bacteria
NEMA	National Environmental Management Authority
NDF	Neutral Detergent Fiber
NFE	Nitrogen Free Extract
NRC	National Research Council
NZW	New Zealand White
ME	Metabolizable Energy
MOLD	Ministry of Livestock Development
MASL	Mean Sea Level
OM	Organic Matter
PUFA	Polyunsaturated Fatty Acids
TDMI	Total Dry Matter Intake

USD	United states dollar
WHC	Water Holding Capacity
WRSA	World Rabbit Science Association
4K-Club	Kuungana, Kufanya, Kusaidia Kenya club
CRD	Completely Randomized Design

ABSTRACT

A study was carried out to assess the performance, cost of production and carcass characteristics of New Zealand White (NZW), California White (CAL) and NZW x CAL crossbreed (ZxC) growing rabbits under two feeding regimes (Concentrate based diet and forage based diet supplemented with varying amounts of the concentrate). The parameters assessed were feed intake, weight gain, time taken to reach the average market weight of 2kg and the cost of weight gain.

Twenty females of each NZW and CAL breed were mated to obtain the purebreds litters. To obtain the crossbreed (Z×C) litters, another 20 NZW females were mated with CAL males to produce 60 litters with a target of 360 kits for the two feeding levels study. The experimental animals were recruited at weaning done at (6) weeks of age.

A completely randomized design (CRD) with a 3 × 2 factorial arrangement of treatments (two genetic groups plus their cross) and two feeds (Concentrate or forage based diet) was applied with the breed and feeding regime as the treatments.

At the end of the feeding experiment, 30 rabbits, 5 from each breed and feeding system were slaughtered and the carcass characteristics evaluated. The parameters assessed were live weight at slaughter, dressed weight, drip loss, meat to bone ratio, carcass fat and internal organs weights. The animals on concentrate based diet reached the 2 kg target weight faster (12 weeks) than those on forage based diet (17 weeks). The crossbred rabbits also attained the 2kg target weight 1 week and 2 weeks earlier than the purebreds under the concentrate and forage based diets respectively. The total feed intake was lowest ($P < 0.05$) for the Z×C group under both feeding regimes explained by the shorter time to the market weight of 2kg. The daily weight gain across

the breeds was not significantly different ($P > 0.05$) within a feeding regime and ranged between 23 to 36gd^{-1} for concentrate based diet and 10 to 30gd^{-1} for forage based diet. The FCR ranged from 3.97 to 4.82 and 6.27 to 7.39 under the concentrate and forage based diets respectively and was significantly different ($P < 0.05$) across the breeds for concentrate based diet.

The rabbits dressed at weights ranging from 1061 to 1294g and weight of internal organs did not differ ($P>0.05$) across the breeds, between or within the feeding regimes. Of the other carcass parameters only dressing percentage, full gut, perirenal fat and the drip loss were different ($P<0.05$).

The estimated total cost per unit weight gain (N kg^{-1} gain) differed significantly ($P < 0.05$) within breeds and between the feeding regimes and was higher on the concentrate based diet at Sh.213.3, Sh.187.7 and Sh.178.4 for NZW, CAL and Z×C respectively. The respective cost with the forage based diet were Sh 167.7, 178.7 and 155. Though production costs were higher on the concentrate based diet, the economic returns were also significantly higher due to an improved off-take.

The conclusions from the study were that the crossbreed was better for meat production regardless of the feeding regime and carcass characteristics of the rabbits were similar when slaughtered at the same weight of 2 kg.

CHAPTER 1

1.0 INTRODUCTION

Shortage of protein, particularly that of animal origin, is prevalent in all parts of Africa where it is estimated that on the average, 10g of animal protein is consumed per day, compared to a recommended daily intake of 35g (F.A.O, 2001). Additionally, the rising cost of agricultural inputs, high unemployment rate and malnutrition occasioned by the rising cost of cereal grains have heightened the need for resource poor farmers to explore alternative agricultural enterprises including rabbit production (Owen, 1981; Lukefahr and Cheeke, 1991). Due to the decrease in individual land holdings in the high agricultural potential areas, farmers are being encouraged to adopt rearing of animals such as pigs, chicken, dairy goats, bees and rabbits which require less space (Kiptarus, 2005). Traditionally, the main type of livestock species kept has been cattle which require large amounts of forages. With the observed decrease in areas of land under pastures, there is need to change this tradition. As such, animal breeds that have a high feed conversion efficiency, less space requirements, early maturity and low investments cost will be perceived to correct for these deficiencies. Rabbit (*Oryctolagus cuniculus*, Linnaeus, 1758) production has this potential as it encompasses the above mentioned attributes (Lukefahr, 1998; Omotoso, 2011).

The productive performance of the rabbit, as is true of other food animal species, is affected by the genetic makeup and environmental factors. The common rabbit breeds have been broadly classified into four groups based on weight at maturity. Heavy breeds are those with more than 5kg at maturity and include the Flemish Giant and the French Lop. Average size breeds (3.5-4.5kg mature weight) which include New Zealand White and California White; the basic breeds in intensive rabbit production for meat. Lightweight breeds (2.5-3kg at maturity) include Small

Himalayan and the Dutch (USDA, 1973; F.A.O., 1997). Serem, (2014) from a baseline study in Kenya reported the main breeds kept by the farmers as New Zealand white (29%), crossbreds (24%), California white (12%), Chinchilla (11.5%), Dutch (8%), Flemish giant (5.5%) and French Lop (4%).

Feed cost is estimated to represent over 70% of the total cost of producing livestock intensively (Oluyemi, 1984). This high cost of conventional feed ingredients has necessitated the use of agro-by-products in animal feeds. With an aim of cutting down the cost of production, farmers have adopted different feeding strategies which are often based on cheap, locally available feed resources. Serem, (2014) noted that in Kenya 38.3% of the farmers fed their rabbits on locally available forages/weeds as the sole diet while 57.0% fed a combination of locally available forages and purchased concentrates. A very small proportion of farmers (2.4%) fed their rabbits on purchased concentrates only. In Uganda as reported by Lukefahr (1998) farmers fed rabbits on sweet potato vines and other legume forages and barely any concentrate supplementation.

Despite the rabbits' adaptability to a wide range of feedstuffs, nutritionist are still seeking feeding strategies capable of reducing digestive disorders (Lebas et al, 1997; Gidenne and Garcia, 2006; Xiccato and Troccino, 2010), enhance reproductive performance, increase feed efficiency thus lower feed cost and eventually total production costs (Maertens, 2009).

Therefore, this study aimed at assessing the performance of the two rabbit breeds (New Zealand white, California white) and their crosses under two feeding regimes i.e. concentrate based complete ration and forage based diet supplemented with different levels of the concentrate.

1.1 PROBLEM STATEMENT

With increasing human population and the attendant decreasing per capita landholding in the high potential agricultural areas, poverty and malnutrition, especially, common in most developing countries, there is need for sound and sustainable livestock production systems to alleviate these problems. Rabbit meat production can be an alternative means of alleviating world food shortages and poverty due to the virtues attributable to the rabbit such as high rate of reproduction and early maturity, rapid growth rate, high genetic selection potential, efficient feed and land space utilization, limited competition with humans for similar foods and high quality nutritious white meat.

Feed costs may account for over 70% of the total production cost (Oluyemi, 1984). The cost of feed is particularly high when concentrates which incorporate raw materials like maize grain are used. Therefore to maximize profit and alleviate the above mentioned problems, a livestock production system with the least production cost that favors resource poor farmers will be favorable.

1.2 JUSTIFICATION

In recent years there has been rising global awareness on the virtues of rabbit meat production in developing countries as an alternative means of alleviating food shortages and poverty as well as a source of high quality protein.

Concentrates as feed are relatively expensive compared to forage hence cheaper feeding regimens that will not compromise on growth and slaughter weight at the target age will be of economic importance. It is also noteworthy that rabbits fed on forages as sole diet generally grow at a lower rate and attain the target slaughter weight at a later age, necessitating supplementation with concentrates. This study was designed to assess the performance and cost of feeding rabbits on two regimes: intensive with concentrates as main diet and semi-intensive with forages as main diet.

1.3 OBJECTIVES

1.3.1 OVERALL OBJECTIVE

To assess the performance, cost of production and carcass characteristics of two rabbit breeds namely New Zealand White and California White and their Cross under two feeding regimes.

1.3.2 SPECIFIC OBJECTIVES

The specific objectives were:

1. To assess the performance of growing New Zealand White and California White breeds and their cross on a concentrate based ration and on forage based diet supplemented with different levels of the concentrate.
2. To determine the cost of production of growing New Zealand White and California White breeds and their cross on a concentrate based ration and on forage based diet supplemented with different levels of the concentrate.
3. To assess the carcass characteristics and economics of production of New Zealand White and California White breeds and their cross on a concentrate based ration and on forage based diet supplemented with different levels of the concentrate.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Rabbit industry in Kenya

The rabbit population in Kenya was estimated at 600,000 with highest population in Central, Western and Rift valley provinces (APD, 2010). The rabbit industry dates back to the colonial days but has experienced slow growth due to social and economic constraints. In 1980, there were efforts to improve the rabbit industry through a partnership between Government of Kenya (GoK) and German International Development Agency (GTZ). This resulted in the establishment of a national rabbit breeding center located in Ngong near Nairobi which was mandated to provide breeding stock for farmers throughout the country. Breeding does and bucks were imported from the then West Germany. Other centers were later established in Machakos, Embu, Wambugu F.T.C (Nyeri) and Kilifi. (APD, 2010)

In the last few years there has been a resurgence of interest in rabbit keeping with numerous rabbit keeping groups being formed throughout the country, the major group being Rabbit Breeders' Association of Kenya (RABAK) located in Thika town (APD, 2010, Serem, 2014). Although there is no documented evidence to explain the rapid growth, it is assumed that reduction in land holdings, is forcing farmers to seek alternative livestock with low demands on feed resources. A baseline survey by Serem (2014) showed that rabbit keeping farmers tended to have smaller landholdings averaging 0.77±0.93 hectares compared to 1.86±0.81 hectares for those not keeping rabbits. Lukefahr and Cheeke (1991) noted that rabbits pose no competition with humans over food since they can be fed on forages as sole diet and leftover vegetables. Rabbit production has experienced a steady growth in the past few years, with gender and age group biases associated with its production fading away (APD, 2010). This is a significant change considering that for many years' rabbit production in Kenya was confined to the youth, mainly 4-K club members and young farmers (Borter and Mwanza, 2010).

The appreciation that rabbits are well suited to rapid production of animal protein has led to the increase in number of industrialized production units just like with poultry (National Farmers Information Service, 2012). Despite the rapid growth of the industry, the main production system still remains small scale (APD, 2010). Production is not well planned which makes it difficult for a farmer to predict the number of rabbits the market can absorb at any one time. Previously, rabbit production was mainly for home consumption. This has since changed to income generation with highest returns being realized from production of breeding stock for sale to other farmers where rabbits fetch as much as Ksh3,000 (US$ 35) to Ksh10,000 (US$ 118) per rabbit (APD, 2010). Financial motivation has also been reported in Egypt where rabbit production has been driven by the high returns of the export market since rabbit meat consumption is estimated at a mere 3.3% of all meats (Alboghdady and Alashry, 2010).

In Uganda, Lukefahr (1998) reported that rabbit production increased because farmers had the perception that it was a get rich quick scheme. The same appears to be true of the industry in Kenya. A survey carried out by Serem (2014) indicated that some respondents had discontinued keeping rabbits due to lack of a market for rabbits and rabbit products despite earlier hopes of extremely high returns. To support the industry in Kenya, several rabbit meat outlets have opened up in various parts of the country including Gilgil butchery, New Mugwathi motel-Nyeri and Tana View Tavern -Murang'a (APD, 2010). Additionally, many five star hotels also provide market for rabbit meat (National Farmers Information Service, 2012).

2.2 Opportunities for rabbit sector in Kenya

There has been an increasing awareness of the advantages of rabbit meat production in developing countries as a means to alleviate world food shortage. Mamattah (1978) reported that rabbit rearing in Ghana was socially accepted on the basis of its low space requirements; the animal's high reproductive rate; lack of competition with humans for the same foods; the minimal zoonotic health hazards and low capital investment involved. These traits have also been noted by Lebas *et al* (1997) and Hassan *et al*, (2012). These factors are generally true for many developing countries including Kenya

In Kenya, MOLD (2010) reported that there were market opportunities for rabbits and rabbit products both locally and internationally. Hoffman *et al*, (2004) reported a higher demand for rabbit meat than supply in Europe and South Africa who are major consumers. However, the need for proper consumer information and marketing strategies was noted. Such would involve information on the benefits of rabbit meat over other meats and demonstrating rabbit meat as chic to promote the local rabbit industry (Export promotion council, 2010). Additionally, it was noted that to exploit the international market opportunities, there was need to promote proper rabbit rearing methods and transportation to markets, slaughtering facilities, packaging and other handling procedures to meet international standards.

2.3 Constraints to rabbit production in Kenya

Constraints to rabbit production in many developing countries have been reported as: perception of rabbits as pets rather than food animals, possibility that rabbits could become agricultural pests (feeding on farmed crops vegetables and cereals) and most important that there is limited market opportunity for rabbit meat (Lukefahr and Cheeke, 1990). Lukefahr and Goldman (1985) in Cameroon reported that rabbit projects targeted women and children resulting in stereotyping.

Other constraints include inadequate knowledge by the farmer on feeding and nutrition and disease control (APD, 2010, Mailu *et al*, 2013, Serem, 2014). Poor housing of low sanitation standards, inadequate monitoring for illness and incorrect timing of mating does have also been reported as constraints by Cheeke, (1986). Poor housing was reported to be more common in the less developed countries than developed countries (McNitt et al, 2000). High disease incidence with inadequate availability of veterinary drugs (Schiere, 2004) is also a major constraint in rabbit production.

Most common diseases in rabbits are digestive disorders caused by bacteria such as *Escherichia coli* and protozoan parasite of the genus *Eimeria* that causes coccidiosis (Aduku and Olukosi, 1990; El-Shahawi *et al*, 2012). Currently there are no rabbit specific vaccines and drugs in the country nor is rabbit disease control and treatment adequately addressed in the curricula for training animal health service providers resulting in limited capacity to address these (MOLD, 2010).

Consumption of rabbit meat has been reported to be low resulting in lack of market. In a survey done in seven counties in Kenya Mailu *et al*, (2013) reported that only 60% of the respondents had even consumed rabbit meat. However, the frequency of rabbit meat consumption was very low with 59.5% of the respondents consuming rabbit meat only once every 12 months White meat which includes pork, fish, rabbit and poultry consumption was 19% of all meats (EPZA, 2005) consumed in Kenya with Poultry taking up 71% leaving only 29% to be shared among the rest. Lukefahr (1998) in a study in Uganda noted that taboos and the fact that rabbit morphologically resembles rats which traditionally are not consumed contributed to low rabbit meat consumption. This has been made worse by insufficient promotion of rabbit meat and its benefits (Gittens, 2000, Schiere, 2004), unsteady product supply, relatively high prices, competition with other meats such as broiler chicken (Lukefahr, 2007), lack of product diversification and poorly developed marketing channels (Owen, 1981, Gaspari, 1984, Lukefahr and Goldman, 1985, Bondoc *et al*, 1986).

In many tropical regions high environmental temperatures (>30^{0}C) adversely affect rabbit productivity (Lebas et al, 1997). This is because for most animals, the increase of temperature over the thermo-neutral zone reduces feed intake, and consequently growth (Lebas and Ouhayoun, 1987; Chiericato et al, 1993, Lebas et al, 1997). Temperatures below the thermo-neutrality increase feed intake but is associated with higher energy demands for heat generation and where feed is limited will again reduce performance (Prud'hon, 1976) Therefore seasonal temperature changes are economically unfavorable (Dalle-Zotte, 2002). However if environmental temperature can be controlled around the thermo-neutrality range, seasonal effect on growth performance can be strongly reduced (Rouvier, 1970). This can be achieved either by modifying the micro-climate or rearing rabbits in the highland areas where temperatures are moderate (Cheeke, 1986).

Availability of breeding stock is another major constraint in many developing regions of the world. There are few high quality rabbit breeders and these charge exorbitant prices for the rabbits giving a false impression of high returns to farmers (Lukefahr, 1998). In Kenya the prices were reported to be as high as Ksh.5,000 (about US $ 57) with an average at Ksh.2,000 (about US $ 23) for a breeding doe or buck (MOLD, 2010). At the government multiplication center in Ngong the current (2014) average cost is at Ksh. 1,500 (about US $ 17).

There is inadequate research on local rabbit production due to inadequate funding, resulting in little or no information on feeds and feeding, breeding, health management, housing requirements and marketing of rabbit products and by-products. Even the little information available locally, is not accessible to farmers due to a poorly structured extension service (MOLD, 2010).

2.4 Rabbit breeds

According to the American Rabbit Breeders Association (ARBA) there are 47 distinct rabbit breeds in the world (ARBA, 2010). Only a handful of these are reared in Kenya, the most common being New Zealand white and California white. These two breeds combine both the desirable meat quality and a high meat to bone ratio (Oseni *et al*, 2008, Mailafia *et al*, 2010).

Table 1 : Some characteristics of common rabbit breeds in Kenya

Breed	Color	Mature weight (Kg)	Major uses
Californian	Body white; nose, ears and tail black colored	4 - 4.5	Meat, exhibition
Dutch	Body black, blue, turquoise, chocolate, steel gray with white saddle or band over the shoulder, under the neck and over front legs and hind feet	3.5 - 5.5	Exhibition, laboratory
New Zealand White	Body white, red or black	4 – 5	Meat, exhibition and laboratory.
Chinchilla	Body shiny grey and ears erect	4 – 6	Meat, Fur, exhibition
French lop	Has two colors, one solid and the other broken	4 -5.5	Meat, Exhibition
Flemish Giant	Body black, blue, fawn, light grey, sandy, steel grey or white.	5 - 7	Meat, exhibition
The Dutch	Body black, blue, brown, grey with a white band around the neck	1.6 – 2.5	Meat, exhibition
[1]Kenya White	White color with black eyes	3 -3.5	Meat

Source: Gillespie, 1998.

[1] ***Source: Mutettika, 1987***

Other popular breeds are Flemish Giant, French Lop, Chinchilla, Kenya white and Dutch. (National Farmers Information Service (NFIS), 2012, Serem, 2014). Some of the characteristics of the common breeds are shown in Table 1.

2.5. Rabbit production systems

At least 82% of the world's rabbit meat is produced in the developed countries (Lebas et al, 1984) where they are produced under intensive system attaining slaughter live weight of 2kg in 12-13 weeks (Lukefahr and Cheeke, 1990) and more recently in 11 weeks (Maertens et al, 2006). The production system is characterized by feeding on commercial feeds compounded to meet the recommended nutrient requirements of rabbit thus high growth rates and minimized labor requirements by use of automated feeding and drinking facilities (Walsingham, 1972). Rabbits produce 8.7 liters each of 6.4 live kits per year (Ayyat and Marai, 1998) which would translate to 40-50 fryers (assuming a post weaning mortality of 10%) under intensive feeding system compared to 20-35 marketable fryers per doe per annum (Lebas et al., 1997; Lukefahr and Cheeke, 1991) under semi intensive feeding common in developing countries (Lukefahr and Goldman, 1985). In this less intensive production system, farmers practice more intensive rabbit breeding during favorable seasons, particularly when forage supply is abundant, while breeding less intensively during adverse seasons (Lukefahr and Cheeke, 1990). Such a system would translate to fewer marketable fryers per year.

Under extensive production rabbits will take longer to attain the slaughter weight for example Cheeke (1987) reported that 3.71 months was required to produce a 1.82 kg fryer rabbit and approximately 4 months for a 2 kg fryer rabbit. However, the author argued that the economic considerations may in some cases well justify the lowered productivity under extensive production systems due to substantially low capital requirements. Lukefahr (2007) also notes that cost of production in this production system is substantially low since it is characterized by low initial costs of establishment and low feeding costs as the rabbits are raised purely on forages that are locally available.

2.6 Rabbit feeding

The rabbit is a herbivore and will consume most types of grains, greens and hay (NRC, 1977, Gidenne and Garcia, 2006). Rabbits have an enlarged cecum that allows them to digest fibrous materials. Animals of this type are called "hind-gut fermenters". The rabbit practices cecotrophy whereby it produces two types of fecal matter, hard and soft. The soft feces or cecotrophs are eaten directly from the anus and are a source of B vitamins and bacterially synthesized proteins (Lebas, 1973, NRC, 1977, Lebas and Gidenne, 2000).

2.6.1 Anatomy of the rabbit digestive tract

The alimentary canal, which develops rapidly in the young rabbit, is nearly mature in an animal weighing 2.5 kg, when it has reached only 60 to 70 percent of adult weight (Lebas et al, 1997; Carabano and Piquer, 1998). In rabbits weighing between 2.5 to 4.5kg the total length of the alimentary canal is 4.5 to 5 m. After a short esophagus there is a simple stomach which stores about 90 to 100 g of a rather pasty mixture of feedstuffs (Carabano and Piquer, 1998). The adjoining small intestine is about 3 m long and 0.8 - 1 cm in diameter. The small intestine ends at the base of the cecum (Lebas et al, 1997). The cecum is the second digesta storage area, is 40-45cm long, contains 100-120g of a uniform pasty mixture and is the major site for microbial growth and fermentation. This strategy allows them to effectively utilize a forage based diet (Church and Kellems, 1998, Gidenne and Fortune-Lathome, 2002). Very near the end of the small intestine, at the entrance to the cecum, begins the exit to the colon which is 1.5m long, creased and dented for about 50cm in the proximal colon but smooth at the distal colon (Lebas et al, 1984; Lebas et al, 1997).

2.7 Nutrient requirements

Rabbits require a source of energy, proteins and amino acids, essential fatty acids, minerals and vitamins (NRC, 1977; Lukefahr and Cheeke, 1992 and FAO, 1997). Rabbits can efficiently utilize proteins of plant origin such as that from soybean meal, cottonseed cake, peanut meal, rapeseed meal, and sunflower and safflower meal (Church and Kellems, 1998) as well as plant fibre as a source of energy due to their enlarged cecum where fermentation occurs (Gillespie, 1998). They also require fats which are not only a source of energy but also essential fatty acids (Church and kellems, 1998).

2.7.1 Energy and Fibre

The dietary digestible energy requirements by rabbits range between 2400 – 2800 Kcal/kg diet for all classes (Lebas, 1975, Cheeke *et al*, 1977 and FAO, 1997). Like many other animals, rabbits adjust their feed intake to meet their energy needs (NRC, 1977). Fiber is an integral part of a rabbits' diet (Gillespie, 1998) derived from sources such as grass, vegetables and hay. The dietary fiber is required for normal functioning of the digestive tract although rabbits are not efficient users like cattle and horses (Slade and Hintz, 1969, Gillespie, 1998).

Attempts to feed rabbits on high energy, low fiber diets such as those fed to poultry and swine have failed (Cheeke *et al*, 1987) leading to poor performance and high incidences of enteritis (Cheeke *et al*, 1987; Gillespie, 1998). A balance between the fiber and energy should however be struck to prevent a negative energy balance while ensuring normal functioning of the digestive system (Cheeke *et al*, 1987).

To increase the dietary energy content without increasing the levels of starch which may cause carbohydrate overload in the hind gut thus enteritis, inclusion of 3% vegetable fat is recommended *(*Cheeke *et al*, 1987). Fats provide approximately twice as much energy as carbohydrates for the same weight (Lebas *et al*, 1997).

Table 2 : Recommended dietary nutrients content for different classes of rabbits

Components of feed assumed to contain 89%DM	**Young rabbits (4 -12 weeks)**	**Lactating doe**	**Peri-weaning**	**Mixed (maternity + Fattening)**
Digestible energy *(kcal/kg)*	2500	2650	2400	2550
Metabolizable energy *(kcal/kg)*	2380	2520	2280	2420
Fats *(%)*	3-5	4-5	3	3-4
Crude fiber *(%*	12	10	14	12
Indigestible crude fibre *(%)*ADF *(%)*	18	14	20	18
Ratio digestible proteins/digestible energy *(g/1000 kcal)*	45	51	46	48
[2]CP (%)	16	15	15	12
[2]Fats (%)			11-14	
[2]Energy*(kcal/kg)*			2500-1900	
[2]Crude Fiber (%)			12-17	

Source: Lebas, 1989

[2] S***ource: NRC 1977***

Palatability of a diet may also be improved with the addition of vegetable fat as noted by Gillespie (1998). In most intensive production systems, especially in developed countries, rabbits are fed on pelleted concentrate diets. In developing economies, the feeds vary but mostly include forages, household leftovers, homemade concentrates and sometimes supplementation with commercial concentrate (Mutettika, 1987, Lebas *et al*, 1997, Lukefahr, 1998 and Serem, 2014). Table 2 shows the recommended dietary energy and fiber requirements for different classes of rabbits.

2.7.2 Protein and Amino acids

Compared to swine and poultry, rabbits have a much better ability to digest and utilize the proteins in forages such as alfalfa meal (Cheeke, 1988). The relative cost of protein supplement must be considered when formulating rations. Proteins of plant origin are often cheaper than those of animal origin (McDonald *et al*, 1995). The most preferred high protein forage feeds for rabbits is alfalfa *(Medicago sativa)* (Cheeke, 1987) and other protein sources may be derived from oil seed cakes/meals (NRC, 1977). Crude protein levels of 16, 12, 15, and 17% are recommended for growth, maintenance, pregnancy, and lactation, respectively in rabbits (NRC, 1977). Lebas (1989) cited by FAO (1997) recommends a crude protein of 16%, 18%, 15% and 17 % for young rabbits (4 to 12 weeks), lactating does, peri-weaning and mixed (gestating and fattening) respectively. These CP levels are on the assumption that the protein is of adequate quality to meet essential amino acid requirements (Cheeke, 1986).

For rapid growth, rabbits must be supplied with adequate quantities of dietary essential amino acids (NRC, 1977). The essential amino acids requirements for rabbits are: arginine (McWard *et al*, 1967; Gaman and Fisher, 1970 and Cheeke, 1971), histidine, leucine, isoleucine, lysine, phenylalanine plus tyrosine, methionine plus cystine, threonine, tryptophane and valine

(Adamson and Fisher 1973). The amino acids requirements for rabbits are shown in Table 3. In rabbit feeds, the first limiting amino acids are the S-containing methionine and Cystine followed by Lysine as reported by Gillespie (1998). Lysine, besides being an essential amino acid, has an antagonistic relationship with arginine, a naturally occurring phenomenon and this normally induces or exacerbates lysine deficiency (Niccodemus *et al*, 1999). Methionine can be converted to cystine during cystine deficiencies. However, this process is irreversible and may lead to methionine deficiencies (Sugahara *et al*, 1969).

Table 3 : Minimum requirements of essential amino acid by rabbits

Amino acid (% CP)	Growth	Gestation	Lactation
Arginine	1.00	0.80	1.11
Histidine	0.45	0.42	0.45
Isoleucine	0.70	0.70	0.71
Leucine	1.05	1.05	1.25
Lysine	0.70	0.70	0.85
Methionine + cystine	0.60	0.60	0.95
Phenylalanine +tyrosine	1.20	1.20	1.20
Threonine	0.55	0.60	0.64
Tryptophan	0.15	0.15	0.15
Valine	0.70	0.75	0.82
Crude proteins *(%)*	16	18	15

Source: Gidenne, 1987

Although there is bacterial synthesis of proteins in the hindgut which is accessed by cecotrophy, it is not enough to meet the essential amino acid requirements of the rabbit. As such, dietary sources of amino acid should be provided (Cheeke, 1987).

2.7.3 Additives

Use of antibiotics on a regular basis in rabbit rations is not generally recommended (FAO, 1997). Since there is little research to indicate that the regular use of antibiotics as additives in rabbit feeding significantly improves rate of gain or feed efficiency, their use may not be economical (NRC, 1977). Additionally, rabbits are sensitive to disturbance of the hind gut microbes (Gidenne and Garcia, 2006). Thus use of antibiotics such as lincomycin, clindamycin, ampicillin and tylosin may cause diarrhea and mortality as a result of hind gut microbial populations disturbance (Cheeke, 1987). However use of antibiotic growth promoters is not accepted in many countries (Casewell *et al*, 2003).

Lactic acid bacteria (LAB) are the most common types of microbes used as probiotics; but certain yeasts and bacilli may also be used (Maertens *et al*, 2006). Oral probiotics are living micro-organisms which upon ingestion in specific numbers exert health benefits (Guarner and Schaafsma, 1998). Numerous commercial products are available as feed additives and in many cases have shown beneficial effects in reducing enteritis and improving feed conversion efficiency presumably through favorable effects on hindgut microbial balance (Fuller, 1992). According to Simon *et al* (2003), the possible effects of probiotics include an increase in the number of beneficial species, competition with noxious microbial species and production of anti-biotic type substances. Some of the probiotics reported in literature include; Lacto-sacc yeast culture (Luick *et al,* 1992), *Bacillus cereus* var.toyoi (Trocino *et al*, 2004) and PaciflorBacillus CIP 5832 (De Blas *et al*, 1999). Maertens *et al* (2006) have reviewed the effects of a list of other probiotics as feed additives.

2.8 Rabbit nutritional disorders

Nutritional disorders in rabbits can result from both non-infectious and infectious causes. For instance, it has been shown that a significant imbalance between protein and fiber can increase the risk of enteritis (Varela-Alvarez, 1998). Digestive disorders are the main cause of morbidity and mortality in growing rabbits (Marlier *et al*, 2003). Petkova et al (2011), Lebas *et al* (1997) and Gidenne, (2003) demonstrated that the young rabbits were the most severely affected. High incidences of hairballs in the stomach are reported often associated with low-fiber diet and corrected by increasing the fiber in the diet or feeding hay along with the pellets (Gidenne *et al*, 2001). Any factors that create disturbances of the naturally occurring bacteria such as sudden diet changes, antibiotic treatment appear to make rabbits more susceptible to intestinal diseases (Licois, 2004).

Epizootic rabbit enteropathy (ERE) (Licois and Coudert, 2001) a highly contagious disease characterized by abdominal distention and emission of small quantities of watery droppings (Licois, 1998) is the most common digestive disorder. ERE can be managed by nutritional manipulation to ensure adequate dietary fibre and improve rabbits health status (Gidenne, 2003). Other common nutritional disorders is Colibacillosis which mainly affects 4-7 week old rabbits, just after weaning, and is characterized by severe diarrhea associated with dehydration and high mortality rates (Licois, 1992).

Lapine Rotavirus (LRV) although considered mildly pathogenic (Thouless *et al*, 1988) is common in post weaned rabbits and may cause severe enteritis outbreaks in association with *E.coli*, clostridia and protozoa (Cerioli and Lavazza, 2006). Mucoid enteritis also a diarrheal disease of rabbits that causes inflammation, an abnormally high level of secretions, and a buildup of mucus in the small and large intestines (Coudert *et al*, 1995) is also common. Factors that may contribute to the disease include recent dietary changes, too much or too little fiber in the diet (Chao and Li, 2008, Petkova *et al*, 2011).

2.9 Influence of genotype on rabbit production

The growth rate of young rabbits is strongly correlated with adult size and weight where there has been no deficiency (Lebas *et al*, 1997). Animal genotype (breed) has been shown in many species to affect pre-weaning growth. In rabbits, the tendency is for large breeds to weigh more at weaning than light ones. Thus rabbit birth weight has been shown to be genetically positively correlated with weaning weight and heavier litters at birth will have corresponding higher weights at weaning (Lukefahr *et al*, 1984). However, in addition to the above statement, weaning weight in rabbits also greatly reflects the mothering ability of the doe since it is strongly influenced by maternal effects such as milk production that will affect kit nutrition status (Cowie, 1968, Mutetikka, 1987 and Lebas *et al*, 1997).

The New Zealand white is well recognized as a dam breed based on its outstanding maternal genetic merits for litter size, milk production, and general mothering ability (Lebas *et al*, 1997; McNitt *et al*, 2000). The California White on the other hand is well recognized as a sire breed due to its better carcass characteristics (Oseni *et al*, 2008). The good attributes of both breeds are due to their specific selection for improved reproductive performance (King, 1978 and Owen, 1981). However, rabbit breeding experiments in the U.S.A. have documented the New Zealand White and California White pure breeds as generally inferior to crosses for post weaning fryer growth, feed utilization and carcass lean yield traits (Ozimba and Lukefahr, 1991 and Lukefahr *et al*, 1992).

2.10 Rabbit Meat Quality

Meat quality is defined as a combination of traits that provide an edible product that is attractive, appetizing, nutritious and palatable after cooking (Kauffmann *et al*, 1969). The meat quality concept is continually changing and nowadays the consumer is very interested in the healthiness of the meat, ease of cooking and price (Dalle Zotte, 2002, Hoffman *et al*, 2004 and Nakyinsige, 2012). It has been shown that consumers have considerable difficulties in forming meat quality expectations (Grunnert *et al*, 2001).

However 'traceability' ranks the highest with respect to food quality and food safety (Morrison et al, 1997). Rabbits are sold as whole carcass, retail cuts and processed meat products ready to cook thus many attributes of both carcass and meat quality have to be considered (Dalle-Zotte, 2002). Nutritionally, rabbit meat is high in protein but low in fat and cholesterol (Table 4), and highly digestible (Cheeke, 1987, Nyako, 2001 and Yusuf *et al*, 2011). Reviews by Combes, 2004, Dalle-Zotte, 2002 and Combes and Dalle-Zotte, 2005 indicate a high nutritional value of rabbit meat compared with other meats.

Table 4: Protein and Fat content of common meats

	% Protein	% Fat
Rabbit	20.8	10.2
Chicken	20.0	11
Veal	19.1	12
Lamb	15.7	27.7
Beef	16.3	28
Pork	11.9	45

Source: Circular No. 547, US Department of Agriculture

The most frequently measured traits of body composition for carcass quality analysis (Blasco and Ouhayoun, 1996) are dressing out percentage, proportions of fore, intermediate and hind parts in the chilled carcass, carcass fatness estimated by perirenal or dissectible fat weights relative to carcass weight and muscle to bone ratio assessed in the hind leg reported to be the best predictor (Blasco *et al*, 1984; Hernandez *et al*, 1996). The meat to bone ratio is an important quality trait especially for the processor adding value for which boneless meat is used.

2.11 Factors affecting rabbit carcass quality attributes

2.11.1 Environmental Temperatures

As in all livestock, temperatures above the thermo-neutral zone reduces feed intake in rabbits and consequently growth rate (Cheeke 1987, Marai *et al,* 2002 and Zeferino *et al*, 2011) resulting in lower market weight at commercial slaughter age but at times, better slaughter yield because of the lower proportion of skin, empty gut and offal in rabbits (Lebas and Ouhayoun, 1987, Chiericato *et al*, 1993 and Zeferino *et al*, 2013). Chiericato *et al*, (1996) reported that rabbits reared at high environmental temperatures when compared to those reared at thermo-neutral temperatures exhibited paler meat with higher levels of saturated fatty acids. High levels of saturated fatty acids have been demonstrated to be harmful to human health. However, these fatty acids are less oxidisable hence meat shelf-life and lipid stability are favored (Prud'hon, 1976).

Although meat sensory properties are crucial for the consumer's choice (Dalle Zotte, 2002), the effect of heat stress on those traits is not well known. Recently Zeferino *et al* (2011) noted that rabbits maintained at 30^0C during the post-weaning period provide meat with reduced juiciness when cooked. In conclusion, the authors stated that heat stress exerted a small, but negative, effect on meat quality traits and recommended choosing acclimated lines and taking measures to control the environment to minimize the impact on rabbit production.

2.11.2 Housing

It has been demonstrated that housing systems can affect carcass traits as well as meat quality (Maertens and Van Oeckel 2001). For comparison purposes studies on meat quality under extensive housing systems have often been inconclusive due to the numerous variables involved including stocking density, group size, type of pen, and others (Pinheirro et al, 2011). For example, dressing out percentage was depressed for outdoor animals than for caged rabbits (Van der Horst *et al*, 1999) but Luzi *et al* (2000) disagreed with the finding instead reporting higher dressing percentages for outdoor housing. Additionally peri-renal as well as intramuscular fat decreased for outdoor rabbits (Margarit *et al*, 1999 and Cavani *et al*, 2000a) explained as being due to increased physical activity. Cavani et al (2000b) also reported higher levels of polyunsaturated fatty acids (PUFA) in open air reared rabbits. Although this group of animals exhibited lower meat pH, the ultimate WHC as well as cooking loss was not significantly different from that of the caged animals (Cavani, 2000b)

2.11.3 Nutrition

All factors influencing the growth by changing the relative growth of tissues and organs lead to modifications of carcass and meat quality (Ouhayoun, 1998). Best performance in meat production is achieved when rabbits are fed ad libitum with feeds whose DE concentration is higher than 10.45MJ/kg (Lebas *et al*, 1997). Studies have shown that when rabbits ingest less than 85% of their *ad libitum* intake level, not only is growth and feed efficiency compromised but also the slaughter yield, carcass adiposity as well as lipid content (Dalle-Zotte, 2002).

Although feed restriction could have a favorable impact on post weaning enteropathy (Gidenne *et al*, 2003), it also has an impact on carcass quality (Xiccato and Trocino, 1999). It has been reported that early restriction between 35d-56d where animals received 70% followed by 90%of the *ad libitum* feed to slaughter was more favorable to carcass yield, hind leg meat to bone ratio and the ultimate pH than in non restricted animals (Perrier and Ouhayoun, 1996 and Perrier, 1998). The carcasses of late feed restricted rabbits showed lower dressing percentages, fat percentage and meat to bone ratios (Larzul *et al*, 2004).

Fat inclusion in the diet at high rates results in higher DE, higher feed intake and growth but poor meat quality, due to increased adiposity (Pla and Cervera, 1997) especially when inclusion rate is above 9 %. Additionally, vegetable fat or animal fat inclusion can be detected in the meat sensory qualities (Hernandez *et al*, 2000; Oliver *et al*, 1997).

2.11.4 Genetic effects and biological factors

In rabbits, the genetic variability in adult weight between pure-breeds can be very high. For example, a giant rabbit such as Flemish giant is 5 times heavier than a dwarf rabbit such as Dwarf lop (Dalle-Zotte, 2002). However, rabbits reared for meat have been derived from selection programmes based on a three-way cross consisting of two breeds selected for litter size to produce the crossbred dams and a large size terminal sire line (Hernandez and Gondret, 2006). The target adult weight has been between 4.5-5kg. The slaughter weight at commercial slaughter age (11-13weeks) of such animals will be similar and their carcass quality will not differ much from each other (Ouhayoun, 1998). The differences between lines in terms of meat quality are weak and there seems to be a certain consistency in their meat quality characteristics (Lambertini *et al*, 1996; Hernandez *et al*, 1997). However, for several breeds it has been proposed that the age at slaughter is increased so as to increase meat sensory qualities (Hernandez and Gondret, 2006) but this will have a detrimental effect on FCR (Maertens, 2009).

Breed type differences for carcass traits have often been reported (Lukefahr *et al*, 1984, Ozimba and Lukefahr, 1991 and Nofal *et al*, 2004). Comparing Pannon White (PW) and Danish White

(DW), Nofal *et al.* (2004) obtained higher dressing percentage on PW x DW crossbreds while DW purebreds had the lowest. There was no significant effect of breed type on meat/bone ratio of the hind leg. Litter size at birth significantly affected individual weight at 35 d, ADG, live weight at 63 d and commercial carcass weight (Nofal *et al*, 2004). In contrast the lower the litter size at birth, the heavier the individual weight at weaning, at 63 d and the commercial carcass weight, as reported by Orengo *et al.* (2004). In terms of carcass quality, rabbits coming from litters of 4 live kits or less had the best fore part yield (31.7%) while those from litters of 7 kits were better for intermediate part yield (30.7%) as reported by Ouyed and Brun (2008).

2.12 Cost of production

Feed cost is estimated to represent above 70% of the total cost of producing livestock intensively (Oluyemi, 1984). This high cost of diets constituted with conventional feed ingredients has necessitated the use of agro-by-products in animal feeds. This high cost of feed has been demonstrated in poultry production previously seen as the quickest way to bridge the animal protein deficiency gap and is driving a shift to other farm animals able to utilize non-conventional feeds such as the rabbit (Mmereole *et al*, 2011). Rabbits efficiently utilize forages, a cheaper feedstuff (Anugwa *et al*, 1982; Lebas *et al*, 1986). Additionally, forages are abundant throughout most of the year in high rainfall areas of the Tropics, and can be preserved for the dry period and for the low rainfall areas (Mutettika, 1987).

Though rabbits have been reported to perform best when fed on high concentrate diets, (Farinu, 1994), the ever increasing costs of grains, on which such feeds are based, has created a need to augment both the energy and protein requirements with forages (Mmereole *et al*, 2011). For any livestock enterprise to be profitable and sustainable, it has become necessary to find alternative cheaper feedstuffs which can adequately replace those that are more expensive (Akpodiete *et al*, 1999). Farinu, (1994) evaluated the effects of feeding a compounded diet based on cassava, a non-conventional feedstuff, on growth and organ characteristics of the rabbits and concluded that it was economical to rear rabbits on mixed diet consisting of cassava based concentrate and forage. Ekpo et al (2009) also made similar observations. In a review on cassava as feed for rabbits, Omole (1988) clearly showed that with proper processing, cassava root and cassava root peel can be safely used as a source of energy and the leaves as a source of plant protein.

CHAPTER 3

PERFORMANCE AND COST OF PRODUCTION OF NEW ZEALAND WHITE, CALIFORNIA WHITE AND THEIR CROSS UNDER TWO FEEDING REGIMES.

3.0 MATERIALS AND METHODS

3.1 Study site

The experiment was carried out at the rabbit unit, Department of Animal Production, College of Agriculture and Veterinary Sciences (CAVS), University of Nairobi, Upper Kabete Campus. Kabete. lies at 36°45'E and 1°14'S with an elevation of 1960 masl. It is characterized by low temperatures with a mean minimum and maximum of 12.6°C and 23.4°C respectively. The cold months are usually June and July. It has a bimodal rainfall pattern with the long rains starting in March through May and short rains towards the end of October through December. The annual average rainfall is 1046mm

3.2 Experimental animals and their management

The rabbit breeds used in the study were the Californian white (CAL), New Zealand White (NZW) and their cross (ZxC). Twenty females of each NZW and CAL breeds were mated to obtain the purebred litters. To obtain the crossbreed (Z×C) litter, another 20 NZW females were mated with CAL males, thus, 60 litters were produced with a target of 360 kits for the two feeding trials. All the does were managed in a uniform manner on the same diet and housing. The experimental animals were recruited at weaning which was done at six (6) weeks of age. A doe was expected to wean a minimum of six kits. The weaners (litter mates) were housed in twos or threes (regardless of the sex), depending on litter size to allow for three replicates per doe in a 70x50x45cm metallic cage equipped with feeders and waterers.

3.3 Experimental design

A completely randomized design (CRD) with a 3 × 2 factorial arrangement of treatments (three genetic groups) and two feeds (Concentrate or forage based diet) was applied with the breed and feeding regime as the treatments. For each breed there were 30 replicates or cages and a minimum of 60 animals. For the two feeding regime experiment a total of 360 test animals were used.

3.4 Experimental diets and feeding

Two experimental diets were evaluated using grower rabbits from weaning to attainment of 2kg. These were a concentrate based and a forage based ration, the details of which follow.

3.4.1 Concentrate based ration.

The concentrate ration was formulated to meet the recommended nutrient requirements of pregnant, lactating and growing rabbits by NRC, (1977) and pelleted. The feed was offered *ad libitum* but water was restricted to two hours daily (between 9-11am) for the first three weeks of the experiment, to reduce digestive disorders common in weaners, then fed *ad libitum* until they attained the target weight of 2kg. In addition, about 150g of wilted kales (*Brassica oleracea acephala*) per day/per cage was offered three (3) days in a week. The kales were placed hanging from the top of the cage.

3.4.2 Forage based diet supplemented with different levels concentrate.

Rhodes grass hay (*Chloris gayana*) was harvested at 70% flowering from the Veterinary farm (CAVS), University of Nairobi. To cure the grass, it was spread indoors on racks for two weeks to reduce moisture content to between 16-18%, chopped to about 1-2cm length then packaged in gunny bags for storage. Prior to feeding in earthen bowls, the hay was sprayed with molasses diluted with water at the ratio of 5:1 water to molasses respectively (to improve palatability) and then offered *ad libitum*. The hay offered to the rabbits was weighed weekly and the intake estimated as the difference between initial weight of the hay and final weight of the left over hay. The left over hay was collected, dried then sampled for analysis to determine selection by the rabbits.

The rabbits were supplemented with the formulated concentrate diet at 50% of expected *ad libitum* of the balanced concentrate intake (i.e. 25g/d, 35g/d 45g/d 55g/d for week 6-9) then fixed at 60g/d per animal from 10th week till the end of the experiment.

3.5 Data Collection

3.5.1 Grower rabbit parameters

The data collected on the animals was; Initial body weight at 6 weeks of age, live weight (average of the animals per cage as each cage was an experimental unit) on weekly basis until the end of the trial.

Feeds offered and the left-overs were weighed on a weekly basis for each cage and treatment to determine intake. Feed conversion ratio was calculated as the amount of feed intake per unit of live weight gain.

Mortalities were recorded as they occurred.

3.6 Chemical Analysis

3.6.1 Experimental diets

The chemical composition (dry matter (DM), crude fiber (CF), crude protein CP), ash, ether extract (EE) and nitrogen free extracts (NFE)) of the experimental diets (concentrate diet and hay as fed) were assayed according to the Association of Official Analytic Chemist methods (AOAC, 1998).

Dietary fiber (Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF)) for Rhodes grass hay determination was conducted according to Van Soest *et al* (1991).

Digestible energy (DE) and metabolisable energy (ME) for the concentrate diet and DE for the Rhodes grass hay was calculated according to Noblet and Perez (1993) as quoted by NRC (1998).

Concentrate DE (kcal/kg) = 4,151 - (122 x % Ash) + (23 x % CP) + (38 x % EE) - (64 x % CF).

Concentrate ME = DE x (1.003 - (0.0021 x % CP))

Forages DE (kcal/kg) = 4,340 - 79X, where X is the CF of the feed on dry matter basis),

The CPI calculated as Average Total Feed Intake (on DM basis) x % CP of the diets as fed.

The DEI was calculated as Average Total Feed Intake (on DM basis) x DE.

3.6.2 Left over hay analysis

To determine selectivity behavior of the rabbits, the hay left-overs per treatment was collected weekly, labeled and dried until the end of the feeding trial. Leftovers from each breed group were then mixed together and three representative samples collected for Crude protein and Crude Fiber analysis (AOAC, 1998). The results were compared to those of the hay as fed and inferences made.

3.7 Statistical analyses

The data was captured using Excel 2007 spreadsheet, Windows 2007. Data collected for live weight and weight gain as well as feed intake was subjected to Analysis of Variance (ANOVA) procedure using the package Genstat software (Genstat, 13th edition, 2011) for windows. When analysis of variance indicated significance for treatment effects, specific differences between means were ranked using the Bonferroni Test.

3.8 Assessment of production costs and returns.

Cost of feed was calculated based on prevailing cost of ingredients per kilogram as at the time the experiment was conducted (estimated at sh.31/kg for concentrate and sh.10/kg for Rhodes grass hay)

The quantity of feed consumed for the experimental period per unit weight gain of rabbits was used to assess the cost of feed kg^{-1} weight gain.

In addition to the feed costs, rabbit production will also be associated with other costs such as labour, power (electricity), water and depreciation of facilities which were not costed in this study. In order to allow assessment of total production costs, assumptions were made that feed accounted for 70% and 57% of the costs under the concentrate and forage based diets respectively (Oluyemi, 1984; Mmereole et al, 2011). Thus the respective other costs accounted for 30% and 43% of the total.

The prevailing shilling to dollar exchange rate at the time of the experiment was at 85.

For the purpose of estimating the returns, the prevailing market price of meat per kg was used. The value of the pelt was also based on the prevailing market price set by the Kenya Leather Developmental Council (KLDC).

CHAPTER 4

4.0 RESULTS AND DISCUSSION

4.1 Diet composition

4.1.1 Concentrate ration composition

The ingredients of the experimental diet are presented in Table 5 and results of chemical analysis presented in Table 6.

Table 5: Ingredient composition of the complete ration diet

Ingredient	Percentage
Maize grain	15.3
Wheat Bran	15
Pollard	28.8
Rice Bran	12.6
Rhodes Hay	10
Cotton seed cake	6.3
Soybean Meal	6.3
Limestone	2.3
Dicalcium Phosphate	0.3
Premix*	0.09
Hcl-Lysine (100% CP)	0.27
DL-Methionine	0.27
Molasses	1.8
Urea	0.45
Salt	0.27

**2 kg of premix contains: Vit A;12,500,000.00IU: Vit D_3;2,500,000.00IU: Vit E;25,000.00IU: Vit K;2,250.00mg: Vit B_1;2,000.00mg: Vit B_2;5,000.00mg: Biotin; 60.00mg: Folic acid;1,000.00mg: Iron; 40,000.00mg: Cobalt; 800.00mg: Copper; 6,000.00mg: Manganese;80,000.00mg: Vit B_6; 5,000.00mg: Vit B_{12}; 20.00mg: Pantothenic Acid; 10,000.00mg: Niacin;25,000.00mg: Choline-Cl;300,000.00mg: Zinc;50,000.00mg: Iodine;1,500.00mg: Selenium;300.00mg: Antioxidants;qs: Carrier:qs.*

This feed was offered to the breeding stock during gestation period as well as during the lactation period up to weaning at 6 weeks. The same feed was also offered to grower rabbits from weaning to the target slaughter weight either as the sole feed or as supplement.

The moisture content (11.4%) was within the recommended range (<12%) for storage purposes to avoid growth of molds that may cause feed poisoning in animals (NRC, 1981).

Table 6: Chemical composition of the concentrate diet on dry matter basis

Chemical composition	Percentage	Calculated composition based on book values
Moisture (%)	11.40	10.85
Crude protein (%)	16.05	17.8
Ether extract (%)	4.12	7.18
Crude fiber (%)	11.29	11.29
Total ash (%)	8.56	8.56
Nitrogen free extract (%)	48.58	48.58
Calcium (%)	1.14	0.88
Phosphorus (%)	0.56	0.54
DE (kcal/kg)	2910.18	2583
ME (kcal/kg)	2820.82	2287

The crude protein at 16.1% was lower than the recommended level of 17.5% for growing rabbits (Cheeke et al, 1987). The ether extract (4.12%) was within the recommended range of 3-5% (Gillespie, 1998; Cheeke, 1997). Although fat was not included in the formulation, the high EE can be explained by inclusion of the oil seed meal/cakes in the formulation and whose oil content is dependent on the extraction method (Church and Kellems, 1998).

The crude fiber content (11.29%) was less than the recommended (15-16%) for rabbit diets (Fekete and Gippert, 1985) but within range (10-14%) recommended by (FAO, 1997). Fiber is required by rabbits for normal functioning of their digestive system (Gillespie, 1998). Davidson and Spreadbury (1975) reported that dietary fiber levels of less than 6% fiber may increase incidences of diarrhea. Lebas (1975) also noted that fiber levels lower than 12% may promote diarrhea. However studies show that to avoid compromise on density of other nutrients in the ration, a fiber content of 10-14% should be satisfactory (FAO, 1997; Hall and Johnston, 1976; Gidenne, 2003).

Phosphorus (0.56%) and Calcium (1.14%) content for this feed was within the recommended range (0.3-0.6%) for Phosphorus and (0.4-1.20%) for Calcium (Varela-Alvarez, 1998).

The estimated energy (DE and ME) levels of the complete ration were well above the recommended levels of 2400kcal - 2600kcal/kg diet for digestible energy and 2200-2500kcla/kg diet for Metabolizable energy (FAO, 1997). It has been suggested that during feeding of rabbits the need for fiber precedes the need for readily available carbohydrates as suggested by Cheeke *et al*, (1977). He reported that rabbits preferred barley or wheat to corn not only due to palatability but also because of the higher fiber levels in the former feedstuffs. For this reason, while formulating the concentrate diet, the energy sources were mostly fibrous feedstuffs (wheat and rice bran, Pollard), and Rhodes grass as a fiber source. However, to boost energy level of the concentrate, maize rather than barley or oats was added to achieve the energy levels to a DE of 2583Kcal/kg and ME of 2287Kcal/kg based on book values of nutrient content of the ingredients. The estimated energy values based on the proximate analysis of the ingredients were higher at 2910.18kcal/kg diet and 2820.82kcal/kg DE and ME respectively. The differences may be due to underestimation of the contribution of the oil seed cake/meal to the supply of energy from the residual oil (Church and Kellems, 1998)

4.1.2 Forage (Rhodes grass hay) composition

Table 7 shows the chemical composition of the Rhodes grass hay.

Table 7: Chemical composition of Rhodes grass hay on dry matter basis

Chemical Composition	%
Dry matter	91.4
Crude Protein	8.32
Organic matter	86.95
Ash	13.05
CF	34.2
Neutral detergent fiber	66.25
Acid detergent fiber	40.51

Prior to sprinkling with the diluted molasses, the Rhodes grass moisture content was recorded at 8.6% which translates to a DM of 91.4%. This is similar to the 91.5% DM reported by Mutettika (1987) for Rhodes grass hay. Abdulrazak *et al* (2005) reported a DM of 94.6%, ash of 10.3%, NDF of 71.8% and a CP of 7.2%. The NDF and ADF of the Rhodes grass in this study was higher than that reported by Adegbola and Oduozo (1992) at 66.25 and 40.51% compared to 38.9 and 28.2% respectively by these authors. The CF content was recorded at 34% compared to 48.70% by the same authors while Ouda (2009) reported a CF of 37%. These variations may be due to differences in agronomic practices (Raharjo *et al* 1986), stage of maturity at harvesting (Tagari and Ben-Ghedalia, 1977; Mero and Uden, 1998) and preservation conditions for the hay (Raharjo and Cheeke, 1985) all of which will bear on the quality of the resulting hay (Mentese *et al* (2006).

4.2 Performance of rabbits on concentrate based ration

4.2.1 Weight gains

Table 8 shows the weekly live weight of the three groups from 6 weeks to the target fryer weight of 2000g while Table 9 shows their estimated average daily weight gains. Although rabbits recorded different weekly weights (Table 8), the daily weight gain (Table 9) was similar (P>0.05) across the three genotypes at 28.4g, 28.6g and 29.8g for the NZW, CAL and the cross respectively. The animals with the highest weaning weights (Table 8) recorded higher weights throughout the growing period. These weights were highly significantly different (P<0.001) across all three genotypes of animals. Throughout the feeding trial the crossbreed maintained the highest weights and attained the target weight earliest at 12 weeks followed by New Zealand White and California White at 13 weeks of age.

Table 8: Mean weekly live weight of rabbits on concentrate based diet

Week	NZ	CW	Crossbreed	SEM	Sig
6	781.8 ± 20.45^{b}	670.9 ± 34.58^{a}	885.9 ± 22.61^{c}	26.6	***
7	948.4 ± 20.98^{b}	838.4 ± 30.69^{a}	1075.5 ± 20.32^{c}	24.4	***
8	1153 ± 21.53^{b}	1055 ± 29.63^{a}	1303 ± 21.79^{c}	24.6	***
9	1389 ± 21.81^{b}	1296 ± 27.75^{a}	1557 ± 10.05^{c}	23.5	***
10	1604 ± 20.33^{b}	1512 ± 28.12^{a}	1790 ± 22.81^{c}	24.1	***
11	1804 ± 419.93^{b}	1715 ± 28.03^{a}	1960 ± 27.36^{c}	24.4	***
12	1981 ± 21.40^{a}	1903 ± 21.97^{a}	2079 ± 16.97^{c}	23.5	***
13	2093 ± 16.98^{ab}	2037 ± 20.97^{a}		20.3	**

^{a,b,c} *Means within same row with different superscripts are significantly different NS- Non significant (P>0.05); P<0.05)* ***; (P<0.01*****)*

Niedzwiadek (1979) also reported that the Crossbreed of California White and New Zealand White grew at a higher rate and reached 2,000g live-weight earlier than the pure breeds. Similar observations were also reported by Ozimba and Lukefahr (1991). Brun and Ouhayoun (1989) observed that the Crossbreed of these two breeds was heavier than purebreds at 79 d by 181g on average. This is comparable to results of this study. At 79 d the crossbreed weighed more than the New Zealand White purebred by 186 g and 278 g for the California White.

However, Reyntens *et al* (1970) reported that the performance of the crossbreed between New Zealand white and Blanc de Termonde was intermediate, although not statistically significant, with a weight of 2.33kg compared to 2.49kg and 2.29kg for the respective purebreds at 10-12 weeks of age.

Table 9: Daily weight gain (g/day) of rabbits on concentrate based diet

Time (weeks)	New Zealand White	California White	Crossbreed	SEM	Significance
6	23.8	25.0	27.1	4.9	NS
7	29.6	30.0	32.0	15.8	NS
8	33.5	34.3	36.4	6.4	NS
9	30.7	30.9	33.2	6.9	NS
10	28.5	29.0	29.2	6.5	NS
11	26.7	27.0	26.1	7.9	NS
12	25.6	26.1	24.8	11.7	NS
Average daily gain	28.4	28.6	29.8	9.9	NS

NS- Non significant (P>0.05)

A similar trend was observed by Hamilton *et al* (1997) with crosses of California White (2.13kg) and Blanc de Termonde (2.29kg) with the crossbreed reaching a weight of 2.14kg at the same age (10-12 weeks) indicating intermediate performance. The intermediate performance of the crossbreed was probably due to genetic variance for example, being affected by dominance and disequilibrium (Lukefahr and Hamilton, 1997).

Kabir et al (2012) reported a higher maternal heterosis in the cross between CAL×NZW but better growth and carcass performance was recorded in the. NZW×CAL

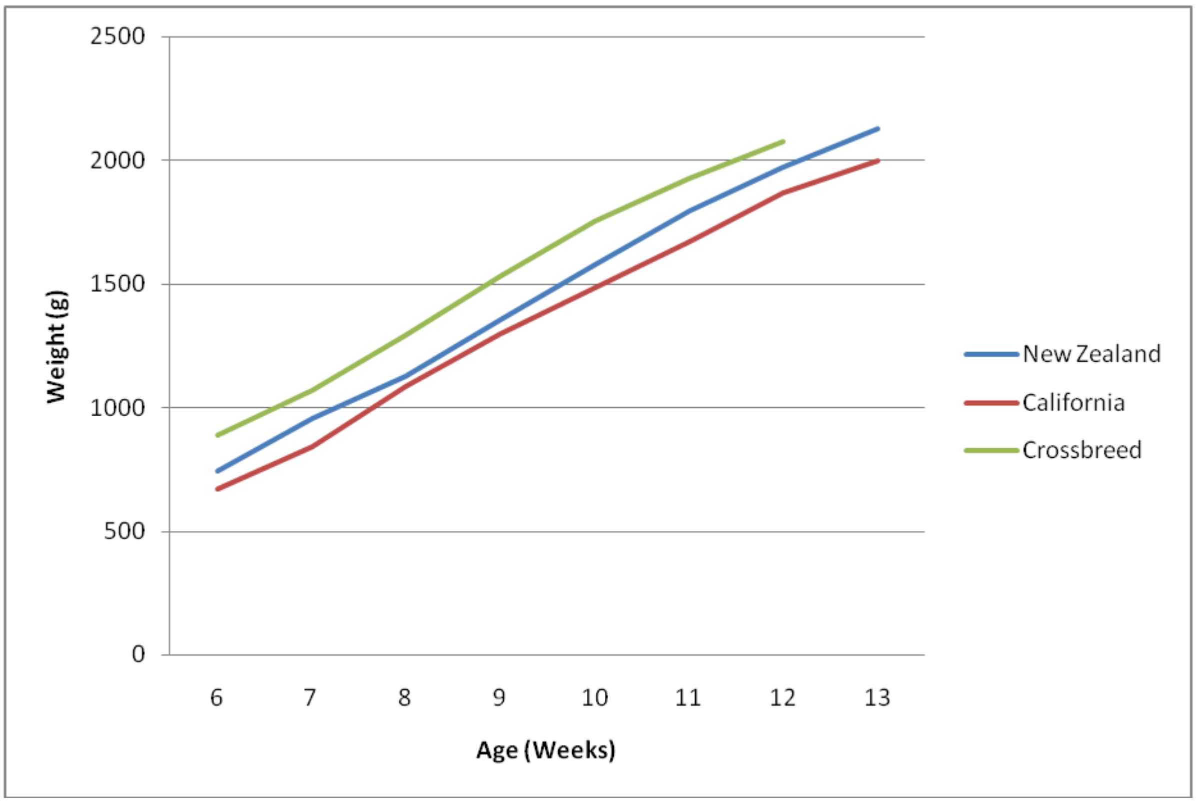

Figure 1: Mean values of weekly live weights (g) of rabbits on concentrate based ration

Several authors have also reported that in modern rabbitries, the Californian and New Zealand breeds reach the market weight of 2kg at 10-12 weeks. Reyntens *et al* (1970) recorded weights of 2.49kg for New Zealand White and 2.13kg for California White. Di Lella and Zicarelli (1969) also recorded a similar weight of 2.12kg at week 12 and 2.47kg at week 13 of age for New Zealand White. The slight differences between these observations and the current study could be explained by the fact that although the animals were on concentrate based diets, these were unlikely to be identical and neither would the physical environment, which is also reported to impact on feed intake and thus growth rates, be similar (Eberhart, 1980, Finzi *et al*, 1992., F.A.O, 1997). The noted superiority in growth performance of New Zealand white over that of California white is in agreement with other authors (Di Lella and Zicarelli 1969; Reyntens *et al* 1970; Lebas *et al*, 1997).

Ozimba and Lukefahr (1991) noted that the NZW×CAL and FG (Flemish giant) crossbred litters consumed more feed as was the case for crossbreed in this feeding trial; (Table 10) than purebred litters, thus higher growth rates despite all animals having a similar weaning weight in their trial. The higher growth rate of the crossbreed compared to the pure breeds was also observed by Pinheiro *et al* (2011) although at higher values than for this trial, probably due to the difference in the nutrient content of the feed. In the current feeding trial, although not significantly different ($P>0.05$) (Table 9 and 15) the growth rate for the crossbreed was slightly higher throughout the growing period followed by the California White then New Zealand White. At weaning when the animals were recruited into the study, the crossbreed was heavier and the advantage in weight during the growing period may reflect their superior weaning weight rather than a higher growth rate. Ozimba and Lukefahr (1991) also noted no significant differences in average weight gains across the three groups though this was higher in the crossbreed.

The role of the genotype in rabbit production was clearly demonstrated in the current feeding trial by the higher post-weaning growth rate of the California White than the New Zealand White. Despite starting off at a lower weight, the former caught up with New Zealand White breed to attain the target weight of 2kg weight at the same age of 13 weeks. These observations are in agreement with Mutettika (1987) who also recorded a similar trend between California white and New Zealand White. Although litter weight at birth affected weaning weight (Mutettika, 1987), it does not always affect the post-weaning growth rate.

In rabbits it has been shown that higher birth weights result in higher weaning weights and is affected by genotype and environment especially the feeding level (Lukefahr *et al,* 1984). Additionally, nutrition plays an important role in post weaning growth (Lebas *et al*, 1997). Elmagrabby (2011) noted that even within the same breeds, feed restriction will lead to a slower growth rate compared to those animals fed *ad libitum*.

The growth rates for animals in this trial were lower compared to those of Jaouzi *et al* (2004) who reported a mean daily weight gain of 35gd-1 for the period of 5th to 11th week compared to 29gd-1 for the same period (Table 9). The difference may be due to the physical environment as well as feed nutrient composition. The slightly lower growth rates in this trial resulting in a later age at target market weight (12-13 weeks) compared to Maertens et al, 2006) (11 weeks) could be due to inadequate nutrient intake especially essential amino acids. Urea, an NPN, was included in the formulation of feed for this trial and does not provide the essential amino acids. Growing rabbits have a dependence on dietary essential amino acids (Cheeke, 1972). Despite bacterial protein synthesis in the cecum available through caecotrophy, it does not make a large contribution to the essential amino acids supply of the young rabbit. Hence the need for adequate supply from feeds (NRC, 1977). Additionally, physical environment especially temperature has an effect on performance (Finzi *et al*, 1992) since it influences feed intake.

4.2.2 Feed intake of rabbits on concentrate based ration

Weekly feed consumption of the rabbits post weaning is shown in Table 10. The intake differed between the three breeds with the crossbreed consuming the highest amount of feed followed by the New Zealand White and California White.

Table 10: Weekly feed intake of rabbits on concentrate-based diet (g)

Time (weeks)	New Zealand	California	Crossbreed	SEM	Significance
6	422.9±8.94^{ab}	398.3±10.24^{a}	434.9±11.33^{b}	10.22	**
7	529.8±11.63^{ab}	498.3^{a}±11.99^{a}	559.2±10.90^{b}	11.52	**
8	660.2±16.10^{ab}	608.3±17.54^{a}	692.7±17.08^{b}	16.92	**
9	745.1±15.38^{ab}	694.1±16.03^{a}	777.0±16.27^{b}	15.89	***
10	806.4±12.80^{ab}	760.5±16.57^{a}	833.7±16.07^{b}	15.24	**
11	875.1±9.07^{b}	829.1±11.39^{a}	907.2±13.43^{b}	11.46	***
12	930.7±7.95^{b}	879.8±12.22^{a}	943.9±9.92^{b}	14.78	***
13	942.4±6.60^{ab}	921.4±8.50^{a}		8.48	**
Total average feed intake (g)	5912±67^{b}	5591±320^{ab}	5148±203^{a}	160	**

^{a,b,c} Means within same row with different superscripts are significantly different NS- Non significant (P>0.05); P<0.05) **; (P<0.01***)

These results are in agreement with Mutettika (1987) who reported higher feed intake in New Zealand than Californian. The results reflected the differences in the animal's size where heavier animals tend to consume more feed (Lebas *et al*, 1997). The New Zealand was heavier than the Californian and the crossbred higher than the New Zealand throughout the feeding trial (Figure 1). Ozimba and Lukefahr (1991) also reported crossbreeds as having higher weekly feed intake compared to the purebreds. They attributed this to increased appetite in favor of the crossbreed.

In rabbits, appetite is controlled either by physical factors, especially the volume ingested and its transit time in the gut, or by chemostatic mechanism by which the total quantity of energy ingested daily tends to be constant (Xiccato and Trocino, 2010). This regulation occurs only with feeds whose DE concentration is higher than 9.2MJ/Kg (Parigi Bini and Xicatto, 1998, Xiccato and Trocino, 2010). This should be true for this trial considering the concentrate had a calculated DE of 2910Kcal/Kg (12.18MJ/Kg). DMI ranged from 5.7% to 7.5% of body weight for California White, 5.7% to 7.0% and 5.7% to 6.0% for New Zealand White and the Crossbreed respectively. These intake values again reflect the live weight trends being slightly higher for the smallest, the Californian, and lower for the largest animals, the crossbred (Ozimba and Lukefahr (1991).

Table 11: Crude protein, digestible energy and metabolizable energy intake of animals on concentrate diet

	New Zealand	California	Crossbreed	SEM	Significance
Total CPI (g)	948.5^{a}	897.5^{a}	826.3^{a}	23.2	NS
Total DEI (Kcal)	17205^{b}	16269^{b}	14982^{a}	516	**
Total MEI (Kcal)	12433^{b}	12367^{b}	10676^{a}	406.4	**
Total DMI (kg)	5.912±1.10^{b}	5.591±1.32^{ab}	5.148±1.35^{a}	0.16	**

^{a,b,c} Means within same row with different superscripts are significantly different NS- Non significant (P>0.05); P<0.05)**; (P<0.01***)

As presented in Table 11, the CPI was estimated at 948.5g, 897.5g, and 826.3g for New Zealand, Californian and the crossbreed respectively. The respective estimated DEI was 17.2MJ, 16.2MJ and 14.9MJ for New Zealand White, Californian and the crossbreed for the total of 13 weeks for the purebreds and 12 weeks for the crossbreed.

Though the weekly feed intake was higher for the crossbred rabbits, these had a lower total feed, CP and DE intakes because they took a shorter time to attain the target market weight of 2Kg.

The crossbreed intake for both energy and protein was the least, but they had the best performance in growth showing positive heterosis for growth genes as attributed also by Ozimba and Lukefahr (1991). The CP, energy and total feed intakes were also different between the pure breeds with higher intake for New Zealand White (Table 11).

4.2.3 Feed Conversion Ratio (FCR)

The FCR for the three groups are shown in Table 12.

Table 12: Feed Conversion Ratio of rabbits on concentrate ration

Time (weeks)	New Zealand White	California White	Crossbreed	SEM	significance
6	2.5±0.09	2.3±0.11	2.4±0.13	0.11	NS
7	2.6±0.06	2.4±0.09	2.4±0.08	0.08	NS
8	2.9±0.09	2.6±0.09	2.8±0.10	0.09	NS
9	3.6±0.14	3.3±0.10	3.5±0.17	0.14	NS
10	5.0±0.71	3.5±0.10	3.8±0.28	0.61	NS
11	5.8±0.90	5.1±0.41	5.2±0.27	0.46	NS

The weekly feed conversion ratio did not differ significantly between the breeds, though the California White tended to have slightly lower values than the others throughout the study period. Generally, the feed utilization efficiency worsened with age. Maertens (2009) also observed that young and quick growing animals had a much more favorable FCR compared to those near slaughter weight. Differences in content of tissue accretion (fat *vs*. protein and water) and the increased maintenance requirement with increasing weight explain the trend (Maertens, 2009). The trend of these results across breeds agree with Ozimba and Lukefahr (1991) who reported the New Zealand White as having the poorest feed conversion efficiency. The average feed conversion ratio over the feeding period was 4.8, 4.3 and 4 for New Zealand White, California White and the crossbreed respectively (Table 19). The lower feed conversion ratio for the crossbreed can be explained by the earlier attainment of the slaughter weight and thus a lower overall total feed intake. The observed better feed utilization efficiency of the crossbreed is in agreement with several authors (Maertens, 2009, Garcia-Ruiz *et al*, 2006) who observed that in commercial farms, there is an increasing use of the cross between a fertile dam line and a sire line selected for growth rate and by inference better FCR.

4.3 Performance of rabbits fed on Forage based ration

4.3.1 Weekly weight and average weight

The weekly weights for the three groups of rabbits are presented in Table 13 while the average daily weight gains across the study period are presented in Table 14. The initial weight was similar to those fed a concentrate ration as they were from mothers treated similarly pre-weaning. Although the weekly live weight were much lower than those on the concentrate based ration, a similar trend in growth across the breeds was observed with the crossbreed attaining the target weight of 2kg earliest (15 weeks) while the Californian took the longest time (18 weeks).

The observed better performance of the New Zealand compared to California White in this trial is similar to the findings of Mutetikka (1987) in a feeding trial with different forages supplemented with a concentrate diet. However, it took a longer period for all the breeds to attain the target weight of 2kg at 15, 17 and 18 weeks for the crossbreed, New Zealand White and California White respectively, compared with rabbits on the concentrate based ration (see Table 8). The slower growth rate of rabbits in feeding regime 2 (forage based ration) compared to regime 1 (concentrate based ration) was because of the lower dietary nutrients concentration and by extension reduced nutrients intake (Table 17).

Table 13: Weekly live weights of rabbits on forage based diet

Time (weeks)	New Zealand White	California White	Crossbreed	SEM	Sig
6	779.2±20.88[b]	673.6±10.92[a]	885±12.11[c]	15.29	***
7	846.4±20.62[b]	754.5±11.52[a]	974.3±11.87[c]	15.19	***
8	932.8±20.48[b]	850.2±12.36[a]	1074.1±10.95[c]	15.2	***
9	1087±23.15[b]	1010±13.89[a]	1242±12.65[c]	16.73	***
10	1270±24.11[b]	1202±14.88[a]	1440±12.18[c]	17.9	***
11	1471±23.80[c]	1409±16.54[a]	1651±10.22[b]	18.2	***
12	1629±19.56[b]	1572±17.26[a]	1818±9.52[c]	22.88	***
13	1757±19.18[b]	1701±14.83[a]	1954±11.54[c]	15.04	***
14	1863±19.58[a]	1812±13.72[a]	1983±22.38[b]	15.4	***
15	1923±14.29[a]	1903±13.38[a]	2086±14.46[b]	16.25	***
16	1964±11.81[a]	1966±13.68[a]		13.15	NS
17	2000±10.58[a]	1984±13.43[a]		11.8	NS

[a,b] Means within same row with different superscripts are significantly different NS- Non significant (P>0.05); P<0.05) [**]; (P<0.01[***])

Mutetikka (1987) fed Rhodes grass hay with commercial pellet supplementation at 50g/day and reported a weight of 1.3 kg for both California and New Zealand White at 12th week of age. In the current experiment, the weights of New Zealand White and California White at the 12th week were 1.63 kg and 1.57 kg respectively.

The difference in the performance of animals in these two trials may be due to differences in the nutritive value of the Rhodes grass and/or the concentrate supplement. The Rhodes grass hay for example had a CP of 2.65% in Mutettika's study compared to 8.32% CP for this trial. Addition of molasses to improve the palatability of the Rhodes grass in this study may also have enhanced the energy intake.

Table 14: Daily weight gain (g/day) of rabbits fed on forage based diet

Time (weeks)	New Zealand White	California White	Crossbreed	SEM	Significance
6	10.36±0.50[a]	11.56±0.45[ab]	12.76±0.62[b]	0.53	**
7	12.34±0.62	13.66±0.90	14.25±0.60	0.72	NS
8	22.07±1.13	22.87±0.88	23.94±0.53	0.88	NS
9	26.13±0.63	27.26±0.85	28.37±1.03	0.86	NS
10	28.66±1.03	29.59±1.26	30.01±0.65	1.01	NS
11	22.54±1.92	23.20±1.08	23.80±0.90	1.37	NS
12	18.36±1.35	18.97±0.89	19.46±0.77	1.04	NS
13	15.15±1.43[b]	15.81±0.59[b]	7.47±1.28[a]	1.16	***
14	12.64±1.69	13.10±1.43	10.33±1.85	1.63	NS
15	9.49±1.08	10.04±1.01	10.75±1.94	1.23	NS
16	7.45±1.04	7.77±1.23		1.13	NS
17	6.75±1.18	7.20±0.95		1.06	NS
Average daily weight gain (g)	20.07±1.12	21.01±1.30	22.4±1.22	1.41	NS

*[a,b] Means within same row with different superscripts are significantly different NS- Non significant (P>0.05); P<0.05) **; (P<0.01***)*

However, the weight gain pattern was similar (see figure 1 and 2) for rabbits in the two feeding regimes. Growth rates were characterized by an initial low weight gain (week 6 and 7) then high growth rate (week 8–11) and then slowed down (week 12–17). The initial slow growth rate could be due to weaning shock in young ones as they adapted to a new feed. Prior to weaning they would have started feeding on the concentrate diet offered to the dams. As rabbits start to reach maturity weight, growth rate declines (Rao et al, 1977) a trend exhibited by the animals under both feeding regimes in this study. The observed growth rate pattern is similar to that reported by

Rao et al, (1977) who plotted the growth rates of 270 New Zealand rabbits for a period of 1 year. The slow growth towards maturity is because of fat accretion which requires more thus lower growth rates (Maertens, 2009).

Table 15 shows the comparison of the weight gain of rabbits on the feeding regimes. The average weight gain of the rabbits in feeding regime 2 was highly significantly (P<0.01) lower compared to those in feeding regime 1 except during weeks 11 and 12. The daily weight gain during weeks 6 to 7 was recorded at 23.8 *vs.* 10.4 for New Zealand White, 25 *vs*. 11.7 for Californian and 27 *vs.* 12.7 for the Crossbreed on feeding regime 1 *vs.* 2 respectively.

Table 15: Comparison of weekly live weight gain of rabbits under the two feeding regimes

	Feeding regime 1			Feeding regime 2				
Time (weeks)	New Zealand White	California White	Crossbreed	New Zealand White	California White	Crossbreed	SEM	Significance
7	166.6^{cx}	175.1^{cdxy}	189.6^{dy}	72.5^{ax}	80.9^{abxy}	89.32^{by}	4.92	***
8	207.5^{b}	209.9^{b}	224.1^{b}	86.4^{a}	95.6^{a}	$99.75.9^{a}$	5.75	***
9	234.4^{c}	240.4^{c}	254.5^{c}	154.5^{bx}	160.1^{bx}	167.5^{ay}	6.39	***
10	$214.8b^{c}$	$216b^{c}$	232.7^{c}	182.9^{ax}	190.8^{abxy}	198.5^{aby}	6.9	***
11	199.8^{a}	203.3^{a}	204.6^{a}	200.6^{a}	207.1^{a}	210.8^{a}	16.49	NS
12	187^{a}	188.8^{a}	182.7^{a}	157.8^{a}	162.4^{a}	166.6^{a}	17.85	NS
13	179.5^{b}	182.7^{b}	173.8^{b}	128.5^{a}	132.8^{a}	107^{a}	11.66	***
Average weekly gain (g)	198.5^{cx}	200.0^{dy}	208.9^{deyz}	140.5^{ax}	147.1^{abxy}	156.6^{by}	10.0	***

*[a,b,c.d,e]Means within same row with different superscripts are significantly different between the feeding regimes. [x,y,z] Means within same row with different superscripts are significantly different within a feeding regime. NS- Non significant (P>0.05); P<0.05) **; (P<0.01***)*

Similarly Pinheiro *et al* (2011) observed that rabbits kept under an intensive system on high concentrate diets recorded twice the weight gain of those kept under an extensive system on forages. Lukefahr (1998), in his baseline survey in Uganda, where rabbits are mainly reared on forages, also reported that it took around 4-5 months to produce a 2 kg fryer. Cheeke (1997) observed that it takes twice the amount of time for fryers to reach a 2 kg weight under the extensive production systems common in developing countries compared to intensive production systems common in developed economies, which is a reflection of nutrition level.

It was noted by Dalle-Zotte (2002) that the best meat production performance in rabbits is achieved by *ad libitum* feeding of a balanced diet with over 10.45MJ/kg. Additionally, low energy diets also cause an increase in cecotrophs production and ingestion (Jenkins, 1999) thus animals access more of their proteins and B vitamins intake from cecotrophy. However, these nutrients may not be sufficient to compensate for the low dietary intake hence the need for supplementation for high performance of rabbits on forage based diets (Gillespie, 1998).

Figure 2 shows the weekly weights of the three rabbit breeds under feeding regime 2. The crossbreed maintained the weight advantage at the beginning of the experiment attaining the 2kg target weight earlier than the purebreds. This shows the importance of high weaning weight in rabbit production. Additionally, though the New Zealand started off and maintained a higher weight than the Californian, the latter caught up at week 15 due to a higher average weight gain of 147.1 compared to 140.5g/week for the former (Table 15).

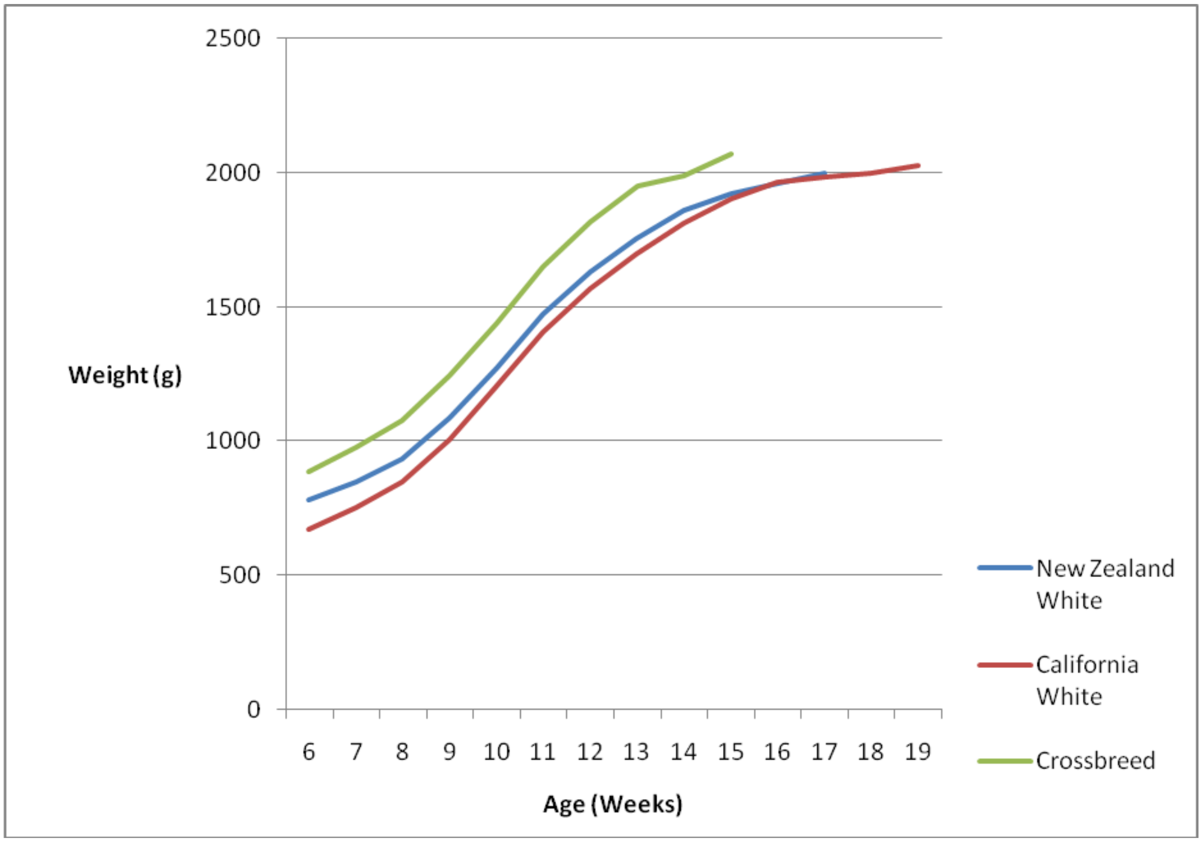

Figure 2: Mean values for live weight of rabbits on forage-based diet.

4.3.2 Feed intake of rabbits on forage based diet

The total feed intake of rabbits on forage based diet is presented in Table 16. The crossbreed had a higher daily intake and the Californian the lowest throughout the experimental period. This trend was similar to that for the rabbits on the concentrate-based diet. This can be explained by the fact that in both feeding regimes the crossbred animals were heavier than the other two breed groups while the Californian had the lowest weights throughout the study (Figure 2). This observation agrees with Mutetikka (1987) and Ozimba and Lukefahr (1991) who reported a higher daily feed intake for the crossbreed (NZW×CAL) than the purebreds.

Table 16: Weekly feed intake of rabbits on forage-based diet (g)

Time (weeks)	New Zealand White	California White	Crossbreed	SEM	Significance
6	346.9±4.89 ^{b}	321.5±2.67 ^{a}	366.5±2.91 ^{c}	3.63	***
7	502.9±7.14 ^{ab}	494.2±6.78 ^{a}	516.2±4.82 ^{b}	6.33	**
8	597±3.58 ^{ab}	564.5±5.09 ^{a}	617.6±4.15 ^{c}	4.32	***
9	693.1±5.69 ^{b}	662.8±5.76 ^{a}	720.4±5.45 ^{c}	5.63	***
10	777.7±6.63 ^{b}	732.4±4.60 ^{a}	801.7±3.34 ^{c}	5.04	***
11	835.9±3.77 ^{b}	811.9±2.38 ^{a}	852.5±2.64 ^{c}	3	***
12	884.6±3.82 ^{b}	863.8±3.00 ^{a}	901.9±2.64 ^{c}	3.19	***
13	923.3±2.54 ^{b}	909.2±1.71 ^{a}	934.7±1.30 ^{c}	1.93	***
14	952.7±2.91 ^{b}	936.6±0.85 ^{a}	955.8±3.46 ^{b}	2.6	***
15	961.5±3.06 ^{b}	945±1.15 ^{a}	962.5±3.10 ^{b}	2.59	***
16	965.4±2.84 ^{b}	953.9±1.64 ^{a}		2.37	**
17	972.2±2.23 ^{b}	962.5±2.46 ^{a}		2.5	**
Total average feed intake (g)	8635±430 ^{b}	9660±880 ^{c}	7533±30 ^{a}	1.6	***

^{a,b} *Means within same row with different superscripts are significantly different NS- Non significant (P>0.05); P<0.05)* ***; (P<0.01* ****)*

The average weekly feed intake at similar live weight was comparable to that of rabbits on concentrate based diet. The animals on the forage based diet would have been expected to have a lower DM intake due to the greater bulkiness of the Rhodes grass hay compared to the concentrate based diet. This higher than expected intake of the hay based diet could be explained by a more rapid feed transit time through the gastrointestinal tract which may have been enhanced by chopping (Medugu et al, 2012).

As shown in Table 16 the daily and total feed intake across the groups was highly significantly different (P<0.001). Feed intake increased from week 6-12 weeks but from week 13-17 intake ranged between 900 g and 970 g for all groups, probably signifying gut maturity and size. The crossbreed had the lowest total feed intake which is explained by the shorter time to target weight of 2kg. However, of the purebreds, the CW had a higher total feed intake than the NZ, a reversal of the trend exhibited with the concentrate based diet.

These breed differences in total DM, DE and CP intakes were significant (Table 17). The total CPI and DEI was higher for feeding regime 1 compared with feeding regime 2 for the NZW and ZxC but all were higher on forage based diet for CW. The higher nutrients intake by the Californian breed on the forage based diet may be explained by the longer time taken to reach target weight.

Table 17: Nutrient (CP and DE) intake of animals on forage based diet

	New Zealand	California	Crossbreed	SEM	Significance
Total CPI (g)	838.5[a]	932.9[b]	740.3[a]	23.2	**
Total DEI (Kcal)	16205[b]	18139[c]	14382[a]	516	***
Total DMI (kg)	8.635±4.3[b]	9.66±8.8[ab]	7.533±3.0[a]	0.16	**

[a,b,c] *Means within same row with different superscripts are significantly different NS- Non significant (P>0.05); P<0.05)* ***; (P<0.01*** *)*

The overall poor performance in feeding regime 2 can be attributed to lower nutrients supply on the Rhodes grass *(Chloris gayana)* based diet (Raharjo et al, 1986; Mutetikka, 1987) compared to concentrate diet. Mutetikka et al. (1990) observed that when compared with two other forages; sweet potato vines and dried maize leaves, *Chloris gayana* hay produced the lowest growth rate, particularly if the concentrate was limited However, Rhodes grass can be used as a source of the all important fiber in rabbit feeding (NRC, 1977). This may explain the fact that the post weaning mortalities for the rabbits on the hay based diet was much lower at 6.3% compared to

14.6% for those on the concentrate based diet which would have had lower fiber content. Elmaghraby (2011) reported a mortality of 12.5% for rabbits on concentrate ration. Generally, as the total dietary NDF level increases, voluntary feed intake as well as total nutrients intake tend to decline. Though the total DMI in the current study was higher on the fiber based diet, the reduced total nutrients as noted earlier would explain the poorer performance of the rabbits on the hay based diet compared to those on the concentrate diet. However, if NDF is too low, digestive disorders may occur and mortality as a consequence of this (Robinson *et al*, 1999).

4.3.3 Left over hay analysis

Results for left over hay analysis are presented in Table 18. The rabbits selected for NDF, ADF and lignin as shown by the lower levels of these DM components in the refusals. This observation is in agreement with Cheeke (1972) who reported that when given a choice, rabbits preferred barley to corn, either because of palatability or higher fiber content or both.

Table 18: Detergent fibre content of hay as fed and leftovers

Parameter	Hay offered	California White	Crossbreed	New Zealand White	SEM	Significance
NDF	66.25±1.49[c]	45.59±1.74[a]	52.08±0.68[b]	48.79±0.53[ab]	1.25	***
ADF	40.51±0.94[b]	26.30±1.08[a]	30.12±0.93[a]	27.79±0.90[a]	0.97	***
Lignin	8.58±0.82[b]	6.90±0.67[ab]	5.36±0.29[a]	5.58±0.30[a]	0.57	***

*[a,ab,b,c] Means within same row with different superscripts are significantly different NS- Non-significant(P>0.05); P<0.05) **;(P<0.001 ***)*

Hall and Johnston (1976) also reported that corn-based diets gave poorer growth responses with rabbits than either barley- or oat-based diets and in lactation diets, oats gave the best performance of the four grains suggesting factors other than energy content are involved. Other scenarios depicting the preference of fiber by rabbits are shown by the preference of fibrous alfaalfa *(Medicago sativa)* hay over oil seed cakes (Cheeke, 1986). For reasons that were not apparent, breed had a significant effect (P<0.001) on selectivity.

4.4 Cost of Production

Table 19 shows the total feed intake to the target weight of 2kg, the feed to gain ratio and the total costs for each breed and feeding regime.

Table 19: Cost of production to 2kg fryer for the two feeding regimes

	Feeding regime 1			Feeding regime 2				
	New Zealand White	California White	Crossbreed	New Zealand White	California White	Crossbreed	SEM	Sig
Total feed intake (kg)	5.912±67^{by}	5.591±32^{abxy}	5.148±20^{ax}	8.635±43^{dy}	9.66±88^{ez}	7.533±3.0^{cx}	0.16	***
Concentrate supp (kg)				1.6	1.68	1.48		
Total hay intake (kg)				7.03	7.98	6.05		
Total weight gain (g)	1227±22^{ab}	1319±1.9^{b}	1278±2.1^{ab}	1255±8.52^{ab}	1291±11^{ab}	1201±10.20^{a}	34.6	**
FCR	4.818±0.1^{by}	4.230±0.03^{abxy}	3.966±0.02^{ax}	6.898±0.05^{c}	7.393±0.11^{c}	6.272±0.06^{c}	0.232	***
Feed Cost(Ksh)	183.2±2.1^{dy}	173.3±0.99^{dy}	159.59±0.7^{cx}	120±0.43^{abxy}	131.9±0.88^{by}	106.4±0.30^{ax}	3.21	***
Other costs estimates	78.5	74.3	68.4	90.5	98.8	80.3		
Total cost	261.7	247.6	228	210.5	230.7	186.7		
Cost/Kg weight gain(sh)	213.3	187.7	178.4	167.7	178.7	155.5		

$^{a,b,c.d,e}$Means within same row with different superscripts are significantly different between the feeding regimes. ^{x,y,z} Means within same row with different superscripts are significantly different within a feeding regime. NS- Non significant (P>0.05); P<0.05) **; (P<0.01***)

The results on fryer production cost estimates reflected those of total feed intake and thus lowest for the Crossbreed compared to Californian and New Zealand white under both feeding regimes. The cost observations were highly significantly (P≤0.01) different across the three groups.

Additionally, the cost per kilo weight gain was lower under feeding regime 2 due to the fact that on a per unit weight basis the forage based diet would be cheaper than the concentrate diet. However, with this cheaper diet the animals took an average of five weeks longer to the target fryer weight of 2kg. Practically this would translate to fewer animals, almost 50% less, being available for the market under this system compared to the more intensive concentrate based diet. Of the two purebreds, the New Zealand appears to have performed better, in terms of cost of feeding and weight gain, under the less intensive feeding system and the Californian under the intensive system (Table 19). This suggests that the New Zealand is a better breed for production systems based on forages than the California white. The same trend was also observed for feed utilization efficiency assessed as feed per unit live weight gain.

These observations are in agreement with Ozimba and Lukefahr (1991) who noted that at 70 d the crossbreed and California White yielded better returns than New Zealand White under intensive systems of feeding. Ekpo *et al* (2009) cited Obikaonu and Udedibe (2006) also concluded that rabbit production systems based on unconventional feeds (cassava tuber meals) resulted in lower cost of production due to lower cost of the raw material.

The poor FCR for rabbits under the feeding regime 2 was as observed by Mmereole *et al* (2011) who reported FCR values of between 5.11±0.016 to 6.01±0.053 after feeding graded levels of *Tridax procumbens* (common name: tridax daisy). This reflects the lower nutritive value of the forage based diet thus the higher quantity required per unit weight gain.

4.5 Effect of Breed and feeding interaction on rabbit performance

The interaction between breed and feeding regimes for the different parameters are shown in Table 21. Within both feeding regimes, total feed intake ($P<0.01$) and total feed cost were significantly (P<0.05) affected by breed with the crossbred consuming the least (Table 20). Additionally more feed was consumed in feeding regime 2 irrespective of the breed.

Table 20: The effect of breed and feeding regime interaction on feed intake, weight gain and the FCR of weaner rabbits

		P-Value	
Parameters	**Breed**	**Feed**	**Interaction (B×F)**
Total feed intake	<.01	<.01	<.01
Total weight change	0.039	0.454	0.054
FCR	0.007	<.001	0.078
Total feed cost	<.01	<.01	0.015

Non significant (P>0.05); Significant (P<0.05); highly significant (P<0.01).

The other variables FCR and total weight gain were not affected. The lack of significance (P>0.05) for total weight changes could be due to the fact that for all the regimes, the target weight was 2 kg for all breeds.

4.6 Conclusion and Recommendation

1. California White had superior growth rate under the concentrate feeding regime. Additionally, the cost of feeding (which is the major cost in rabbit production) was also lower compared with the New Zealand White under the same feeding regime.

2. The crossbreed performed best regardless of the feeding regime, when both biological and economic traits were considered. For these reasons, therefore, of the breeds in the study it would be the best breed for meat production.

3. Although feeding regime 2 may be most suitable for resource poor farmers as it is characterized by low production cost, estimated returns under the more intensive feeding regime 1 would yield better returns due to higher offtake rates.

4.7 Policy Recommendation

This study recommends to stakeholders in the rabbit industry to adopt the crossbreed genotype which has better growth parameters and better economic returns and should be considered especially by farmers targeting the rabbit meat market.

CHAPTER 5

EVALUATION OF CARCASS CHARACTERISTICS OF NEW ZEALAND WHITE, CALIFORNIA WHITE AND THEIR CROSS UNDER TWO FEEDING REGIMES

5.0 MATERIALS AND METHODS

New Zealand White, California White and their cross from the two feeding regimes (Concentrate based ration and forage based ration) were selected and slaughtered for carcass analysis as per the following description.

5.1 Evaluation of carcass characteristics

Five fryers per breed per feeding regime (total 30) were randomly selected for slaughter to evaluate the carcass characteristics. The rabbits sampled for slaughter were between the weights of 2000 – 2500g. The carcasses were dissected in accordance with the norms of the World Rabbit Science Association (WRSA) (Blasco and Ouhayoun, 1996).

5.1.1 Pre-slaughter handling and Stunning of rabbits

The rabbits were not fasted prior to slaughter. This was because research has shown a non-significant loss of only 1.4 to 4.6% due to pre-slaughter handling and transportation from 1 to 7 h. For this trial there was no transportation involved. The selected rabbits were weighed to determine the live weight at slaughter then stunned with a sharp blow to the base of the neck which results in instant death of the animal. Killing the rabbit humanely is critical. Stress during the butchering process may result in release of stress hormones reported to negatively affect flavor of rabbit meat and to toughen it.

5.1.2 Slaughter of animals

The rabbits were slaughtered by severing both the jugular vein and the carotid arteries below the jaw. The carcasses were allowed to bleed for 10 minutes then skinned immediately and hung again for maximum bleeding for another 30 minutes.

5.2 Processing of rabbit carcasses and data collected

The data collected and analyzed were live weight at slaughter, hot carcass weights, chilled carcass weights, reference carcass weight, dressing percentage, weight of organs (kidney, heart and lung, liver), drip loss as well as the meat to bone ratio.

5.2.1 Slaughter weights and hot carcass weights

The slaughter weight as used in the thesis was the live weight of the animal at slaughter. Carcasses with the head, liver, kidneys, and thoracic viscera (lungs, thymus, esophagus, and heart), but without the skin, legs, the gastrointestinal system beyond the esophagus and contents as well as reproductive organs were weighed to get the hot carcass weight.

5.2.2 Chilled carcass weight, dressing percentage and drip loss

The hot carcasses were then placed in labeled plastic bags and arranged in a refrigerator set at 4 °C for 24 h. The carcasses were then weighed to obtain the chilled carcass weight. The dressing percentage was calculated as the (chilled carcass weight ÷ live weight) x 100).

The drip loss percentage (DLP) was determined as the difference between the hot carcass weight and chilled carcass weight, relative to the hot carcass weight.

5.2.3 Reference carcass and organ weights

The head, liver, kidneys, and thoracic viscera were removed from the chilled carcass and weighed to obtain the reference carcass. The head, liver, and reference carcass weights were expressed as a percentage of the chilled carcass weight.

5.2.4 Determination of carcass fat

The carcass intra-muscular and inter-muscular fat content is a factor of meat quality, but it is laborious and expensive to evaluate (Hernandez *et al*, 1996). Peri-renal fat depot was reported to be a good predictor of total dissectible fat in rabbit carcasses by Varewyck and Bouquet (1982) and is accepted in rabbit carcasses evaluation studies. Peri-renal fat (abdominal fat surrounding the kidneys) was physically removed from the chilled carcass, weighed and used to estimate the dissectible carcass fat weight and carcass fatness as suggested by Varewyck and Bouquet (1982) and recommended by WRSA. The dissectible fat weights were expressed as a percentage of the reference carcass weight i.e.

(Dissectible carcass fat weight ÷ reference carcass weight) x 100

5.2.5 Determination of Meat to bone ratio

The hind leg was used as a sample joint to estimate the meat to bone ratio. It has been used successfully as an easy and inexpensive method to estimate the amount of edible meat in the rabbit carcass for application in genetic improvement programs or simply in economic carcass evaluation (Blasco et al, 1984). The hind legs were manually deboned with a knife. The flesh and the bones were weighed separately and the weights used to calculate the meat to bone ratio of the hind leg.

For more precise assessment of meat to bone ratio, the weighed bones in a plastic container were further treated with 50ml of 5M KOH immersed in a water bath at 65^0C for 4hrs followed by 50 ml of 5M NaOH for another 4hrs at the same water bath temperature for thorough deboning. The bones were then rinsed with distilled water, oven dried at 65^0C for 12hrs, cooled and weighed.

5.3 Statistical analyses

All data was captured using Excel 2007 spreadsheet, Windows 2007. Data collected for meat parameters assessment were subjected to Analysis of Variance (ANOVA) procedure using the package Genstat software (Genstat, 13^{th} edition, 2011) for windows. When analysis of variance indicated significance for treatment effects, specific differences between means were ranked using the Bonferroni Test.

5.4 Analysis of costs and returns.

Cost of feed was calculated based on prevailing cost of ingredients per kilogram as at the time the experiment was conducted (sh.31/kg for concentrate feed and sh.10/kg for Rhodes grass hay)

The quantity of feed consumed for the experimental period per unit weight gain of rabbits gave the cost of feed kg^{-1} weight gain. The other costs associated with rabbit production were estimated as stated in Section 3.8.

Value of meat, pelt and animals sold as breeding stock was calculated at the prevailing market prices. (Sh.400/kg dressed meat, sh.50 per piece of pelt and sh.850 per 2kg live animal)

5.5 RESULTS AND DISCUSSION

5.5.1 Slaughter weights, Dressing percentages and Drip loss

The meat characteristics of the rabbits on concentrate based diet (feeding regime 1) and forage based diet (feeding regime 2) are presented in Table 21. There were no significant differences between the three breeds in feeding regime 1 for most of the parameters except for full gut weights and drip loss percentages. For the forage based diet, of the carcass traits assessed only the full gut weights, dressing percentage and drip loss percentage were significantly different between breeds.

The average slaughter weights of rabbits in this study were 2262 g and 2370 g for feeding regime 1 and 2 respectively. This is within the range of weights that Kenyan farmers slaughter their animals (Serem, 2014).

Level of nutrition affects intake, growth, feed efficiency, slaughter yield, carcass adiposity and lipid content in rabbits (Ferreira and Carregal, 1996, Jerome *et al*, 1998, Gondret *et al*, 1998, Dalle-Zotte, 2002). Additionally, it has been observed that if rabbits were slaughtered at a constant body weight rather than age, differences in hot carcass, chilled carcass and reference carcass parameters are eliminated (Elmagraby, 2011). As such, these parameters are dependent on weight rather than age. In this study, rabbits slaughtered from feeding regimes 1 and 2 were of different chronological ages, but their weights were almost similar and thus the similarity in almost all the parameters observed. Tumova *et al* (2002), Boisot *et al* (2004), Dalle Zotte *et al* (2005) and Yakubu *et al* (2007) also noted that there is little impact on carcass traits under a variety of restriction protocols as long as slaughter weights are similar.

Table 21: Carcass characteristics of rabbits on either of the feeding regime

	Feeding regime 1			Feeding regime 2			SEM	Sig
Parameter	New Zealand	California White	Crossbreed	New Zealand White	California White	Crossbreed		
Weights (g)								
Slaughter weights	2249	2312	2225	2349	2531	2229	83.2	NS
Hot Carcass	1399	1484	1401	1402	1481	1373	41.2	NS
Chilled carcass	1381	1464	1379	1384	1461	1353	41.4	NS
Reference carcass	1086	1122	1099	1078	1294	1061	51	NS
Percentage of slaughter weight								
Dressing %	61.46^{ab}	63.36^{ab}	62.01^{ab}	58.46^{ax}	60.68^{abxy}	57.95^{ax}	0.96	**
Skin	8.56	8.57	7.94	8.83	9.16	8.81	0.44	NS
Full gut	20.23^{by}	18.71^{ax}	18.75^{ax}	20.98^{by}	21.38^{cz}	19.05^{abx}	0.6	***
Percentage of chilled carcass								
Head	6.48	7.84	6.16	7.97	9.62	7.104	0.62	NS
Liver	4.45	5.03	4.69	5.65	5.78	5.47	0.43	NS
Kidneys	1.29	1.36	1.09	1.34	1.95	1.24	0.24	NS
Heart and lungs	1.55	1.68	1.49	1.64	1.85	1.54	0.11	NS
Reference carcass	78.6	76.7	79.7	77.8	88.3	78.2	1.87	NS
Percentage of reference carcass weight								
Perirenal fat	0.87^{ab}	0.87^{ab}	0.76^{ab}	0.35^{a}	0.57^{a}	0.27^{a}	0.36	**
Drip loss %	1.28^{bx}	1.35^{bcxy}	1.57^{dy}	1.08^{ax}	1.28^{by}	1.45^{cz}	0.08	***

$^{a,b,c.d}$ *Means within same row with different superscripts are significantly different between the feeding regimes.* ^{x,y,z} *Means within same row with different superscripts are significantly different within a feeding regime. NS-Non significant (P>0.05); P<0.05)* ***; (P<0.01*****)*

Dressing percentage is an important economic variable in the meat market. This is because more profit would be realized from rabbits with higher yield as most sales are on carcass weight. The commercial criterion used for rabbits is a slaughter yield of between 56 % and 58 % from chilled carcass (Pla et al., 1998). The dressing percentage in this experiment ranged between 61.4 and 63.4 % for feeding regime 1 and 58.0 and 60.7 % for feeding regime 2. These values are higher than those reported by Omojola (2007) of 52.8 for New Zealand White slaughtered at an average weight of 2000g. The dressing percentages of rabbits on forage based diet averaged 59.1% and were lower than those on concentrate based diet (62.3%). Within feeding regime 1, differences in dressing percentage between breeds were non significant ($P>0.05$) which is explained by the similarity of weights at slaughter. Within feeding regime 2 the dressing percentage for the Californian was higher ($P<0.05$) than both New Zealand and the Crossbreed. This may be explained by the fact that the Californian rabbits on forage based diet were slaughtered at a higher weight (Table 21) and consequently dressed at a higher percentage than the New Zealand and crossbreed.

In agreement with the current results, Maertens and van Oeckel (2001), Dalle Zotte *et al*. (2008) and Prayaga and Eady (2003), the results of dressing percentage in the current study were similar for animals slaughtered at similar weights. According to Dalle Zotte and Ouhayoun (1998), dressing percentage increased up to 91 days (13 weeks) in animals receiving *ad libitum* feeding, after which a decline is exhibited due to an increase in organ size. Other factors that affect dressing percentage are the proportion of skin, gut content and offal (Lebas and Ouhayoun, 1987). In the current experiment, the rabbits on the forage based diet had higher organ, skin and full gut weights which would have contributed to the lower dressing percentage for this group compared to those on the concentrate based diet.

The drip loss percentages were higher for the carcasses of rabbits in feeding regime 1 than for those in feeding regime 2. In agreement, Pinheiro *et al* (2011) and Emalgraby (2011) noted higher drip losses in rabbits under *ad lib* concentrate feeding than with rabbits under restricted feeding. Drip loss is dependent on the ultimate pH in muscles which is a factor of glycogen levels at slaughter. The ultimate meat pH affects meat quality properties, including WHC, a determinant of carcass drip loss, and color in rabbits (Hulot and Ouhayoun, 1999). Postmortem, glycogen is converted to H+ and lactic acid, resulting in decreased pH which causes reduction in water holding capacity (WHC) of the muscle thus higher drip loss (Gondret *et al*, 2005, Pla *et al*, 1998). Therefore, the expected higher glycogen levels in rabbits on the higher plane of nutrition in feeding regime 1 would have contributed to the higher drip loss for this group. However, literature data on effect of diet on ultimate pH are contradictory, with reports of higher pH (thus expected higher WHC hence lower drip loss) (Pla *et al*, 1998), resulting in lower WHC (Cabanes-Roiron and Ouhayoun, 1994), or the same value (Hernandez *et al*, 1997) in rapid-growing rabbits compared with rabbits undergoing a slower growth rate due to feed restriction. These controversies can be explained by the fact that pH is mainly affected by pre-slaughter handling and the time taken for the hottest part of the carcass to chill at 4^0C (FAO, 2007). The crossbreed had the highest drip loss which differed ($P<0.05$) from the two pure breeds regardless of the feeding regime. This can be explained by the differences in carcass fat content. It has been shown that animals with leaner carcasses especially exhibited in young rabbits, will have a higher drip loss due to lower WHC (Piles *et al*, 2000). The crossbreed recorded the lowest fat content which could explain the higher drip loss, regardless of the feeding regime.

The full gut content differed ($P<0.01$) between breeds as well as within and between feeding regimes, being higher in feeding regime 2. Under concentrate based diet, the New Zealand had the highest full gut content (20.2%) while on forage based diet the Californian the highest (21.3%). Rabbits have high fiber intake and equally high fiber elimination rate from their gastrointestinal tract (Carabano and Piquer, 1998). The higher feed intake could explain the higher gut fill in the forage based diet rabbits compared to the concentrate based diet rabbits. Additionally, due to the older age at slaughter (Lebas *et al*, 1997), the gut size of the rabbits on the forage based diet would be proportionately larger compared to those on concentrate based diet slaughtered at a lower chronological age.

The dissectible carcass fat content, assessed from the peri-renal fat weight, of the rabbits in the feeding regime 2 were significantly ($P<0.05$) lower than that for the rabbits on concentrate based ration. Reduced levels of energy available for growth and fat deposition on the forage based diet likely contributed to this effect. Dal Bosco *et al* (2000) observed a lower fat content in the carcasses of rabbits reared on restricted concentrate ration than those on unrestricted diet. Ouhayoun (1998) and Cavani *et al* (1991) also noted that feed restrictions that lead to lower nutrient intake by the rabbit usually reduces not only the carcass fat at slaughter but also the dressing percentage a function of slaughter weight, which was also evident in this trial.

Generally, the lack of significant differences in carcass parameters between the two feeding regimes can be explained through Piles *et al*, (2000) postulation. The authors stated that lower degree of physiological maturity at slaughter of rabbits selected for a high growth rate would not lead to appreciable changes in carcass composition, except carcass fatness, when compared with a control group.

5.5.2 Effects of breed and feeding interaction on carcass characteristics

The interaction between breed and feeding regimes for the different parameters are shown in Table 22. The breed feed interaction had a significant ($P<0.05$) effect on dressing percentages, full gut as well as the drip loss. There was no significance ($P>0.05$) of the interaction for the rest of the parameters assessed. This shows that regardless of the diet or the feed, the meat characteristics were similar in all parameters evaluated. Further explanations for these observations are given in section 5.6.1.

Table 22: The effects of Breed and Feeding interaction on carcass characteristics in rabbits

	P-Values		
Parameter	Breed *(B)*	Feed *(F)*	Interaction *(B × F)*
Weights (g)			
Slaughter weights	0.105	0.773	0.112
Hot Carcass	0.074	0.720	0.922
Chilled carcass	0.080	0.794	0.929
Reference carcass	0.047	0.300	0.139
Percentage of slaughter weight			
Dressing %	0.163	0.288	0.01
Skin	0.545	0.285	0.421
Full gut	<.01	0.225	<.01
Percentage of chilled carcass			
Head	0.058	0.096	0.987
Liver	0.227	0.831	0.413
Kidneys	0.453	0.126	0.064
Heart and lungs	0.687	0.730	0.669
Reference carcass	0.171	0.078	0.022
Percentage of reference carcass weight			
Perirenal fat	0.480	0.845	0.389
Drip loss %	0.138	0.01	0.018

Non significant (P>0.05); Significant (P<0.05); highly significant (P<0.01).

5.5.3 Meat-to-bone ratio and Carcass fatness

In the commercial meat industry, the ratio of muscle to bone is a very important characteristic and directly affects the value of an animal carcass (McIntyre, 2007). The goal is to maximize the muscle to bone ratio (Machen, 1997).

Table 23: Meat to bone ratio of rabbits fed on complete ration

	Feeding regime 1			Feeding regime 2				
Parameter	New Zealand	California White	Crossbreed	New Zealand White	California White	Crossbreed	SEM	Sig
Hind leg muscle weight (g)	132.5±4.3	131.1±4.8	144.1±2.4	134.8±9.3	135.9±0.5	136.8±5.3	5.37	NS
Bone weight (g)	25.85±1.0	24.05±2.2	24.53±2.1	26.72±2.1	25.82±0.3	26.12±1.2	1.08	NS
Meat/Bone ratio of the hind leg	5.15±0.3	5.49±0.3	5.9±0.3	5.04±0.42	5.12±0.04	5.50±0.25	0.28	NS

The meat to bone ratio for the three breeds and two feeding regimes is shown in Table 23. This was assessed from the hind leg, a sample cut that has been shown to be a good predictor and widely accepted for the evaluation of meat to bone ratio of rabbit carcasses (Hernandez et al, 1996). There were no significant differences (P>0.05) in the meat to bone ratio across the three groups within and between the feeding regimes with a mean of 5.5 and 5.2 for feeding regime 1 and 2 respectively. Though not significant, the crossbreed had slightly higher values than the purebred on both feeding regimes. Ouyed *et al* (2011) also reported a moderately higher meat-to-bone ratio for the crossbreed of the same breeds used in this study of 6.3 compared to 6.1 for the pure breeds. In their trial, Ouyed *et al*, (2011) fed rabbits *ad libitum* on a commercial diet balanced to meet the requirements for growth (2375 kcal/kg ME and 16% CP). The slaughter weights ranged between 2200 and 2450. The results of meat to bone ratio in this study are similar to the value reported by Yalcin *et al* (2006) and Dal Bosco *et al* (2002) of 5.29 for 11 week old New Zealand White rabbits.

Pla *et al* (1998) reported that meat-to-bone ratios were similar across breeds selected for high growth rate or litter size when slaughtered at a similar body weight. The two breeds used in the study are described as such (ARBA, 2010) and this would explain the lack of significance of the differences in meat to bone ratio of rabbits in both feeding regimes. These findings also agree with the findings of Maertens and van Oeckel (2001) and Dalle Zotte *et al*., (2008) as well as Pinheiro *et al*., (2011).

5.5.4 Cost and returns analysis

Table 25 shows the costs incurred and the estimated revenue from edible meat yield for the two feeding regimes. For value addition, rabbit meat is sold in butcheries as “Sungura Fry” and it can also be used to prepare different delicacies such as pies, kebabs, “samosas” and sausages. The skin or pelt has a potentially high demand in the garment industry due to its fur which can also be processed to make leathers and leather goods (NFIS, 2012). The head, spleen and heart would make excellent dog food (The organic farmer, 2008) though further processing will be necessary. Although other factors (meat color, taste qualities) were not analyzed in this study it has been noted that rabbits that are slow grown score better in these attributes than fast grown rabbits. It has been suggested that when rabbit breeds with high growth potential are used, they should be slaughtered at an older age so as to attain an adequate maturity for their carcass traits to be fully expressed, such as improved WHC (Dalle- Zotte, 2002). However, this may negatively impact on economic returns because the feed conversion ratio decreases with age and would be lower for such rabbits (Gondret *et al*, 2005).

Since there were no significant differences in the commercially important carcass characteristics between the two feeding regimes except the dressing percentage, the discussion on cost analysis focuses on cost of producing one kilogram of edible rabbit meat. This analysis took into account the variations in dressing percentage.

Table 24: Carcass Cost analysis for the two feeding regimes

	Feeding regime 1			Feeding regime 2				
	New Zealand White	California White	Crossbreed	New Zealand White	California White	Crossbreed	SEM	Sig
Total feed intake (kg)	5.912±67[b]	5.591±32[ab]	5.148±20[a]	8.635±43[d]	9.66±88[e]	7.533±3.0	0.16	***
Concentrate supp (kg)				1.6	1.68	1.48		
Total hay intake (kg)				7.03	7.98	6.05		
Reference carcass (g)	1086±37[a]	1122±31.8[a]	1199±20[a]	1078±56[a]	1294±11[a]	1061±14[a]	51.0	NS
Total feed Cost(Ksh)	183.2±2.1[d]	173.3±0.99[d]	159.6±0.7[c]	120±0.43[ab]	131.9±0.9[b]	106.4±0.30[a]	3.21	***
Other costs estimates	78.5	74.3	68.4	90.5	99.5	80.3		
Total Cost	261.2	247.6	228	210.5	231.4	186.7		
Cost/Ref carcass(sh/kg)	240.5	220.7	190.2	195.3	178.8	176		
Average cost/Ref carcass per feeding regime(sh/kg)		217.1			183.4			

[a,b,c,d] *Means within same row with different superscripts are significantly different NS- Non significant (P>0.05); P<0.05)* ** *; (P<0.01* *** *)*

To calculate the production cost for a 100 breeding does unit for a 1 year production cycle, the following assumptions were made:

1. A doe mortality of 22% (Farghaly et al, 1994) per year thus available does at 78.
2. 5.2 litter crops per doe per year (when weaning and rebreeding is done at 6 weeks post-kindling).
3. Pre weaning mortality at 8.3% with average litter size at birth of 8.6 thus average number of kits at weaning of 6.
4. Post weaning mortality at 14.6% and 6.3% for regime 1 and 2 respectively, thus fryers available for market will be 5.12 and 5.62 per litter.
5. Offtake rate (fryers crops per doe per year) at 4.3 and 3.1 for feeding regime 1 and 2 respectively (based on 12 weeks for feeding regime 1 and 17 weeks for feeding regime 2 to slaughter weight attainment).
6. The estimated total cost per fryer for feeding regime 1 at Ksh.245.6 (total average costs for the three breed groups) and for feeding regime 2 at Ksh.209.3 (total average feed costs for the three breed groups).
7. Average dressed weight for feeding regime 1 at 1.1357kg and for feeding regime 2 at 1.1443kg.
8. The estimated average cost of producing 1 kg of edible meat at Ksh. 217.1 and Ksh.183.4 for feeding regime 1 and 2 respectively (Table 25).
9. Price of rabbit meat at Ksh.400 per kg and price of skin at Ksh.50 per piece.
10. Animals sold as live animals at 2 kg at Ksh. 850 (according to APD rates).

As shown in Table 26, higher returns would be realised by adopting the more intensive feeding system which results in more animals being available either for slaughter or sale of live animals in a year. The returns were higher with both feeding systems when the animals were sold live than when animals are slaughtered. The difference in profit margin between feeding regimes 1 and 2 where the rabbits were slaughtered would be 197,616 (USD 2,325) per annum in favour of feeding regime 1. The same trend persists when the animals were sold live with even larger differences in realisable income of 869,685 (USD.10,232) in favour of the more intensive feeding system.

Table 25: Cost and returns analysis

	Feeding regime 1	**Feeding regime 2**
Meat	4,056,579	3, 234,415
Skin	446,484	353,318
Total Income (Meat + Skin)	4,503,063	3,587,733
Total Cost (Based on edible meat)	2,200,694	1,482,980
Profit Margin	2,302,369	2,104,753
Income for live animal	7,590,236	6,006,409
Total cost (Based on live weight)	2,193.132	1,478,990
Breeding stock profit margin	5,397,104	4,527,419

5.5.5 Conclusion and Recommendations

1. Carcass characteristics of rabbits of the same breed slaughtered at the same weight but different chronological age were similar.

2. Though the less intensive forage based feeding system translated to lower cost of production per unit weight of product, fewer animals would be available for disposal in a year which would result in lower returns from a breeding rabbits unit.

3. More revenue is generated when animals are sold as breeding stock (live animals) rather than as meat for the two feeding regimes adopted in this study.

5.5.6 Policy Recommendation

This study recommends that:

1. Stakeholders targeting rabbit meat for value addition should insist the three genotypes are slaughtered at the weight of 2 kg as the meat characteristics will be similar regardless of whether they were fed concentrate only diet or forage with supplementation diet.

2. Use of concentrate feeds in rabbit production should be promoted by the stakeholders due to the higher productivity and profitability when compared to forage use. However due to high feed costs which resource poor farmers cannot afford, the government, feed manufactures, donors and other stakeholders should come up with ways to reduce these costs for example through use of cheaper raw materials, provision of subsidies and /financing.

CHAPTER 6

6.0 REFERENCES

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