BIOLOGICAL AND ECONOMIC PERFORMANCE OF RABBITS IN KIAMBU COUNTY, KENYA

A Thesis submitted in partial fulfillment of requirements for the degree of Master of Science in Livestock Production Systems, University of Nairobi

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2020

DECLARATION AND APPROVAL

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

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ACKNOWLEDGEMENTS

I thank the Lord for His guidance and protection during my study. Thanks are also extended to the University of Nairobi for awarding me an academic scholarship.

I am grateful to my supervisors, Prof. Margaret Wanyoike and Prof. Charles Gachuiri for their generous and encouraging guidance, support, constructive criticism and suggestions during the study period. I appreciate your unrelenting support throughout the course of my study and thesis writing.

I would like to recognize and thank all the respondents in Kiambu County who took part in the survey for availing needed data, Mr. Waiganjo of RABAK, Mr. Mureithi of Kiambu County and Mr. Kimari of KIMKA for being resourceful in the identification and reaching of the rabbit farmers. Special thanks go to Mr. Denis Ngetich for helping in questionnaire administration.

I wish also to extend my gratitude to Mr. Benjamin Kyalo, Mr. Desmon Ambale, Mr. Samuel Gitua, Mrs. Anne Kimende, Miss. Purity Gakii and Miss. Vera Nyanchama of the department of animal production for their assistance during feed analysis.

The efforts of my family members, colleagues and friends who in one way or another provided a favorable atmosphere during the study, companionship and shoulders to lean on when the going got tough will always be remembered.

Thanks are extended to the National Commission for Science and Technology (NACOSTI) for providing research funds. The work reported in this thesis was carried out as part of the activities under the research project 'Strategies to Promote the Rabbit Value Chain in Kenya' funded by this commission.

DEDICATION

I dedicate this work to my family, who have continually supported me throughout my entire education life, and rabbit farmers in Kiambu who allowed me to use their farms in my study, the findings of which are presented here.

TABLE OF CONTENTS

DECLARATION AND APPROVAL ii

ACKNOWLEDGEMENTS iii

DEDICATION iv

TABLE OF CONTENTS v

LIST OF FIGURES ix

LIST OF TABLES x

LIST OF ABBREVIATIONS AND ACRONYMS xi

LIST OF APPENDIXES xii

CHAPTER ONE 1

INTRODUCTION 1

1.1 Background 1

1.2 Statement of the problem 3

1.3 Objectives of the study 3

1.4 Research questions 3

1.5 Justification 4

CHAPTER TWO 5

LITERATURE REVIEW 5

2.1 Introduction 5

2.2 World Rabbit production 6

2.3 Rabbit industry in Kenya 7
2.4 General performance of rabbits 8
2.4.1 Reproductive performance 9
2.4.2 Growth rate and age at slaughter 12
2.5 Factors influencing on-farm productivity of rabbits 14
2.5.1 Farm and farmer attributes 14
2.5.3 Feeds and feeding practices 19
2.5.4 Rabbit health 22
2.5.5 Environmental conditions 24
2.6 Cost of production 26
CHAPTER THREE 29
RABBIT PRODUCTION PRACTICES IN KIAMBU COUNTY 29
3.1 Introduction 29
3.2 Materials and methods 30
3.2.1 Study Area 30
3.2.2 Sampling criteria and sample size 31
3.2.3 Study type and data collection 31
3.2.4 Data analysis 32
3.3 Results and discussion 32
3.3.1 Socio-economic characteristics of rabbit farmers 32

3.3.2 Breeds and breeding practices 39
3.3.3 Feeds and feeding practices 46
3.3.4 Diseases and health management of rabbits 54
3.4 Conclusions 61
CHAPTER FOUR 62
EVALUATION OF PERFORMANCE OF RABBITS ON SELECTED FARMS IN KIAMBU COUNTY 62
4.1 Introduction 62
4.2 Materials and methods 63
4.2.1 Experimental farms and their attributes 63
4.2.2 Experimental animals and their management 64
4.2.2 Sampling and Proximate analysis of feeds 64
4.2.3 Nutrient intake 65
4.2.4 Data analysis 65
4.2.5 Assessment of cost of production 65
4.3 Results and discussion 66
4.3.1 Type and quality of feeds offered to rabbits in the study farms 66
4.3.2 Feed and nutrient intakes of rabbits 72
4.3.3 Weight gains 75
4.3.4 Feed conversion efficiency 80

4.3.6 Cost of production ... 82

4.4 Conclusions ... 85

CHAPTER FIVE ... 86

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS ... 86

5.1 General discussion ... 86

5.2 General conclusions ... 88

5.3 Recommendation ... 89

REFERENCE ... 90

APPENDICES ... 119

LIST OF FIGURES

Figure 1: Land ownership by rabbit farmers in the study area..366

Figure 2: Reasons for ownership of rabbit enterprise in study area...38

Figure 3: Types of feed offered to rabbits in the study area. 47

Figure 4: Forage post-harvest handling, preparation, production and feeding practices in the study area 4949

LIST OF TABLES

Table 1: Gender, age and education status of rabbit keepers in study area 35

Table 2: Types and average numbers of animals kept by rabbit keepers in the study area 37

Table 3: Breeds of rabbits kept by farmers in the study area 40

Table 4: Years spent in rabbit farming and mean number of rabbits kept 43

Table 5: Breeding practices 46

Table 6: Forages used and farmer proportion 48

Table 7: Types of forages considered harmful to rabbits in the study area. 51

Table 8: Farmer's attributes influencing concentrate use as rabbit feed in the study area 53

Table 9: Common rabbit diseases and frequency in study area 55

Table 10: Actions taken on disease occurrence by rabbit keepers in the study area 60

Table 11: Chemical composition of the forages offered to rabbits in the study farms 67

Table 12: Proximate composition (%DM) of concentrates used in study farms 70

Table 13: Weekly feed intake and total nutrient intake of rabbits in the study farms 73

Table 14: Weekly weight gains of rabbits in the study farms 77

Table 15: Weekly feed conversion ratio of rabbits in the six study farms 81

Table 16: Cost of production of fryers in the study farms 84

LIST OF ABBREVIATIONS AND ACRONYMS

4K Club: Kuungana, Kufanya, Kusaidia, Kenya Club

AgGDP: Agricultural Gross Domestic Product

ARBA: American Rabbit Breeders Association

AOAC: Associations of Official Analytics Chemists

FAO: Food and Agriculture Organization of the United Nations

GDP: Gross Domestic Product

KES: Kenya shilling

MALF: Ministry of Agriculture, Livestock and Fisheries

MDG: Millenium Development Goals

MOLD: Ministry Of Livestock Development

NACOSTI: National Commission for Science and Technology

NRF: National Research Funds

RABAK: Rabbit Breeders Association of Kenya

SDG: Sustainable Development Goal

LIST OF APPENDIXES

APPENDIX I: QUESTIONNAIRE 119

ABSTRACT

Rabbit rearing has in the past received minimal attention, but due to reduction in individual land holdings and increasing awareness of the advantages of the rabbit as a food animal, interest in its farming for income generation has increased. However, despite the increased interest, there is a lack of information about both on-farm performance and cost of production which are important in determining profitability of the enterprise.The current study aimed at assessing these 2 parameters in selected farms in Kiambu County. A cross-sectional survey was undertaken where data on current rabbit management practices was collected through a pre-tested semi-structured questionnaire in 45 farms. Thereafter, 6 of the 45 farms were selected based on the availability of weaner rabbits and data recording ability for the longitudinal study. In each of the 6 farms, 40 weaner rabbits were randomly selected and their weekly feed intake and weight monitored from weaning at 8 weeks of age to a target body weight of 2 kg.

The results showed that 66.6% and 46.6% of the respondents kept rabbits for income generation and as a source of family food respectively. Rabbit keepers depended on locally accessible resources for feeding the rabbits (Green vegetables-66.7%; grasses-57.8% and local weeds-53.3%). The majority (82.2%) fed rabbits a mixture of forages and concentrate. Treatment of sick rabbits was by the farmers (60.5%) and animal health experts (28.9 %) while the main source of information on animal health was from non-professionals (62.7%) while 53.3 % used traditional disease treatment methods. The most prevalent breeds kept by the respondents were New Zealand White (82.2%), California white (75.6%) and crossbreeds (71.6%). The total number of rabbits recorded was 1665 with a mean of 37±19.1. The majority of the respondents (57.8%) kept more than 10 does. The majority of respondents (71.1%) weaned the kits at 8 weeks of age while does were rebred at 9 weeks after kindling on 68.9% of the farms. Constraints identified by respondents included poor quality (22.2%) and high cost (88.9%) of feeds, diseases (84.4%) and lack of markets for rabbits and rabbit products (71.1%).

Results from the longitudinal study showed that the quality and amounts of feeds offered to the grower rabbits did not meet the nutrients requirements for optimal performance. The mean digestible energy and crude protein contents for the forages which were the main feeds were 1892.7kcal/kg and 10.3% respectively which was lower than the recommended 2500 kcal/kg and 15-16% respectively. Although the nutrient content of concentrate feeds (average 3240.6 kcal/kg and 18.3%) were above the recommended values, the limited amounts availed to rabbits (maximum, 100g/day) limited their ability to support optimum growth. The time required to produce a 2 kg liveweight fryer rabbit under farm conditions averaged 18 weeks. The feed conversion ratio differed between the farms with mean of 6.3±0.71, range 5.6-7.0.The cost per kilogram weight gain also varied between farms and ranged from KES 233.1 to 331.2 with a mean of KES 280.2±33.7.

This study concluded that rabbit farming in Kiambu County is practiced on small scale characterized by limited resource allocation and small flock sizes which may not support a sustainable off-take rate to meet the intended purpose of income generation. Additionally, rabbits at farm level did not receive the required amount of energy and protein resulting in low growth rates and high cost per kilogram live weight gain making the enterprise unprofitable.

CHAPTER ONE

INTRODUCTION

1.1 Background

Despite the reduction of poverty by half in 2010 under the Millennium Development Goals (MDGs), many people around the world remain extremely poor and undernourished (World Bank Group, 2016). Most of these less fortunate people live in Sub-Saharan Africa with about 80% living in remote areas, depending on agriculture for their livelihoods (World Bank Group, 2016). In Kenya, malnutrition is a public health problem with over 10 million people classified as being chronically food insecure (Mohajan, 2014). Among the United Nations' Sustainable Development Goals are poverty and hunger eradication by 2030 (UN, 2016).

Agriculture remains a key sector in the developing world, with the potential to lessen food shortages and the challenges of poverty if well exploited (Ogbalubi and Wokocha, 2013). In Kenya, for example, the sector contributes about 25% of the Gross Domestic Product (GDP) and another 27% of GDP indirectly through linkages with other sectors (MALF, 2017). Both crop and livestock subsectors generate over 95% of the Agricultural Gross Domestic Product (AgGDP), of which the latter contributes about 20%. Livestock subsector employs half of the agricultural labor force, and has the potential to provide a variety of animal products needed both locally and internationally (MALF, 2017).

Despite this enormous contribution, agriculture (thus farmers) in less developed countries continues to face challenges that continue to block the realization of its potential (Rwelamira, 2015). Climate change and reduction in land size reserved for production are among these challenges (Stern and Kaufmann, 2005). Recently, for example, cereal production has declined and this scenario is likely to continue in the future (MALF, 2017). In addition, keeping of large animals, for example cattle, as was the custom of many communities, has become particularly constrained by reduction of individual land holdings (MALF, 2017). This has necessitated exploration, evaluation and adoption of appropriate ways to address the growing demand for foods of animal origin amid these challenges (Upton, 2004).

A feasible solution is currently perceived to be the adoption of small domestic animals with short cycles and efficient feed and land use. These include animals like chickens, pigs and rabbits (Ume *et al*., 2016). Chickens and pigs, however, compete for similar feed ingredients with humans (Ozor et al., 2005; Chah et al., 2017). On the other hand, rabbits have some unique attributes that make them good farm animals with an incredible potential to contribute to the resolution of food shortages faced by many in the developing world (Chah *et al*., 2017). Such attributes include high prolificacy, short gestation and generation intervals, high growth rate and feed efficiency, relatively low production costs, exceptionally nutritious white meat, and limited competition for similar feed resources with humans (Nasimiyu, 2015). These positive attributes have led to an increase in the promotion of rabbit production in many developing nations (Mbutu 2013). In Kenya, this is exemplified by the establishment of rabbit breeding and multiplication centers (Borter and Mwanza, 2011).

Despite these valuable qualities and efforts directed to rabbit production, low productivity has limited their expansion and potential to improve the nutritional and economic status of farmers (Mailu *et al*., 2012). Furthermore, most rabbit keepers operate on a small scale characterized by small flock sizes, limited resource allocation and use of many and diverse management practices

(Serem, 2014). The performance of rabbits under these many and diverse management practices has hardly been documented. The purpose of this study was to assess on farm performance and cost of production of rabbits in selected farms in Kiambu County.

1.2 Statement of the problem

Despite the valuable qualities of rabbits and the efforts directed to promoting its production by government and other stakeholders, low productivity has limited their expansion and potential to improve the nutritional and economic status of farmers. Most rabbit keepers work on a small scale characterized by small flock sizes and limited resource allocation. In an attempt to cut down the cost of production, these farmers have adopted many and diverse feeding practices mainly based on cheap, locally available feed resources. The performance of rabbits under these many and diverse management practices has hardly been documented. The purpose of this study was to assess performance and cost of production of rabbits in selected farms in Kiambu County.

1.3 Objectives of the study

The overall objective of this study was to assess performance and cost of production of rabbits in selected farms in Kiambu County.

The specific objectives were to:

1. Document rabbit farming practices and constraints in Kiambu County
2. Assess grower rabbit performance in selected farms in Kiambu County
3. Assess the cost of producing grower rabbits in selected farms in Kiambu County

1.4 Research questions

1. What are the common rabbit farming practices and constraints in Kiambu County?

2. What is the performance of rabbits in selected farms in Kiambu County?
3. What is the cost of growing a rabbit to a desired market weight in selected farms in Kiambu County?

1.5 Justification

For a long time, Kenyans viewed rabbit keeping as an endeavor for school going boys and 4K clubs. However, reduction in individual land size and increasing awareness of advantages of the rabbit as a food animal have led to increased interest in rabbit farming with the emergence of many new farmers and the formation of distinctive self-help organizations such as Rabbit Breeders Association of Kenya (RABAK) established in Thika (Borter and Mwanza, 2011; Serem, 2014). With this upsurge in the production of rabbits, many and diverse management practices currently used by farmers and their impact on the performance of rabbits needs to be determined and farmers advised in order to make the enterprise profitable. This study was designed to document the performance of rabbits under the prevailing feeding systems in Kiambu County.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In the recent past, there has been increased interest in rabbit farming in Kenya with an emergence of many new entrants and the formation of distinctive self-help groups such as Rabbit Breeders Association of Kenya (RABAK) based in Thika (Borter and Mwanza 2011; Serem, 2014). Establishment of a rabbit abattoir in Thika is also an indication of this increased interest. High prolificacy, rapid growth, lower input requirements, better feed use and valuable output products are among valuable qualities associated with rabbits (Hungu, 2011; Kale *et al*., 2016). However, low productivity has hindered the realization of their potential to improve income and food generation leading to demotivation of rabbit farmers with some discontinuing the enterprise (Serem, 2014).

Productivity of food animals which is expressed as a ratio of an output per unit of input over a specific period of time is determined not only by the genetic makeup but also management to realize their full potential (Lebas, 2005; Lamy *et al*., 2012). Good management practices include providing quality feeds in adequate quantities as per the requirements of the animals (Lebas, 2005; Chah *et al*., 2017). Nasimiyu (2015) carried out an on-station study to assess the potential productivity and cost of production from the two most common rabbit meat breeds and their crosses. The conclusion from the study was that rabbit farming can be a viable commercial enterprise in Kenya.

To address the often reported low productivity and low returns from rabbit production by farmers, this study assessed and documented (1) rabbit farming practices and constraints, and (2) performance and cost of production of rabbits on selected rabbit units in Kiambu County. This chapter expounds on rabbit production and uses in the world, rabbit industry in Kenya, general performance, factors influencing performance and the cost of rabbit production.

2.2 World Rabbit production

The domesticated rabbit of today, *Oryctolagus cuniculus* emanated from wild European rabbits and belongs to *Laporidae* family in the *Lagomorpha* order (Das *et al*., 2014). It is functionally raised for meat, research use, wool and as a companion animal among others. Universally, meat is the main product of the modern rabbit production with an annual output of nearly two million metric tonnes (Dalle Zotte, 2014) with China being the world's leading rabbit meat producer and exporter (Matics *et al*., 2014; Dorning and Harris, 2017). The other main producers of rabbit meat are Italy, France and Spain. In Africa rabbits are only traditionally kept in the Mediterranean region, are important in Ghana and Nigeria while in other countries, including Kenya, rabbit farming is gaining momentum (Mailafia *et al*., 2010; Kale *et al*., 2016).

Rabbit meat is nutritious and known to contain high levels of proteins, vitamin B_{12} and phosphorus among other nutrients (Chah et al., 2017). The meat also has less fat, sodium and cholesterol than other popular meats (Dalle Zotte, 2014). These properties make rabbit meat safe for consumption today when lifestyle diseases are on the increase and is particularly recommended to aged and persons with cardiovascular diseases as a special diet (Mbutu, 2013; Serem, 2014). Pelt, a derivative of rabbit meat production with some industrial use, is in high demand globally (Das *et al*., 2014), but modern rational production strategies, in which rabbits

are slaughtered at an early age, cannot supply quality skin. Other by-products from rabbit farming are rabbit urine and manure. Rabbit produces urine which contains high levels of nitrogen which can be used as organic fertilizer and insecticide (Dalle Zotte, 2014). Rabbit manure is rich in phosphorous, ammonia and nitrates than many other animals' manure and is good for crop agriculture (Dalle Zotte, 2014).

2.3 Rabbit industry in Kenya

Rabbit keeping in Kenya has been associated with the arrival of missionaries two centuries ago (MOLD, 2012). However, deliberate efforts to promote rabbit production in the country were initiated in 1980 following a bilateral agreement between the Kenya government and German International Development Agency, which led to both establishment of a national breeding centre for rabbits in Ngong Veterinary Farm and importation of the first exotic breeds from the then West Germany (Borter and Mwanza, 2011). The center was charged with responsibility of providing breeding stock and information on rabbit farming throughout the country. Later, other multiplication centers were opened across the country (Borter and Mwanza, 2011; MOLD, 2012).

However, for many years rabbit keeping was left in the hands of young boys in schools and 4K Clubs (MOLD, 2004; Borter and Mwanza, 2011). Thus the anticipated growth of rabbit production was not realized resulting in the closure of the multiplication centres with the exception of the Ngong Rabbit Breeding Centre. In the recent years there has been a renewed interest in rabbit keeping as a business with the formation of various self-help producer groups (Borter and Mwanza, 2011).

The Kenyan rabbit industry with an estimated population of 0.88 million rabbits (Mutsami, 2018) is currently marked by an increase and shift from when rabbits were raised for domestic consumption and for leisure to an industrial one where rabbits are raised for sale (APD, 2010;

Borter and Mwanza, 2011; MOLD, 2012; Serem, 2014). The associated age and gender biases are diminishing and a diverse social group is currently engaged in rabbit production (MOLD, 2012; Serem, 2014). Of the 49 breeds of domestic rabbits recognized in the world by American Rabbit Breeders Association, (ARBA, 2016) in the world, less than a third are available in Kenya. Among the breeds reared in Kenya, New Zealand white, California white, Flemish Giant, French Lop, Chinchilla and Dutch are the famous breeds (Serem, 2014; Nasimiyu, 2015; Ogolla *et al*., 2017; Chebet *et al*., 2018) with the former two as the most dominant breeds.

The industry faces a number of challenges and the most common ones include lack of a stable market for rabbits and rabbit products, inadequate information on rabbit husbandry by the farmers, lack of quality breeding stocks, high prevalence of diseases, scarcity of funds for expansion and, insufficient, poor quality and costly feeds (Mailu *et al.*, 2014; Serem, 2014; Kale et al., 2016; Ogolla et al., 2017).

2.4 General performance of rabbits

In the recent past the rabbit has been thought of as one amongst the most appropriate means of producing top quality animal protein that could help bridged the gap between production and demand of animal protein existing in the developing world (Das *et al*., 2014). This is due to its low cost of management, high and fast reproduction, and ability to thrive well in grain-free diet and in a variety of production systems. For instance, a doe is capable of producing 145 kg of meat per year compared to 109 kg generated by a cow that would require 2 acres of land

(Cheeke, 1980). Similarly, a kit has a high growth rate and approximately doubles its birth weight within a week compared to 2 and 7 weeks for a piglet and a calve respectively (Iyeghe-Erakpotobor, 2001).

2.4.1 Reproductive performance

Reproductive performance is an important trait which directly affects the productivity and thus economic success of a livestock enterprise. High prolificacy and fast growth make the rabbit (*Oryctolagus cuniculus*) an ideal animal for meat production (Fadare and Fatoba, 2018). The rabbit is an induced ovulator with ovulation commencing 10 hours following induction (Iyeghe-Erakpotobor, 2001). Ostensibly, a doe can be served 24 hours post kindling and has a gestation length of one month and thus can give up to 11 litters annually (Serem, 2014).

Profitability of the rabbit enterprise depends on the number of kits raised till slaughter weight from each litter (Castellini *et al*., 2010). Litter size has been identified as one of the main economic traits affecting the profit of a rabbit farm and can be genetically improved to maximize productivity (Belhadi 2004; Nofal *et al*., 2004; Pasupathi *et al*., 2014; Rajapandi *et al*., 2015). According to Moce and Santacreu (2010), most maternal lines are selected based on litter size at weaning, since this trait reflects both the prolificacy and mothering ability of the doe. Varying litter sizes have been reported in tropics. For instance, Wanjala *et al* (2016) reported an average litter size at birth and weaning of 9.4 and 8.6 in Kenya, while Apori et al (2015, in Ghana) and Fadare and Fatoba (2018, in Nigeria) reported an average of (5.9 and 4.9 kits) and (5.4 and 4.1kits) at birth and weaning respectively. Small litter sizes of rabbits in tropics has been associated to heat stress and poor nutrition that is common in the region as well as inbreeding depression (Iyeghe-Erakpotobor, 2001) . The average litter size of 9-10 at birth (Marykutty and Nandakumar 2000; Lebas, 2009) has been reported in the temperate regions of the world. According to Dim *et al* (1990), small litters have discouraged a number of farmers from raising rabbits in tropics and if litter size could be improved, animal protein shortage in the less developed countries would be improved and more people will undertake rabbit production both commercially and as a hobby.

While studying the common meat breeds (New Zealand white and California white) in tropics, Apori *et al* (2015), reported an overall means of 319.4g and 2816.1g for litter weight at birth and at weaning (6 weeks of age). For the temperate regions, the current reported values are 387.6g for litter weight at birth (Rajapandi *et al*., 2015) and 2957.4g at weaning (Ferraz *et al*., 1991). Lower litter weights in tropics might be due to non-conducive environmental conditions prevailing in the region particularly high ambient temperatures and also due to lack of good quality feed. Iyeghe-Erakpotobor (2001) reported that breed of doe affects litter weight at weaning with Chinchilla (1787.6g) doe weaning heavier litters than New Zealand White (1117.9g) and California (1044.2g) does (for total weaning weight at 6 weeks of age).

Nutrition, doe age and breed, season, maternal environment and disease affect litter size (Marykutty and Nandakumar 2000; Iyeghe-Erakpotobor, 2001; Fadare and Fatoba 2018). Of these, nutrition is considered to be by far the most important (Iyeghe-Erakpotobor, 2001). Environmental temperature is related to litter size, with the largest litters being born during periods of high temperature (McNitt and Lukefahr, 1983; Iyeghe-Erakpotobor, 2001). Total litter size at birth and number born alive per litter has been shown to exhibit a seasonal trend (Bhatt *et al*., 2002; Kumar *et al*., 2005; Tuma *et al*., 2010).

A doe can be served when it attains 80-85% of the mature weight for their breed (Lebas *et al*., 1997). This mature weight is reportedly attained at 6-7 months of age depending on level of feeding (Serem, 2014). Age at which first service is done would influence the life time productivity of the doe. Though it may lead to a greater number of litters, early breeding has been reported to negatively impact on growth and development of the animals affecting their ultimate productivity (Serem, 2014).

Several studies have been done comparing breed reproductive performance. Ozimba and Lukefahr (1991) reported no significant differences in litter size and litter weight at weaning between New Zealand White and California breeds. Kumaresan *et al* (2011) and Apori *et al* (2015) also reported similar litter size at birth and weaning for New Zealand White and other breeds. However, Irekhore (2007) and Kabir *et al* (2012) observed a significantly higher litter size at birth for California White does than the New Zealand White does while Fadare and Fatoba (2018) reported that the New Zealand white had significantly higher number of kits born alive compared to California and other breeds. Strychalski *et al* (2014) compared some performance indicators in California white and Flemish Giant (FG) rabbits and reported a better reproductive performance in the former breed. For example, they noted a significantly (p=0.033) higher number of kits reared until the age of 35 days of 6.2 for California does compared to 5.3 for FG mothers.

Pre-weaning survival rate of kits is of importance in commercial rabbit farming as it plays a major role in determining the net productivity of the farms (Rashwan and Marai 2000). These scholars reported a mortality rate of 12 to 20 % in rabbits aged 4 to 8 weeks. While comparing reproductive traits, Fadare and Fatoba (2018) reported a significant difference in mortality rate

for the common meat breeds, New Zealand white and California white at 26.5% and 39.0% respectively. Selection of suitable breed of rabbit to particular environment conditions is essential for successful rabbit production (Kumaresan *et al*., 2011).

The New Zealand White and California white are generally regarded as most suitable for meat production (Strychalski *et al*., 2014; Mailafia *et al*., 2010; Oseni *et al*., 2008; McNitt *et al*., 2000). This is because the two breeds are reported to have good mothering abilities, large litter sizes (average, 6-7 live kits), better meat to bone ratio, rapid growth rate and higher adult weight (4-5kg) compared to most other medium size breeds (Oseni *et al*., 2008; Mailafia *et al*., 2010; Hungu. 2011). The two breeds and their crosses had high growth rates attaining a liveweight of 2 kg in an average of 14.7 weeks (average for intensively and extensively fed rabbits) under tropical conditions as reported by Nasimiyu (2015). These animals have been shown to perform well under intensive production systems common in developed countries with rabbits attaining 2 kg liveweight at around 11 weeks (Lebas, 2005; Maertens *et al*., 2006).

2.4.2 Growth rate and age at slaughter

Growth rate is one of the most important parameters in rabbit production since it influences the rate of attainment of slaughter weight (Onyiro et al., 2008; Assan, 2018). It is mainly dependent on breed, birth weight and maternal effects such as nutrition status and milk production (Iyeghe-Erakpotobor, 2001). Doe characteristics would affect the growth of rabbits from birth up to weaning with the first 3 weeks of life when the kit feeds on milk from the doe only being crucial (Pasupathi *et al*., 2014). Rabbit kits grow at a high rate with almost doubling their weight every week in the first three weeks of life (Iyeghe-Erakpotobor, 2001). Zerrouki *et al* (2007) recorded an average kit weight of 51g at birth and, 119, 308 and 475g at the age of 1, 3 and 4 weeks respectively translating to an average pre-weaning growth rate of 15.7g/d for local Algerian rabbits.

Post-weaning growth which is influenced by both genetic and non-genetic factors is the major determinant of profit making in a rabbit enterprise since it affects the rate at which slaughter weight is attained (Onyiro *et al*., 2008; Assan, 2018). Understanding growth rate of a weaner rabbit could therefore aid in developing an appropriate management practices and genetic selection programs which will result in an improved overall productivity (Suárez-López *et al*., 2008). Consideration of growth rate post weaning while selecting breeding sires has been reported to vastly enhanced total meat production and profits in rabbit meat production (Cheeke, 2004). According to Assan (2018), sustaining high returns in rabbit production is underpinned by enhanced post-weaning growth.

Maternal effects exist in post-weaning growth traits (Krogmeier *et al*., 1994) and both good feeding and crossbreeding are shown to enhanced post-weaning growth potential (Piles *et al*., 2000; Saleh *et al*., 2005; Nasimiyu, 2015). Nasimiyu (2015) compared and reported a postweaning average growth rate of 28.9 g/day for intensively fed rabbits against 21.2 g/day for extensively fed rabbits. These values are lower than 38g/day commonly observed in temperate regions (Cheeke, 1992) and poor nutrition common in tropical conditins could be attributed to the diference (Iyeghe-Erakpotobor, 2001).

Slaughter age and weight for rabbits vary with breed and feeding level but will also be determined by the market requirements. Nasimiyu (2015) assessed time to achieve 2 kg which is a target weight for production of fryers. The author observed that the crossbreed (NZWXCW)

attained the target weight earliest at 12 weeks followed by New Zealand White and California White at 13 weeks of age each for concentrate-based diet and 15, 17 and 18 weeks for rabbits under forage-based diet. Hassanien and Baiomy (2011) also observed an average slaughter weight of 2.3 kg for New Zealand White and Californian white rabbits at the age of 16 weeks.

Kenyan farmers slaughter their animals within a range of 2-2.5kg (Serem, 2014; Nasimiyu, 2015). Many studies have shown that rabbits slaughtered at a similar body weight rather than age, eliminates the differences in carcass traits (Tůmová *et al*., 2002; Boisot *et al*., 2004; Dalle Zotte *et al*., 2005; Yakubu *et al*., 2007; Elmagraby, 2011; Nasimiyu, 2015). As such, these parameters are dependent on weight rather than age. However, the dressing percentage which is an important economic variable in the meat market is age dependent. According to Dalle Zotte and Ouhayoun (1998), dressing percentage increased up to 13 weeks in rabbits receiving ad libitum feeding, after which there is a decline due to an increase in organ size. More profit would be realized from rabbits with higher yield as most sales are on carcass weight basis. According to Lebas (2009), weight and age at slaughter are different between countries because of the differences in local market demands.

2.5 Factors influencing on-farm productivity of rabbits

The goal of any meat-animal producer is to get their animals to market weight in the shortest time possible. Animal performance can be influenced by several factors among them those related to farm and farmer attributes, feeds and feeding practices, breed and health status of the animal, climatic and housing conditions.

2.5.1 Farm and farmer attributes

One of the factors that could impact rabbit productivity is farm size (Baidoo *et al*., 2016). According to Serem (2014), land size is a significant factor that determines the number of rabbits a household keeps. As farm size declines, the pressure on animal feed resources increases and thus animals may not receive enough feed to meet their requirements hence may perform poorly (Serem, 2014). McIntire (1992) also argued that as the household landholding declines, farming tends to shift from extensive to more intensive systems which are always characterized by increased management and care resulting in better performance of the animals.

Another factor that would likely to influence productivity of rabbits is educational level of the keeper. Many studies have shown that the level of education has a positive influence on farm productivity and income. According to Mendoza *et al* (2008) and Oduro-Ofor *et al* (2014) better educated farmers can think critically, make better decisions and choices and are quicker to adopt and practice new farming technologies. Better decision making and use of farming technologies will have positive effects on productivity. Quisumbing (1994) concurred that level of education is significant in dynamic agricultural settings where modern technologies have been introduced.

Gender of the farmer would also affect the productivity of rabbits. Women who are reported to be responsible for half of food produced in developing countries both in time and energy spent on production are often associated with less access to productive resources and services which are critical determinant of animal productivity (Patton et al., 2008). Like men, women are efficient farmers, however their farm's yields are often lower due to use of lower levels of inputs and human capital compared to men (FAO, 2011). Men have access to more resources, better market opportunities and technology and are more frequently considered in ownership and

decision making process than women (Chirwa, 2005; Sanginga *et al.*, 2007). Women on the other hand will more likely implement farming activities because most remain at home and are engaged in farming (Nhemachena and Hassan, 2007; Mutsami, 2018).

Gender inequality may thus restrict animal productivity and consequently food production and economic development (FAO, 2011) especially with changes in many countries' demographics leading to increasing numbers of female headed households (World Bank 2009). However, the benefits of rabbit production as investment destination due to its low investment requirement including start-up cost and labour may encourage female headed household to venture into the enterprise. Women are increasingly taking up enterprises that requires little investment even if profit may be low as such receives minimal intereferance from men who prefer enterprises that are to more profitable (Quisumbing and Meinzen-Dick, 2001; Kimaro *et al*., 2013).

Farmer's age may also influence animal farm management and productivity. Farmers in the older age category may have more knowledge and experience in farming and also have better access to productive resources that enable them to invest more in rabbit farming compared to younger people (Lizárraga *et al*., 2007; Gbetibouo, 2009; Abdoulaye *et al*., 2014). On the other hand, younger farmers, even where constrained by resources which may affect productivity negatively are more likely to adopt new and improved technologies relative to the older counterparts (Baidoo *et al*., 2016). This may result in higher production and profits. The fact that rabbits require little space would also favor entry by young people who often don't have access to land. According to Osei *et al* (2012) increased involvement of young people in rabbit rearing is an indication a bright future for the enterprise since the aging farmers are likely to be succeeded by active keepers who by then would be highly productive due to accumulated knowledge and

experience in rabbit rearing they would have gained.

Attitudes of farmers to rabbit keeping is another factor determining productivity. Attitudes towards animals are regarded as an important factor in the prediction of behaviour towards animals (Coleman *et al*., 2003; Ikinger *et al*., 2016) which can in turn affect animal welfare and productivity (Kielland *et al*., 2010; Kauppienen, 2013). Research shows that farmers' attitudes towards farm animals influence the management decisions they make and how they handle them

(Hemsworth, 2003; Waiblinger *et al*., 2002). For instance, positive attitude is associated with a positive handling which is reported to reduce handling stress and thus increases the fitness and productivity of the animal (Lensink *et al*., 2000; Hemsworth *et al*., 2000; Waiblinger *et al*., 2002; Gebregeziabhear and Ameha, 2015). Stress induced by negative handling agitates and excites animals, resulting in increased body temperature, heart rate and glucocorticoid values, and reduced immune function translating into reduced productivity.

A study by Hemsworth and Coleman (2011) showed that the growth rate of positively handled animal was higher than that of negatively handled animal and the reduced growth in the later case was associated with the animal stress response. Unfavourable attitude of the farmers towards rabbit enterprise would lead to a slow growth of the enterprise (Prathap and Ponnusamy, 2006). According to these authors, attitude is a major cause for relactunce by farmersto adopt production technologies. Farmers who are fully convinced of the benefits of rabbits rearing would exhibit favourable attitude towards their rearing as opposed to when they are still not convinced of all aspects of rabbit rearing (Prathap and Ponnusamy, 2006). Since rabbits require meticulous care and management, positive attitude towards them would lead to better management and by consequence productivity.

2.5.2 Breed types

Globally, there are 49 distinct rabbit breeds according to ARBA (2016). These breeds have further been categorized based on maturity size and weight into small (1-2kg), medium (4-5kg) and large breeds (6-7kg) (USDA, 1972). There are breed variations in both reproductive and productive performance.

Small breeds are reported to produce smaller litters while large breeds produce large litters (Iyeghe-Erakpotobor, 2001). Litter size is a component that influences overall maternal productivity and small light breeds are generally less prolific than medium and large breeds. The litter size range of 8 to 10 has been reported in tropics for common meat rabbits (Wanjala *et al*., 2016). Although associated with high pre weaning mortality (Ibrahim et al., 2003), larger litter size production by the doe would translate to larger number of rabbits reaching market weight and thus the profitability of the rabbit production enterprise (Iyeghe-Erakpotobor, 2001) if mortalities are prevented through better management. On the other hand small litters result in fewer rabbits reaching market weight. Additionally, small rabbit breeds attain slaughter weight after a relatively longer time and meat yield would be lower compared to medium and large breeds at any given time (Nasimiyu, 2015). This would result in low performance and productivity in general.

Medium size breeds, particularly the New Zealand White (NZW) and the California White (CW) are most frequently used in commercial rabbitries alongside their hybrids due to their desirable growth rate, size at slaughter and mothering ability (Serem 2014; Mailafia *et al*., 2010; Oseni *et al*., 2008). The two breeds and their crossbreed had high growth rates attaining a liveweight of 2 kg in less than 4 months under tropical conditions (Nasimiyu, 2015). However, a significant growth performance difference was reported between purebreeds (NZW and CW) and crossbreed (NZW X CW) rabbits in favour of the later (Nasimiyu, 2015). This can be explained by growth performance heterosis when crosses compared to purebred rabbits are used. In order to increase productivity, several authors suggest use of crossbreds instead of purebreds (Iyeghe-Erakpotobor, 2001; Nasimiyu, 2015; Ajayi *et al*., 2018).

2.5.3 Feeds and feeding practices

Animal performance is dependent on nutrition which is often the most limiting factor (Geerts, 2014). Feed can either enhance or delay growth in animals, depending on the level of nutrient contents. Feed costs typically represent the highest cost item in livestock production reaching up to 70 % for intensively raised rabbits hence would have a great effect in determining profitability of the enterprise (Roy et al., 2004; Muller et al., 2007; Mmereole *et al*., 2011; Nasimiyu, 2015).

Majority of the developing countries have their rabbits raised on locally accessible feed materials, often forages, with or without concentrate supplementation (Border and Mwanza, 2011; Mailafia, *et al*., 2010). Commonly used forages include green vegetables, potato vines, grasses and local weeds. Though the importance of feeding concentrate to rabbits have been demonstrated, rabbits are not commonly fed concentrates and when concentrates are fed, it is provided in small quantities, and therefore low returns are achieved from their inputs (Serem, 2014).

Pinheiro *et al* (2011) and Khan *et al* (2016) reported a higher performance for rabbits grown intensively on concentrate based diets than those on forage based diets. The higher performance was attributed to higher nutrient content in the concentrate diet compared to forage diet. Nasimiyu (2015) reported that rabbits raised on intensive concentrate-based diet grew at a higher rate to attain the target weight of 2 kg at 12 weeks compared to 16 weeks for those on forage-based diets. The author concluded that more intensive feeding regime would yield better returns due to higher offtake rates.

Supplementary feeding with nutrient rich feeds is especially important in tropics because rabbit diets mainly consist of fibrous crop residues and low quality hay which are low in content and availability of nutrients required to support optimal productivity. Supplementation would help compensate for low availability and nutritional value of forage especially during dry periods (Bosing et al., 2014). An optimal combination of ingredients would ensure a rational use of available resources while meeting the nutritional requirements of the animal.

Rabbits are herbivores which can be raised on grain-free diet mostly utilizing forages and crops by-products that are often available on most farms in tropical countries and not suitable for human consumption (Phimmasan, 2005; Iyeghe-Erakpotobor and Uchegbu 2016). However, many of these feed stuffs are low in digestibility and protein content due to their high lignin content (Mailafia *et al*., 2010). In addition, many contain toxic substances, are less palatable to rabbits and often scarce during dry seasons (Lukefahr and Cheeke, 1990). It is the reliance on these low nutritional value seasonally limited feed resources that have been associated with low productivity of high genetic potential animals in the tropics compared with that achieved in the developed world (Lukefahr and Cheeke, 1990; Garg and Harinder 2012).

In the developed countries meat rabbits are produced under intensive systems where they are fed compounded feeds providing recommended nutrient levels for rabbits associated with high growth rates (Walsingham, 1972) and early attainment of slaughter weights of 2kg in 11-13 weeks (Lukefahr and Cheeke, 1990; Maertens *et al*., 2006). Under such a system, rabbits are reported to produce 8.5 litters each of 7-8 viable fattening rabbits reaching the slaughter weight (EU, 2017) which would translate to 60-68 fryers. This is higher than 20-35 kits and 10-15 marketable fryers per doe per annum under semi-intensive and extensive feeding systems respectively common in developing countries (Lukefahr and Goldman, 1985; Lukefahr and Cheeke, 1991; Lebas *et al*., 1997).

Farmers in tropics have been reported to practice either intensive or extensive rabbit breeding based on seasons with the former being done during favorable seasons when forage is abundant, and the latter during adverse seasons (Lukefahr and Cheeke, 1990). Such a practice would translate to fewer marketable fryers per year. About 16 weeks is needed to produce a 2 kg liveweight meat rabbit under these extensive production conditions in which growing rabbits are maintained on diets consisting of green roughage and concentrate mixtures (Nasimiyu, 2015). Use of concentrate feeds to supplement the available forages and thus enhance rabbit performance in many areas of the tropics is generally constrained by their high cost. This is because the bulk of such feeds consist of cereals, mostly maize, and cereal by-products which constitute the main food for humans particularly in many countries of Africa hence the competition may limit their use in animal feeding.

As a hind-gut fermenter, the rabbit is capable of digesting fibrous feed stuffs and allow for rapid gut transit (Gidenne and Garcia, 2006). Fibre is an important part of rabbit's diet and is necessary for maintaining gut health, stimulating gut motility, reducing fur chewing, and preventing enteritis (McNitt *et al.,* 1996). The fibre acts as a source of energy for bacteria living in the caecum. For growing rabbits a 12-17% crude fibre in the diet is recommended (NRC, 1977). A disturbance of the digestive system of the rabbit on low fiber diet can result in severe, potentially fatal gastro-intestinal stasis. Low-fiber diet has also been associated with high incidences of hairballs in the stomach of rabbits (Gidenne *et al*., 2001), gut hypomotility, reduced cecotroph fermentation, prolonged retention time in the hindgut and enteritis (Cheeke, 1994).

2.5.4 Rabbit health

Rabbits are affected by a wide range of diseases which can result in production losses due to morbidities and mortalities (Okumu *et al*., 2014; Martino and Luzi, 2008). Rabbit health combined with feeding determines its production performance (Sanchez *et al*., 2012). Diseases would affect revenues earned from farm animals through deaths, slowed growth, costs incurred on treatment and prevention, market restrictions and carcass condemnation among others (Rushton 2009).

Rabbits are prone to nutritional disorders and infectious diseases that would impact their health and consequently performance and productivity. Bacteria are the main pathoens causing rabbit digestive disorders which mainly manifest as a diarrhea and attributed to a mortality above 10% during fattenuing period (Koehl, 1995; Licois, 2004). Other factors that predispose rabbits to disease are poor/unhygienic housing and feeding conditions which lead to high prevalence of bacterial infections especially those caused by *Escherichia coli.(E. coli)* associated with gut oedema and enteric colibacillosis manifesting as diarrhoea and sudden death in rabbits (Gross, 1991).

Keeping of rabbits in a clean house is therefore critical in safeguarding them against adverse environmental conditions which can affect their performance (Moritz *et al*., 2008). The house should be constructed in a manner that eases drainage and not receive direct sunlight to reduce heat stress on the rabbit (Lukefahr and Cheeke, 1991). Furthermore it should be well aerated to avoid build-up of toxic gases and be fitted with troughs for feeding and drinking (Hoy, 2008).

Parasitism and diseases such as coccidiosis in rabbits are normally transmitted through feed contaminated with feaces thus separating rabbits from their droppings is very critical and therefore rabbits should be reared on raised houses (Lukefahr and Cheeke, 1991; Fanatico and Green, 2012). Additionally, hygiene should be maintained at a high level in rabbit units. Feeders and drinkers should be consistently cleaned, scattered feed gathered and waste evacuated (Hoy and Verga, 2006; Moritz *et al*., 2008). Raw, (2017) maintained that simple hygienic observation without inclusion of costly drugs are effective in the prevention of the infectious diseases.

It has been noted that the level of intensification has an impact on disease levels with high prevalence of diseases being common in intensively kept rabbits (Serem, 2014). This has been attributed to low management quality per animal as operation expands as well as close confinement which may favour high outbreak and spread of a disease (Lukefahr and Cheeke, 1991; Mercks, 2010; Serem, 2014).

Coccidiosis cause digestive disorders associated with high morbidity and mortality, stunted growth and liver condemnation (Darzi *et al*., 2007; Okumu *et al*., 2014). This is caused by *Eimeria* species which infects either the intestines or liver and are supposedly always present in rabbit farms and are difficult to eradicate (Vancraeynest et al., 2008). The disease is common in young rabbits and those kept under poor housing and hygienic conditions (Papeschi *et al*., 2013). Okumu *et al* (2014) and Ogolla *et al* (2017) reported high prevalence of rabbit coccidiosis in Kenya of 49% and 85% respectively. Poor housing and hygiene, mixed age group-housing of rabbits, inadequate control of concurrent infections, and ingestion of fecal contaminated feed and water by the rabbits are some of the factors that have been associated with high prevalence of the disease (Dal Bosco *et al*., 2002; Okumu *et al*., 2014; Ogolla *et al*., 2017). Rabbits infected with coccidiosis exhibit weight loss, diarrhea anorexia, rough hair coat and unthriftiness and subsequent mortality (Aduku and Olukosi, 1990; Okumu *et al*., 2014).

Rabbits can be also infested with ectoparasites including mites which is economically important in Kenya (Chebet *et al*., 2018). Mange, a highly contagious and severe infection of rabbits caused by mites is of significant effects on rabbit production (Sant and Rowland 2009; Panigrahi and Gupta 2013; Okumu et al., 2014). The disease is characterized by intense pruritus, erythema and crusty lesions, scratching, alopecia among other signs (Wall and Shearer 2008; Sharma et al., 2018) and its high prevalence in the country has been associated with unprudent use of treatment regimes by farmers, unhygienic conditions in rabbitries and the practice of obtaining breeding stock from non reputable sources (Chebet *et al*., 2018). The latter practice would lead to introduction of diseases to otherwise disease free herds.

Other conditions that have been reported in rabbitries include pinworm, ear mites and infectious myxomatosis (Rai, 1988). The latter is a fatal disease caused by a virus and is transmitted by mosquitoes, biting flies and by direct contact (Aduku and Olukosi, 1990).

2.5.5 Environmental conditions

The production efficiency of farm animals is largely dependent on their productive and reproductive performance which can be affected by the prevailing climatic conditions and location. The climatic conditions (mostly temperature and rainfall) will affect feed availability, quality and intake by the rabbits. Performance levels attained by rabbits in developed countries have not been achieved in tropics (Marykutty and Nandakumar 2000; Fadare and Fatoba 2018). According to Lukefahr and Cheeke (1990), a growth rate of up to 20 g/day is reported in tropical countries which much lower than 40 g per day commonly observed in temperate regions and this is probably due to heat stress as well as diet.

Among other factors, climatic conditions could explain the lower production levels in the tropics. The number of consumable rabbits reported from tropical countries ranges from 10 to 20 rabbits per doe per year depending on management level (Lebas, 1983). Lebas (2005) cited up to 35 fryers in tropics and 50 in temperate regions. Litter size is a component that influence overall maternal productivity. While estimating the specific effect of tropical climate through performances observed in temperate and tropical regions, Lebas (2005), reported an average of 6.8 litters of 9.5 born alive and 8.0 at weaning (thus about 50 rabbits per doe per year) in temperate regions. The respective figures in tropics are 6.4, 6.5, 5.5, and 35 respectively (Lebas, 2005).

The larger the litter size produced by the doe, the larger the number of rabbits that will reach market weight and thus the profitability of the rabbit production enterprise (Iyeghe-Erakpotobor, 2001). Lebas (2005) argued that the different in numerical productivity of rabbits in different climatic conditions is a consequence of small litters size combined with high mortality and of a small number of litters per year. For instance 50 rabbits per doe per year is reported in France while this is 20-34 and 18-25 in Benin (Kpodekon *et al*., 2004).

Tropical areas are characterized by high temperatures and heat stress which are shown to negatively affect rabbit production (Iyeghe-Erakpotobor, 2001). Rabbits are intolerant to higher temperature and perform optimum in temperatures ranging from 15 to 25 °C (Rajapandi et al. 2015). Elevated temperature is reported to affect feed intake and utilization, and weight gain of growing rabbits (Ondruska *et al*., 2011). Temperatures higher than 25°C induce an important feed intake reduction (Lebas, 2005), the consequence of which is always a reduction of performance (Dalle Zotte, 2002; Lebas, 2005; Lebas 2013).

Rabbits thus need protection from adverse environmental conditions including predators for optimal performance which is usually achieved through proper housing. According to Dal Bosco *et al* (2000) and McNitt (2009) housing system affects growth of rabbits with poor housing limiting growth and consequently overall productivity. Rabbits require space to avoid stress, fights and injuries (Lehmann, 1987). Matics *et al* (2014) recorded a significantly higher feed intake, daily gain and final weight in rabbits kept in cages than that in pens with those in straw-littered platform showing the lowest growth performance. In a study to assess effect of housing conditions on productive performance of rabbits, Dal Bosco *et al* (2000) reported lowest feed intake, live weight and feed efficiency in pen-raised rabbits compared to caged rabbits.

The rabbit hutch should be constructed in a way that the recommended temperature range of 10°c to 20°c is maintained. The rabbit house should also safeguard them against other dangers such as predation (Hoy, 2008; Mailafia *et al*., 2010). It should be constructed in a manner that eases drainage and not receive direct sunlight to reduce heat stress on the rabbit. Furthermore it should be well aerated to avoid build-up of toxic gases and be fitted with troughs for feeding and drinking (Hoy, 2008). To reduce stress due to sudden noises a rabbit unit should be located in a quiet place that is safe from rabbit predators.

2.6 Cost of production

The significance of generating a quality product at low cost is paramount and understanding the cost of production is essential for every enterprise to achieve profit and sustainability. Feed cost is generally accepted as the highest recurring cost, accounting for around 70%of total cost in an intensive rabbit production unit (Mmereole *et al*., 2011; Nasimiyu, 2015). Unsuitable management of rabbits more so with feeding can therefore be detrimental to the profits of farmers hence the need for careful management to ensure well-balanced feedings that would see the animal receive the required nutrients and cost effective methods used (White, 2013).

Although studies have shown that rabbit performance is higher when raised intensively on concentrate diets, the rising cost of grains, on which such diets are constituted, has necessitated the use of alternative cheaper feedstuffs for such enterprises to be profitable and sustainable (Iyeghe-Erakpotobor *et al*., 2006). These include forages and agro-by-products (Mmereole *et al*., 2011; Nasimiyu, 2015). Forages are a cheap feed that is abundant in high rainfall regions of the tropics, and can be preserved for the dry period and for the low rainfall regions (Iyeghe-Erakpotobor and Muhammad 2008). As herbivores, rabbits efficiently utilize forages and in many tropical areas constitute their sole diet. Application of good feeding methods including use of good quality feed can lead to better use of feed without increasing the cost of production. It has been noted that use of feed with high nutritive value may not indispensably lead to a good return but better feed management does (Hasan, 2010).

In conclusion, rabbits can be a suitable means from which protein source for human use can be obtained from and aid in mitigating meat shortage existing in underdeveloped countries (Abdel-Azeem *et al*., 2007). The growth of rabbit would be influenced by feed intake which in turn is influenced by breed, age and physiological status of the animal, and palatability of the feed among others. Rabbits performance in tropics is curtailed by hash environmental conditions present in the region majorly high ambient temperatures which induces physiological stress and

by consequent reduced feed intake, high feed conversion ratio, and low body weight gain ((Marai et al., 2001; Ondruska *et al*., 2011). Therefore, for a successful rabbit productin, selection of rabbit breeds bearing in mind the environment conditions as well as good housing of rabbits is very much essential (Kumaresan *et al*., 2011).

CHAPTER THREE

RABBIT PRODUCTION PRACTICES IN KIAMBU COUNTY

3.1 Introduction

The demand for food derived from animals is increasing, being driven by among other factors, the expanding human population (Delgado *et al*., 2001). In African countries, average daily consumption of animal protein stands at 17g (Ume *et al*., 2016), which is well below FAO's recommendation levels of 35g (Adetunji and Adepoju, 2011). This shortfall in supply presents an opportunity to livestock producers to sustainably develop and improve their livelihoods by increasing production and thus the profit. Increasing the productivity of small, short-cycle animals, which do not compete directly with humans for similar feed ingredients, is key if the growing demand for quality livestock products is to be met.

Rabbits have several attributes that make them ideal to alleviate protein shortages including high prolificacy, rapid growth, low input requirement due to their small size, high feed efficiency, and valuable products, including meat, pelt, manure and urine (Kale *et al*., 2016; Hungu, 2011). However, low productivity attributed to poor performance of rabbits including slow growth has hindered the realization of their potential to improve income and food generation leading to demotivation of rabbit farmers with some discontinuing the enterprise (Serem, 2014). Productivity of food animals is determined not only by the genetic makeup but also management to realize their full potential. Good management practices include providing quality feeds in adequate quantities as per the requirements of the animals.

Rabbit production for commercial purposes is increasing in Kenya (Borter and Mwanza, 2011;

Kale *et al*., 2016). Nasimiyu (2015) carried out an on-station study to assess the potential productivity and cost of production from the two most common rabbit meat breeds (NZW and CW) and their crosses (NZW X CW) concluding that rabbit farming can be a viable commercial enterprise in Kenya. To address the often reported low productivity and low returns from rabbit production, this study assessed and documented feeds and feeding practices among other management practices in selected rabbit production units in Kiambu County. The county was selected for the study due to the documented popularity of rabbit production as an income generating activity (Serem, 2014) and ease of access.

3.2 Materials and methods

3.2.1 Study Area

The study was carried out in Kiambu County, which was purposefully selected on the basis of the population of rabbit keepers (MOLD, 2010), and the level of intensification and commercialization of rabbit production (Serem, 2014). Kiambu County is one of the 47 counties in Kenya and is considered one of the wealthiest counties. It is bordered by other five counties namely; Nakuru, Kajiado, Murang'a, Nyandarua and Nairobi. It occupies an area of 2543.42 km^2, and geographical coordinates of 1° 10' 0" South, 36° 50' 0" East. According to the most recent census (KNBS, 2019), it is the second most populated county in Kenya with an estimated population of 2.4 million and an average of 943.61 persons per Km^2. The county has a warm climate with temperatures ranging from 12- 24°C with rainfall aggregate of 1000mm annually (Ogola et al., 2017). The soil and climate favour agriculture and the main occupation of the majority of its inhabitants are crop and livestock production. Crops grown in the county include, among others, maize, tea, coffee and bananas. Dairy cattle, poultry, pigs, sheep and goats are the common animal enterprises in the county. Although not traditional, rabbit keeping is gaining popularity in the county due to decreasing land size and increasing awareness of nutritional and economic benefits of rabbits as food animals.

3.2.2 Sampling criteria and sample size

The sample for this study was obtained using a snowball sampling technique. County livestock extension officers and officials from Rabbit Breeders Association of Kenya (RABAK) were asked to identify known rabbit farmers who in turn identified others. Small population and the lack of comprehensive lists of rabbit farmers in County or National livestock offices warranted the use of this sampling technique, which uses few existing respondents to locate other respondents. At the onset, 5 respondents were identified who led to the identification of other 40 respondents by means of chain-referrals, giving a total of 45 participants who formed the sample size for this study.

3.2.3 Study type and data collection

A cross-sectional survey was carried out in the 45 farms using a pretested semi-structured questionnaire. On the basis of interviews with rabbit farmers and personal observations, baseline data on feed types, sources, availability, presentation form, preservation, feeding times and constraints were collected from these farms. At the same time, data were collected on rabbit breeds, housing practices as well as prevailing diseases, their treatment and prevention.

Both closed and open ended questions designed to flow with some logical order were used. The questionnaire was pre-tested with rabbit keepers and then modified as necessary. It was subsequently administered by the researcher assisted by trained field research assistants. Filled questionnaires were examined weekly for completeness and any inconsistencies noted and communicated to the assistants as an additional data quality control measure. County livestock extension officers and officials from the Rabbit Breeders Association of Kenya (RABAK) provided logistical support and helped identify known rabbit keepers. The respondents included, small to large scale rabbit farmers. The study was conducted between July and August 2018. The questionnaire used is presented in Appendix I.

3.2.4 Data analysis

Responses were organized, categorized and coded to enhance analysis and entered into the computer. The data was analyzed using SPSS version 22 to obtain descriptive statistics and frequencies for the different variables. Mean and standard deviation as well as frequency were used to analyse the spread of distribution. Chi-square test ($p<0.05$) was used to determine the relationship between independent variables (age, gender, education, farm size, occupation, and experience) and dependent variables.

3.3 Results and discussion

3.3.1 Socio-economic characteristics of rabbit farmers

Gender, age and education status of the rabbit farmers is shown in Table 1. Of the total 45 rabbit owners, 76% were males and 24% females. Men who formed the majority of the owners of the rabbit enterprises were the mostly involved in the routine management of rabbits at 44.4% followed by women (20%), children (17.8%) and workers (15.6%). The high number of male ownership was earlier reported by several authors (Hungu, 2011; Serem, 2014; Chebet *et al.*, 2018). Osei *et al* (2012) linked the high predominance of male owners to a high prevalence of men as household heads and land proprietors. In addition, gender difference may be due to cultural beliefs that rabbit farming is meant for men and boys (Borter and Mwanza, 2011;

Mutsami, 2018). Men have access to more productive resources, farming information, better market opportunities and better technology than women (Asfaw and Ademassie, 2004; Sanginga *et al*., 2007; FAO, 2011). This gender inequality may restrict farm productivity and consequently food production and economic development (FAO, 2011). Women on the other hand are more likely to engage more on farming activities as majority remain at home (Nhemachena and Hassan, 2007; Mutsami, 2018) as was seen in 24.4% of the farms.

Only 6.7% of the farmers were below 30 years while those between 30 to 60 years and above 60 years constituted 71.1% and 22.2% respectively (Table 1). According to Oseni *et al* (2008) and Tembachako and Mrema (2016), individuals aged 30 years and above will most likely have families who require food and school fees among other needs hence their increased participation in food and income generating activities. Over ninety percent (93.3%) of the farmers were 30 years and above, an observation that negates the historical perception that rabbit farming is a pastime activity for young boys (Hungu, 2011; MOLD, 2012; Serem, 2014).

Numerous studies have demonstrated a renewed interest in rabbit farming in Kenya (Hungu, 2011; Serem, 2014; Chebet *et al*., 2018). This may be explained by among other factors the decreasing landholdings and thus the necessity to keep animals that require less space alongside government support to the enterprise through establishment of a rabbit breeding centre in Ngong (Hungu, 2011) and increasing consciousness of the advantages of the rabbit for food and income generation. This increased adoption of rabbit farming by mature persons suggests a better management and bright future for rabbit business in the county due to the fact that older people may have more experience in farming (Gbetibouo, 2009) and also have better access to productive resources that enable them to invest more in rabbit farming compared to younger people (Abdoulaye *et al*., 2014). However, contrasted with younger farmers, older farmers may be slow in adopting new technologies (Baidoo *et al*., 2016).

Of the respondents, 24.4% were degree holders, 37.8 % post-secondary certificate/diploma holders, 20% form four leavers while 13.3% had primary education as shown in Table 1. This finding shows that graduates are adopting rabbit farming. Fifty seven percent (57.8%) of the farmers had undergone training on rabbit production at least once. Several authors have reported a positive relationship between farmer's level of education and productivity where educated farmers were more productive (Gasperini, 2000; Reimers and Klasen, 2013; Oduro-Ofor *et al*., 2014). Farmers with higher education levels can think critically, make better decisions and choices (Oduro-Ofor *et al*., 2014) and more easily adopt new farming technologies (Mendoza *et al*., 2008), all of which have positive effects on productivity.

Table 1: Gender, age and education status of rabbit keepers in study area

Variable	Category	Frequency (%)
Gender	Male	75.6
	Female	24.4
Age (years)	<30	6.7
	30-60	71.1
	>60	22.2
Education status	Degree	24.4
	Certificate/diploma	37.8
	Form 4 leavers	20
	Primary	13.3
	No formal education	4.4

Of the respondents, 51.1% were in formal employment, 11.1% were retirees while the remaining 37.8% were either self-employed (24.4%) or engaged in non-formal employment (13.3%). Involvement of elderly persons including retirees in this enterprise may be attributed to health benefits associated with white meat consumption (Dalle Zotte, 2014) and less demand by this enterprise in terms of energy expenditure and capital outlay (Mutsami, 2018). 26.7% of the respondents belonged to at least one of the 3 well organized rabbit-producer organizations (KABAYO, KANJIENDO, RABAK) operating in the study area. Some of the advantages associated with such organizations are assessment and introduction of new certified production technologies to farmers (Rwelamira, 2015), supporting producers to lobby for better services, offering forums through which members learn from each other to improve their production skills and enabling them to work in groups which makes it easier for them to access large markets. According to Davis *et al* (2012) as cited by Mutsami (2018) farmer groups are increasingly being used by agricultural extension staff to train a wider audience through strategies such as Farmer Field School (FFS).

Land ownership by the respondents is shown in Fig 1. Most of the farmers (44.4%) owned 1-3 acres, 42.2% owned less than 1 acre while 13.3% more than 3 acres of land. The average land size among rabbit farmers was 1.6±1.7 acres. According to Serem (2014), land size was a significant factor in determining whether a household kept rabbits or not. Rabbit farming is gaining popularity among small landholders particularly those in urban and peri-urban areas mainly because they require less space than other types of livestock (Hungu, 2011).

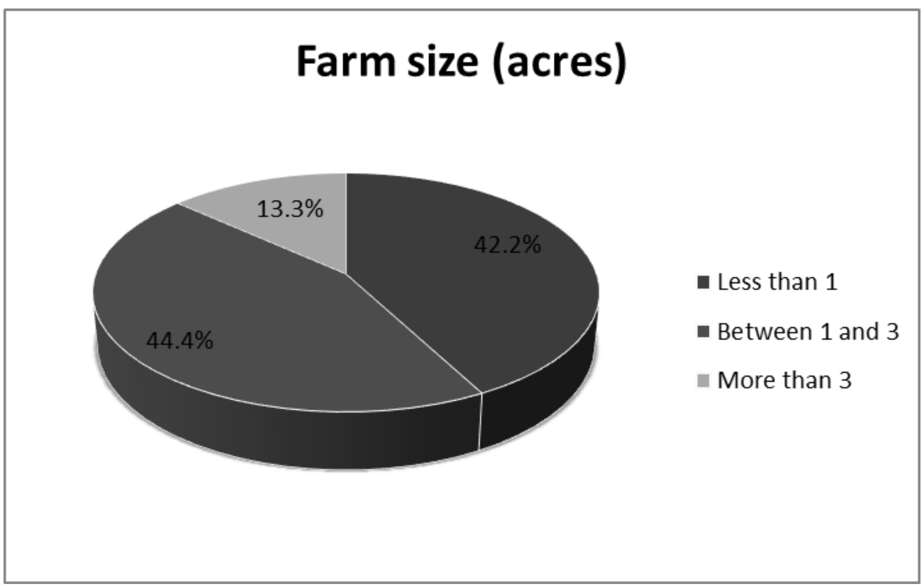

Figure 1: Land ownership by rabbit farmers in the study area

Other types of livestock owned by the respondents are shown in Table 2 with 84.4% of the farmers keeping other livestock species alongside rabbits. Of these farmers, 57.9%, 36.8%, 28.9% and 15.8% kept poultry, small ruminants, dairy cattle and pigs respectively. Fifty three percent (53.3%) of the farmers kept a combination of the livestock which majorly consisted of poultry and ruminants. Among small landholding farmers (<1 acre), 94.7% kept small stock compared to 61.5% and 30.8% for larger size landholdings of 1-3 and more than 3 acres respectively. Serem, (2014) reported that farmers in Kiambu had more of small stock such as rabbits, poultry, goats and pigs compared to those in other counties in Kenya where farm sizes were larger. Hungu (2011) and Ogolla *et al* (2017) observed and associated high popularity of poultry (particularly chicken) among rabbit keepers, to the fact that they are relatively cheaper to keep and require less space. A moderate correlation (r = -0.6) between land size and number of other small stock kept in this study existed suggesting an increase of 0.6 of small stock as the land size reduced by 1 unit. Farmers are expected to shift from keeping large to small stock that require less feed and space as land sizes decline and pressure on feed resources increases as was the case in this study.

Table 2: Types and average numbers of animals kept by rabbit keepers in the study area

Variable	Farmer frequency (%)	Average land size owned (acres)	Average number of animals owned
Poultry	57.9%	2.1±2.3	38.3±14.8
Small ruminants	36.8	1.8±1.6	6.1±4.4
Dairy cattle	28.9	2.9±1.2	4.2±3.6
Pigs	15.8	2.4±1.8	13.2±1.4

The main reasons given by respondents for establishing rabbit enterprises are shown in Fig 2. These included income generation (54%), source of family food (33%) and a combination of family food source and income generation (13%). These findings are in agreement with Serem (2014) in four rabbit producing counties in Kenya that majority (51%) of the respondents kept rabbits for income generation. In contrast it was reported that 60% and 57% of rabbit producers in Nigeria (Oseni *et al.*, 2008; Abu *et al.*, 2008) and Zimbabwe (Tembachako and Mrema, 2016) respectively, kept rabbits primarily as a source of food for their families. Other useful but, not primary reason for keeping rabbits were manure (91.1%), urine (51.1%) and pelts (8.9%).

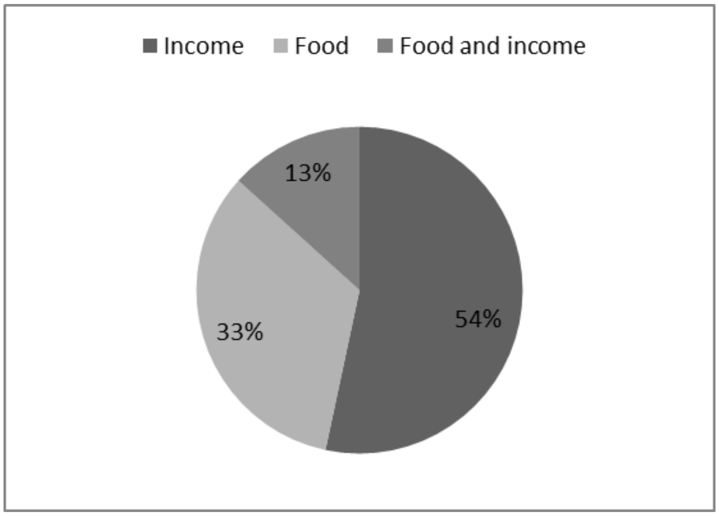

Figure 2: Reasons for ownership of rabbit enterprise in study area.

To achieve intended purposes, 71.1 % of the respondents had sold rabbits while 68.9% had slaughtered for home consumption in the last twelve months. The main outlet for sale of rabbits was farmgate (75%) followed by local markets (21.9%) and hotels (9.4%) with 56% and 32.3% of the farmers stating that rabbits sold were meant for slaughter and breeding respectively. The mean age and market price for an estimated 2 kg liveweight rabbit were 4 months and 350 Kenya shillings respectively. In agreement, Borter and Mwanza (2011) reported that meat market was one of the main outlets for rabbits while Mailu *et al* (2012) noted that 82% of the respondents had slaughtered rabbits for home consumption during the last one year. Education (post-secondary-75% vs. secondary education and below-58.8%) and gender (males- 79.4%, vs. female-36.4%) influenced the frequency at which the respondents slaughtered rabbit for home consumption. Years spent in rabbit farming also influenced rabbit slaughter for home consumption with proportion of respondents slaughtering rabbits decreasing from 81.8% to 68.8% to 61.1% as the number of years spent reduces from >7 to 3-7 to <3 years. Those with higher education may be more informed on the superior qualities of rabbit meat (Mailu *et al*., 2012) and therefore high frequency of rabbit slaughter for home consumption.

A poorly developed market for rabbits and their products was cited as the main constraint by 71.1% of respondents to income generation. This was attributed to inadequate knowledge about the benefits of rabbit meat among the population (26.7%) and competition of meat from other livestock species (26.7%). Serem, (2014) argued that a population with better knowledge of the benefits of rabbit meat would create a high demand thereby improving the market and price. Lack of well-developed rabbit markets has been identified as a major constraint facing rabbit production in developing countries (Schiere, 2004; Oseni *et al*., 2008; Serem, 2014; Mutsami, 2018). According to Mutsami (2018), farmers complained of lack of market (57%) and low prices (44.8%) for rabbits and their products attributing the latter to the mushrooming of middlemen who end up benefitting at the expense of the rabbit farmers. Serem (2014) reported that farmers who had previously kept rabbits cited lack of markets as the main reason for discontinuing rabbit keeping.

3.3.2 Breeds and breeding practices

The breeds of rabbits kept by respondents are shown in Table 3. The three most commonly kept breeds in the study area were New Zealand White (82.2%), California white (75.6%) and crossbreed (71.6%). The respective preference frequencies for these common breeds were

42.2%, 26.7% and 17.8%, and the main reasons cited for this were good mothering ability (35.6%), large litter sizes (26.7%), rapid growth (22.2%) and high carcass weight at slaughter (15.6%). Similar dominance in rabbit breeds on farms and the high preference by farmers of New Zealand and California Whites has been reported by others (McNitt *et al*., 2000; Oseni *et al*., 2008; Mailafia *et al.*, 2010; Hungu, 2011; Serem 2014) and their popularity associated with their good growth characteristics and high carcass weight.

Table 3: Breeds of rabbits kept by farmers in the study area

Breed	Frequency	Percentage (%)
New Zealand white	37	82.2
California White	34	75.6
Crossbreed	32	71.6
Chinchilla	27	60
Dutch	25	55.6
Flemish Giant	18	40
Checkered Giant	13	28.9
Angora	4	8.9
French lopped	3	6.7
Palomino	3	6.7

Breed choice is an important determinant of the productivity of a rabbit enterprise (Kumaresan *et al.*, 2011; Fadare and Fatoba 2018). Several studies on rabbit productivity have established that breed has significant effect on a number of economic traits and thus performance (Prayaga and Eady, 2003; Jaouzi et al., 2004; Ghosh et al., 2008; Nasimiyu, 2015). For instance, breed has significant effect on mothering ability, body weight, growth rate among other traits (Sivakumar *et al*., 2013). The New Zealand and California White are widely accepted as meat breeds (Mailafia *et al*., 2010; Oseni *et al*., 2008; McNitt *et al*., 2000). The two breeds and their crossbreed had high growth rates attaining a liveweight of 2 kg in 12-15 weeks under tropical conditions as reported by Nasimiyu (2015).

Under intensive production systems common in developed countries and characterized by feeding on commercial feeds compounded to meet the recommended nutrients of rabbits, these rabbit breeds have been shown to perform well attaining slaughter live weight of 2 kg in 11-13 weeks (Lukefahr and Cheeke, 1990; Maertens *et al*., 2006). The New Zealand and California White are reported to have good mothering abilities, large litter sizes (average, 6-7 live kits), better meat to bone ratio, rapid growth rate and higher adult weight (4-5kg) compared to most other medium size breeds (Oseni *et al*., 2008; Mailafia *et al*., 2010; Hungu, 2011).

The number of rabbits kept ranged from 6 to 320 with a mean colony size of 37. The majority (57.8%) operated medium-large scale enterprises keeping more than 10 does while 42.2% kept less than 10 does. In contrast, Serem (2014) reported a small mean colony size of 18. The higher average colony size recorded in this study may be attributed to the fact that rabbit production is increasingly becoming a major commercial undertaking of the respondents. This could also be attributed to the enhanced demand for rabbits generated by the opening of a rabbit abattoir in Thika or increasing popularity of rabbit meat triggered by the resulting higher visibility of the product, encouraging more farmers to switch to large scale production. Though the majority kept rabbits for sale and home consumption, the average number of 37 may be too small to sustain a family economically.

The number of rabbits per farm varied and was influenced by farm size and number of years of raising rabbits. The average number of rabbits kept by the farmers with less than 1 acre of land was 35±8 while for those with 1-3 and more than 3 acres were 40±7 and 31±12 respectively. Normally it is expected that those with larger pieces of land would keep a larger number of animals as it was the case in the first and second groups. However, the lower number of rabbits by those with more than 3 acres of land could be due to the fact that those with large farms had an option of keeping other larger size animals.

The length of time that the famers had kept rabbits is shown in Table 4. Majority of respondents (40%) had kept rabbits for <3 years while 36% and 24% had spent 3-7 and more than 7 years respectively. These results confirm that rabbit farming continues to attract new entrants in Kenya as reported by Borter and Mwanza (2011) and Serem (2014). More experienced rabbit producers would be expected to be better informed and able to improve farm productivity (Tembachako and Mrema, 2016). These researchers also reported that experience significantly affected commercialization of the enterprise. The results in this study may also reflect this since the number of rabbits kept by the respondents increased from 33 to 35 and 46 as years of rabbit farming increased from <3 years to 3-7 and >7 years respectively. This increasing level of commercialization of rabbit production with years of experience could also be due to a realization of the economic benefits of the enterprise.

Table 4: Years spent in rabbit farming and mean number of rabbits kept

Years spent	Farmer proportion (%)	Mean number of rabbits kept
< 3 years	40	33
3-7 years	35.6	35
>7 years	24.4	46

The main source of foundational stock by the majority of respondents was from other rabbit farmers (76.5%), a practice that Hungu (2011) and Serem (2014) also observed. The remaining 24.4% obtained from breeding/research centers mainly the Ngong National rabbit breeding station. Though the choice of breeding stock source is largely dependent on its reliability (Serem, 2014), the practice of acquiring rabbits from other farmers denies farmers a guaranteed access to and continuous supply of quality and diverse breeds of rabbits including improved and/or imported ones (Oseni *et al*., 2008; Hungu, 2011).

Additionally, this practice can contribute to spread of diseases between farms (Ogolla *et al*., 2017). Serem (2014) reported that the limited number of rabbit multiplication/breeding centers in Kenya was the main reason why many farmers buy breeding stocks from unreliable sources, mostly from other farmers. This raises the need for the government to open and equip additional multiplication centers throughout the country to ensure that rabbit farmers are supplied with good quality breeding stocks.

Of the respondents, 89% replaced their breeding stock from their own especially breeding females and only obtained replacement bucks off-farm in order to prevent inbreeding. Serem (2014) dismissed the possibility that such methods would prevent inbreeding since most of the rabbits grown in the country originated from the same point, Ngong rabbit breeding centre. This could be further exacerbated by poor record keeping observed in the study area as only 28.9% of the respondents kept breeding records. Precise and coherent record-keeping provides key information to farmers such as animal pedigree (McLaughlin, 2018).

Inbreeding leads to a general drop in performance of the animals due to reduced growth rates and increased both mortality and frequency of hereditary defects (Kristensen and Sørensen, 2005; Nagy *et al*., 2012). Breed (56%) and reproductive performance (37%, particularly litter size) of the animal were the key determinants to breeding stock selection in the study area which is in agreement with Hungu (2011). Huish (2005) stated that consideration of rabbit performance while doing selection ensures passage of excellent traits on to the offspring which ultimately will improve performance. Other selection criterion was availability (11.1%).

The age at first breeding, litter size, litter size at weaning and time to rebreeding is shown in Table 5. The mean age at first service varied from 5 months (64.4%), 6 months (20%) to > 7 months (15.6%, Table 5). Lebas *et al* (1997) suggested that rabbits should be bred when they reach more than 80% of the their mature weight which is reportedly attained at 6-7 months of age depending on level of feeding (Serem, 2014). Early breeding has been reported to negatively impact on growth and development of the does affecting their ultimate productivity (Serem, 2014). The majority of respondents (71.1%) weaned the kits at 8 weeks of age while does rebred at 9 weeks after kindling in 68.9% of the farms (Table 5) giving an estimated average of 90-day kindling intervals and 4 litters per doe per year.

The estimated average of 90-day kindling intervals and 4 litters per doe per year, is a performance which as per Lukefahr and Cheeke (1990) may be regarded as the most suitable for tropical regions taking into account the general existence of sub-optimal level of breeding, health, housing , nutrition and overall management. Some respondents cited lack of space to keep large number of rabbits as the reason for delayed rebreeding at 12 weeks post kindling (22.2%). Despite weaning the kits at 6 weeks, 8.9 % did not rebreed their does until 8 weeks post kindling.

The 4 litters per doe per year is close to 4.4 reported by Serem (2014). A higher litter size, final weight and feed conversion efficiency and decreased mortality were recorded by Alfonso-Carrillo et al (2014) for rabbits weaned at 46 days compared to those weaned at 32 days of age. They reported a final litter size and average weight of 8.04 and 2039.3g for late weaning compared to 7.07 and 2003g for early weaning. Feed conversion ratio was 2.8 and 3.3 for the respective weaning ages as per these authors. In the present study an average litter size at birth and at weaning of 6 and 4 was observed thus a pre-weaning mortality rate of about 33%. This mortality rate was higher than 12-20% reported by Rashwan and Marai (2000) for rabbits aged 4 to 8 weeks.

The weaning litter size of 4 was lower than 5 reported by Serem (2014) but was within the range of 4-6 reported by Adu et al (2005). However, the 90-day kindling interval was twice that recommended by the American rabbit breeders association (ARBA, 2012). Litter size is the most important economic character in rabbit production (Belhadi 2004; Nofal et al., 2004). The combination of longer kindling interval with a small average weaning litter size would impact on the profitability of the rabbit enterprise as this translates to fewer animals for sale and/or slaughter for home consumption.

Table 5: Breeding practices

Performance Indicator	Frequency (n=45)	Percentage (%)
Age at first service (Months)		
5	29	64.4
6	9	20
7 and above	7	15.6
Litter size		
5	8	17.8
6	27	60
7 and above	10	22.2
Litter size at weaning		
4	28	62.2
5	11	24.4
6 and above	6	13.3
Weaning age (weeks)		
<8	4	8.9
8	28	62.2
>8	13	28.9
Rebreeding period (weeks post kindling)		
8	8	17.8
9	31	68.9
>9	6	13.3

3.3.3 Feeds and feeding practices

The types of feed offered to rabbits in the study area are shown in Fig 3. The majority (82.2%) fed rabbits a mixture of forages and concentrates, out of which 56.8 % provided concentrates daily while 25.4%, were irregular. Only 4.5% of respondents fed concentrate alone and 13.3% offered forages alone. These findings are similar to those of Hungu (2011) and Serem (2014) who reported that majority of the farmers fed their rabbits on both forage and concentrate with the later being supplied only as and when available. To maximize productivity, it is essential to ensure that animals receive adequate quantities of a balanced feed which is free from toxins and contaminants (FAO, 2014). Rabbits that are well fed grow faster and attain the slaughter weight earlier which would translate to more animals being available for sale and/or slaughter in a given period of time. A study by Nasimiyu (2015) and Khan *et al* (2016) showed that the cost per weight gain was lower under extensive forage-based feeding than intensive concentrate-based feeding. However, with the former feeding regimen, the rabbits grew at a relatively low rate and would take longer time to the target weight. Further, the grower rabbits on the concentrate based diet had a better lifetime feed conversion efficiency.

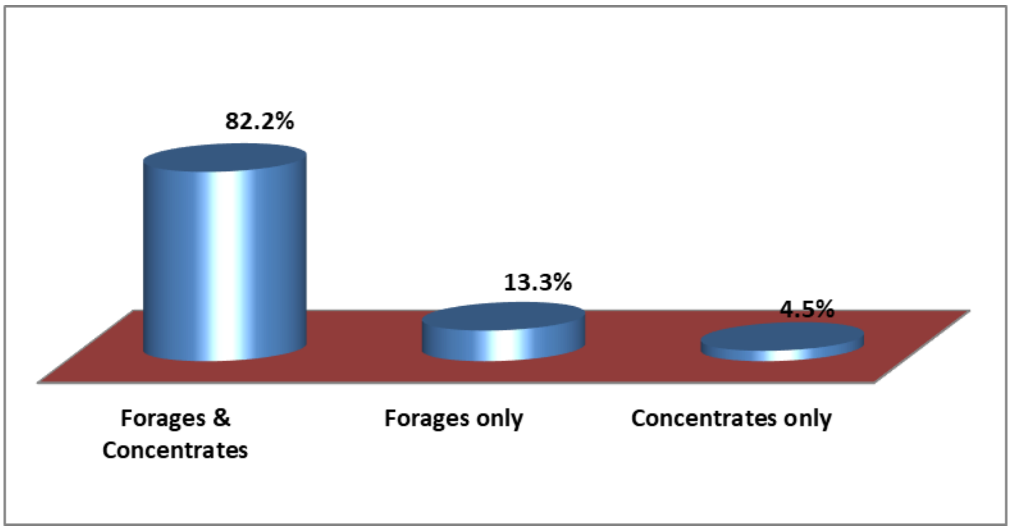

Figure 3: Types of feed offered to rabbits in the study area.

The types of forages fed to rabbits in the study area are shown in Table 6. Both fresh and dry forages were fed with Kales (66.7%), Rhodes grass (53.3%), Cabbage leaves (48.9%) and sweet potato vines (33.3%) being the most common. In agreement, Serem (2014) reported use of similar forages for feeding rabbits in other parts of the country. According to Iyeghe-Erakpotobor and Muhammad (2008), high cost of rabbit concentrate feeds has made the use of forages in feeding rabbits a common practice especially in tropics. However, use of forages alone cannot sustain optimum productivity of rabbits. This is especially so when such consist of tropical grasses, which are said to be relatively less digestible, low in protein content and high in lignin content compared to temperate ones (Mailafia et al., 2010). These authors suggested that rabbits can be raised entirely on green forages and household vegetable wastes but careful management and balancing of diets is needed. Additionally such animals will take longer to attain slaughter weight and thus reduced productivity (Nasimiyu, 2015).

Table 6: Forages used and farmer proportion

Forage	**Proportion (%)**
Kales (*Brassica oleraceae var acephala*)	66.7
Rhodes grass hay (*Chloris gayana*)	53.3
Cabbages (*Brassica oleraceae var capitata*)	48.9
Sweet potato vines (*Ipomoea batatas*)	33.3
Kikuyu grass hay (*Pennisetum clandestinum*)	28.9
Gallant soldier (*Galinsoga parviflora*)	24.4
Household vegetable wastes	24.4
Napier grass (*Pennisetum purpureum*)	20
Black jack (*Bidens pilosa*)	15.6
Amaranthus (*Amaranthus spp.)*	13.3
Banana leaves and peels (*Musa spp*.)	11.1
Alfalfa (*Medicago sativa*)	8.9
Wandering Jew (*Commelina ensifolia*)	6.7
Maize leaves (*Zea mays*)	4.4
Pumpkin leaves (*Cucurbitaceae*)	4.4

The choice of forage to be fed was based on availability of forage (57.8 %), palatability (28.9%) and nutritional value (13.3%). Many studies carried out in rabbit farms have shown that for most producers the important determinant of feeds offered to rabbits is what is available locally (Aduku and Olukosi, 1990; Lukefahr, 1998; Serem, 2014). This may be indicative of the low level of commercialization of the rabbit enterprise as suggested by Serem (2014) in many areas of the tropics. Knowing the nature and quality of animal feed is important in determining how to best meet the quantities of nutrients required for animal maintenance and production. According to Hasan (2010), inappropriate feed quality and feeding strategy leads to poor feed usage and low feed utilization efficiency. Providing adequate quality feed at suitable amounts, and maintaining the proper feeding duration, frequency and timing may contribute to the proper use of feed without raising production cost.

Forage post-harvest handling, preparation, production and feeding practices in the study area are summarized in Fig 4. Most (93%) of the farmers wilted forages either in or outdoors for 1 to 3 days before feeding to rabbits to reduce moisture content which was reported to prevent bloating (75%), diarrhea (20%) and increase forage intake (5%). High water content in fresh greens is reported to cause gastrointestinal disturbances in rabbits (Adjare, 2003; Borter and Mwanza, 2011). According to Abu and Turner (2005) wilting does not only reduce moisture content, but also reduces microbial load and any toxin or anti-nutritional factors in the forages. About 13.3% of respondents chopped the forage before feeding.

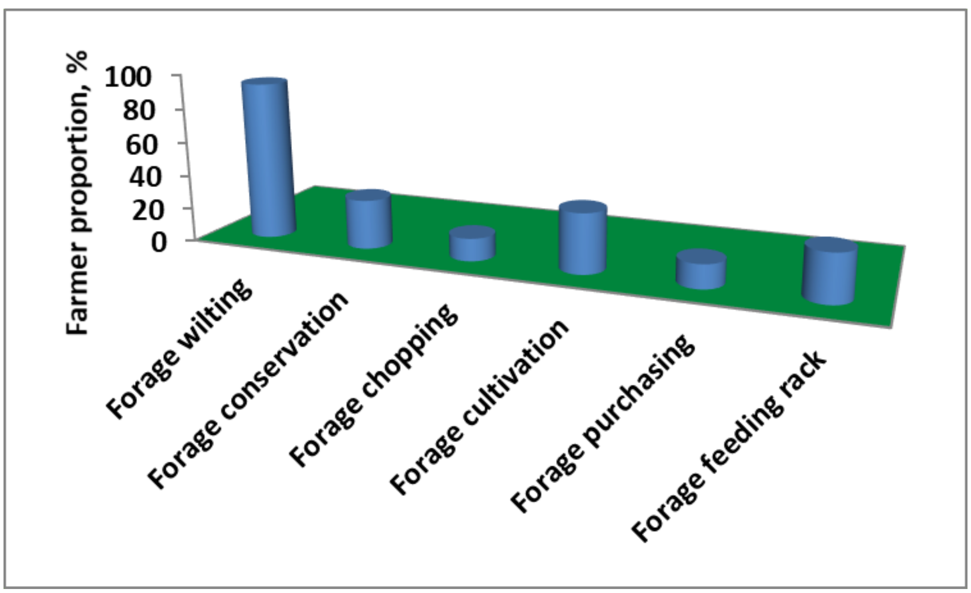

Figure 4: Forage post-harvest handling, preparation, production and feeding practices in the study area

All of the respondents using forages (95.5%) reported periodic forage scarcity mainly during the dry season with 29% conserving forages mainly as hay. The cultivated forages by 35% of respondents included lucerne (25%), kales (56.3%), sweet potatoes (62.5%) and Napier grass (43.8%) while 14% purchased forages for the rabbits. Many studies have shown that majority of farmers do not conserve forages for use during the dry seasons when feeds shortage is a constraint to production (Chah *et al*., 2017). This is an indication of lack of preparation for the dry season which may reflect a lack of information on feed conservation and/or a generally low availability of forages and therefore no surpluses to conserve (Serem, 2014).

Farmers used different methods of offering forages to the rabbits, where 36.7% placed them directly on the cage floor, 28% used forage racks, 26.3% hanged inside the rabbit cage using materials like wires and 9% used feed troughs. Brzozowski *et al* (1998) reported a significant increase in litter size at weaning when forage rack is frequently used. This can be attributed to improved health and reduced mortality that may arise due to consuming feed contaminated with faeces and urine when rabbits feed on forages placed on the floor. Hanging of forages inside the rabbit cage at a comfortable height also helps prevent rabbits from trampling on and soiling the feed (Borter and Mwanza, 2011).

Several forage plants were reported as containing compounds harmful to rabbits by 26.7% of respondents. The 3 most common were cassava leaves (15.5%), tomato leaves (8.9%) and Irish potato (6.7%) (Table 7) and were associated with stomach upsets (58.3%) and death of rabbits (33.3%) when fed.

Table 7: Types of forages considered harmful to rabbits in the study area.

Forage type	Percentage (%)
Cassava leaves	15.5
Tomato leaves	8.9
Irish potato leaves	6.7
Jimsonweed (*Datura stramonium)*	4.4
Mexican marigold (*Tegetes minuta*)	4.4
Common madder (*Rubia cordifolia*)	2.2

Of the 39 (86.7%) farms that fed concentrate to rabbits, the majority 97.4% purchased commercial concentrates while 2.6% use the home formulated. Rabbit pellets were the most common form of concentrate used (89.7%) and this was mainly due to its availability (73.1%). Chick mash was used in 10.3% of the farms. According to Serem (2014), a lack of confidence in feed manufacturing companies who do not indicate nutritional composition of their feeds and high prices of pellets compel farmers to look for other options such as chick mash and/or self-formulated concentrates using locally available ingredients.

The amount of concentrate fed to rabbits ranged between 25 and 150g/d with an average of 91.5g. Serem (2014) reported a considerably lower mean daily concentrate allowance at 70g/d. Majority of the farms (80%) lacked proper records on rabbit feeding, thus, the amounts of concentrates offered to rabbits were estimated. Where homemade feeds were used, there were chances of formulating unbalanced ration thus limiting animal performance as they may not be able to obtain all the nutrients at a required level. Where forage constitutes the bulk of the rabbit diet, a minimum concentrate supplementation level of 25 grams per day is recommended

(MOLD, 2012). Supplementation is important to compensate for low availability and/or low nutritional value of available forage (Bosing *et al.,* 2014).

Use of concentrates to feed rabbits was influenced by gender of the respondents with 91.2% of the farms headed by males using concentrate feeds compared to 72.7% of those headed by females (Table 8). Female headed households tend to have lower access to resources and may have less money to invest in improved feeding of their rabbits. Education and years spent in the production of rabbits also influenced concentrate feeding, with more than 91.9% of post- primary educated respondents feeding commercial concentrate, compared to 62.5% for less educated group (primary and non-formally educated). Many authors have associated good education with better husbandry of rabbits hence the importance of continuously educating farmers for better management (Mailafia *et al*., 2010; Serem, 2014; Ogolla *et al*., 2017). Among respondents with 3 years and above of rabbit farming, 93.3% used commercial concentrate feeds, which was higher than 77.8% for those with less than 3 years (Table 8). It can be argued that longer experience with rabbit keeping would allow learning of what works or does not and the benefits of a particular management practice.

Of the respondents, 88.9% used feed troughs for concentrate feed and were made of clay (77.5%), metal (15%) and plastic 7.5%. The feeders varied in size holding between 400 to 1650 g of pellets. Many studies have reported high use of rabbit feeders made of clay in Kenya associating their popularity with the fact that they tend to be heavy and are not easily tipped over to cause feed spillage and their low cost (Hungu, 2011; Border and Mwanza, 2011; Serem, 2014).

Table 8: Farmer's attributes influencing concentrate use as rabbit feed in the study area

Category	% of farmers using concentrate feed
Gender	
Male (n=34)	91.2
Female (n=11)	72.7
Years of rabbit farming	
< 3 (n=18)	77.8
3 and above (n=27)	93.3
Education level	
Primary and below (n=8)	62.5
Post-primary (n=37)	91.9

Provision of drinking water, environmental hygiene and ambient temperatures will have an effect on rabbit feeding thus performance. Eighty nine percent (89%) of the respondents provided rabbits with drinking water while 11% never watered their rabbits. Rabbits require water and will cease to eat if not provided with water (Tschudin *et al*., 2011). Bawa *et al* (2006) reported a lower growth rate and an increasing mortality rate among water deprived rabbits and concluded that water should be availed to rabbits for at least 12 hours per day for optimum performance. This, however, depends on environmental conditions primarily temperatures and relative humidity under which rabbits are kept as well as the moisture content of the feed.

Among the households studied, 57.8% and 31.1% considered environmental temperature and wind direction respectively when siting rabbit houses. High consideration of temperature in siting rabbit houses was also noted by Chah *et al* (2017). High temperature affects the productivity of rabbits in that it causes low feed intake leading to reduced growth rate. It also induces discomfort and agitation in rabbits. Most respondents (92.5%) had iron sheet roofed houses for their rabbits. Availability (57.8%) and durability (35.5%) warranted the use of iron sheet as a roofing material by most of the respondents. Use of such materials causes the houses to be hot particularly during the day increasing temperature in the houses thus affecting rabbits as already mentioned. To avoid these high temperatures, it is recommended that whenever such materials are used for roofing, insulation must be placed between the roof and the animals to prevent excessive heat and its effects on the animals (McNitt, 2009). This was not the case in the current study.

3.3.4 Diseases and health management of rabbits

Disease occurrence was reported in 84.4% of the farms with the most common being bloat, pneumonia and diarrhea which mainly affected young rabbits (40%, 31.1% and 17.8%), mange, ear canker and eye infection mostly affecting the adults (44.4%, 26.7% and 8.9%), and coccidiosis and worm infestation that commonly affected all ages (20% and 4.4%, Table 9). In the current study level of intensification as reflected by the number of rabbits kept and the number of cage layers used influenced disease occurrence. Those reporting disease occurrences kept an average of 37.8 rabbits per farm compared to 32.9 for those who did not report disease occurrence. This was further reflected in the number of tiers used as 90.6% of multi-tiered cage users reported disease occurrence compared to 69.2% for single-tiered cage users.

Table 9: Common rabbit diseases and frequency in study area

Diseases/conditions	% of farmers reporting disease	Common age affected (%)		
		Young	Adults	All ages
Bloat	68.9	40	11.1	17.8
Mange	62.2	4.4	44.4	13.3
Ear canker	42.2	6.7	26.7	8.9
Pneumonia	37.8	20	6.7	11.1
Coccidiosis	26.7	-	6.7	20
Diarrhea	24.4	17.8	2.2	5.6
Snuffles	22.2	13.3	4.4	4.4
Eye infection	11.1	2.2	8.9	-
Worm infestation	4.4	-	-	4.4

High occurrence of diseases in farms with relatively high number of rabbits and/or multi-layered cages may be attributed to a higher level of intensifications which result in inadequate ventilation and sanitation in rabbit houses (Mercks, 2010), in addition to decreased management quality and increased confinement of animals (Mercks, 2010; Serem, 2014), all of which have impact on disease occurrence. According to the majority of the respondents, disease occurrence was more frequent in New Zealand whites (28.9%), California whites (23.7%) and Crossbreeds (20%). This may be attributed to the high population of these breeds in the study area. FAO (2015) noted that though farm animals are crucial in supporting the livelihoods of farmers in the developing world, diseases continue to devastate performance and by consequence overall productivity of animals. Rabbits can be affected by a wide range of disease occurrence which can result in production losses due to morbidities and mortalities (Martino and Luzi, 2008; Okumu *et al*., 2014). Rabbit health combined with feeding, determines its production performance (Sanchez *et al*., 2012).

Bloat occurrence was reported in 68.9% of the farms (Table 9) and was mainly associated with use of fresh non-wilted forages (42.2%) and excessive feeding of the commercial pellets especially of weaned rabbits (18%). It was for bloat control that most farmers (75%) opted to wilt forages prior to feeding rabbits. High moisture content in fresh greens has been reported to cause gastrointestinal disturbances including bloat in rabbits (Adjare, 2003; Borter and Mwanza, 2011).

Mange was reported by 62.2% of the respondents (Table 7) with the following clinical signs being indicative of this condition; scratching (51.6%), skin wounds (26.1%), crusts (29.9%), head tilting (15.3%), ear scabs (36.3%) and alopecia (24%). Okumu *et al* (2014) and Chebet *et al* (2018) reported rabbit mange as one of the most important disease affecting rabbits in Kenya. Majority of the mange cases (71.4%) in this study were reported by farmers who purchased breeding stock from other farmers. The practice of acquiring breeding animals from non-reputable sources may contribute to the spread of diseases to otherwise disease-free farms. The type of housing and poor hygiene in rabbit houses may have also contributed to the occurrence of this condition since all of the eleven farms (24.4%) with loose group housing and 66.7 % of those that never cleaned their rabbit houses reported the disease. According to Okumu *et al* (2014), rabbit mange causes weight loss and predisposes rabbits to secondary bacterial infections all of which impairs on rabbit welfare and production performance.

Occurrence of ear canker was associated with rabbits reared in loose groups, density and level of cleanliness of bedding materials. All the farms where rabbits were housed in loose groups reported canker. The mean number of rabbits kept were higher in farms experiencing this condition (47.9) compared to 29 in farms that did not report the condition. Bedding materials also seemed to play a role since 57.9% of the farmers encountering the condition had soiled and less frequently changed bedding material. The mite *Psoroptes cuniculi* causes ear canker in rabbits and is transmitted through direct contact and its infestation may lead to secondary bacterial infections (Ogolla *et al*., 2017).

Of the 37.8% respondents that reported pneumonia, 52.9% (20% of the total respondents, Table 9) said the condition was common in young rabbits and majorly occurred during cold season (41.2%). Like ear canker, pneumonia significantly occurred in farms with large colony size (30 rabbits and above per farm) (58.8%) compared to farms with small colony size (less than 30 rabbits per farm) (41.2%) and in farms with more than two layers of cages (41.6%). Serem (2014) reported a strong association between the number of rabbits kept and pneumonia occurrence. Studies have shown that pneumonia occurs and causes death in rabbits (Wesonga and Munda, 1992; Patton *et al.,* 2008) with commonly observed signs being difficult breathing and nasal discharge. *Pasteurella multocida* is the most common bacteria isolated from the respiratory system of sick rabbits (Patton et al., 2008). The best control for this condition is good management measures that would ensure good ventilation, low ammonia levels, and low humidity within rabbitries (Mendlowitz, 2002).

Snuffle which is another respiratory tract condition like pneumonia was reported in 22.2% of the study farms. It is characterized by occurrence of nasal discharge and sneezing. The rabbit often rubs its nose with its forepaws, the fur of which becomes matted and dirty (Lebas *et. al.,* 1997). Stress resulting from extremes of temperature, high humidity, and high ammonia levels in the rabbit house is primary factor that encourage development of this disease (Patton et al., 2008).

Diarrhea in rabbits was reported in 11 farms (24.4%). Intestinal diseases, mainly manifesting through diarrhea are the most costly to rabbit producers and the major obstacle to rabbit enterprise expansion (Serem, 2014). Diarrhea is a serious economic threat, primarily in young weaned rabbits and can be prevented by good sanitation and hygienic feeding (Koehl, 1995; Licois, 2004). Feeding, particularly use of unbalanced diet and abrupt feed changes is a prime factor in the occurrence of diarrhea (Licois, 2004).

Of the farms surveyed, 26.7% reported occurrence of coccidiosis. Ogolla *et al* (2017) reported coccidiosis prevalence of 47.9% among rabbit farms in Kiambu County and associated it with poor hygiene due to high number of wooden floors and poor cleaning methods coupled with housing rabbits of different age groups in the same cage. In this study, the majority of the respondents (66.7%) raised rabbits on wooden floor cages while 8.9% practiced loose group housing in which rabbits were reared together irrespective of age.

Placement of rabbit feed especially forages directly on the cage floor (41.6% of the farms) and poor hygiene indicated by presence of feces in the cages (66.7% of the farms) may have also contributed to the occurrence of coccidiosis. Wooden cages are often difficult to clean as wood absorbs urine and also increases accumulation of fecal matter in the house compared with wire meshed floor (Schiere, 2004). Beside wooden floor, use of multiple tiers which was practiced by 57.8% also made cleaning of rabbit houses difficult.

According to Hungu (2011) and Ogolla *et al* (2017) coccidiosis which is caused by Eimeria species is one of the most commonly reported disease by rabbit farmers and is the major cause of massive losses to rabbit farmers due to high morbidity and mortality. The disease interferes with intestinal function particularly intestinal motility leading to bad feed conversion and growth depression (Licois, 2004). The disease is highly contagious in rabbits and is spread through ingestion of faecal contaminated feed or when the rabbit cleans its feet or fur that has been contaminated with the faeces of other infected rabbits (Meredith and Jepson, 2001).

According to Serem (2014), disease control in caged rabbits can be managed more easily compared to grouped animals. Group housing is thought to be relatively cheaper in terms of construction and maintenance (Serem, 2014), but is associated with high mortality of kits, increased aggression, difficulty in controlling infectious diseases, high labour costs and high production costs, all of which may have a negative impact on productivity (Ruis, 2006; Hoy et al., 2006). There is need for proper hygiene in rabbit units, especially as a mechanism for the prevention of diseases (Ogolla *et al*., 2017). Animal's defense against diseases and other external attacks which can affect their productivity is fundamentally dependent on good hygiene standards in the rabbitry (FAO, 1997a). Regular cleaning of rabbitry will reduce the number of pathogens present in there making it viable and productive for a longer period.

Of the respondents reporting disease occurrence, 60% treated their rabbits while 28.9%, 6.7% and 4.4% called animal health providers, slaughter the animals and did nothing respectively (Table 10). The course of action was mainly determined by the type (52.6%) and severity (26.3%) of the disease. Other determinants were number and age of rabbits affected each with 10.5% frequency. Similar findings were reported by Serem (2014). Actions such as slaughtering of sick animals or letting the disease take its course by doing nothing by some farmers when there is a disease in the rabbit units has been attributed to insufficient information on management and control of rabbit diseases among the farmers (Ogolla *et al*., 2017: Hungu, 2011). This might also be contributed by low availability and accessibility of veterinary services and where available they are very expensive.

Table 10: Actions taken on disease occurrence by rabbit keepers in the study area

Action taken when there is disease	Frequency	Percentage (%)
Self-treat	27	60.0
Call animal health providers	13	28.9
Slaughter the sick animal	3	6.7
Do nothing	2	4.4%

During the 6 month period prior to the study, 53.3% (24) of the respondents had their rabbits treated of various diseases. The farmers administered the treatment themselves (62.5%), used animal health experts (25%) and others (12.5%) requested for assistance from neighboring rabbit farmers. Of those who treated their rabbits, 46.7% used contemporary medicine, 20% traditional medicines while 33.3% combined both medicines. The knowledge on the management of rabbit diseases and drug use had been obtained either from non-professional sources including fellow farmers (62.7%) or professional sources including veterinarians (37.5%).

Farmers treating their sick animals using both modern and traditional therapeutics are widely reported among Kenyan rabbit farmers (Serem 2014; Ogolla *et al.*, 2017; Chebet *et al.*, 2018). The most common contemporary drugs used were ivermectin (25%) and sevin (15.6) for management of external parasite infestation, and Sulphonamides mostly Amprolium for coccidiosis treatment. The traditional therapeutics agents were liquid paraffin (50%), Aloe vera (37.5%) and car engine oil/kerosene (12.5%) being used mainly for conditions such as mange, ear canker and other conditions of the skin. The aspect of farmers purchasing drugs and administering to their animals without professional consultation may not be prudent and may lead to drug resistance due to misdiagnosis, varying treatment regimes and frequency of application of drugs (Ogolla *et al*., 2017; Chebet *et al*., 2018).

Farmers treating their own rabbits can be attributed to low availability and accessibility of veterinary services in the area (46.7%) and where available very expensive as well as lack of rabbit-specific drugs. Schiere (2004) reported that lack of both veterinary drugs and animal health experts impedes rabbit farming in the tropics. According Ashfaq *et al* (2014), many farmers rely on traditional methods rather than seeking proper veterinary advice for their animals when it comes to livestock diseases treatment which is detrimental to their incomes and development of the livestock business.

A small proportion (15.6%) of the respondents kept health records. Only 20% of the farmers dewormed their rabbits with other disease control measures used being use of feed additives mainly coccidiostats (48.7%), isolation of sick and/or newly acquired animals (31.1%) and spraying of rabbit houses (8.9%).

3.4 Conclusions

1. Majority of farmers keep rabbits in Kiambu County for food security and income generation. Rabbit farmers depend on locally accessible materials for feeding and housing construction. The prevalent breeds are New Zealand and Californian whites and their crosses.

2. Constraints to rabbit farming include high cost and poor quality of rabbit feeds, occurrence of rabbit diseases coupled with absence of rabbit specific drugs and rabbit health experts, and lack of markets for rabbits and rabbit products.

CHAPTER FOUR

EVALUATION OF PERFORMANCE OF RABBITS ON SELECTED FARMS IN KIAMBU COUNTY

4.1 Introduction

Over many years, domestic ruminants and chickens were the primary food animals among many Kenyan communities (Borter and Mwanza 2011). However, due to decreasing landholdings and the increasing cost of concentrate feeds, the production of ruminants that need large quantities of forages and chickens which compete for more expensive cereals with humans continue to pose serious challenges raising the need for alternatives. According to MALF (2017), cereal production has and continues to decline while keeping of large animals such as cattle as was the custom of many communities is being constrained by the reduction of individual landholdings. Given this and with the necessity to increase food production for the growing human population, the need for a livestock species that can be raised easily and cheaply like a rabbit has emerged.

In the recent past, there has been an increased interest in rabbit farming with emergence of many new rabbit farmers and the formation of distinct self-help organizations such as Rabbit Breeders Association of Kenya (RABAK) based in Thika (Borter and Mwanza 2011; Serem, 2014). Establishment of a rabbit abattoir in Thika town is also an indication of this increased interest. Low cost needed to set up the enterprise, and the ability of the rabbit to multiply and grow fast, and thrive well on cheap cereal-free diet yet providing meat which is classified as white meat rich in protein and less of cholesterol and fat are among the favourable qualities of this animal. (Dalle Zotte, 2014). With this upsurge of interest in rabbit farming, many and diverse management practices currently utilized by farmers and their impact on rabbit performance needs to be determined and farmers advised in order to make the venture profitable. This study aimed at assessing performance and cost of production of rabbits under prevailing management and feeding systems in Kiambu County.

4.2 Materials and methods

4.2.1 Experimental farms and their attributes

Six out of the 45 farms participating in the cross-sectional study (see Chapter 3) were purposely recruited for the longitudinal study based on the availability of weaner rabbits, consistency in feeding and ability of the farmer to record data. The attributes of the six farms were that they had more than 10 breeding does, kept breeding and feeding records, and had been rearing rabbits for a period of between 3 and 10 years at the time of the study. The rabbits on these farms were kept indoors in cages made of wire mesh and wood, arranged mostly in 2-4 tiers, with a floor area of 3600 to 8100 cm^2 and could accommodate 2 to 6 weaner rabbits per cage.

Feeding of rabbits was done once a day between 0800 and 1100 hours, and except in one farm where concentrate feed was offered as a sole diet, the rest of the farms provided a mixture of concentrate and forage feed, which were served in bowls made of clay for the former and either hanged or placed directly on the cage floor for the latter type of the feed. The amount of concentrate given ranged from 30-100g per rabbit per day depending on the farm and age of the rabbits. Rabbits received water ad libitum, kits weaned at 8 weeks of age, and does re-mated soon after weaning. These farms would sell their rabbits at a mean price of KES 350/kg live weight.

4.2.2 Experimental animals and their management

In each farm, 40 weaner rabbits were selected and monitored from 8 weeks of age to a target body weight of 2 kg without alteration of farm management practices during data collection. Using a portable platform digital weighing scale with an accuracy of 1g, the initial body weight, and liveweight on weekly basis for these rabbits were recorded until the target weight was achieved. The total feed allowance for the selected rabbits was weighed, recorded, and stored at the beginning of each week based on the farmer's feeding practice.

For feed with high moisture content such as sweet potato vines and kales, the amount given on the day of visit was measured and with the assumption that this was the forage offered throughout the preceding week multiplied by seven to get an estimate of weekly forage intake. Daily feed leftovers were collected in the morning before offering fresh feed, weighed and recorded. The weekly feed intake was calculated as the difference between the amounts availed at the beginning of each week and the total of what remained of the feed allowance and the total left-overs for the week. Feed conversion efficiency was calculated as the amount of feed intake per unit of live weight gain.

4.2.2 Sampling and Proximate analysis of feeds

During study period, all types of feeds fed to the rabbits in all the farms were sampled and analyzed for dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF), ash and nitrogen free extract (NFE) using AOAC (1998) methods. Neutral detergent fibre (NDF) and Acid detergent fibre (ADF) for forage feeds were determined using Van Soest *et al* (1991) method while Noblet and Perez (1993) formulas as cited by Nasimiyu (2015) were used to estimate digestible energy (DE) and metabolisable energy (ME) as follows:

DE (Conc. Feed, Kcal/kg) = 4151- (122 x % Ash) + (23 x % CP) + (38 x % EE) - (64 x % CF)

ME (Conc. Feed, Kcal/kg) = DE x {1.003 - (0.0021 x % CP)}

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

4.2.3 Nutrient intake

Protein and energy intakes were estimated as follows:

Crude protein intake (CPI, g) = average total feed intake (g/d DM basis) x %CP of diets

Digestible energy intake (DEI Kcal) = average total feed intake (g/d DM basis) x DE (Kcal/g) value of diets.

4.2.4 Data analysis

The data was analyzed using SPSS (Version 22). Data on live weight, weight gain,feed intake, and costs was subjected to the Analysis of Variance (ANOVA) procedure and any significant differences between means ranked using the Scheff test.

4.2.5 Assessment of cost of production

The cost of feed prevailing at the time of the study was used to determine the cost of feeding. This was estimated at KES 43, 15, 25, 20, and 16.5 per kg of rabbit pellets, grass hay, alfalfa hay, kales and sweet potato vines respectively. These were averages of prices given by the different study farms. The quantity and the average cost of feed consumed during the experimental period per unit weight gain of rabbits were used to assess the cost of feed per kg weight gain.

To cover other costs of production that were not assessed in this study such as labour, power, water and depreciation of facilities, feeding cost was estimated at 57% for forage-based diets (Nasimiyu 2015; Mmereole *et al*., 2011) and thus the other costs were estimated at 43% of the total. However in farm 1, where pelleted feed was used as a sole diet, this was estimated at 70% and 30% respectively. The prevailing shilling to dollar exchange rate at the time of the experiment was at KES100/1US$. For the purpose of estimating the returns, the prevailing market price of a 2 kg liveweight rabbit which averaged KES. 350, according to earlier survey (see Chapter 3), was used.

4.3 Results and discussion

4.3.1 Type and quality of feeds offered to rabbits in the study farms

During the study period, different types of forages were offered to rabbits on the different farms. Grass hay was the most common forage and was used on 5 study farms (Rhodes grass-3 farms, Kikuyu grass-2 farms) while lucerne was used in 2 farms (Table 11). Kales and sweet potato vines were only offered to rabbits in one farm. Feeding rabbits on diets with high forage content is recommended to either increase fibre intake in order to maintain gut health or to utilize the vast forage resources often available on most farms (Iyeghe-Erakpotobor and Uchegbu 2016). Sweet potato vines have been recommended as high potential rabbit feed in tropics due to its palatability and good nutritional content (Lukefahr, 1998; Akinmutimi and Osuagwu, 2008; Chah *et al*., 2017). The on-farm grown forages including lucerne, kales and sweet potato vines were wilted either outdoors or indoors prior to feeding. Grass hay were grown on-farm in 2 and purchased in 3 farms.

Table 11: Chemical composition (DM basis) of the forages offered to rabbits in the study farms

Forage type:	Grass hays					Lucerne hays		Kales	SPV
	Kikuyu grass		Rhodes grass						
Farm:	**2**	**4**	**3**	**5**	**6**	**3**	**4**	**4**	**4**
Moisture (%)	12	9.6	8.4	7.7	8.8	13.4	11.6	68.6	76.3
CP (%)	7.6	6.7	6.2	7.1	9.7	17.7	20.2	17.3	21.2
EE (%)	1.4	1.5	1.7	1.6	1.4	2.3	3.0	3.4	3.3
CF (%)	37.4	37.8	38.6	38.2	38.7	33.1	23.3	13.7	18.0
Ash (%)	13.6	12.8	14.3	13.3	12.5	10.8	10.5	14.3	16.4
NFE (%)	25.3	30.6	27.3	27.6	24.2	32.5	39.5	37.2	37.5
NDF (%)	76.5	73.6	75.5	75.6	69.8	49.7	39.1	53.4	44.1
ADF (%)	40.8	42.8	45.4	43.0	38.2	37.8	25.5	14.7	26.4
ADL (%)	7.3	6.2	9.9	5.1	4.7	7.1	3.0	5.8	7.5
DE (kcal/kg)	1385.4	1353.8	1290.6	1322.2	1282.7	1725.1	2499.3	3257.5	2918

Crude protein (CP), Ether extract (EE), Crude fibre (CF), Nitrogen free extract (NFE), Neutral detergent fibre (NDF), Acid detergent fibre (ADF), Acid detergent lignin (ADL), Digestible energy (DE), Sweet potato vines (SPV)

The chemical composition of the different types of forages offered to rabbits in the study farms is shown in Table 11. The mean proximate composition of the grass hays (8.1% CP, 13.3% ash, 38.1%CF, 74.2%NDF) was comparable to the Rhodes grass hay (8.3 % CP, 13.1 % ash, 34.2% CF and 66.3% NDF) fed to rabbits in a study by Nasimiyu (2015). The CP content of the grass hay ranged between 6.2 and 9.7% which is below the recommended 15-16% in rabbit diets (NRC, 1977). Thus, the rabbits fed on this hay would receive inadequate CP if fed as sole diet.

The hay CF content of 37.4 to 38.7% was above the recommended 12-17% in rabbit diets (NRC, 1977). Though fibre is an important component for rabbit diets, the current level could trigger caecal impaction and restrict feed intake and availability of nutrients (Medugu *et al*., 2012: Iyeghe-Erakpotobor and Uchegbu 2016). In contrast, the mean CP content of lucerne (19.0%), kales (17.3%) and sweet potato vines (21.2%) was above the threshold for rabbit diets while the CF content at 13.7 and 18% for kales and sweet potato vines respectively were close to the recommended levels. The mean CF of the lucerne hay in this study (28.2%), was slightly lower than 32.5% used in the study by Khan *et al* (2016). Since most rabbits are fed on forage, it is considered an important source of protein and crude fibre (Heuzé *et al*., 2016).

The high level of CP in sweet potato vines (17.3%) and kales (21.2%) qualifies them as rich sources of protein to rabbits (Unigwe *et al*., 2014) and were fed to rabbits by most farmers in the study area. However, their high moisture content (68.6 and 76.3%) renders them bulky and too low in energy for efficient rabbit production (NRC, 1977). Additionally, high moisture content in forages has been associated with gastrointestinal disturbances (Adjare, 2003; Borter and Mwanza, 2011). The farmers were aware of this and 93% (section 3.3.3) wilted the forage prior to feeding it to prevent bloating and diarrhea and/or increase forage intake. The two were also lower in CF (14 and 18%) than the other feeds which was within or close to the recommended level for rabbit diets of 12-17% (NRC, 1977).

The estimated DE for the forages were low compared to the requirements for growing rabbits of 2500 kcal/kg (NRC, 1977) except for sweet potato vines (2918 kcal/kg) and kales (3257.5 kcal/kg DM). However, the later 2 are high in moisture and the rabbit may not be able to consume sufficient feed to meet its energy requirement for maximum growth. The deficiency of key nutrients particularly proteins and energy limits forages from sustaining optimum productivity of rabbits when used as a sole diet (Iyeghe-Erakpotobor and Muhammad, 2008). This is so especially where such forages consist of relatively low digestibility and low protein tropical grasses (Mailafia *et al*., 2010). Performance is dependent on the quality of feed (Geerts, 2014) and as such rabbits in the area would be expected to perform poorly. This necessitates the use of more nutritious supplements to correct the deficiencies and boost productivity of the rabbits.

The chemical compositions of the two types of grasses used varied from one farm to another. For instant, the crude protein of Rhodes grass ranged from 6.2 to 9.7% with a mean of 7.7% which is slightly higher than 7.2% reported by Abdulrazak *et al* (2005) but lower than 8.3% by Nasimiyu (2015). The mean CF was 38.5% (range, 38.2-38.7%) which was comparable with 37% by Ouda (2009), slightly higher than 34% by Nasimiyu (2015) and much lower than 48.70% by Adegbola and Oduozo (1992).

The variations in chemical composition of grasses may be due to differences in agronomic practices, stage of maturity at harvesting and preservation conditions, all of which will bear on the quality of the resulting hay (Menteşe *et al*., 2006; Nasimiyu, 2015). The quality of kikuyu grass used was low compared with many studies. It had a mean CP of 7.2% and CF of 37.6%. The average content of CP in this hay (7.2%) is lower than11.4-15.8%, 22.9% and 20.5% found by Apráez and Moncayo (2000), León et al (2007) and Correa et al (2008) respectively. According to Marais, (2001) chemical composition of Kikuyu grass would vary depending on the growth stage and environmental conditions during growth.

The proximate composition of concentrate pellets fed to rabbits in the different study farms is shown in Table 12. All the pellets were sourced from commercial feed outlets except in farm 3 where it was mixed and pelleted at home.

Table 12: Proximate composition (%DM) of concentrates used in study farms

	Farms						
Contents	**1**	**2**	**3**	**4**	**5**	6	Mean
Moisture (%)	11.5	11.0	10.7	11.8	13.4	12.1	11.8±0.4
CP (%DM)	18.9	17.6	11.8	21.6	19.8	19.9	18.3±1.4
EE (%DM)	3.8	3.7	4.1	3.6	3.5	3.3	3.7±0.1
CF (%DM,)	9.6	9.7	7.1	9.9	10.6	8.4	9.2±0.5
Total ash (%DM)	7.2	7.5	10.4	7.2	7.0	6.6	7.7±0.6
NFE (%DM)	51	50.2	64.9	46.9	49.7	57	53.3±2.7
EDE (kcal/kg DM)	3237.3	3213.5	3175	3272.6	3207	3338.4	3240.6±23.6
EME (kcal/kg DM)	3118.5	3088.8	3105.8	3134	3083.3	3225	3125.9±21.2

Crude protein (CP), Ether extract (EE), Crude fibre (CF), Nitrogen free extract (NFE), Estimated Digestible energy (EDE), Estimated Metabolizable energy (EME)

The moisture content ranged between 10.7 and 13.4 % which is within the 12% recommended by the National Research Council (NRC, 1981) to avoid mold growth during storage of feed. The crude protein ranged from 11.8-21.6%. The recommended CP content in feed for growing rabbits is 15-16% (NRC, 1977) thus only the home made concentrate in farm 3 (11.8%) was deficient.

It appears from these results and other studies that the key determinant of type of feed offered to rabbits is availability rather than quality (Aduku and Olukosi, 1990; Lukefahr, 1998; Serem, 2014). This can be associated with the lack of knowledge of the nutrients contents of potential feeds as well as the nutritional needs of rabbits by rabbit farmers. Protein is one of the most important nutrients for animals, and as the key component of cells, plays an important role in the process of life (Liu *et al*., 2015). Growth rate and feed efficiency of rabbits improves with increase in dietary protein up to where the animal requirements are met (Wang *et al.*, 2002) thus feed provision without assessing the real need can eventually lead to wastage.

The estimated digestible and metabolizable energy content for the concentrates were 3175-3338 kcal/kg and 3083-3225 Kcal/kg respectively. These values were above those 2910 and 2820 Kcal/kg respectively for concentrate feed used by Nasimiyu (2015) and the recommended levels of 2400-2600kcal/kg for digestible energy and 2200-2500kcla/kg diet for Metabolizable energy for growing rabbits (FAO, 1997b). Mixing the concentrate feed with forage would correct any nutrient deficiency mostly of energy and protein.

However, the limited amounts of concentrate offered to rabbits (the maximum was 100g/day/rabbit or an average of 91.5g/day in the larger study presented in Chapter 3) could sabotage supply of nutrients to rabbits to support optimum growth. In farm 1, where rabbits were fed solely on pellets, the diet seems inadequate in terms of CF content since the concentrate supplied 9.6% CF which is lower than recommended 12-17% CF. This explains the importance of forage use in rabbit units in the study area since available pellets alone which had a CF ranging from 7.1-10.6% would not meet the requirement for this nutrient.

From the above results, forages used in farms had an average crude protein of 12.6% which is lower than 17.5% recommended for rabbits (Lebas *et al*., 1998) and commercial concentrates had an average fibre content of 9.2% which is below the 15-16% recommended for rabbits (NRC, 1977). As such it can be concluded that supplementation should be carried out in order to balance the crude fiber and crude protein among other nutrients for the optimal rabbit performance.

4.3.2 Feed and nutrient intakes of rabbits

Weekly and total feed intake, protein intake and DE intake by rabbits from week 8 to attaining 2kg weight in the study farms is shown in Table 13. Weekly feed intake varied between the farms across the study period and the total intake ranged from 5450 to 8059g with a mean of 6622g. The mean amount of 6.7kg consumed to attain 2 kg target weight was lower than the 8.6 kg reported by Nasimiyu (2015) for rabbits raised on the forage-based diet. The difference in weekly and consequently the total amount of feed consumed to the target weight between the farms can be explained by the difference in the type, quality and quantity of feed offered in these farms. For instance the lowest total feed intake (5450g) was recorded in farm 1 where rabbits were on concentrate feed alone. Khan *et al* (2016) also noted a lower total feed intake for rabbits supplemented with concentrate feeds (4030g) compared with those on forages alone (4215g).

The difference in time taken to attain the target weight also had an effect on total feed consumption. Except in farm 1 where only concentrate feed was used, total feed consumed increased from 5511 to 5922 to 6839 to 7951-8059g when time taken to attain the target weight increased from 16 to 17 to 18 to 19 weeks respectively. These results are in agreement with Nasimiyu (2015) who reported higher feed intake for rabbits that took longer to reach market weight and this is a logical response as it is expected that animals that take a longer period will need more feed for maintenance compared to animals reaching market weight earlier.

Across the farms, weekly feed intake gradually increases from a mean of 431.3g at week 8-9 to 848.8g at week 18-19 giving an average of 38.6g increase in feed intake per week. Since

Table 13: Weekly and total feed intake, protein intake and digigestible energy intake of rabbits in the study farms (g, DM)

	Farms							
Week	**1**	**2**	**3**	**4**	**5**	**6**	**Mean**	**SEM**
8-9	352±9.9^{a}	409±17.0^{b}	444±10.3^{c}	503±10.0^{d}	445±18.5^{c}	417±8.8^{b}	431.3±47.7	5.3
9-10	420±11.2^{a}	513±11.4^{b}	535±9.1^{bc}	583±12.2^{d}	546±15.0^{c}	520±9.6^{b}	522.7±64.9	4.6
10-11	455±12.4^{a}	598±12.1^{b}	619±11.2^{cd}	634±6.5^{de}	649±10.7^{e}	601±6.0^{bc}	596±63.9	4.1
11-12	490±11.6^{a}	672±9.4^{bc}	677±6.6^{c}	683±12.6^{c}	730±13.7^{d}	652±11.2^{b}	654.3±69.6	4.5
12-13	525±14.3^{a}	731±13.4^{bc}	704±18.0^{b}	716±17.4^{b}	750±14.8^{c}	701±15.3^{b}	691.3±65.3	6.4
13-14	560±6.3^{a}	785±11.5^{c}	726±13.4^{b}	737±12.2^{b}	780±11.2^{c}	734±16.0^{b}	723.7±65.8	5.0
14-15	630±15.1^{a}	816±8.9^{c}	765±15.5^{b}	744±9.6^{b}	801±13.5^{c}	755±8.9^{b}	755.2±65.4	5.2
15-16	667±16.2^{a}	838±14.3^{d}	785±6.8^{c}	750±8.2^{b}	814±12.9^{d}	762±18.1^{b}	772.8±65.3	5.5
16-17	672±10.4^{a}	852±14.9^{d}	790±10.7^{c}	-	834±11.6^{d}	780±7.7^{bc}	785.8±64.3	5.7
17-18	679±10.9^{a}	864±11.7^{c}	794±11.4^{b}	-	846±15.5^{c}	-	795.0±69.9	5.1
18-19	-	873±11.9^{c}	-	-	864±13.8^{c}	-	846.8±78.5	5.6
AWI(g)	545±116.5^{a}	735±156.2^{cd}	704±117.1^{c}	678±88.3^{b}	744±133.6^{d}	671±124.3^{b}	684±136.6	38.0
TFI(g)	5450±33.5^{a}	7951±64.9^{d}	6839±127.6^{c}	5511±57.4^{a}	8059±97.5^{d}	5922±67.6^{b}	6622±1254.9	32.4
CPI (g)	937.4^{d}	845.3^{b}	761^{a}	962.2^{d}	857.4^{bc}	886^{c}	874.9±163.6	11.3
DEI (Kcal)	17643.3^{e}	15421^{d}	11535^{a}	14731.6^{c}	15400.6^{d}	13607^{b}	14723±1868.7	48.1

Average weekly intakes (AWI), Total feed intake (TFI), Crude protein intake (CPI), Digestible energy intake (DEI), Means within a row with different superscripts are significantly different ($P < 0.05$)

liveweight is a major determinant of feed intake, it is expected that as animals grow, feed intake also increases. The mean weekly feed intake was 684±136.6g. This was slightly lower than 759.5g for rabbits under forage-based diet as observed by Nasimiyu (2015). This difference in weekly feed intake which could be attributed to the amount of feed availed to rabbits in these studies, can be the reason behind slightly later age at market weight of 18 weeks (average of the six farms) compared to 16.3 weeks for Nasimiyu's study.

The estimated CPI and DEI varied from one farm to another (Table 13). The CPI ranged from 761 to 962g (mean, 874.9±163.6) while the DEI ranged from 11535 to 17643.3 kcal (mean, 14723±1868.7). The type of feed offered to rabbits influenced total crude protein intake with farm 4 having the highest (962.2g), the farm on which mixtures of concentrate and forages were used with rabbits receiving up to four different types of forages (grass hays, lucerne hays, Kales, SPV, Table 9). The lowest total crude protein intake (761g) was in farm 3 where rabbits were offered home-made concentrate which was of low crude protein content (11.8%). In addition, rabbits consumed the least total concentrate feed in this farm (1260g). The respective total concentrate feed intake for the other farms (1, 2, 4, 5 and 6) were 5450, 2410, 2564, 2423 and 1917g.

The total amount of concentrate consumed also influenced energy intake with rabbits in farm 1 (with total concentrate intake of 5450g) registering highest DEI (17643.3 Kcal) whereas those in farm 3 consumed a total of 11535 Kcal. The type of diet given to rabbits has been shown to affect the nutrient intake with Nasimiyu (2015) reporting higher CPI (890.8g) in rabbits raised on concentrate based diet compared to 837.2g for rabbits on forage based diet. This difference is due to different nutrient contents in offered feeds.

The mean daily digestible energy and crude protein intakes were 117.9 kcal/day and 7.0g/day respectively. These were lower than 224.5kcal and 11.57g per day for forage-fed rabbits in an earlier study (Nasimiyu, 2015). This indicates that even with supplementation, rabbits in the experimental farms, as would apply in most of the other farms in the study area, do not receive adequate nutrient supply to meet their requirements for maximum growth. This could be attributed to poor quality of most forage feeds used and limited amounts of concentrate feeds availed to rabbits.

Crude protein has been shown to positively and significantly contribute to daily weight gain of rabbits (Adeosun and Iyeghe-Erakpotobor, 2014). Low daily nutrient provision can be attributed to the overall poor performance of rabbits in the study farms. In comparison with rabbits raised on concentrate based feeds, rabbits raised on forage-based diets grow at a lower rate and take longer to achieve a target weight, particularly if the supplementation of concentrate is limited (Nasimiyu, 2015). Lebas and Gidenne (2000) indicated that energy and protein demands for growth depend on a number of factors, including weight at weaning and the target growth rate.

4.3.3 Weight gains

The respective initial weights of rabbits in the study farms 1, 2 3, 4, 5 and 6 were 1012.3±26.5 744.0±20.2, 924.5±40.4, 1058.3±47.6, 846.3±39.7 and 1123.8±32.6g (mean, 951.5±141.2) and weekly weight gains from 8 weeks to the target weight of 2 kg is shown in Table 14. The time taken to attain the target weight of 2 kg ranged from 16 to 19 weeks (mean, 18). Breed variation effect together with varying experimental conditions across the study farms could explain the variation in weaning weight from 744g (Farm 2) to 1123.8g (Farm 6).

A total of 8 different breeds of rabbits were kept in the study farms with each farm keeping at least 4 different breeds which were part of the study (New Zealand white-27.9%, Crossbreeds-25.8%, California White-21.3%, Checkered Giant-7.1%, Dutch-5.4%, Chinchilla-4.6%, Flemish Giant-4.6% and French lopped-3.3%). This variation of breeds kept by different farms could have contributed to the observed difference in weaning weight. For example, in farms 6, 4 and 1 where the highest weaning weights (1124g, 1058g, 1012g) were recorded, common medium breed rabbits (New Zealand white and California whites) formed the majority of the breeds in the study at 73%, 60% and 58% respectively. These values were 45%, 35% and 25% for farms 3, 5 and 2 respectively. These two breeds have been associated with good mothering ability and rapid growth rate compared to others (Oseni *et al*., 2008; Mailafia *et al*., 2010; Hungu, 2011).

In the present study, weekly weight gains varied between the farms during the study period. The mean weekly weight gains at the start of the study (week 8-9), for example ranged from 85.2 to 127.1g/week with a mean of 103±16.4g/week and such variations in weekly weight gains were observed throughout the study period. These variations in animal performance between the study farms are explained by differences in the quality of feed offered. For instance, in farm 4, the concentrate feed had a mean crude protein of 21.6% compared to 11.8-19.9% in the rest of the farms. In addition, rabbits in farm 4 received proteineous forages; lucerne hay, kales and sweet potato vines (Table 9) which contributed to a high total crude protein intake (962.2g). Pinheiro et al (2011) observed that rabbits raised on sufficient high quality feed (concentrate diets) recorded a significant weight gain than those under low quality feed (mainly forage-based diet).

Although rabbits in Farm 1 were raised on concentrate based diet, their growth rate was similar to those of other farms. They grew at an average rate of 15.9g/day to attain target weight at 18

Table 14: Weekly weight gains of rabbits in the study farms (g)

Week	Farms							
	1	**2**	**3**	**4**	**5**	**6**	**Mean**	**SEM**
8-9	114.2±7.1^{bc}	127.1±9.2^{c}	93.7±11.4^{a}	98.1±9.9^{ab}	85.2±10.0^{a}	99.9±6.8^{ab}	103±16.4	2.7
9-10	162.7±8.2^{c}	95.9±6.3^{ab}	98.6±6.6^{ab}	110.1±10^{b}	92.9±8.6^{a}	106±7.2^{ab}	111±25.3	4.2
10-11	121.3±6.0b	151±4.5c	101.8±7.4a	119.8±6.3b	103.7±4.2a	128.9±5.3b	121.1±17.5	2.9
11-12	104.5±5.6a	103±9.1a	122.3±5.3b	152.4±6.3c	125.7±5.4b	136.1±8.2b	124±18.6	3.1
12-13	132±6.9b	128±5.7b	137±8.5b	163.9±4.7c	136.5±5.4b	112.1±6.2a	134.9±16.7	2.8
13-14	102.2±4.5ab	109±5.5b	146.5±7.5cd	136.2±6.1c	148.6±6.4d	96.7±5.3a	123.2±22.2	3.7
14-15	103.5±4.6b	124.7±6.5c	129.7±7.5c	79.7±6.4a	143.5±6.0d	100.5±3.6b	113.6±22.2	3.7
15-16	89.1±5.0c	126.7±4.7e	107.1±4.2d	75.7±5.9b	120.7±6.1e	64.4±4.5a	97.3±23.6	3.9
16-17	47.2±5.0a	119.6±6.8c	93.2±4.9b	-	126.4±6.0c	38.1±6.7a	84.9±37.4	6.8
17-18	23.1±6.6a	81.1±5.6d	46.5±4.6b	-	59.1±5.5c	-	52.5±22.1	4.5
18-19	-	52.1±6.2	-	-	14.4±6.1	-	33.3±20.6	5.9
Average(g/w)	100±40.1	110.7±27.0	107.6±28.5	117±32.4	105.2±40.5	98.1±30.8	106.3±32.8	4.3

Means within a row with different superscripts are significantly different at 5% level of significance ($P < 0.05$)

weeks. It would have been expected that rabbits on concentrate based diet would grow at a higher rate compared to those on forage based diet due to the higher dietary nutrients concentration in the former diet. The low performance of these concentrate feed-based rabbits in farm 1 can be attributed to limited amount of feed consumed (mean 78g/d) resulting in low nutrients intake (mean daily CPI-14.4g). Low performance can also be due to low crude fibre in diets of rabbits since rabbits in this farm were raised entirely on concentrate feed with crude fibre of 9.6% which was lower than the recommended level of 12-17%.

The dietary fiber is required for normal functioning of the digestive tract (Gu, 2002; Battaa et al., 2013) and attempts to feed rabbits on low fiber diets have led to poor performance (Cheeke *et al*, 1987; Gillespie, 1998). One of the alternatives to feeding rabbits only with pelleted commercial diets is to provide some fresh or dried forage in addition to the balanced feed (Szendro *et al*., 2015). Results of the experiments in which forages were not used as part of diet of rabbits showed low productive performance (Taiwo *et al*., 2005; Omoikhoje *et al*., 2006; Szendro *et al*., 2015; Khan *et al*., 2016).

The differences in weight gains could also be due to animal breed variations as this study involved varying breeds of rabbits in different study farms. Nasimiyu (2015) reported a varying mean weekly weight gains which ranged from 169.5g to 173.6g to 183g for New Zealand White

(NZW), California White (CW), and their crossbreed (CWXNZW) respectively. According to Iyeghe-Erakpotobor (2001) there is a significant difference in productive performance among rabbit breeds with NZW and CW being the most frequently used in commercial rabbitries alongside their hybrids due to their desirable growth rate (Serem 2014; Mailafia *et al*., 2010; Oseni *et al*., 2008).

On average, the weekly weight gains increased from 103±16.410g/week (week 8-9) to 134.9±16.7g/week (week 12-13) before it started declining to 33.3±20.6g/week at the end of the study period. The overall mean weight gain was 106.3±32.8 g/week which was similar to 105 g per week reported by Khan et al (2016) for forage fed rabbits, but less than 148.1g/week reported by Nasimiyu (2015) for rabbits raised on forage based diet. The variations in performance between these studies can be attributed to the fact that while the study by Nasimiyu was carried out on-station where experimental conditions including the breeds used were controlled, the current study was on-farm where different breeds were used and experimental condition would vary between farms. Limited feed availability/intake which does not sufficiently provide adequate nutrients (as was in this study) would also be associated with low performance of rabbits and late age at slaughter weight attainment (Iyeghe-Erakpotobor *et al*., 2002; Nasimiyu, 2015).

The results of this study are in agreement with others, that approximately 4 months was needed to raise a 2 kg fryer rabbit under extensive production system. Nasimiyu (2015) determined that rabbits kept under an extensive system on forage diets attained this weight at 16.3 weeks of age (average of the 3 breeds studied). Lukefahr (1998), in his baseline survey in Uganda, where rabbits are primarily reared on forages, also reported that it took around 4-5 months to produce a

2 kg fryer. According to Cheeke (1987) rabbits on extensive production system take twice the amount of time to reach a 2 kg weight compared to intensive production systems, which could be a reflection of nutrition level.

4.3.4 Feed conversion efficiency

The feed conversion ratio of rabbits in the study farms is presented in Table 15. The weekly feed conversion ratios differed between the farms, with rabbits in farm 1 having slightly better FCR throughout the study period. During the whole study period, the average feed conversion ratio across the farms ranged from 5.6-7 with overall mean of 6.3 (Table 15). The lower feed conversion ratio for the rabbits in farm 1 can be explained by the lower overall total feed intake of 5.45kg compared to the rest of the farms and this is in agreement with Khan *et al* (2016). The higher FCR for rabbits in this study was as observed by Mmereole *et al* (2011) who reported FCR value of 5.1-6.0 after feeding graded levels of Tridax procumbens. The higher feed conversion ratio observed can be attributed to lower quality feed particularly forages thus reduced growth rate and delayed attainment of slaughter weight and a higher overall total feed intake. The longer the animal takes to slaughter weight, the lower the lifetime feed utilization efficiency due to increased amounts of nutrients used for maintenance rather than for growth. F

The high FCR observed might have also been due to higher feed wastage associated with the feeding systems on farms. Placement of feeds directly on the floor inside a rabbit house in the study farms might have led to high feed wastage. This was evidenced by the fact that during farm visits some forages had been trampled on by rabbits and mixed with rabbit's excrement on the floor. Feed waste is always taken as consumed increasing the FCR, since it is not utilized for animal growth. Using feeders that ensure minimal feed wastage have been reported to enhance FCR (Agostini *et al*., 2014; Pierozan *et al*., 2016). Standards for feeders should be considered, as feed wastage may increase substantially if such equipments are improperly regulated (Pierozan *et al*., 2016).

Table 15: Weekly feed conversion ratio of rabbits in the six study farms

	Farms							
Week	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**Mean**	**SEM**
8-9	3.0±0.82[a]	3.2±0.61[a]	4.7±0.55[b]	5.3±0.67[b]	5.2±0.61[b]	4.1±0.51[ab]	4.3±1.1	0.26
9-10	2.5±0.72[a]	5.3±0.72[b]	5.4±0.60[b]	5.4±0.41[b]	5.8±0.42[b]	4.9±0.71[b]	4.8±1.2	0.25
10-11	3.7±0.68[a]	3.9±0.54[a]	6.0±0.38[b]	5.4±0.43[b]	6.2±0.68[b]	4.6±0.44[a]	4.9±1.2	0.22
11-12	4.6±0.46[a]	4.8±0.45[ab]	5.5±0.42[cd]	4.6±0.54[a]	5.8±31[d]	4.7±0.30[ab]	5.0±0.6	0.17
12-13	3.9±0.46[a]	5.7±0.49[cd]	5.1±0.45[bc]	4.4±0.50[ab]	5.4±0.45[bcd]	6.2±0.66[d]	5.1±0.9	0.21
13-14	5.4±0.64[a]	7.2±0.70[b]	4.9±0.61[a]	5.5±0.52[a]	5.2±0.53[a]	7.5±0.69[b]	6.0±1.2	0.25
14-15	6.0±0.63[a]	6.5±0.58[ab]	5.9±0.51[a]	9.5±0.77[c]	5.5±0.49[a]	7.5±0.42[b]	6.8±1.5	0.24
15-16	7.4±0.41[a]	6.6±0.38[a]	7.3±0.70[a]	9.4±0.59[b]	6.7±0.42[a]	11.8±0.73[c]	8.2±1.8	0.23
Mean	5.55±0.41[a]	6.34±0.32[ab]	6.35±0.72[ab]	5.89±0.28[ab]	6.97±0.66[c]	6.70±0.79[ab]	6.3±0.71	

Means within a row with different superscripts are significantly different at 5% level of significance ($P < 0.05$)

The mean weekly feed conversion ratios from week 8-15 were 4.3, 4.9, 5.0, 5.1, 5.2, 6.0, 6.9 and 8.2 respectively (Table 13). Similar trend of FCR increasing as rabbits grew to slaughter weight was also observed by Maertens (2009) and Nasimiyu (2015) who attributed it to the difference in content of tissue accretion (fat *vs*. protein and water) and the increased maintenance requirement with increasing weight. Growth performance is better appreciated when feed conversion ratio is considered as this shows how much weight the animals gains per kilogram of feed consumed (Amata and Okorodudu, 2016). Animals with a lower feed conversion ratio are considered efficient feed users and generally, the feed utilization efficiency worsened with age with young and quick growing animals being associated with a better FCR (Maertens 2009).

4.3.6 Cost of production

The costs incurred in raising rabbits in the study farms are shown in Table 16. The total cost per kilogram weight gain ranged from KES 255.4 to 334.7 with a mean of KES 297. The type and amount of feed used influenced, to an extent, the total cost of production. The highest cost of KES 334.7 was in farm 1 which used concentrate feed alone and registered the highest concentrate intake of 5.5kg. This was followed by Farms 5 and 2 which recorded total production cost of KES 331.1 and 327.5 respectively. The remaining farms had a total cost ranging from KES 250-283.3. Khan *et al* (2016) reported an increasing cost of rabbit production as feeding regimes shift from forage based to concentrate-based diets.

As observed in this study, Nasimiyu (2015) reported a higher production cost for concentrate fed rabbits in comparison to rabbits fed extensively on forages. The author further noted that on a per unit weight basis the forage based diet would be cheaper but rabbits would take a longer time to the target weight translating to fewer animals being available for the market than the concentrate diet. Contrary to this observation, the animals in farm 1 where concentrate was the main diet did not record better performance than those majorly on forages, attaining target weight at 18 weeks. This could be explained in part by limited amount of concentrate availed to the rabbits in this farm (maximum of 100g/ rabbit/ day). Varying environmental conditions and breeds of rabbits between the farms may have also contributed to this.

The average production cost per kilogram weight gain of KES 280.2 is higher than 155.5-178.7 and 178.4-213.3 reported by Nasimiyu (2015) for less intensive feeding system and intensive system respectively. The production cost difference can be partly explained by the difference in the time of the study reflected in increasing cost of feed ingredients with time. Also the weakening of Kenyan shilling depicted by the rising of dollar exchange rate from 85 during Nasimiyu's study to 100 in this study could explain high values reported in this study. In the earlier study, the author purchased ingredients and formulated the concentrate feeds for the rabbits while in this study all the concentrate feeds except in farm 1 were purchased from the market by farmers. Purchasing of already formulated feeds from the market is more expensive than self-formulated feeds and this may explain the increased production cost in the current study.

Feed cost varied from KES 142.5 to 234.4. The highest feed cost was recorded in Farm 1(KES234.4) followed by farm 5 (KES 188.7) then farm 2 (KES 186.7). The lowest feeding costs (KES142.5 and 161.5) were recorded in farms 6 and 4, on which farms the rabbits had attained target weight earlier and consumed less amount of feed compared with the other farms apart from farm 1. Thus, the feeding cost estimates reflected to an extent the total feed intake and was lowest for the farms with lowest total intake except for farm 1 where the more expensive

Table 16: Cost of production of fryers in the study farms

	Farms						
	1	**2**	**3**	**4**	**5**	**6**	**Average**
TFI(kg)	5.45[a]	7.951[d]	6.839[c]	5.511[a]	8.059[d]	5.922[b]	6.622
Concentrate (kg)	5.45	2.41	1.26	2.564	2.423	1.917	2.837
Forage (kg)	-	5.541	5.579	2.947	5.636	4.005	4.542
Grass	-	5.541	4.809	1.387	5.636	4.005	3.475
Lucerne	-	-	0.77	0.44	-	-	0.605
Kales	-	-	-	0.28	-	-	0.28
SPV	-	-	-	0.84	-	-	0.84
TWG (g)	999.8±15.9[c]	1254.2±8.5[f]	1076.4±13.7[d]	935.9±23.2[b]	1156.7±12.2[e]	883.5±16.5[a]	1067±136.7
FCR	5.55±0.41[a]	6.34±0.32[ab]	6.35±0.72[ab]	5.89±0.28[ab]	6.97±0.66[c]	6.70±0.79[ab]	6.3±0.71
FC (KES)	234.4±4.4[d]	186.7±2.6[c]	145.6±4.3[a]	161.5±3.2[b]	188.7±2.8[c]	142.5±3.7[a]	176.6±32.1
Other costs (KES)	100.3	140.8	109.8	121.8	142.4	128.6	120.4
Total cost (KES)	334.7	327.5	255.4	283.3	331.1	250.0	297.0
Cost/Kg gain (KES)	331.2	256.1	233.1	296.8	280.7	283.1	280.2

Total feed intake (TFI), Total weight gain (TWG), Feed conversion ratio (FCR), Feed cost (FC), Sweet potato vines (SPV), Kenya shilling (KES), Means within the same row with different superscripts are significantly different at 5% level of significance ($p<0.05$)

concentrate feed was used as sole diet for rabbits. In agreement with current study, Mutetikka et al (1990) reported a reduction in cost of producing a kg of edible carcass when the amount of feed offered/intake was decreased.

According to the survey (Chapter 3), the mean market price for slaughter rabbits is KES 350 /kg liveweight. Based on the results from this study, where an approximately 18 weeks are required to produce a 2 kg fryer at an estimated total production cost of KES 280.2 per kg gain, only for post-weaning period, then there is small profit realized if a fryer is sold for KES 350/kg liveweight. Based on these findings, it is evident that general commercial rabbit fryer production is unprofitable. The recent study by Mutsami (2018) showed that consumers particularly those from urban areas pay an average of KES 615 per kg of rabbit meat. Rabbit meat prices are thus higher than that of the potential white meat substitute, broiler chicken, making it non-competitive and discouraging market demand. This latter situation together with unprofitability of commercial rabbit fryer production could be the cause of low rabbit production in the county and in the country at large.

4.4 Conclusions

1. Rabbits in the study farms received limited/low quality feed which did not sufficiently provide adequate nutrients resulting in the overall poor performance. Rabbits showed low growth rate, higher feed conversion ratio and attained target weight at a delayed age.

2. Commercial rabbit fryer production in Kiambu County is unprofitable due to high cost of production incurred and low return. This is further worsened by non-competitiveness of rabbit meat with the other common meats.

CHAPTER FIVE

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 General discussion

Despite the many valuable qualities of rabbits and efforts directed to their production, their low productivity has limited their expansion and potential to improve the livelihoods of farmers in Kenya. An earlier study under controlled on-station conditions clearly showed that production of rabbits for slaughter is economically viable (Nasimiyu, 2015). However, on-farm animal performance is often lower than on-station since the production environment is less controlled (Magwisha *et al*., 2002; Hørning *et al*., 2003; Dos Anjos, 2005). Rabbit farmers have reported low productivity and low returns from the enterprise. This study assessed the performance of rabbits under prevailing on-farm management systems in selected production units in Kiambu County. Kiambu County was deliberately chosen on the basis of the population of rabbit keepers (MOLD, 2010), and the level of intensification and commercialization of rabbit production (Serem, 2014).

To document how rabbits are managed in the county, a survey was done using a semi-structured questionnaire in 45 rabbit units. Six (6) of the 45 farms surveyed were then selected and subjected to a longitudinal study to obtain data on the performance of rabbits. Descriptive statistics were computed to characterize rabbit farming system while Analysis of Variance (ANOVA) was used to analyze data on rabbit performance.

The survey results show that rabbit producers in Kiambu County majorly operated on small scale characterized by small flock sizes and limited resource allocation. The farmers depended on locally accessible feed ingredients such as kales, grasses and weeds and materials such as wood for rabbit house construction. The results indicated little change in either flock sizes or management systems from what was reported in an earlier study in the same area (Serem, 2014). Although majority (53.3%) of farmers indicated that rabbits were kept for income generation, the flock sizes (average, 37±19.1) were too small to support a sustainable off-take rate.

Due to the difficulty of identifying rabbit keepers, the use of snowball sampling technique to identify the 45 rabbit keepers was used (Section 3.2.2).The results showed that a majority (76%) of the respondents had kept rabbits for only up to seven (7) years suggesting that farmers earlier recorded as keepers of rabbits had abandoned the enterprise. The major complaint of the farmers was the same as earlier recorded by Serem (2014): costly and poor quality feeds, diseases and a lack of market for rabbits and rabbit products and low prices for the same. Mutsami (2018) reported that due to asymmetry of information, lack of vertical coordination and imbalanced bargaining power, farmers are exploited by other actors along the value chain such as brokers, retailers and wholesalers.

Assessment of feeds offered to rabbits in the farms showed that none of the individual forages or concentrate feed provided all the nutrients in the required amount hence would be inadequate as sole diet for rabbits. Animal performance is dependent on the quality of nutrition and it would therefore be expected that rabbits in the area, especially those fed mainly on forages, will perform poorly. Animals on such feeds will take longer to attain slaughter weight. Assessment of performance revealed that an average of 18 weeks was needed to produce a fryer rabbit weighing 2000g. Where forage was supplemented, it is expected that the higher nutrient density concentrate feeds would correct the deficiency of the forage in terms of protein and energy.

However, limited amounts of concentrate feeds were availed to rabbits by most farmers which would sabotage supply of nutrients to rabbits to support optimum growth resulting in prolonged time to target weight. A proper supplementation at a recommended level should be carried out in order to balance the crude fiber and crude protein among other nutrients for the optimal rabbit performance in various rabbit farms in the study area. The longer the animal takes to slaughter weight the lower the lifetime feed utilization efficiency due to increased amounts of nutrients used for maintenance rather than for growth. The assessment of cost of production showed that farmers produce their rabbits at an average cost of KES 280.2/Kg weight gain. The survey results showed that the market prices for slaughter rabbits averaged KES 350/Kg liveweight in the current market. This leaves the farmers with a small profit.

5.2 General conclusions

1. Majority of farmers in Kiambu County keep rabbits for food security and income generation. Rabbit farmers depend on locally accessible materials for feeding and housing construction. The prevalent breeds are New Zealand and Californian whites and their crosses. Constraints to rabbit farming include high cost and poor quality of rabbit feeds, occurrence of rabbit diseases coupled with absence of rabbit specific drugs and rabbit health experts, and lack of markets for rabbits and rabbit products.
2. Rabbits in the study farms received limited and/or low quality feed which did not sufficiently provide adequate nutrients resulting in their poor performance. Rabbits showed low growth rate, poor feed conversion and attained target weight at a delayed age.

3. Commercial rabbit fryer production in Kiambu county is unprofitable and uncompetitive. In addition, farmers would have to wait for a relatively longer period (mean, 18 weeks) to have their rabbits attain slaughter/market weight of 2kg.

5.3 Recommendation

1. To reduce the occurrence of poor feeding of rabbits, farmers should be educated on the benefits of feeding balanced rations to rabbits. They should be trained on how to carry out proper supplementation at a recommended level in order to balance the crude fiber and crude protein among other nutrients for the optimal rabbit performance in various rabbit farms in the study area.
2. Better quality feeds and feeding practices would improve performance of rabbits as well as profitability of the enterprise.

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APPENDICES

APPENDIX I: QUESTIONNAIRE

Date of interview: …………………………………..... Time started: ……………..

Interviewer's name: …..……………………………………… Questionnaire No: ……………

Household GPS: Latitude :……………………..(N/S) Longitude…………………… (E/W)

A. HOUSEHOLD IDENTIFICATION	
A1.	Household head: Name: | ID No (optional): Mobile No: | Gender: [ ]Male [ ]Female
A2.	Survey respondent details (if not the household head) Name: | Mobile No: | Gender: [ ]Male [ ]Female Relationship to the household head: [ ] Spouse [ ] Son/Daughter [ ] Worker [ ] Others (specify)
A3.	Location of the farm: Sub-County: | Ward: | Village:
B. HOUSEHOLD HEAD ATTRIBUTES	
B1.	What is the age of the household head? [ ] < 20 years [ ] 21-30 years [ ] 31- 45 years [ ] Over 45 years
B2.	What is the highest level of education attained by the household head? [ ]No formal education [ ]Primary [ ]Secondary [ ]Tertiary/University
B3.	What is the main occupation of the household head?

	[ ]Farming [ ]Farm employment(elsewhere) [ ]Non-farm employment [ ]Other (specify)
C. PRODUCTION ON THE FARM	
C1.	For how long have you been keeping rabbits on your farm? [ ] < 3years [ ] 3-5 years [ ] 5-10 year [ ] > 10 years
C2.	What is the main objective of keeping rabbits? [ ]Home consumption [ ] For sale [ ] For wool [ ] a hobby [ ]Other (Specify)
C3.	What other benefits do you derive from keeping rabbits? [ ]Manure [ ] Sales of pelts [ ]Sales of urine [ ]Others(specify)
C4.	Have you sold any rabbit(s) for the past 12 months? [ ]YES [ ]NO
C5.	If YES, indicate, the main rabbit outlet [ ]Farm gate [ ] Local market [ ] Hotel [ ] Collection centre [ ]Institution(s) [ ]Other (specify)
C6.	What criteria do you use to determine the price at which you sell your rabbits?? [ ] Body weight [ ] Age [ ] Sex [ ] Breed [ ] Purpose [ ] Other (specify)
C7.	At what price would you sell your live rabbits today (in Kenya shillings)? Weaner _____________ Doe ______________________ Buck _______________
C8.	Did you purchase any rabbit/s during the past 12 months? [ ]YES [ ]NO
C9.	If YES, indicate the category of rabbits purchased [ ]Weaners [ ] Bucks [ ] Does
C10.	Indicate the sources of the rabbits purchased [ ]Other farmers [ ]Government farms [ ]Research institutions [ ]Others (specify)

<table>
<tr><td>C11.</td><td>What were the prices for various categories of rabbits purchased (Kenya shillings)?

Weaner ____________ Doe_____________ Buck _____________</td></tr>
<tr><td>C12.</td><td>Indicate the purpose(s) for which rabbits were purchased for

[ ]slaughter [ ]Breeding [ ]Other(specify)</td></tr>
<tr><td>C13</td><td>Did you slaughter any of your rabbits in the past 12 months?

[ ]YES [ ]NO</td></tr>
<tr><td>C14.</td><td>If YES, indicate the reason for slaughter

[ ] For home consumption [ ] For sale [ ] Others (Specify)</td></tr>
<tr><td>C15.</td><td>Do you keep records for your rabbit enterprise?

[ ]YES [ ]NO</td></tr>
<tr><td>C16.</td><td>If YES,

i. Which records do you keep?

ii. What data on growth and reproductive performance of rabbits do you keep?</td></tr>
<tr><td>C17.</td><td>Do you belong to any rabbit producer association?

[ ]YES [ ]NO</td></tr>
<tr><td>C18.</td><td>If YES,

i. What is the name of the association?

ii. What benefits have you derived from membership to such association?</td></tr>
<tr><td colspan="2">D. RABBIT BREEDS AND NUMBERS</td></tr>
<tr><td>D1.</td><td>What are the current number of rabbits on your farm based on age and sex as follows:

<table>
<tr><td>Bucks >4 mo</td><td>Does> 4 mo</td><td>Immature 1-4 mo</td><td>Kits < 1mo</td><td>Total</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>D2.</td><td>Indicate the number of breed/s of rabbits present in your farm.</td></tr>
</table>

Breed	Current No.	Breed	Current No.
New Zealand White		Flemish Giant	
Californian White		Chinchilla	
French Lopped		Angora	
Kenyan White		Cross breed (specify)	
Dutch		Others (specify)	

D3.	Of the breeds mentioned above (D2), which is your most preferred breed? (asked only if more than one breed is indicated)
D4.	Why do you prefer the above breed? [ ]Good mothering ability [ ]High carcass weight at slaughter [ ]Many offspring per litter [ ]Best as a pet [ ]Preferred by other farmers [ ]High disease resistance [ ]High live market price [ ]Most available breed [ ]Best for fur [ ]Other (specify)
D5.	What is the source of breeding stock on your farm? [ ]Own stock [ ]Other farmers [ ]Government farms [ ]Research institutions [ ]Other(specify)
D6.	At what age do you wean the kits (in weeks)?
E. HOUSING STRUCTURES AND EQUIPMENT	
E1.	What is the type of housing? (Observational) [ ]Loose group housing [ ]Caged outdoor [ ]Caged indoor
E2.	If outdoor/indoor caged, indicate whether single or multi-tiered cages are used? [ ] Single-tiered cages [ ] Multi-tiered cages
E3.	If multiple tiers are used, indicate the number of tiers [ ] 2 [ ] 3 [ ] 4 [ ] 5 and above
E4.	Are the rabbits housed together with other animals? [ ]YES [ ]NO

E5.	If YES, indicate the animals housed together with rabbits [ ] Cattle [ ] Sheep/Goats [ ] Pigs [ ] Poultry [ ] Others(specify)
E6.	What factors did you consider when siting rabbit house? [ ]Slope [ ]Temperature [ ]Rainfall direction [ ]Wind direction [ ] Other (specify)
E7.	What materials are used in constructing the following parts of rabbit house? i. **Roof:** [ ] Iron sheet [ ] Polythene bag [ ] Wire gauze [ ] Other(specify) ii. **Floor:** [ ] Earthen [ ] Wood [ ] Concrete [ ] Wire mesh [ ] Other(specify) iii. **Walls:** [ ]Earthen [ ]Wood [ ]stone [ ]Wire gauze[ ]Other(specify)
E8.	What materials are used in the rabbit house for the following? i. **Bedding:** [ ]Wood [ ]Straw [ ]Wood shaving [ ]Grass [ ]Other(specify) ii. **Feeding troughs:** [ ]Metal [ ]Clay [ ]Plastic [ ] Other(specify) iii. **Drinking troughs**: [ ]Metal [ ] Clay [ ]Plastic [ ] Other(specify)
E9.	Do you clean the rabbit hutches? [ ]YES [ ]NO
E10.	If YES, how often do you clean? [ ]Once a day [ ] 3 times a week [ ] 5 times a week [ ] Once a week [ ]Other (specify)
E11.	(Observational) On a scale of 1 to 3 (1=Good/Clean, 2=Fair, 3=Poor/dirty) rate the following indicators of sanitation in the rabbit house. Ventilation: | Lighting: | Fur condition: | Bedding: | Odour:
E12.	Measure the length and width of the rabbit cage? Length ____________________cm Width _______________________cm
F: FEEDS AND FEEDING	

<table>
<tr><td>F1.</td><td>What do you mainly use to feed your rabbits?

[ ]Forages only [ ] Concentrate only [ ] Forage and concentrate [ ] Other (specify)</td></tr>
<tr><td>F2.</td><td>If you use forages, name the forages (common/local names) commonly used and indicate their sources {1=on-farm 2=collect off-farm 3=purchase off-farm 4=other(sp)}
<table><tr><th>Fodder name</th><th>Sources</th></tr><tr><td>1.</td><td></td></tr><tr><td>2.</td><td></td></tr><tr><td>3.</td><td></td></tr><tr><td>4.</td><td></td></tr><tr><td>5.</td><td></td></tr></table></td></tr>
<tr><td>F3.</td><td>Of the above mentioned forages, which one is the most preferred for your rabbits?</td></tr>
<tr><td>F4.</td><td>Why is such forage preferred?

[ ]Readily available [ ]Rabbits like them [ ]Highly nutritious [ ]High biomass [ ] drought tolerant [ ] other (specify)</td></tr>
<tr><td>F5.</td><td>Do you wilt forages prior to feeding?

[ ]YES [ ]NO</td></tr>
<tr><td>F6.</td><td>If YES, Why?

[ ] avoid diarrhea [ ] avoid bloat [ ] increase intake [ ] done by other farmers [ ] advised by extension officer(s) [ ] other(specify)</td></tr>
<tr><td>F7.</td><td>If NO, why?

[ ]Rabbit doesn’t like it dry [ ]Fresh forages are source of water [ ]No time [ ]Not aware of the need to wilt [ ]Other(specify)</td></tr>
<tr><td>F8.</td><td>Are there times in the year when forage availability is a constraint?

[ ] YES [ ] NO</td></tr>
<tr><td>F9.</td><td>If YES, during which season of the year is it constrained?</td></tr>
</table>

	[ ]dry [ ] wet [ ]both
F10.	Do you conserve forages for your rabbits? [ ] YES [ ] NO
F11	If YES, in what form do you conserve? [ ] Harvested hay [ ] Standing hay [ ] Other (Specify)
F12.	In your experience, are there forages that are harmful to rabbits? [ ]YES [ ]NO
F13.	If YES, i. Name any forages that are harmful to rabbits ii. During which season do such harmful forages occur? [ ] Dry season [ ] Rainy season [ ] Both dry and rainy seasons iii. How do these harmful forages affect the rabbits if fed? [ ] Stomach upset [ ] Kill rabbits [ ] Abortion [ ] Other(specify)
F14.	Do you use purchased or homemade concentrate feeds? (those who use concentrate feeds) [ ] purchased concentrate [ ] homemade concentrate
F15.	How much concentrate feed do you give each of the following rabbits per day in grams? Weaner______ fattener_________ Pregnant doe______ Gestating doe______ Buck_____
F16.	Where do you source your commercial feeds? [ ]Manufacturing company [ ]Agrovet []Local suppliers [ ] Producer association [ ]Other (specify)
F17.	While purchasing concentrate feeds, Do you choose between mash and pellets? [ ]YES [ ]NO

F18	If YES, which one do you prefer? [ ] Mash [ ] Pellets
F19.	What is the main reason for your preference?
F20.	What is the cost of concentrate per kg in Kenya shillings?
F21.	What are the constraints to rabbit feeding? [ ]High cost of feed [ ]Scarcity of feed [ ]Poor quality of available feed [ ]Other (specify)
F22.	Do the rabbits have *ad-libitum* access to water? [ ]YES [ ]NO
F23.	If NO, how often do you water your rabbits every day? [ ] Once [ ] Twice [ ] Not at all [ ] Other(specify)
G. DISEASES AND HEALTH MANAGEMENT	
G1.	Are rabbit diseases a problem on your farm? [ ] YES [ ]NO
G2.	If YES, list in the table below the most importance diseases/symptoms that occur frequently among your rabbits and indicate age affected (1= kits 2=weaners 3=adult) and season commonly occurring (1=wet season 2=dry season 3=both dry and wet season). **Disease/symptom** **Age affected** **Season** 1.________________________ ____________ ________ 2. ________________________ ____________ ________ 3 ________________________ ____________ ________ 4 ________________________ ____________ ________
G3.	In your assessment, which of the diseases/symptoms listed above (G2) is the most serious?

G4.	What do you do when there is a disease problem among your rabbits? [ ]Self-treat [ ]Call veterinarian [ ]Slaughter sick rabbits [ ]Do nothing [ ]Other (specify)
G5.	What determines your course of action? [ ] Type of disease [ ] Severity of the disease [ ] No. affected [ ] Age of the rabbits affected [ ]other(specify)
G6.	Have you practiced disease treatment in the last 6 months? [ ]YES [ ]NO
G7.	If YES, What methods of disease treatment did you use? [ ] Modern [ ] Indigenous [ ] Both
G8.	Indicate the common types of indigenous treatments used if any
G9.	Where did you get information on the appropriate drugs to administer for the diseases/symptoms? [ ]Fellow farmers [ ] Media [ ] Veterinarians [ ] Livestock extension officers [ ]NGO representatives [ ] Field days [ ] Internet [ ] Others (specify)
G10.	Which disease control/preventive measures do you practice? [ ] Deworming [ ] Vaccination [ ] Spraying [ ] Use of feed additives [ ] Good hygiene practices [ ] Isolation of sick and newly acquired animals [ ]other(specify)
G6.	Respond to the following set of questions with either YES or NO. i. Are veterinary services readily available? [ ] YES [ ]NO ii. Are drugs to treat rabbit diseases readily available? [ ] YES [ ] NO iii. Is information to farmers on rabbit diseases readily available? [ ] YES [ ] NO iv. Is the cost of drugs and/or veterinary services too high? [ ] YES [ ] NO

H. CONSTRAINTS TO RABBIT PRODUCTION	
H1.	From your experience, state reasons why rabbit production is still low in Kenya?
H2.	What in your own opinion needs to be done to increase rabbit production in Kenya?

THANK YOU!

Time ended interview:____