EFFECT OF WEANING AGE, DIET AND BREED ON PRODUCTION, CARCASS QUALITY AND PROFITABILITY OF RABBIT REARING ON SMALLHOLDER FARMS IN KENYA

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A thesis submitted to the Board of Graduate Studies in partial fulfillment for the requirements of the Master of Science Degree in Livestock Production Systems of Egerton University

Egerton University

August, 2016

DECLARATION AND RECCOMENDATION

DECLARATION

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

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RECOMMENDATION

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

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ABSTRACT

Commercial rabbit production in Kenya is characterized by a long interval of 8 to 12 weeks between kindling and next mating, which yields fewer rabbits for sale to earn income. Changing weaning age regimes can influence the technical and economic results. This study aimed at informing interventions for weaning management by testing associations that weaning age has with feeding practices, market weight, carcass quality and consumer preferences of rabbit meat and profitability. Data on production was from farm records of 100 rabbit farmers randomly selected among members of the Rabbit Breeders Association of Kenya (RABAK) in Counties prominent in commercial rabbit production. Carcass quality and consumer preferences were evaluated using 36 rabbits in a 2 x 2 x 3 factorial design representing weaning ages (4 and 8 weeks), diets (mixed and pellets) and breeds (California White, New Zealand White and Chinchilla) respectively. General linear model and simulation modeling were applied to assess the effects of weaning age, VAT charges and slaughter price. Compared to 8 weeks weaning, farmers weaning at 4 weeks offered more dry matter, whether pellets (166 vs 113 grams) or mixed diets (120 vs 66 grams) and attained higher market weights with California (2.9 vs 2.3 Kg) and with New Zealand white (2.8 vs 1.9 Kg) compared to Chinchilla which was heavier with 8 weeks weaning age (2.7 Kg). Weaning age had effect ($p<0.001$) on the hot carcass weight, all first and second retail cuts but was insignificant ($p>0.05$) on consumer preferences. The interaction effects between weaning age and the breed had effects ($p<0.05$) on consumer preferences which was higher ($p<0.001$) for the hind legs. Three-way interaction effects of weaning age, breed and feeding diets had effect ($p<0.05$) on hot carcass weight, hot and chilled loin weights ($p<0.05$). Compared to weaning at 8 weeks, weaning at 4 weeks was more profitable on mixed diet by 125.04% (KES 53639 vs 23835) and on pellet diet by 131.71% more (KES 106776 vs 46082) while reducing weaning age from 8 to 4 weeks improved profit by 9.5% on mixed diets and by 13.8% on pellets. Inclusion of 16% VAT on pellets reduced profit by 6% when weaning at 4 weeks age and by 8% when weaning at 8 weeks. For rabbits sold at KES 518, profit improved by 35% when sale priced increased to 700 but decreased by 32% if sale priced declined to KES 350 for 4 or 8 weeks weaning regime on pellets. It is concluded that weaning at 4 weeks or 8 weeks of age produce heavier, better quality carcass and more profits if rabbits are fed on quality commercial pellets.

Key words: Rabbits, Smallholders, Weaning age, Carcass quality, Consumer preference, Gross margins, Sensitivity analysis.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
AoFG	Amount of feed given
BR	Breed
CH	Chinchilla
CL	California
COMPEL	Commercial pellets
DM	Dry Matter
DMG	Dry matter given
FAO	Food and Agriculture Organization of the United Nations
FFD	Feeding frequencies in a day
First retail cuts	Hind legs, loin and fore legs
FRWF	Feeding regime for weaning and fattening
GLM	General Linear Model
HPW	Hind part weight
LW	Loin weight
MoALF	Ministry of Agriculture, Livestock and Fisheries
NZW	New Zealand White
PROC	Procedure
RABAK	Rabbit Breeders Association of Kenya
Second retail cuts	Thoracic part
STELLA	Systems Thinking Experimental Learning with Animation
WA	Weaning age

CHAPTER ONE
INTRODUCTION

1.1 Background Information

The per capita meat consumption in developing countries including Kenya is below 10 Kg/year, compared with an average of 80 Kg/year in developed countries (FAO, 2013). With the rapid urbanization and rising incomes, demand for meat of high quality is projected to continue surging upwards. This creates market opportunities for meat producers but smallholder livestock keepers may miss out because of inadequate uptake of market sensitive management strategies. An example of this is rabbit white meat which is attractive to more health conscious consumers who place specific demands on quality attributes. Rabbit producers have to invest in adjusting management interventions to produce for such markets and research has to generate knowledge for these producers to apply in improving housing systems, management, nutrition and reproduction, breeding and genetics and disease management strategies(Lukefahr and Cheeke, 1990; Serem *et al*., 2013). The rabbit industry in many developing countries is still weak for many reasons including inadequate knowledge of consumer preference and profit margins associated with different weaning age regimes (Mailu *et al*., 2012).

Among farmers keeping rabbits in Kenya more than half (53%) have stated in a survey that their objective is to earn income, while more than a third (37%) stated home consumption and a few (10%) stated keeping rabbits as pets (Mailu *et al*., 2013). These authors estimated the average number of litters/doe/year between 4 and 5, which is associated with long kindling interval ranging from 4 to 12 weeks period of parturition to mating (Borter and Mwanza, 2011). Commercial rabbit production has potential to attain 8.7 litters/doe/year (Lukefahr and Cheeke, 1990).

For sustainable and profitable rabbit production, smallholder commercial rabbit producers have to invest more in improving management practices, especially to manipulate weaning and feeding practices because these account for 60 to 70% of the total production costs (Maertens, 2009). They can therefore benefit from knowledge of the association between weaning age and technical and economic performance.

Several studies have reported the influence of weaning age on some production performance indicators including; daily weight gain, daily feed intake, feed conversion index, mortality rate,

carcass quality traits and consumer preferences. For instance, weaning weight or age has influence on production performance and nutrient digestibility of broiler rabbits (Zita *et al*., 2007), on slaughter and physiochemical traits (Marongiu *et al*., 2008; Bivolarski*et al*., 2011) and on growth and slaughter characteristics of Grass cutters (*Thryonomys swinderianus*) raised under intensive management in the Humid Tropics (Henry *et al*., 2012), weaning age (days 21, 28 and 35) can also influence the caecal micro flora and fermentation in rabbits (Kovacs *et al*., 2006). However, these studies did not evaluate the effect of weaning age and feeding practices on market weight, carcass quality and profitability. Moreover, economics on rabbit production has been measured considering the management aspects without including influence of weaning age in association to profit (Cartuche *et al*., 2014). Therefore, this study wants to close the knowledge gap about association of weaning age with feeding practices, market weight, carcass quality, consumer's preferences and profitability on smallholder rabbit farms in Kenya.

1.2 Statement of the Problem

More than half of rabbit keeping farmers in Kenya want to earn some income from rabbit sales but their weaning management practice is characterized by a long interval of 8 to 12 weeks between kindling and next mating. With this weaning practice, the average number of litters/doe/year (3 to 4) is about half below the potential (8) attainable in commercial rabbit production systems, consequently resulting in fewer rabbits produced for sale to earn income. Changing weaning age regime will therefore likely influence the technical and economic results, which can be determined from feeding practices, market weight, carcass quality, consumer preferences as well as economic returns in rabbit production.

1.3 Objectives

The overall objective was to evaluate the determinants of carcass quality and profitability of smallholder rabbit production in Kenya for food and income security.

The specific objectives were as follow:

i. To determine the influence of weaning age on market weight
ii. To determine the relationship between weaning age and carcass quality
iii. To determine the association between weaning age and consumer preferences
iv. To determine the effect of weaning age on profitability of rabbit rearing

1.4 Hypotheses

The following null (H0) hypotheses were postulated for this study:

i. The dry matter offered do not significantly vary with the weaning age
ii. Market weight is not significantly influenced by weaning age
iii. There is no relationship between carcass quality and weaning age
iv. Consumer preferences are not significantly associated with weaning age
v. Age at weaning does not significantly affect profit margins of rabbit farming

1.5 Justification

Commercial rabbit production is a fast growing livestock enterprise in Kenya (Borter and Mwanza, 2011; Mailu *et al*., 2012). Since farmers practice different weaning regimes, knowledge of the technical and economic outcomes can inform targeted management interventions to improve on the litter/doe/year with high quality carcass that are more preferred by consumers in order to earn more cash. The anticipated research outputs were for commercial rabbit producers to apply optimum weaning practices for maximization of productivity and profit, translating into contribution to food security and wealth creation.

CHAPTER TWO
LITERATURE REVIEW

2.1 Rabbit Production Systems in Kenya

In Kenya and majority of developing counties, low-input rabbit production systems is the most popular, characterized by low investment requirements and low economic risks, as well as their contributions to family nutrition, income generation and gender empowerment (Oseni, 2012 ; Oseni and Lukefahr, 2014). The majority of rabbit farmers in Kenya are characterized to be small scale producers with a proportion of 84.8 % distributed in four regions Rift valley (Nakuru county), central (Kiambu and Nyeri Counties), Eastern (Meru County) and coastal (Taita Taveta County) region, and only 15.2% of rabbit farmers are characterized to be medium and large scale in the same regions (Serem *et al*., 2013). Farmers in Kenya they pointed in a survey many reasons for rabbit production and choice of breed; carcass weight, mothering ability, litter size and price (Mailu *et al*., 2013). According to the same author 87% of farmers in Kenya indicated that they keep their rabbits caged and 13 % they keep non-caged.

2.2 Weaning Age in Rabbit Production

Weaning age in rabbit production reported by some authors presents some differences with the range between 4 to 8 weeks of age of the bunnies. Bunnies should be weaned by 4 to 8 weeks, where they should be moved to another cage to give the mother a rest and some producers breed the female when the bunnies are 6 weeks old and wean the bunnies at 8 weeks (Niles, 2010); At about 2-3 weeks of age the litter start coming out of the nestling box depending on the size of the box, amount of milk in the mother, and hygiene of the box, at this stage the young ones are not wholly dependent on the mother's milk they start feeding on what the mother is feeding on, they can be weaned later but should be ready by 6-8 weeks (MoALF, 2013). In experiment "Measuring fluctuating asymmetry in fattening rabbits: A valid indicator of performance and housing quality" done by (Tuyttens *et al*., 2005) considered a weaning age of 4 weeks of age. On evaluation of parity order and reproductive management on the efficiency of rabbit productive systems done by (Rebollar *et al*., 2009) they used two weaning age one at 25 days and another at 35 days. Bunnies can be weaned at about 4-5 weeks of age. The minimum average weaning weight of kittens is about 600g (Industries, 2002).

2.2.1 Effect of Weaning Age on Annual Doe Productivity Indices

The doe annual productivity is influenced by management level at the farm and is an important tool to measure the overall productivity level of a farm (Finzi *et al.,* 2012) as well as the profitability.

2.2.2 Rabbit Performance by Weaning Age

Early weaning between 21-25 days can be a good practice for productive aspects however there is digestive disorders during fattening due to early adaptation to solid feed (Pascual, 2001). Rabbits weaned at 25 and 28 days of age they present higher digestibility of dry matter than those weaned at 28 and 31 days, the feed consumption, average daily weight gain and carcass characteristics did not differ (Tůmová *et al.*, 2006; Zita *et al*., 2007). Rabbits weaned at 28 days present high live weight at 83 days of age than those weaned at 63 days, they also present high daily feed intake, better feed conversion index and daily weigh gain from 64-83 days of age (Marongiu *et al*., 2008).

2.3 Feeding Practices in Rabbits

Feed is one of the most expensive inputs in rabbit rearing; the health and vigor of the animals depend on how well they are fed (MoALF, 2013). In rabbit meat production, as in other livestock, feeding costs represent the largest part of the production costs, depending of mainly the investment costs, amounting to 60-70% of the total production cost (Maertens, 2009). The pellets must be in such a way to fulfill the protein requirements varying by age and physiological state, for growth (bunnies and market animals) 16 %, pregnant 15%, lactating 17% and maintenance 14% (Gidenne *et al*., 2010).

Feeding practices in rabbits can be done to minimize the costs and maximize the performance of production and meat quality. When animals are submitted to a feed restriction practice they present high dressing percentage than when they feed *ad libitum* (Tůmová et al., 2006). In order to increase carcass quality, different feeding practices can be performed to reduce feed conversion ratio (Maertens, 2009).

2.3.1 Amount of Feed Consumed and Feeding Regimes per Weaning age

Feed consumption is likely to vary with weaning age, in some studies weaning early has shown high feed consumption but in others the differences were not significant. Rabbits weaned at 28 days consumed much feed from 64 to 83 days of age than those weaned at 63 days with an average difference of 24.1 g per day (Marongiu *et al*., 2008). Rabbits weaned at 25, 28 and 35 days of age they did not present differences on feed consumption from 35 to 84 days of age (Tůmová, *et al.*, 2006; Zita *et al*., 2007).

Feeding regimes like feed restriction was studied and the conclusion was that it not influence the production indices so it could be exploited in the feeding regimen of rabbits, especially in periods of scarcity of commercial feed and forages for rabbit feeding (Yakubu *et al.*, 2007). Was also concluded that the feeding regimes has an influence on dressing percentage and the loin (Tůmová *et al*., 2006) in this way feeding regime is of important role on rabbit production and it also has an effect on market weight (Romero *et al*., 2010).

2.3.2 Dry Matter Content of Selected Rabbit Feedstuffs

The nutrient composition of feedstuffs for rabbit are summarized in Table 1 from several authors. In overall, the woody leguminous fodders have the highest dry matter as well as energy and protein while grasses have the lowest of these constituents. These values reflect those reported for dry matter content of Cabbage waste (10.1% to 12.3%) by Babalola and Akinsoyinu (2011) Kikuyu grass (*Pennisetum clandestinum*) at (18.3%) reported by (Rajadevan and Schramm, 1989); carrot (*Daucus carota*) (19.9%) wilted sweet potato vines the (14.5%) reported by (Garza *et al*., 2012, Wakili *et al*.,2015) and for wilted kale (*Brassica oleracea*) (18.62%) reported by (Emebu and Anyika, 2011) or B*idens pilosa (* 19.52%) reported by (Adedapo *et al*., 2011). The commercial pellets are higher in dry matter at 88.73% (Dougnon., 2012) while grasses are lower including *Galinsoga parviflora* with 10.17% (Malote, 2012), *panicum maximum* has 15-25% *Pennisetum purpureum* 20-25%, *Amaranthus spinosus*15-17%, *Commelina benghalensis* 19-20%, *Zea mays* (leaves) 15-20% (Lebas, 2004), *Zea mays* (grain) 87.7% (Bhuiayan *et al*., 2012), rhodes grass (*Chloris Gayana*) hay 96.6% (Kanyinji *et al.*, 2014) Lucerne (*Medicago sativa)* 22% (Djordjević*et al*., 2003)

Some of the forages given to rabbits in tropical areas have been evaluated for dry matter content and the composition is as shown below.

Table 1: Dry Matter (%) content of tropical forages fed to rabbits

Forage species	Dry matter	Crude energy	Crude protein	ADF	NDF
Woody Legumes:					
Albizia falcata	74.7	70.3	73.4	58.0	63.1
Calliandra calothyrus	49.5	51.4	49.8	12.5	25.6
Leucaena leucocephala	74.2	69.5	75.9	37.8	54.5
Sesbania formosa	69.5	65.8	64.2	30.9	46.5
Sesbania sesban	79.3	77.5	83.9	62.3	62.6
Non-Woody Legumes:					
Cassia rotundifolia	41.6	40.1	57.5	22.7	6.8
Centrosema pubescens	43.0	54.2	72.9	29.3	32.5
Desmodium heterophyllum	28.1	48.7	52.1	13.4	13.6
Neonatonia wrightii	49.4	39.8	56.6	36.7	38.7
Pueraria phaseoloides	46.4	44.3	62.6	21.1	27.4
Stylosanthes guianensis	43.4	55.1	53.9	23.3	18.5
Grasses:					
Brachiaria brizantha	16.7	24.5	17.8	4.2	11.3
Chloris gayana	38.9	36.3	32.4	33.2	41.9
Panicum maximum	15.7	12.6	5.6	10.3	12.5
Paspalum plicatulum	35.0	33.7	21.2	25.7	29.6
Pennisetum purpureum	46.3	45.2	64.7	34.6	42.8
Setaria splendida	15.0	9.4	6.2	16.1	9.0

Source: Raharjo *et al.*, 1986

2.4 Effect of Weaning Age on Carcass Quality

Carcass quality has an important role in the economics of rabbit production and consumer's health specifically, when the purpose of production is to provide to the market slaughtered animals. Whereby weaning age affects the dressing percentage, the proportion of single parts from the carcass, the proportion of heart and lungs (Zita *et al*., 2007) and fat (Bivolarski *et al*., 2011). Several studies assessed the factors contributing to carcass characteristics and quality. Factors were: feed restriction (Yakubu *et al*., 2007); the type and composition of feed (Chisowa *et al*., 2013; Liu *et al*., 2012); transport duration and gender (Trocino *et al.,* 2003); the breed (Bianospino *et al*., 2006; Chodová *et al*., 2014); housing system (Metzger, 2003; Metzger *et al*., 2010; Pinheiro *et al*, 2011) and Chodová *et al*., 2014; slaughter bleeding (Omojola, 2007). From all these studies, fat content, dressing out percentage, leanness and other factors were considered.

2.5 Evaluation of Consumer Preferences

In every product development the consumer's satisfaction plays an important role to the success of it, in rabbit production also the consumer's preferences have an important role in profitability of the rabbit enterprise. In previous studies done on consumer's preferences sensory evaluation was employed and; it consisted of qualitative, quantitative, or hedonic quality measurement where Hedonic scale for appearance, taste, juiciness, chewiness, texture, aroma and overall acceptability is measured (Dalle Zotte, 2002; Larzul and Allain, 2004; Akinnusi *et al.,* 2007 Arino *et al.,* 2015;).

2.6 Profitability of Rabbit Production

There are many factors that affect the rabbit production and some studies were done to assess the contribution of these factors to profitability. Some of these factors included; the breed kept, integration with other livestock, the objective of the enterprise, the colony size, the feed and feeding patterns, housing system and marketing of rabbit (Baruwa, 2014). The breed aspect on profitability was considered (Olagunju and Sanusi, 2010). The improvement in production technology was also pointed as factor of profitability on rabbit production (Mokoro *et al.*, 2015). Therefore in all those studies the weaning age was not considered.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Data Source and Sampling Procedure

The data for testing the hypothesis of this study was collected from smallholder rabbit farms and slaughter houses in Nakuru and Kiambu Counties where commercial rabbit production is prominent with Rabbit Breeders Association of Kenya (RABAK) actively operating. In Nakuru the study farms were in three sub-counties: Njoro with 150 farms, Molo with 269 farms and Gilgil with 180 farms, while in Kiambu County farms were selected from Thika Sub County with a total number of 100 rabbit farmers which are registered members of RABAK.

The required sample of farms was estimated from Kish (1965) formula:

$$n = \left\lceil 1.96 * \frac{SD}{ME} \right\rceil^2$$

Where n is the minimum sample size; SD is the Standard deviation of weaning age; ME is Margin of error and 1.96 is the confidence interval at 95% level of significance. According to the preliminary survey done on the smallholder rabbit farms the standard deviation of weaning age is 3.75, this value was substituted in the above formula with a marginal error of unity, corresponding to unity (1) to the ability to identify 1 week change in the weaning age as being significant at the 5% with 80% power. The computed sample size (84) was inflated by 20% to account for possible non responses and the number distributed proportionately to the number of registered farmers (Table 2).

The sample farms were selected through stratified random sampling procedure designed to account for heterogeneity in management practices (feeding, weaning and breeds).

For carcass quality and consumer preferences, 36 rabbits were bought from RABAK farmers in Nakuru and Thika stratified by weaning age (4 and 8 weeks), diets (mixed pellet and roughages, pellets only) and breeds (California white, New Zealand white, Chinchilla) corresponding to 2 x 2 x 3 factorial design in a completely randomized design.

Table 2: Sample Size Estimate

County	Sub-County	Number of rabbit farms	Feeding diets	Sample
Kiambu	Thika	100	Mixed diets	7
			Commercial pellets	7
	Molo	269	Mixed diets	19
			Commercial pellets	19
Nakuru	Gilgil	180	Mixed diets	13
			Commercial pellets	13
	Njoro	150	Mixed diets	11
			Commercial pellets	11
Total		699		100

3.2 Data Collection

The data was collected from the farm records, slaughter house records, RABAK farm records and from experiments on consumer preference rating.

Farm records were on production performance, inputs use and management practices related to weaning age, feeding, breeding and health. Measurements were weighing of feeds offered (Plate 1) which were fresh (Plate 1C and Table 4), dry forage (Plate 1D and Table 4) or commercial pellets (Plate 1B) to compute the dry matter using published composition. Flock inventory and diagnosis captured sales, purchases and mortalities.

Plate 1: Direct measurement of feed (A) in category of commercial pellets (B), fresh (C) and dry forage (D)

Plate 2: Breeds; New Zealand White (A), Californian (B) and Chinchilla (C)

Carcass quality on dressing percentage and weight of loin, hind legs and thoracic cage were from weights measured at slaughter house on individual animals identified by their weaning age, breed (Plate 2) and feeding practices.

Carcass quality and consumer preferences were assessed in an experimental design of complete randomized design with 2 x 2 x 3 factorial structure for weaning age (4 and 8 weeks), feeding practices (mixed and commercial pellets with Rhodes grass supplementation) and breeds (NZW, CL and CH), details of which are presented in Table 3, appendix II and III. Three rabbits of each breed were obtained for the experiment.

Rabbits were fasted for 10 hours before slaughtering, with free access to fresh and clean water. Slaughter and dressing methods followed normal commercial procedures (Cavani and Petracci, 2004). Live weight was recorded before slaughtering (Plate 3A) and hot carcass weight (Plate 3B) chilled at 4^{o}C (Plate 3D) for 24 hours (Blasco and Ouhayoun, 1993), computed from the hot carcass weight were the dressing out percentage and weights of first retail cuts (loin and hind legs) and second retail cuts (thoracic cage), illustrate in Figures 4.

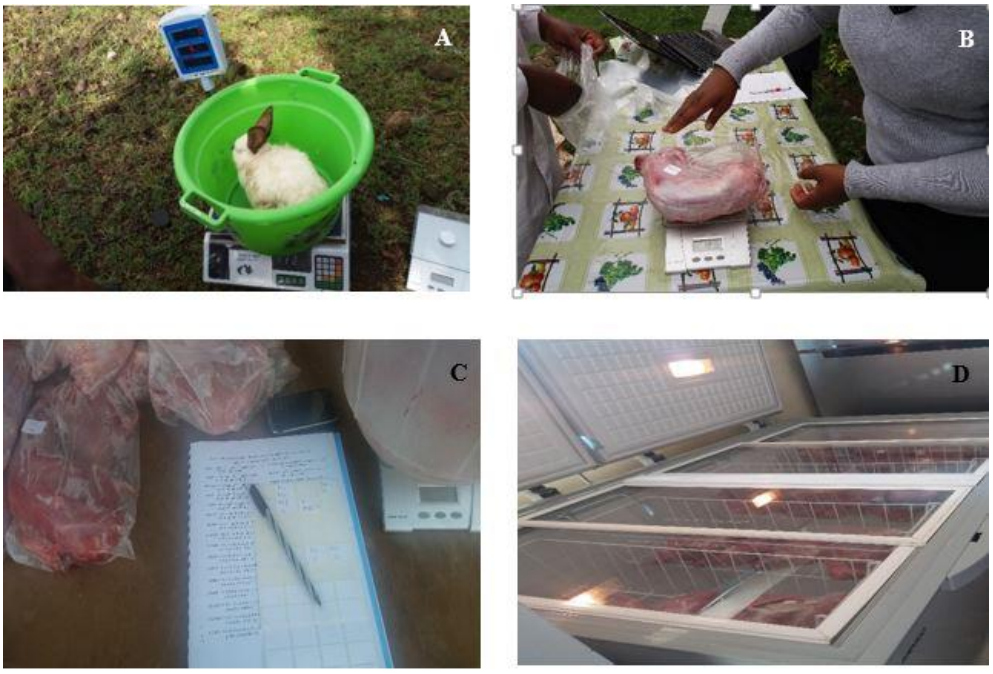

Plate 3: Carcass measurement; live weight (A) and carcass weighing (B), Carcass identification (C) and carcass chilling (D)

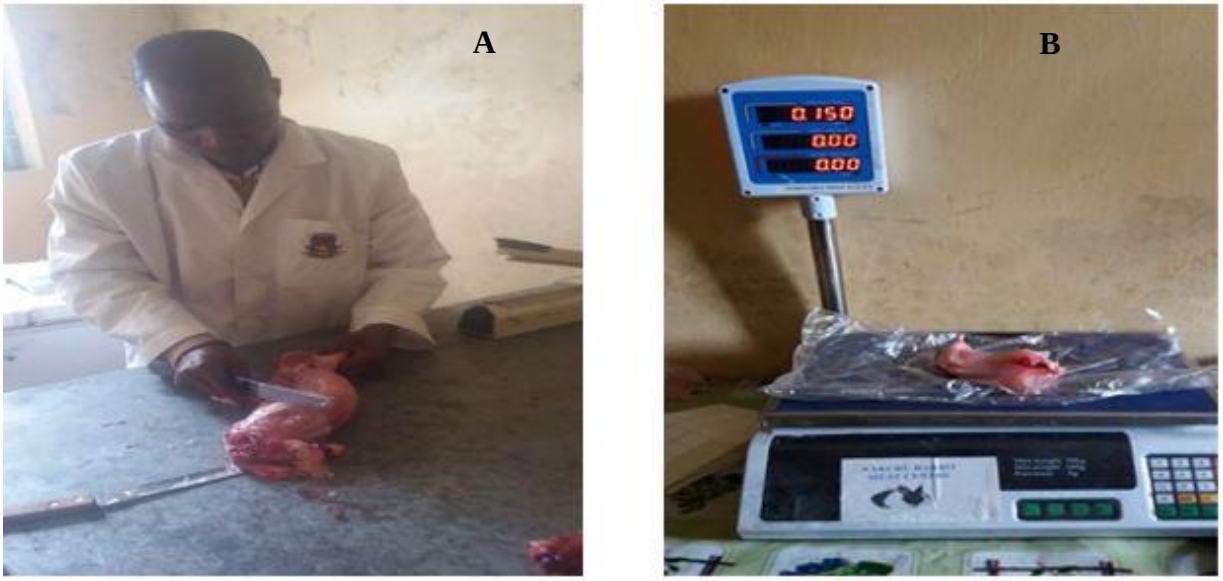

Plate 4: Retail cuts quality measurement; cuts preparation (A) and cuts weighing (B)

Consumer preference was measured on three cuts: the loin, hind legs and thoracic cage, the cuts from the 12 treatments presented to 10 buyers at the slaughter house to rate preference for carcass when purchasing (Plate 5) on Likert scale of 1 for dislike extremely to 5 like very much (appendix IV)

Plate 5: Consumer Preference; retails cuts identification (A) and consumer rating (B)

Table 3: Layout of Factorial Treatments Structure in CRD

Treatments	Weaning age (weeks)	Feeding diets	Breeds
1	4 weeks	Mixed diets	New Zealand White
2	4 weeks	Mixed diets	California White
3	4 weeks	Mixed diets	Chinchilla
4	4 weeks	Commercial pellet diet	New Zealand White
5	4 weeks	Commercial pellet diet	California White
6	4 weeks	Commercial pellet diet	Chinchilla
7	8 weeks	Mixed diets	New Zealand White
8	8 weeks	Mixed diets	California White
9	8 weeks	Mixed diets	Chinchilla
10	8 weeks	Commercial pellet diet	New Zealand White
11	8 weeks	Commercial pellet diet	California White
12	8 weeks	Commercial pellet diet	Chinchilla

3.3 Data Analysis

3.3.1 Data Processing

The feeding practices were expressed in dry matter percentage of fresh forage, dry forage and commercial pellets of the total daily diet offered. Market weight was the weight of rabbits at slaughter, while dressing percentage was in hot carcass weight computed as a percentage of the slaughter weight. Carcass quality and consumer preference were measured on hot and chilled loin, hind parts and thoracic cage. Profit was derived from total revenue less total input cost at the farm level based on the weaning age practiced and the dominant breed kept.

3.3.2 Statistical Procedure

The effect of weaning age was examined from a generic model expressed as:

$$Y_{ijkl} = \mu + W_i + F_j + B_k + (WF)_{ij} + (WB)_{ik} + (FB)_{jk} + (WFB)_{ijk} + \varepsilon_{ijkl}$$

Where:

$Y_{ijkl}$is the dependent variables including dry matter percentage, market weight, carcass quality, consumer preference or profit and the other variables being: μ is the overall mean, W is the weaning age in weeks (4 or 8), F is the feeding diets (Mixed or commercial pellets), B is the breed (NZW, CL and CH), WF is the two ways interaction between weaning age and feeding regime, WB is the two ways interaction between the weaning age and breeds, FB is the two ways interaction between feeding and breeds, WFB is the 3 ways interaction of weaning age, feeding regime and breeds, and ε_{ijkl} is the random error.

3.3.3 Modeling Influence of Weaning Management Intervention and Profitability

Using the empirical data from the production performance, a simulation modeling exercise was performed to identify areas of weaning management intervention sensitive to profit in rabbit enterprise. The simulation modeling explored different intervening sceneries using STELLA software platform version 10.0.2 through sensitivity analysis based on the conceptual model illustrated in Figure 17.

Using the technical and economic performance results, simulation modeling was performed for sensitivity of profit to varying the number of litters per doe per year from 7, 6, 5, 4 and 3 to correspond to weaning age of 4, 6, 8, 10 and 12 weeks respectively.

For the feeding effect, the price of feed sensitivity to profit was performed to assess the effect of levying 16% VAT on feeds to reflect sourcing of feeds as commercial pellets or doing on farm formulation.

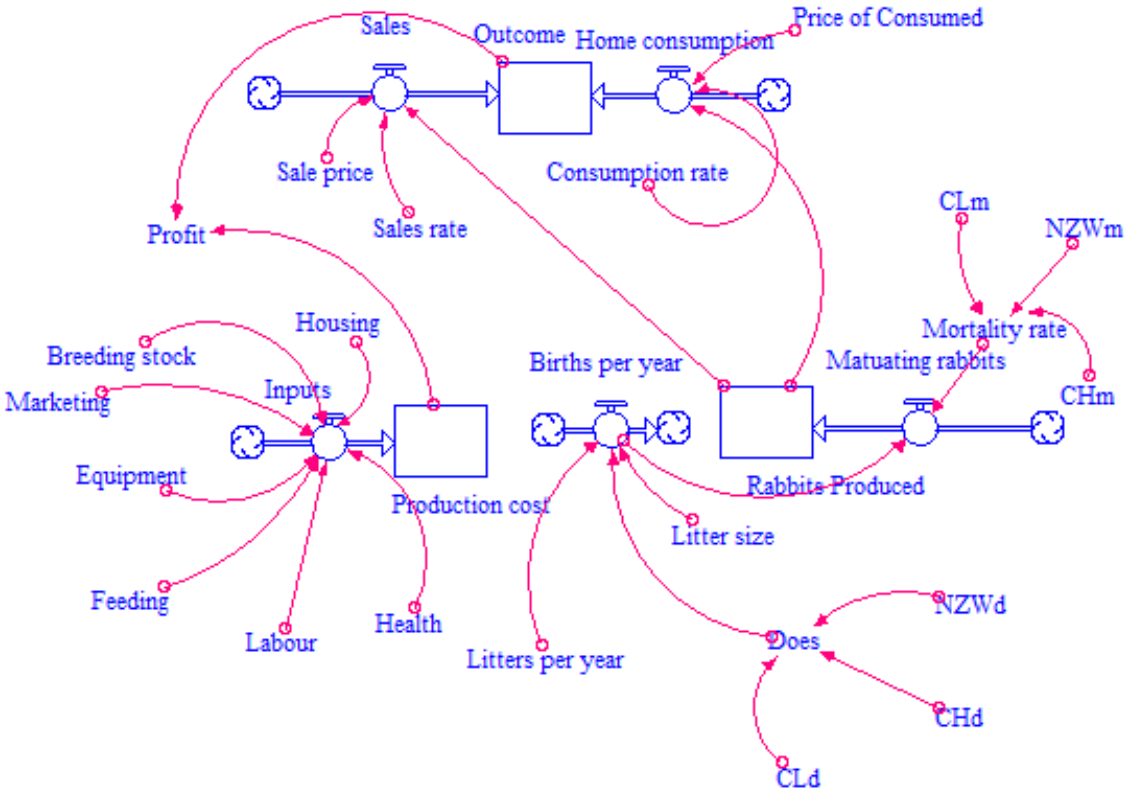

Figure 1: Conceptual model for profit analysis (Author's model)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1 The Dry Matter Offered to Rabbits by Weaning Age, Diets and Breed

Table 4 presents a description of the diets offered by weaning age and by breed on the sample farms. Commercial pellets were offered together with Rhodes grass (*Chloris gayana*), while mixed diets comprise diverse feed resources of both dry and fresh forages in variable amounts.

Table 4: Feedstuff used by farmers in Nakuru and Kiambu counties

Weaning age	Breed	Feeding diets	
		Commercial pellets	**Mixed**
4 weeks 8 weeks	New Zealand White, Californian White and Chinchilla	commercial pellets with Rhodes grass (*Chloris gayana*)	Commercial pellets *Panicum maximum* *Bidens pilosa* *Galinsoga parviflora* Maize grain Sweet potato vines Cabbage waste Kikuyu grass (*Pennisetum Clandestinum)* Carrots *(Daucus carota)* *Brassica oleracea* *Pennisetum purpureum* *Commelina benghalensis*

Results in Table 5 shows that the dry matter offered was variable ($p<0.05$) by diets and by age at weaning but the interaction effects were insignificant ($p>0.05$). Figure 2 illustrates that farmers offered more dry matter when weaning at 4 weeks of age relative to 8 weeks (143 grams

Vs 99 grams), when feeding concentrates relative to feeding mixed diets (140 grams vs 103 grams).

Table 5: ANOVA table with the means for main and interaction effects on dry matter offered to rabbits

Source	Significance level	Least square means	Standard error
Age at weaning (weeks)	***		
4		143	8.16
8		99	4.78
Diets	***		
Pellet		140	7.12
Mixed		103	6.22
Interactions effects (Wean*Diet)	NS		
Weaning 4 x Pellets		166	11.8
Weaning 4 x Mixed		120	11.3
Weaning 8 x Pellets		113	7.96
Weaning 8 x Mixed		86	5.28

NS=non-significant;***(P<0.001)

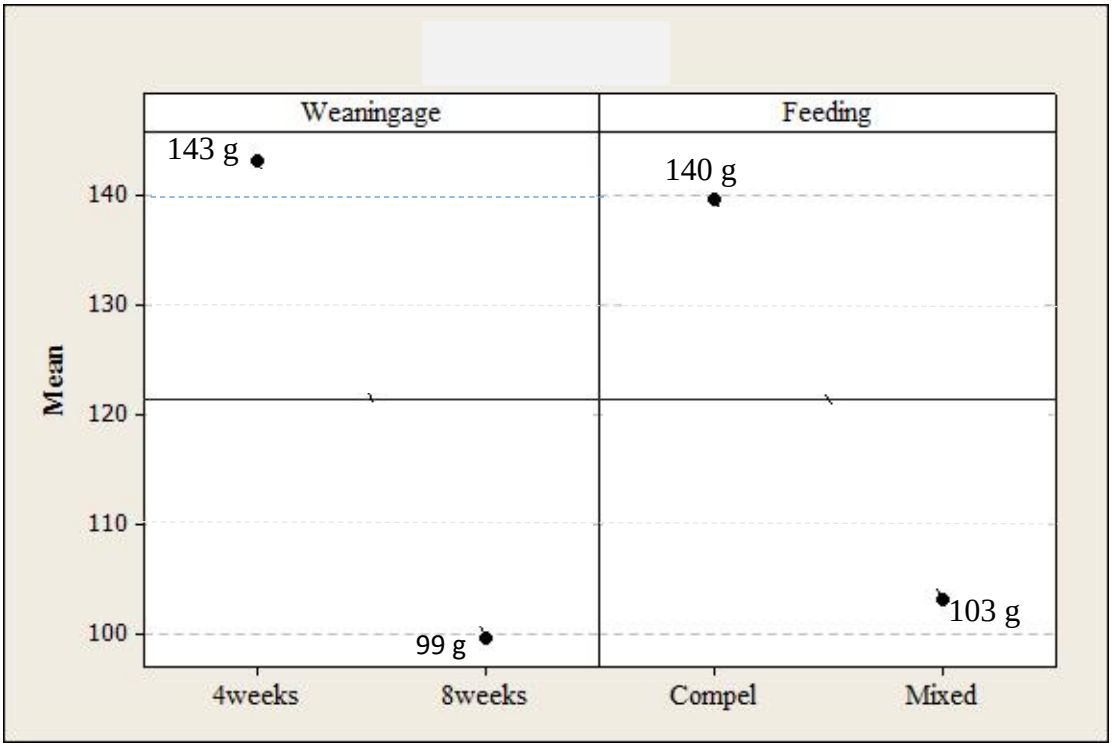

Figure 2: Main effect plot of diet and weaning age for dry matter offered

Though interaction effects show that weaning age by feeding diets was not significant, the dry matter offered was higher for rabbits weaned at 4 weeks under commercial pellets diet followed by rabbits weaned at 4 weeks under mixed diets and rabbits weaned at 8 weeks under mixed diet (Figure 3).

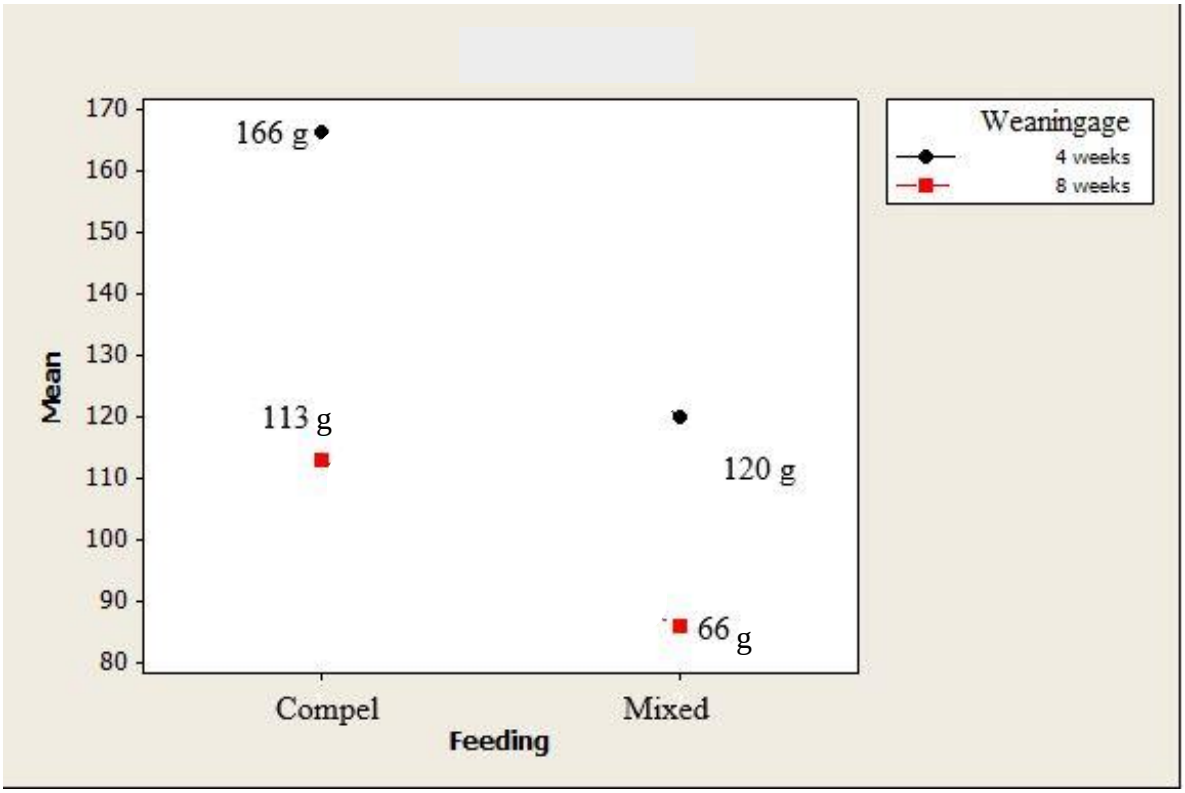

Figure 3: Interaction effect plot for diets and weaning age on dry matter offered

4.1.2 Market Weight of Rabbits by Weaning Age, Diets and Breed

Table 6 summarizes the main and interaction effects for market weight The effects of weaning age, breed and diet were significant ($p<0.5$) as well as for the interaction effects of breed and weaning age, but the other interaction effects examined were insignificant ($p>0.05$). Market weightwas higher in rabbit weaned at 4 weeks (2.37 Kg), fed commercial pellets (2.48 Kg) and for Californian breed (2.33 Kg) (Table 7). For interaction effect weaning California white rabbit breed at 4 weeks on commercial pellets attained heavier market weight then weaning New Zealand White at 4 weeks for on commercial pellets and most light market weight was for Chinchilla breed weaned at 8 weeks on commercial pellets (Figure 4)

Table 6: ANOVA table summary for main and interaction effects on market weight

Source	DF	F value
Model	11	15.12***
Breed	2	5.27*
Weaning	1	28.2***
Diets	1	75.2***
Breed*Weaning	2	18.5***
Breed*Diets	2	0.26^{NS}
Weaning*Diets	1	0.98^{NS}
Weaning*Breed*Diets	2	6.90**

NS=non-significant; *P<0.05; **P<0.01;***P<0.001 for p values of F

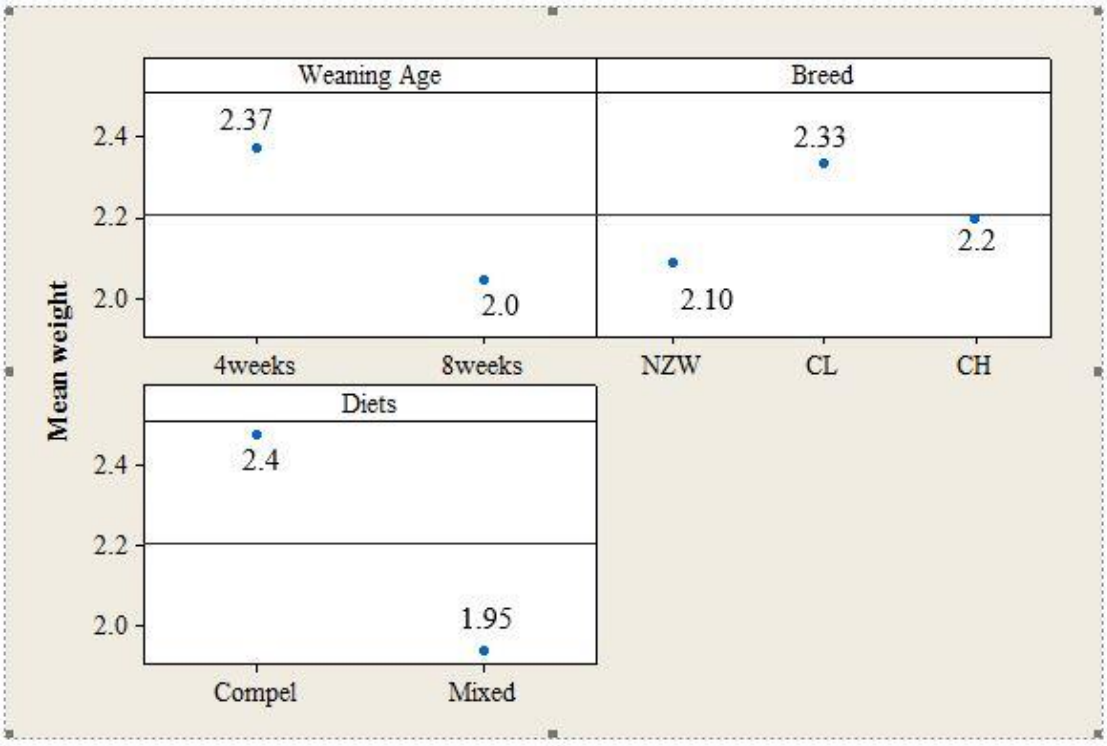

Figure 4: Main effect plot for market weight

The three-way interaction effect show that market weight was heaviest when weaning California white rabbit breed at 4 weeks of age on commercial pellets compared to New Zealand white weaned at 4 weeks on commercial pellets or Chinchilla breed weaned at 8 weeks on commercial pellets (Table 7).

Table 7: Main and interaction effects on market weight of rabbits

Source	Significance level	Least square means	Standard error
Age at weaning (weeks)	***		
4		2.37[a]	0.04
8		2.04[b]	0.04
Breed	*		
CH		2.19[a]	0.54
NZW		2.09[b]	0.54
CL		2.33[a]	0.54
Diet	***		
Pellet		2.48[a]	0.04
Mixed		1.94[b]	0.04
Weaning (weeks) x Breed	***		
4 x CL		2.58[a]	0.08
8 x CL		2.09[b]	0.08
4 x CH		2.1[b]	0.08
8 x CH		2.29[b]	0.08
4 x NZW		2.43[ab]	0.08
8 x NZW		1.75[c]	0.08
Weaning (weeks) x Diets	NS		
4 x Pellets		2.67[a]	0.06
4 x Mixed		2.07[b]	0.06
8 x Pellets		2.28[b]	0.06
8 x Mixed		1.8[c]	0.06
Breed x Diets	NS		
CL x Pellets		2.58[a]	0.08
CL x Mixed		2.09[bc]	0.08
CH x Pellets		2.49[a]	0.08
CH x Mixed		1.89[bc]	0.08
NZW x Pellets		2.35[a]	0.08
NZW x Mixed		1.82[bc]	0.08

Weaning age x Diets x Breed	***		
4 x CL x Pellets		2.91[a]	0.11
4 x CL x Mixed		2.26[abc]	0.11
8 x CL x Pellets		2.25[bc]	0.11
8 x CL x Mixed		1.92[cd]	0.11
4 x CH x Pellets		2.27[abc]	0.11
4 x CH x Mixed		1.93[cd]	0.11
8 x CH x Pellets		2.72[ab]	0.11
8 x CH x Mixed		1.87[cd]	0.11
4 x NZW x Pellets		2.83[ab]	0.11
4 x NZW x Mixed		2.03[cd]	0.11
8 x NZW x Pellets		1.87[cd]	0.11
8 x NZW x Mixed		1.62[cd]	0.11

NS=non-significant; *(P<0.05); **(P<0.01);***(P<0.001); Means with different letters differ at P<0.05;

4.1.3 The Carcass Quality of Rabbits by Weaning Age, Diets and Breed

Table 8 is a summary of analysis of variance with a display of the significance of F values for main and interaction effects. The models were significant except for dressing out percentage and explained between 71 and 87% of the variations except for dressing out percentage and chilled thoracic cage weight, which had 46 to 54% of variance explained. The main effects of weaning age, diet and breed showed significant effect on most of the carcass quality measure attributes. The three-way interaction was significant for live weight (LW) and hot hind legs weight (HHLW) only while the two interactions were insignificant for chilled weights for hot thoracic cage weight (HTCW) and chilled thoracic cage weight (CTCW).

Table 9 presents the least square means for the carcass quality measure attributes for the main and interaction effects. Significant influences on the live weight were observed for the interactive effects of weaning age, diets and the breed (P<0.004); breed and weaning age (P<0.001). Significant effects on hot carcass weight was observed for interactive effects of weaning age and diets (P<0.036) while dressing percentage was sensitive only to diets (P<0.004).

Both hot and chilled loin weight were sensitive to the interaction effects of breed and weaning age (P<0.001) but hot hind legs weight was sensitive to the interaction effects of weaning

age, breed and diet ($P<0.045$). The chilled hind leg weight was sensitive to weaning age and breed ($P<0.0001$), in contrast to hot hind leg weight and hot thoracic cage weight were responded to weaning age ($P<0.004$) and feeding diets ($P<0.0001$), and chilled carcass weight which responded to diet ($P<0.001$).

Table 8: ANOVA table summary for main and interaction effects on carcass quality attributes

Sources	DF	F values for each model of dependent variables								
		LW	**HCW**	**DoP**	**HLW**	**CLW**	**HHLW**	**CHLW**	**HTCW**	**CTCW**
Weaning age	1	28.2***	21.9***	1.17 NS	19.14***	19.5***	14.6***	3.47 NS	9.96**	4.16 NS
Diet	1	75.2***	66.0***	10.1 ***	38.9***	41.9***	61.6***	38.2***	32.9***	15.6***
Breed	2	5.27*	5.11*	1.94 NS	4.89*	11.8***	2.73 NS	16.7***	0.58 NS	0.36 NS
W X D	1	0.98 NS	4.91*	2.93 NS	6.72*	8.06**	0.01 NS	3.35 NS	0.14 NS	0.00 NS
W X B	2	18.5***	10.7***	0.12 NS	8.98**	12.2***	14.3***	13.3***	2.95 NS	1.08 NS
B X D	2	0.26 NS	0.86 NS	0.70 NS	0.31 NS	0.51 NS	0.64 NS	9.43***	3.32 NS	2.62 NS
W X D X B	2	6.90**	3.05 NS	0.12 NS	3.02 NS	3.18 NS	3.53*	2.78 NS	0.87 NS	0.37 NS
Model	11	15.1***	12.0***	1.82 NS	9.02***	11.4***	10.8***	11.8***	5.32***	2.60*
						Model values				
R MSE		0.19	0.13	3.53	69.8	64.8	36	31.8	23.5	31.7
CV		8.42	11.9	6.86	16.0	15.5	11.75	11.1	13.8	18.9
R squared		0.87	0.85	0.46	0.81	0.84	0.83	0.84	0.71	0.54

W=weaning age; D=feeding diets; B=breed

HCW=hot carcass weight; DoP= dressing out percentage; HLW=hot loin weight; CLW=chilled loin weight; HHLW=hot hind legs weight; CHLW=chilled hind legs weight; HTCW=hot thoracic cage weight; CTCW=chilled thoracic cage weight;

NS=non-significant; *(P<0.05); **(P<0.01);***(P<0.001)

Table 9: Least-squares means for carcass and retail cuts weight of rabbits by weaning age, breed and feeding diets

Source	Carcass measure attributes								
	LW (Kg)	HCW (Kg)	DoP (%)	HLW (g)	CLW (g)	HHLW (g)	CHLW (g)	HTCW (g)	CTCW (g)
W4 (4 weeks)	2.37^{a}	1.24^{a}	52.^{a}	486^{a}	465^{a}	330^{a}	296^{a}	182^{a}	179^{a}
W8 (8 weeks)	2.04^{b}	1.03^{b}	51^{a}	384^{b}	370^{b}	284^{b}	276^{a}	157^{b}	157^{a}
CL Breed	2.33^{a}	1.23^{a}	53^{a}	484^{a}	479^{a}	326^{a}	325^{a}	174^{a}	174^{a}
CH Breed	2.20^{a}	1.13^{ab}	51^{a}	397^{b}	351^{b}	303^{a}	282^{b}	164^{a}	164^{a}
NZW Breed	2.09^{b}	1.06^{b}	50^{a}	424^{a}	422^{a}	292^{a}	251^{b}	170^{a}	166^{a}
Pellet Diet	2.48^{a}	1.32^{a}	53^{a}	508^{a}	487^{a}	354^{a}	319^{a}	192^{a}	189^{a}
Mixed Diet	1.94^{b}	0.96^{b}	49^{b}	362^{b}	347^{b}	260^{b}	253^{b}	147^{b}	147^{b}
W4 x CL	2.58^{a}	1.4^{a}	54^{a}	563^{a}	558^{a}	370^{a}	370^{a}	187^{ab}	187^{a}
W8 x CL	2.09^{b}	1.07b^{c}	51^{a}	405a^{b}	400^{b}	281^{bc}	281^{bc}	162^{ab}	162^{a}
W4 x CH	2.1^{b}	1.08b^{c}	51^{a}	378b^{c}	323^{b}	280^{bc}	260^{bc}	165^{ab}	165^{a}
W8 x CH	2.29^{ab}	1.17^{b}	52^{a}	415^{b}	378^{b}	325^{ab}	303^{b}	163^{ab}	163^{a}
W4 x NZW	2.43^{a}	1.25^{ab}	50^{a}	517^{ab}	514^{a}	339^{ab}	257^{bc}	195^{a}	185^{a}
W8 x NZW	1.75^{c}	0.87^{c}	50^{a}	332^{c}	331^{b}	246^{c}	245^{c}	146^{b}	146^{a}
4 x Pellets	2.67^{a}	1.48^{a}	55^{a}	589^{a}	566^{a}	376^{a}	319^{a}	206^{a}	200^{a}
4 x Mixed	2.07^{bc}	1.01^{bc}	49^{a}	383^{b}	364^{b}	283^{b}	273^{b}	158^{bc}	158^{bc}
8 x Pellets	2.28^{b}	1.17^{b}	52^{a}	427^{b}	409^{b}	331^{a}	319^{a}	178^{ab}	178^{ab}
8 x Mixed	1.8^{c}	0.9^{c}	50^{a}	342^{b}	330^{b}	236^{b}	234^{b}	136^{c}	136^{c}
CL x Pellets	2.58^{a}	1.43^{a}	55^{a}	569^{a}	565^{a}	382^{a}	382^{a}	198^{a}	198^{a}
CL x Mixed	2.09^{b}	1.03^{b}	51^{a}	399^{b}	394^{b}	269^{b}	269^{bc}	151^{bc}	151^{ab}
CH x Pellets	2.5^{a}	1.33^{a}	53^{a}	467^{ab}	413^{b}	345^{a}	322^{b}	198^{a}	198^{a}
CH x Mixed	1.9^{b}	0.92^{b}	48^{a}	327^{b}	288^{c}	260^{b}	242^{c}	130^{c}	130^{b}
NZW x Pellets	2.35^{a}	1.2^{ab}	51^{a}	487^{a}	484^{ab}	334^{a}	253^{c}	180^{ab}	170^{ab}
NZW x Mixed	1.83^{b}	0.92^{b}	49^{a}	362^{b}	360^{bc}	250^{b}	249^{c}	161^{abc}	160^{ab}
Mixed x 4 x NZW	2.0^{bc}	1.0^{b}	49^{a}	394^{b}	392^{b}	281^{b}	280^{b}	181^{a}	180^{a}
Mixed x 4 x CL	2.3^{b}	1.3^{b}	51^{a}	439^{b}	435^{b}	308^{b}	308^{b}	160^{a}	158^{a}

Mixed x 4 x CH	1.9^{bc}	0.9^{b}	47^{a}	317^{b}	267^{b}	260^{b}	230^{b}	150^{a}	137^{b}
Mixed x 8 x NZW	1.6^{c}	0.83^{b}	50^{a}	329^{b}	328^{b}	218^{b}	218^{b}	142^{b}	142^{b}
Mixed x 8 x CL	1.9^{bc}	0.9^{b}	50^{a}	359^{b}	353^{b}	230^{b}	230^{b}	146^{b}	144^{b}
Mixed x 8 x CH	1.9^{bc}	0.9^{b}	49^{a}	337^{b}	310^{b}	260^{b}	253^{b}	133^{b}	123^{b}
Compel x 4 x NZW	2.8^{a}	1.5^{a}	53^{a}	640^{a}	635^{a}	396^{a}	395^{a}	211^{a}	209^{a}
Compel x 4 x CL	2.9^{a}	1.67^{a}	56^{a}	686^{a}	682^{a}	433^{a}	433^{a}	218^{a}	215^{a}
Compel x 4 x CH	2.3^{b}	1.26^{b}	55^{a}	440^{b}	380^{b}	300^{b}	290^{b}	207^{a}	193^{a}
Compel x 8 x NZW	1.9^{bc}	0.9^{b}	49^{a}	335^{b}	333^{b}	273^{b}	271^{b}	152^{a}	151^{a}
Compel x 8 x CL	2.3^{b}	1.2^{b}	54^{a}	451^{b}	447^{b}	332^{a}	331^{a}	182^{a}	181^{a}
Compel x 8 x CH	2.7^{a}	1.4^{a}	51^{a}	493^{a}	447^{b}	390^{a}	353^{a}	217^{a}	203^{a}

HCW=hot carcass weight; DoP= dressing out percentage, DoP=HCW/Live weight*100; HLW=hot loin weight; CLW=chilled loin weight; HHLW=hot hind legs weight; CHLW=chilled hind legs weight; HTCW=hot thoracic cage weight; CTCW=chilled thoracic cage weight; Means within same column with different letter superscript differ statistically (*P<0.05)*.

4.1.4 Consumer Preferences for Rabbit Carcass by Weaning Age, Diet Fed and Breed

Table 10 is a summary of consumer preferences expressed for rabbit carcass by age of weaning, diet fed and the breed. Consumer preferences of carcass parts was sensitive ($p<0.05$) to diets but not to ($p>0.05$) weaning age or breed. On a scale of 1 to 5, preference was rated (Table 11) highest for hind legs (4.7) then loin (4.5) and lowest for thoracic cage (4.0). Consumers expressed highest preference for the hind legs, loin and thoracic cage from rabbits of Chinchilla breed weaned at 8 weeks on commercial pellets diet and next was New Zealand white and California breeds weaned at 4 weeks on commercial pellets (Table 11).

Table 10: Consumer preference rating for carcass parts by weaning age, diet and breed of rabbits

Source	Degree of Freedom	F values for each tested model variable		
		Loin	Thoracic Cage	Hind legs
Weaning age	1	0.00NS	3.48S	1.49NS
Diets	1	31.1***	31.3***	37.3***
Breed	2	2.03NS	1.77NS	0.25NS
Weaning age x Diet	1	1.18NS	0.26NS	0.01NS
Weaning age x Breed	2	3.09S	5.36**	9.09***
Diet x Breed	2	0.92NS	0.26 NS	6.70***
Weaning age x Diet x Breed	2	0.62NS	0.03 NS	0.25 NS
Model	11	4.15***	4.54***	6.49***

NS=non-significant; S=significant ($0.05<P<0.1$); *($P<0.05$); **($P<0.01$);***($P<0.001$)

Table 11: Consumer reference rating by weaning age (WA), diet and breed of rabbits

	Loin		Thoracic Cage		Hind legs	
Source	Lsmeans	SE	Lsmeans	SE	Lsmeans	SE
Weaning age (4weeks)	4.3[a]	0.06	3.9[b]	0.07	4.4[c]	0.05
Weaning age (8 weeks)	4.3[a]	0.06	3.8[b]	0.07	4.5[c]	0.05
Breed CH	4.2[a]	0.07	3.9[b]	0.09	4.4[c]	0.06
Breed NZW	4.4[a]	0.07	3.7[b]	0.09	4.5[c]	0.06
Breed CL	4.3[a]	0.07	3.7[b]	0.09	4.5[c]	0.06
Pellets diet	4.5[a]	0.06	4[c]	0.07	4.7[e]	0.05
Mixed diet	4.1[b]	0.06	3.5[d]	0.07	4.2[f]	0.05
WA4 x CL	4.4[a]	0.10	3.9[a]	0.12	4.5[a]	0.08
WA8 x CL	4.3[a]	0.10	3.5[ab]	0.12	4.5[a]	0.08
WA4 x CH	4.1[a]	0.10	3.7[a]	0.12	4.2[b]	0.08
WA8 x CH	4.3[a]	0.10	4[a]	0.12	4.6[a]	0.08
WA4 x NZW	4.4[a]	0.10	3.9[a]	0.12	4.6[a]	0.08
WA8 x NZW	4.3[a]	0.10	3.5[ab]	0.12	4.4[a]	0.08
WA4 (4weeks) x Pellets	4.5[a]	0.08	4.1[a]	0.10	4.6[a]	0.07
WA4 (4weeks) x Mixed	4.1[b]	0.08	3.6[b]	0.10	4.2[b]	0.07
WA8 x Pellets	4.6[a]	0.08	3.9[a]	0.10	4.7[a]	0.07
WA8 x Mixed	4[b]	0.08	3.8[b]	0.10	4.3[b]	0.07
CL x Pellets	4.6[a]	0.10	4[a]	0.12	4.8[a]	0.08
CL x Mixed	4[b]	0.10	3.4[b]	0.12	4.2[b]	0.08
CH x Pellets	4.4[a]	0.10	4.2[a]	0.12	4.7[a]	0.08
CH x Mixed	3.9[b]	0.10	3.6[b]	0.12	4.2[b]	0.08
NZW x Pellets	4.5[a]	0.10	3.9[a]	0.12	4.5[a]	0.08
NZW x Mixed	4.2[a]	0.10	3.5[b]	0.12	4.4[a]	0.08
WA4 x CL x Pellets	4.6[ab]	0.14	4.2[ab]	0.17	4.8[ab]	0.12
WA4 x CL x Mixed	4.3[abc]	0.14	3.7[abcd]	0.17	4.2[cd]	0.12
WA8 x CL x Pellets	4.6[ab]	0.14	3.8[abcd]	0.17	4.8[ab]	0.12
WA8 x CL x Mixed	3.9[bc]	0.14	3.1[d]	0.17	4.2[cd]	0.12
WA4 x CH x Pellets	4.3[abc]	0.14	4[abc]	0.17	4.5[abc]	0.12

WA4 x CH x Mixed	3.8^{c}	0.14	3.5^{bcd}	0.17	3.9^{d}	0.12
WA8 x CH x Pellets	4.7^{a}	0.14	4.4^{a}	0.17	4.9^{a}	0.12
WA8 x CH x Mixed	4^{bc}	0.14	3.7^{abcd}	0.17	4.4^{abcd}	0.12
WA4 x NZW x Pellets	4.6^{ab}	0.14	4.1^{ab}	0.17	4.6^{abc}	0.12
WA4 x NZW x Mixed	4.3^{abc}	0.14	3.7^{abcd}	0.17	4.6^{abc}	0.12
WA8 x NZW x Pellets	4.5^{abc}	0.14	3.8^{abcd}	0.17	4.4^{abcd}	0.12
WA8 x NZW x Mixed	4.2^{abc}	0.14	3.3^{cd}	0.17	4.3^{bcd}	0.12

Means within a Colum with different letter superscripts differ at 0.05

4.1.5 Influence of Weaning Age on Profitability of Rabbit Rearing

Table 12 summarizes gross margins associated with the weaning ages and diets offered. The gross margins were higher when weaning at 4 weeks compared to weaning at 8 weeks and when feeding pellets compared to feeding mixed diets and is higher with 4 weeks weaning on pellets than weaning at 8 weeks on mixed diets.

Table 12: Economic returns of rabbit farms for the weaning age, breed and feeding diets

Weaning management	8 weeks		4 weeks	
options	Pellets	Mixed	Pellets	Mixed
Output value (KES)				
Rabbit sales	141,688	58,542	216,230	103,412
Rabbit consumed	10,340	5,830	18,035	6,493
Total	**152,028**	**64,372**	**234,265**	**109,904**
Input costs (KES)				
Feed Cost	63,429	22,894	70,884	32,711
Housing	6,296	3,026	5,471	3,220
Equipment	287	103	178	214
Rabbits Purchase	2,250	1,078	2,000	1,975

Labour	23,676	9,763	35,619	13,333
Marketing	8,161	3,518	12,463	3,823
Veterinary	1,846	154	871	990
Total	**105,946**	**40,537**	**127,486**	**56,265**
Gross margins (KES/year)	**46,082**	**23,835**	**106,779**	**53,639**

Sensitivity of gross margins to weaning age was evaluated with base situation at 4 or 8 weeks relative to varying weaning age by 2 weeks progressively (Figure 5). For those weaning at 8 weeks, gross margins rise by 13.8% and by 7.4% when reduced to 4 and 6 weeks respectively for pellet diet feeding but by 9.5% and 5.0% for mixed diet feeding.

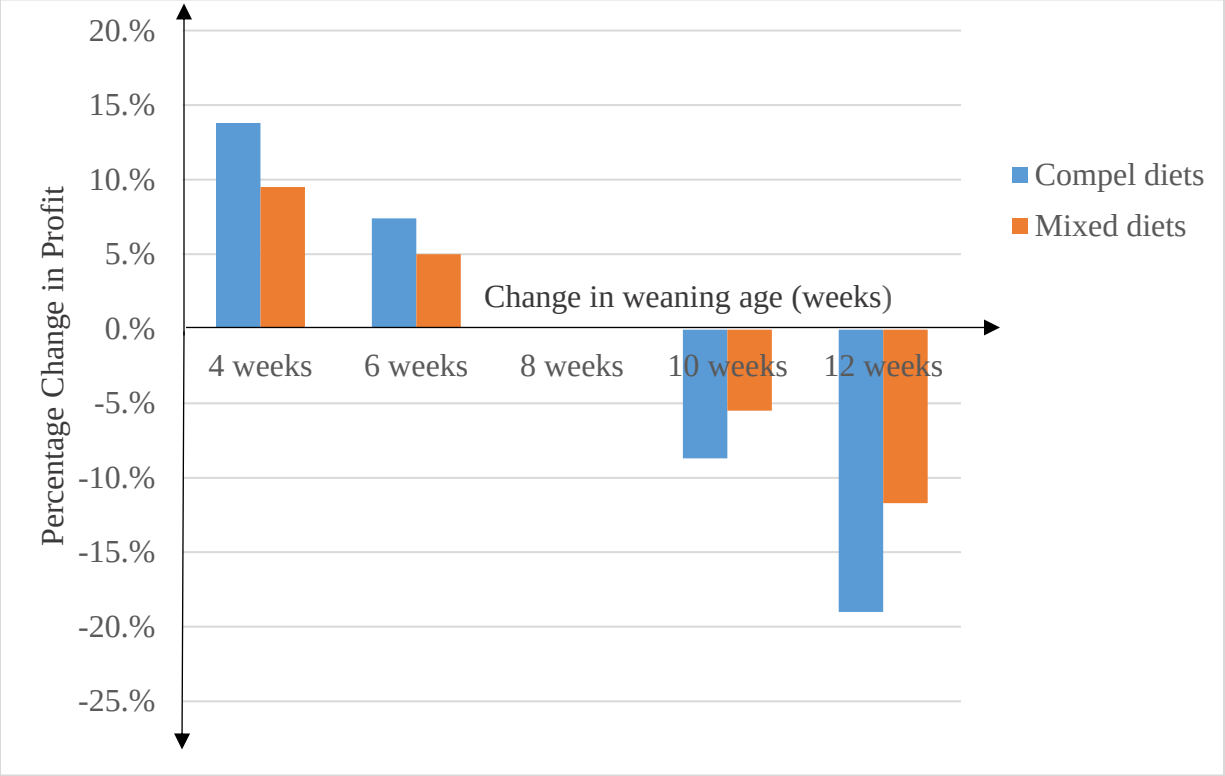

Figure 5: Percentage of change in profit relative to base situation when weaning at different ages (weeks)

Sensitivity of gross margins to 16% VAT charged on animal feeds was evaluated for those feeding pellets. Results are presented in figure 6 showing that inclusion of 16% VAT charged on animal feeds will decrease profit for farmers by 5.72% whether weaning at 4 or 8 weeks of age and whether feeding pellets or mixed diets.

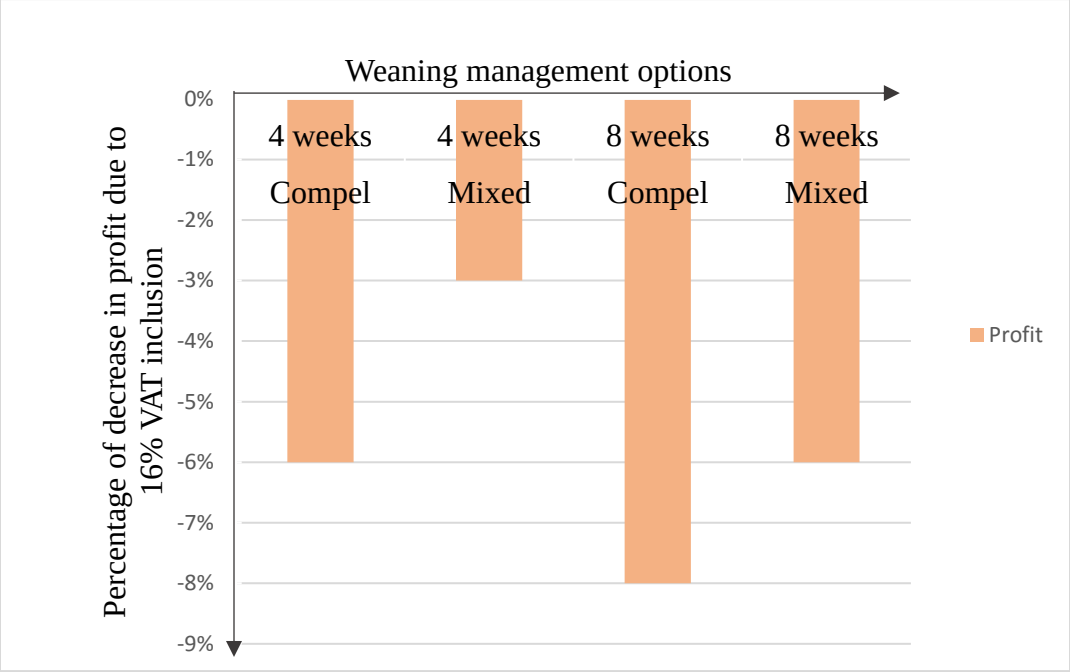

Figure 6: Effect of introducing 16% VAT for feeds on profit

Rabbits may be sold for slaugheter or for breeding and the price varies from KES 350 to 1200 depending on body weight for slaughet rabbits unlike for breeding rabbits. Sensitivity of profit to changes in market price of rabbits was evaluated (figure 7) with results showing huge increases with increasing prices.

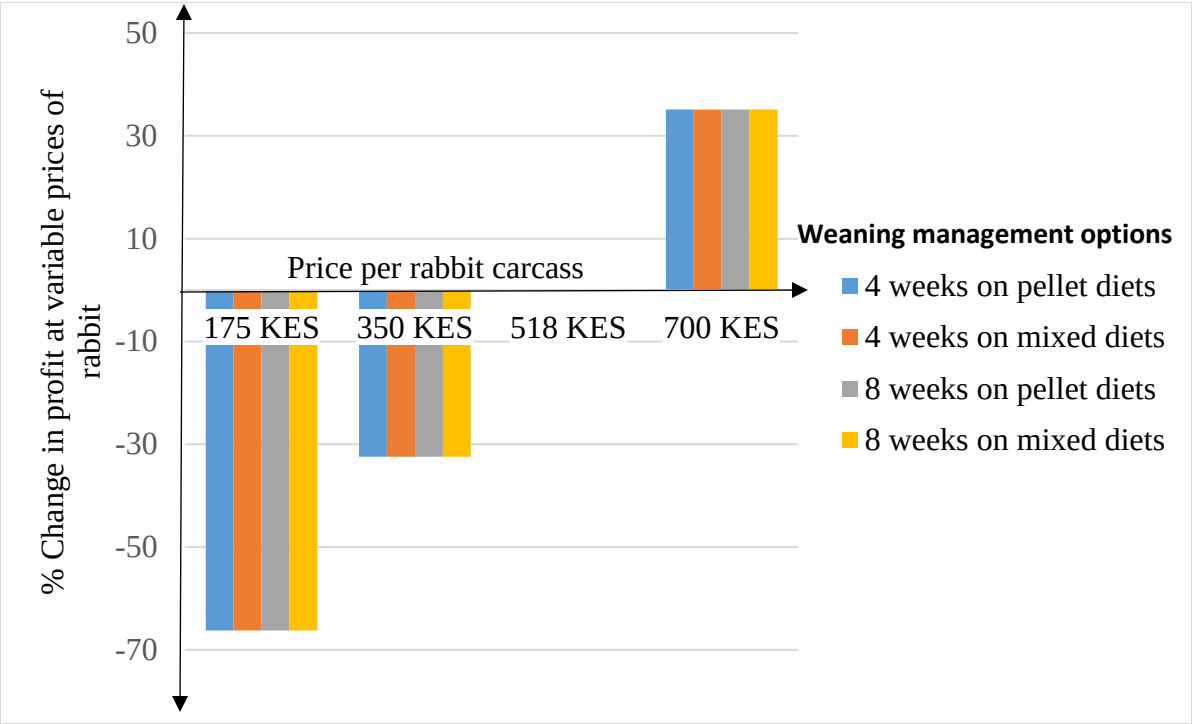

Figure 7: Profit for varying price of rabbits.

4.2 Discussion

4.2.1 Effect of Weaning Age on Dry Matter Intake and Rabbit Market Weight

This study evaluated the effects of weaning age on production and economic performance of rabbit rearing on smallholder farms with variable feeding diets and breed utilization in Kenya. Data was obtained from Rabbit breeders with commercial orientation in production. The hypothesis tested was that weaning age influences the production and economic performance of rabbit rearing. This was informed by farmers' practice of different weaning regimes resulting on variable but largely sub optimal results on productivity and profit, and therefore likely to fail to contribute to food security and wealth creation for the investing households.

Farmers offered rabbits more dry matter when weaning at 4 weeks on pellets compared to when weaning at 8 weeks. The estimates are comparable to those observed by Sundaram *et al*.,1997; Tůmová *et al*., 2006; Orengo *et al.,* 2009; Hewitt *et al*., 2012 and by Dougnon *et al*., 2012. They estimated dry matter of 81 to 108 grams for rabbits weaned at 8 weeks fed *ad libitum*. However, the present estimates are lower than those observed by Rommers *et al.,* 2000 who reported 152 to 169 grams of dry matter offered. In the works of Xiccato *et al*., 2004; Zita *et al*., 2012 and Dal Bosco *et al*., 2012 for rabbits weaned at 4 weeks, the dry matter offered was 120 to

128 grams a day. These results corroborate the present observations that rabbits weaned at 4 weeks of age are offered more dry matter than those weaned at 8 weeks of age. Early weaning is a practice in intensive feeding with quality diets aimed at attaining market weight early.

Higher market weight of 2.9 Kg was reached in Californian weaned at 4 weeks fed commercial pellets compared to Chinchilla weaned at 8 weeks (2.7 Kg) on same pellet diets, which was similar to rabbit slaughtered at age of 84 days reported by Xiccato *et al*., 2004 and Marongiu *et al*., 2008. However, Zita *et al.*, 2007 and Pinheiro *et al*., 2011, found no significant difference in market weight between 25, 28, 31 and 35 days of weaning. This deviates from the present results which may be explained by the long interval between the weaning ages.

4.2.2 Effect of Weaning Age on Carcass Quality and Consumer Preference

Weaning age had no effect on dressing out percentage instead it was higher in rabbits fed commercial pellets with hay supplementation without significant breed effect (Bianospino *et al.*, 2006) yet Chodová *et al.*, 2014 registered significant differences between dressing percentage of different ecotypes. In this study dressing out percentage might have been influenced by other factors related to management not considered in the fitted model which could only explain 54.5% of the variation. This may be explained by different housing system used by farmers which could have influenced the dressing out percentage as observed in some studies (Dal Bosco *et al*., 2000; Metzger *et al*., 2003 and Chodová *et al.*, 2014).

The first retail cuts were higher in Californian and New Zealand white weaned at 4 weeks and fed commercial pellets. The weights were 686 g, 640g and 433g 396g for hot loins and hind legs respectively, which differs with the findings of Bianospino et al., 2006 where loin weighed between 295.5 and 308.7 grams and hind parts between 401.4 and 412 grams in straight bred and crossbred respectively. The second retail cut (thoracic cage), yielded less on rabbits weaned at 8 weeks and fed mixed diet for all the three breeds.

Consumer preference were less sensitive do the weaning age for all the cuts and breeds probably because consumers 'choice of rabbit meat may be influenced by the type of feed offered to rabbits during the rearing period. This may be explained by better appearance of meat of commercial pellets fed rabbits and appearance is most important to consumers (Buitrago-Vera *et*

al., 2016). Consumers preferred more Chinchilla weaned at 8 weeks more than New Zealand white weaned at 4 weeks, Californian weaned at 8 weeks fed commercial pellets.

Among the cuts, hind legs were more preferred for rabbits weaned at 8 weeks and this corroborates results of a study of by Hoffman *et al.* 2004 where consumers had more preference for hind legs because of greater weight. There are some other factors which may have influenced the choice of consumers for the cuts of rabbits weaned at different ages than just the quality. Dalle Zotte, 2002 and Mailu *et al*., 2012 have observed that rearing regime, price, cooking easiness, pre slaughter conditions, stunning conditions, feeding (as factor of high effect to the meat quality) may have some influence too at varying degrees.

5.1.3 Effects of Weaning Age on Profitability of Rabbit Enterprise

Weaning age influences profits through influence on the number of litters per year (Lukefahr and Cheeke, 1990 and Kovitvadhi *et al.*, 2016). According to Grannis, 2002 a rabbit doe can produce up to 8 litters per year depending on the intensiveness of the management. Under the smallholder farms in Kenya intensifying the weaning age to 4 weeks gives 7 litters per doe per year and the annual profit improved by 13.8% and 9.5% for commercial pellets and mixed diets fed rabbits respectively.

Early age at weaning depends on utilization of quality pellets. In Kenya, government levied 16% VAT on animal feeds, which consequently increases feed costs and lowers the profit margins (Njagi *et al.*, 2013) and because feeding accounts for over 60% of production costs (Maertens 2009). Sensitivity analysis showed that charging a 16% VAT on animal feeds discourages commercial rabbit production through decrease in profit, by about 5.72%.

Market price of rabbits is very variable in Kenya, depending on whether farmer sells for slaughter or for breeding. Slaughter rabbits are sold on weight basis while for breeding the prices are higher and are not weight dependent (Gono *et al.*, 2013; Mutisya, 2014). A change from 518 to 700 KES in the price of rabbit increase the annual profit by 35% either for farmers weaning at 4 or 8 weeks in commercial pellets or mixed fed rabbits while a change from 518 to 350 KES in the price of rabbit carcass decreases the annual profit by 32% for all the weaning management options. Therefore improving the carcass weight making sure that after slaughtering the carcasses weigh between 1.43 to 2 Kg or providing rabbits for diversified market need (selling live animals

as breeding stock and/for meat) will improve the gross margins at the farm. However, this strategy need to be accompanied with adoption of organized and updated record keeping to guide informed management decisions (Moreki, 2007).

CHAPTER FIVE

CONCLUSION AND RECOMENDATIONS

5.1 Conclusion

From the findings, it is to conclude:

i. Rabbit farmers offered more dry matter when weaning at 4 weeks of age compared to 8 weeks (143 vs 99 grams), when feeding concentrates relative to feeding mixed diets (140 vs 103 grams).

ii. Market weight was higher in New Zealand White and Californian White breeds weaned at 4 weeks (2.8 and 2.9 Kg respectively) and in Californian Chinchilla breed (2.7 Kg) all under commercial pelleted diets.

iii. For the carcass quality, weaning California white and New Zealand white rabbit breeds at 4 weeks of age on commercial pellets produce heavier and better quality carcass for both first retail cuts (loin and hind legs) and the second retail cuts (thoracic cage), and weaning Chinchilla rabbit breed at 8 weeks on commercial pellets feeding produce better quality carcass for both first retail cuts (loin and hind legs) and the second retail cuts (thoracic cage).

iv. Consumer's preference was not significantly associated with weaning age but was driven by the type of feeding offered to rabbits with the commercial pellets fed rabbits being the most preferred.

v. Farmers realized higher gross margins when weaning their rabbits at 4 weeks compared to weaning at 8 weeks 13.8% of difference) and when feeding pellets compared to feeding mixed diets.

5.2 Recommendation

In order to maximize the production and economic returns of rabbit rearing on the Kenyan smallholder rabbit farms is to recommend that farmers should adopt the earlier weaning (4 weeks) and feed rabbits on commercial pellets diets.

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APPENDIXES

Appendix I: Data Collection Sheet

Section A1: Farm Information

Name of the owner _____

County: **Sub-County:**

10 Nakuru ☐ 101Njoro ☐

20 Kiambu102Molo ☐ ☐

103Gilgil ☐

201Thika ☐

Time in Rabbit Farming: _____years and _____months

Management practices

Feeding diets				**Breed dominant**	
Mixed diets (forages and pellets)				New Zealand white	
Commercial pellets only				California White	
				Chinchilla	
Weaning age practiced				Others, specify	
4 weeks	8weeks	Others, specify			

Section A2: Rabbit Inventory

Category	Breed					
	NZW	CL	CH			**Total**
Buck	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Doe	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Weaners	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Kindling	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Total	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]

Section A3: Births in the last 12 months

	Breed					Total
Sex	NZW	CL	CH			
Males	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Females	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Total	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]

Section A4: Deaths in the last 12 months

Class	**Total number**	**Breed**				
		NZW	**CL**	**CH**		
Buck	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Doe	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Weaners	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Kindling	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]

Section B1: Feeding Practices

Feedstuffs	Amount in Kg	DM %	DM Kg
Commercial pellets			
Fresh forage			
Napier grass			
Desmodium			
Lucerne			
Oats			
Fodder beet			
Vetch			
Leucaena			
Sesbania			
Grevillea			
Calliandra			
Thatch grass			
Other "specify below "			
Dry Forage			
Napier grass			
Desmodium			
Lucerne			
Oats			
Leucaena			
Sesbania			
Grevillea			
Calliandra			
Vetch			

Fodder trees			
Fallow and planted pasture			
Thatch grass			
Other specify below			

Section B2: Investments in the last 12 months

Type of Investment	Description	Total units	Unit cost	Total cost
Housing				
Equipment				
Purchased Bucks				
Purchased Does				
Purchased Weaners				
Purchased kindling				

Section B3: Inputs

Type of Input	Unit	Quantity	Unity cost	Total Cost
Commercial pellets “Brand”				
Fresh forage feed				
Napier grass				
Napier grass				

Desmodium				
Lucerne				
Oats				
Leucaena				
Sesbania				
Grevillea				
Calliandra				
Vetch				
Fodder trees				
Fallow and planted pasture				
Thatch grass				
Other specify below				
Dry forage feed				
Napier grass				
Napier grass				
Desmodium				
Lucerne				
Oats				
Leucaena				
Sesbania				
Grevillea				
Calliandra				
Vetch				
Fodder trees				
Fallow and planted pasture				
Thatch grass				

Other specify below				
Vet drugs “specify below”				
Water				
Credit payment				

Section B4: Labour

Type 1 = Family 2 = Hired	No	Sex 1 = M 2 =F	Percentage of time spent on rabbit rearing	wage per unit of time (KES)	unit of time	number of units per year
[___]		[___]	[__ __%]	[__ __ __]	[___]	[___ ___]
[___]		[___]	[__ __%]	[__ __ __]	[___]	[___ ___]
[___]		[___]	[__ __%]	[__ __ __]	[___]	[___ ___]

Section B4: Market Cost

Description	number	Unit cost	Total
Slaughter fee			
Group membership fee			
Transport to slaughter house			

Section C1: Sales in the Last 12 Months

	Rabbit sold						
No	**Breed**	**Age at weaning**	**Number**	**Category**	**Weight at sale**	**Purpose**	**Price**
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Section C2: Purchases in the Last 12 Months

	Rabbit purchased						
No	**Breed**	**Age at weaning**	**Number**	**Category**	**Weight at Purchase**	**Purpose**	**Cost**
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Appendix II: Consumer Preference Experimental Design Layout

			Rabbit Cuts		
Weaning age	Feeding diets	Breeds	Loin cut	Hind cut	Thoracic cut
4 weeks	Mixed diet	NZW			
		NZW			
		NZW			
		CL			
		CL			
		CL			
		CH			
		CH			
		CH			
	Commercial pellet diet only	NZW			
		NZW			
		NZW			
		CL			
		CL			
		CL			
		CH			
		CH			
		CH			
8 weeks	Mixed diet	NZW			
		NZW			
		NZW			
		CL			
		CL			
		CL			
		CH			
		CH			
		CH			
	Commercial pellet diet only	NZW			
		NZW			
		NZW			
		CL			
		CL			
		CL			
		CH			
		CH			

		CH			

Appendix III: Carcass Quality Datasheet

Rabbit No	Sample ID	Live Weight (Kg)	Hot Carcass Weight (Kg)	Dressing out percentage	Loin Weight (g)	Thoracic cage Weight (g)	Hind legs Weight (g)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							

24							
25							
26							
27							
28							
29							
30							
31							
32							
33							
34							
35							
36							

Appendix IV: Consumer Preference Rating Sheet

Rabbit Number	Product Name	Sample ID	**5** - Like very much	**4** - Like	**3** - Neither like nor dislike	**2** - Dislike	**1** - Dislike extremely
	Loin						
	Thoracic Cage						
	Hind legs						

Appendix V: Sample Id for Analysis of Market Weight, Carcass Quality and Consumer Preference

NZ4M1 - New Zealand weaned at 4 weeks fed mixed diet (rabbit 1)

NZ4M2 - New Zealand weaned at 4 weeks fed mixed diet (rabbit 2)

NZ4M3 - New Zealand weaned at 4 weeks fed mixed diet (rabbit 3)

NZ4P1 - New Zealand weaned at 4 weeks fed pellets diet (rabbit 1)

NZ4P2 - New Zealand weaned at 4 weeks fed pellets diet (rabbit 2)

NZ4P3 - New Zealand weaned at 4 weeks fed pellets diet (rabbit 3)

NZ8M1 - New Zealand weaned at 8 weeks fed mixed diet (rabbit 1)

NZ8M2 - New Zealand weaned at 8 weeks fed mixed diet (rabbit 2)

NZ8M3 - New Zealand weaned at 8 weeks fed mixed diet (rabbit 3)

NZ8P1 - New Zealand weaned at 8 weeks fed pellets diet (rabbit 1)

NZ8P2 - New Zealand weaned at 8 weeks fed pellets diet (rabbit 2)

NZ8P3 - New Zealand weaned at 8 weeks fed pellets diet (rabbit 3)

CL4M1 - California weaned at 4 weeks fed mixed diet (rabbit 1)

CL4M2- California weaned at 4 weeks fed mixed diet (rabbit 2)

CL4M3- California weaned at 4 weeks fed mixed diet (rabbit 3)

CL4P1 - California weaned at 4 weeks fed pellets diet (rabbit 1)

CL4P2 - California weaned at 4 weeks fed pellets diet (rabbit 2)

CL4P3 - California weaned at 4 weeks fed pellets diet (rabbit 3)

CL8M1 - California weaned at 8 weeks fed mixed diet (rabbit 1)

CL8M2 - California weaned at 8 weeks fed mixed diet (rabbit 2)

CL8M3 - California weaned at 8 weeks fed mixed diet (rabbit 3)

CL8P1 - California weaned at 8 weeks fed pellets diet (rabbit 1)

CL8P2 - California weaned at 8 weeks fed pellets diet (rabbit 2)

CL8P3 - California weaned at 8 weeks fed pellets diet (rabbit 3)

CH4M1 - Chinchilla weaned at 4 weeks fed mixed diet (rabbit 1)

CH4M2 - Chinchilla weaned at 4 weeks fed mixed diet (rabbit 2)

CH4M3 - Chinchilla weaned at 4 weeks fed mixed diet (rabbit 3)

CH4P1 - Chinchilla weaned at 4 weeks fed pellets diet (rabbit 1)

CH4P2 - Chinchilla weaned at 4 weeks fed pellets diet (rabbit 2)

CH4P3 - Chinchilla weaned at 4 weeks fed pellets diet (rabbit 3)

CH8M1 - Chinchilla weaned at 8 weeks fed mixed diet (rabbit 1)

CH8M2 - Chinchilla weaned at 8 weeks fed mixed diet (rabbit 2)

CH8M3 - Chinchilla weaned at 8 weeks fed mixed diet (rabbit 3)

CH8M3 - Chinchilla weaned at 8 weeks fed mixed diet (rabbit 3)

CH8P1 - Chinchilla weaned at 8 weeks fed pellets diet (rabbit 1)

CH8P2 - Chinchilla weaned at 8 weeks fed pellets diet (rabbit 2)

CH8P3 - Chinchilla weaned at 8 weeks fed pellets diet (rabbit 3)

Appendix VI: Equations for Modelling the Profit