GROWTH OF SAHIWAL AND THEIR CROSSBRED WEANER CALVES FED ON PASTURE WITH SUPPLEMENTATION UNDER PASTORAL SYSTEM

BY

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DECLARATION

Declaration by the Candidate

This thesis is my original work and has not been presented for examination in any other University.

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Declaration by Supervisors

This thesis has been submitted for examination with our approval as University Supervisors.

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DEDICATION

I would like to dedicate this thesis to my husband, David K. Lelgut and children, Daisy Lanoi, Kasaine Kigen, Wilfred Saidimu and Perez Lemayian whose paramount support and inspiration enabled me to carry out the research towards the writing of this thesis

ABSTRACT

A cross-sectional survey was conducted by direct interview of 51 livestock farmers using a structured questionnaire in Transmara sub-County, Narok County. The households were selected randomly from a sampling frame from the sub-County wards. The objectives were to identify socio-economic and nutritional factors affecting growth of Sahiwal and Sahiwal/Zebu crossbred weaner calves under the pastoral conditions. Data collected was analysed using SPSS software, version 20.0, 2009. A feeding trial was also conducted in Naivasha at the Dairy Research Institute using 12 weaner calves (six Sahiwal calves; age 9.8 months and average live-weight, 74.7kg and six Fresian x Sahiwal crosses; age, 13.7months and average live-weight, 99.5 kg) fed natural pasture-based ration with either cottonseed cake or lucerne hay as protein supplements in a randomized complete block design. The objective was to compare the effect of breed and protein source on the performance of the calves. Feed samples were exposed to in-vitro gas production procedure to estimate their metabolizable energy (ME) and organic matter digestibility (OMD) content. A comparison of the ME and the OMD values between the two protein sources was done using the general linear model of SAS software whereas the comparison of the animal performance variables between breeds and proteins sources were done using repeated measure in a 2x2 factorial arrangement by Linear Mixed Models of SAS software and the treatments were separated at 5% level of significance by the Tukey method. Results of the survey indicated more than 90% of the livestock enterprise in this area were managed by men and that cattle (65%) formed the largest part of the livestock kept in each farm, followed by sheep and goats in that order. A majority (98%) of the farmers practiced extensive grazing system and the natural pastures were of low quality (crude protein, 4-6% and neutral detergent fibre, 70-75%). Livestock were also fed crop residues and concentrate supplementation was non-existent in most (93%) farms. The major feeding challenges encountered while raising weaner calves were the inadequate skills and knowledge on feed production and feeding. For the animal performance trial, the quality of the Lucerne hay was higher as compared to that of the cotton seed cake ($P < 0.05$) based on the results of the gas production at 24 hours (46.77 vs 40.84 ml), gas production rate (1.42 vs 1.26 ml / hr), ME (9.37 vs 8.60 MJ / Kg DM), and OMD (63.37 vs 58.10 %). On the other hand, the dry matter intake (3.75 vs 2.84), water intake (21.08 vs 18.02 lt / day), feed cost (74.86 vs 57.75 KES / day) average live-weight gain (0.68 vs 0.46 kg / day), feed conversion efficiency (5.64 vs 6.32 kg DM / kg live-weight gain) and net profit (60.76 vs 44.97 KES / kg live-weight gain) were higher for the crosses than the Sahiwal calves ($P < 0.5$). The weaner crosses of local and exotic breeds can perform better and attain the required service live-weight at an early age than the local breeds. On the other hand, Lucerne hay can substitute cotton seed cake as protein supplement without affecting growth performance and production of the weaner calves.

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LIST OF ABBREVIATIONS

ADF: Acid Detergent Fiber

ADG: Average Daily Gain

ADL: Acid Detergent Lignin

AFC: Age at First Calving

ALWG: Average Live Weight Gain

ASAL: Arid and Semi-Arid Lands

BCF: Body Condition Score

Ca: Calcium

CGP: Cumulative Gas Production

CP: Crude Protein

CSCR: Cotton Seed Cake based Ration

DM: Dry Matter

DMD: Dry Matter Digestibility

DMI: Dry Matter Intake

DMIE: Dry Matter Intake Efficiency

DMIMW: Dry Matter Intake per Metabolic Weight

DOMD: Digestible Organic Matter in Dry Matter

GPR: Gas Production Rate

KALRO: Kenya Agricultural and Livestock Research Organization

LHR: Lucerne Hay based Ration

LWTBW: Live-Weight at beginning of each week

LWTEW: Live-Weight at end of each week

ME: Metabolizable Energy

MLFD: Ministry of Livestock and Fisheries Development

N: Nitrogen

NDF: Neutral Detergent Fiber

OMD: Organic Matter Digestibility

P: Phosphorus

SSA: Sub-Saharan Africa

TDN: Total Digestible Nutrients

WI: Water Intake

WIMW: Water Intake per Metabolic Weight

WTGPW: Weight Gain Per Week

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CHAPTER ONE

INTRODUCTION

1.1 Background information

Livestock production plays key socio-economic roles such as providing the domestic requirements of meat, milk, dairy products, eggs, and other livestock products while accounting for about 30 % of the total marketed agricultural products (National Livestock Policy Paper, Feb. 2019) in many African societies. It also plays a critical role in socio-cultural functions including source of wealth, dowry, prestige, and settlement of family disputes, agricultural traction, agricultural diversification and sustainable agricultural production, family and community employment, ritual purposes and social status (Nyariki and Ngugi, 2002; Moyo and Swanepoel, 2010). In Kenya, livestock production is a major economic earner accounting for approximately 45% of the agricultural Gross Domestic Product (GDP) and representing about 10-12% of the overall national GDP (SNV, 2008; IGAD, 2013). In Kenya, the sub sector is supported by various livestock species which include 17.5 million cattle, 17.1 million sheep, 27.7 million goats, 43.8 million chickens, 3 million camels, 0.33 million pigs, 1.8 million donkeys and an undetermined number of companion, game and aquatic animals (MoLD. 2009; KNBS, 2010; ILRI, 2019). About 60% of these livestock population is found in the Arid and Semi-Arid Lands (ASALs) where the industry employs nearly 90% of the population. In the high rainfall areas, the sector provides employment and income mainly through dairy, poultry and pig production.

According to KNBS (2017),livestock production as a whole contributes about 13.4% (USD 3.1 billion) to agricultural value added products (cattle being the most important contributor), while the economic worth of livestock in ASAL areasstand at USD 1.04 billion accounting for 92% of the economy (Nyariki and Mwango'mbe, 2009). The country produced over 4.48 billion litres of milk in 2014 valued at KES 243 billion, of which 76 percent is from cows and the rest from camels and dairy goats (FAO, 2017). The largest contributor to agricultural GDP in Kenyais the beef industry, at around 35 percent (Kosgey *et al*., 2011; Otieno *et al*., 2012). It is an important contributor to the Kenyan economy in terms of value and employment (Alarcon *et al*., 2017), especially in the arid and semi-arid lands (ASALs), where beef production from pasture is the main economic activity (Kinyamario and Ekeya, 2001; Kahi *et al*., 2006).The poultry sector is highly heterogeneous and produces more than 35000 tonnes of meat and 1.6 billion eggs annually (ILRI, 2019).

Kenya is characterized by a wide diversity of agro-climatic conditions indicated by the variations in altitude, temperature, soil conditions and level and reliability of rainfall. The high and medium rainfall areas exhibit ample rainfall and are rich in volcanic soils. The rangelands, commonly referred to as the arid and semi-arid lands (ASALs) are characterized by high ambient temperatures and humidity; low and erratic rainfall; and poor soils (Jaetzold & Schmidt, 1982). These areas are also characterized by poor-quality feed resources, high solar radiation and high incidences of livestock diseases (Kahi, *et al*., 2006). While humid, sub humid and semi humid areas are associated with arable farming characterized by intensive and semi intensive production of livestock. The systems in semi-arid, arid and very arid regions are predominantly characterized by extensive production of livestock under free range, pastoralism and ranching.

The production subsystems for beef cattle in Kenya are classified as extensive grazing system (both pastoralism and ranching), semi-intensive grazing system (agro pastoralism) and intensive. Over 60% of the cattle population are found in the arid and semi-arid lands (ASALs) which are mainly characterized by pastoral production systems (MOLD, 2008; 2009). Local Zebu cattle breeds (mainly the Small East African Zebu (SEAZ) and unimproved Boran) are predominant in this system (Mwacharo & Drucker, 2005;Rewe *et al*., 2006; Ouma *et al.*, 2007). These breeds have evolved to adapt to the prevailing harsh environmental conditions and traditional husbandry systems. However, their production potential is sometimes perceived to be relatively low and thus producers sometimes resorted to crossbreeding with both exotic *Bos taurus* and other introduced Zebu breeds in order to exploit the tradeoffs that exist in regard to production and adaption (Muhuyi *et al*., 1999; Mwacharo and Drucker, 2005; Roessler *et al*., 2010).

The SEAZ has been described as a small cattle breed with genetic potential for meat production (Galukande *et al.,* 1962*).* However, some *Bos indicus* breeds of cattle, such as the Sahiwal and Boran combine adaptability to tropical environment with ability to produce substantially higher milk quantity and growth rate of calves. In areas where husbandry remains relatively poor and cattle are not only used for beef but also for milk production, cross breeding between tropically adapted breeds would be a better approach to produce the most suitable dual purpose type of animal for the production of milk and meat. Cross-breeding of Sahiwal with Friesian, Jersey or Ayrshire increases milk production of its daughters(Ngigi, 2005). A Sahiwal-Friesian crossbreed gives higher milk yields compared to a purebred Sahiwal, yet it does not eat as much as the Friesian breed.

Lifetime productivity of these livestock is slow because of low growth rate resulting into late maturity and light weight at the onset of production, long dry period and calving interval (Jabbar *et al.*, 2000). Growth rate is an important determinant for beef and dual purpose cattle. It is primarily expressed and described by body weight and average daily weight gain (ADG). Body weight changes of cattle are dependent on genetic and environmental factors (Manzi *et al*., 2017). One of the major environmental factors that control cattle growth is feed to which the availability itself depends on climatic conditions. High ADG is a very important parameter for both beef and dual purpose cattle. Higher ADG in early life is one of the most important economic traits in beef production. It has got a high and positive genetic correlation with feed efficiency and puberty. The fast growing animals attain physiological weight at an early age and at less amount of feed consumption which helps to trigger the sexual maturity (Mwacharo and Drucker, 2005).

Pre-weaning and post-weaning ADGs are important traits to select for in cattle (Pravia *et al*. 2014). Calf ADGs of most *Bos indicus* cattle has been reported to range between 0.3 kg to 0.5 kg per day depending on the level of management and mothering ability of dams, which is closely related to the amount of milk produced by the dam (Mwandoto *et al.*, 1988). Maiwashe *et al*. (2002) observed that animals with favourably high ADG have higher sale weight due to the existing relationship between ADG and selling weight. In Kenya, growing cattle depend on availability of feeds that varies with season according to the rainfall patterns. The differences in degree of weight loss within animal breeds during the dry season when feed quantity is limited may be a useful indicator of efficiency of an animal in maintaining its weight (Davis, 1993). The ability to grow or maintain weight under different feed management regimes determines age to maturity thus affecting market weight. Some of the important breed characteristics in cattle breeding are birth weight and pre-weaning growth rate because they are considered as an initial reference point with regard to subsequent growth of individual cattle as well as other characteristics.

Supplementation is among the critical aspect of successful weaner management. Nutrient supplementation should be based on weaner age and weight. To achieve the targeted weight gains of 0.5 kg/head/day the total weaner diet on offer needs to be nutritionally balanced, palatable and digestible to meet the daily nutrient requirements. Supplements should be available to weaners as soon as they are weaned. Rations need to be balanced to meet the needs of the calf and to reach targeted growth goals. The interruption to feed supply for weaners can compromise the weaner's immune system. With proper management and nutrition, there is no growth disadvantage of small weaned calves compared to their similar unweaned counterparts of the same age.Animal productivity in arid and semi-arid areas depends upon quantity and nutritive quality of vegetation available to grazing animals. The nutritional requirements of livestock vary with age and physiological functions of the animal such as growth, maintenance, gestation, fattening and lactation.

Plant material is divisible into fibrous and non-fibrous fractions. Chemical composition varies from plant to plant and within different parts of the same plant (Driehuis *et al*., 1997). It also varies within plants from different geographic locations, climate, ages and edaphic conditions. Most of grasslands in Kenya have insufficient forages due to over-stocking and competition with wildlife. Many studies have assessed the nutritional value of forage in natural rangelands (Islam *et al*., 2003; Nasrullah *et al*., 2003). Natural grazing land has both annual and perennial species of grasses, shrubs and trees. Grass intake is directly related to the quantity and quality on offer (Ramirez *et al*., 2004). While there are many quality characteristics that influence the intake of grasses by livestock, the most useful are digestibility and crude protein content hence, where available, this information is provided for individual species.

Poor nutrition is one of the major limitations to livestock production (Osuji *et al*., 1993). As a result, ruminants are incapable to meet their energy, protein and mineral requirements (Van Niekerk, 1997; Simbaya, 1998). Grasses are the main source of nutrition during wetter months of the year; however, mineral contents in grasses become deficient for normal maintenance of health and growth of ruminants during dry season (Moe, 1994). The majority of grass species in the Maasai plains start germination, flowering and seed setting in the wet season, while in the dry season the residue of nearly all grasses become lignified and indigestible. Although these grasses grow readily and are important source of feed for grazing livestock, their nutritional composition is low. Therefore, this study is geared towards improving the utilization of local forages by Sahiwal and their crossbred weaner calves for increased productionunder pastoral system.

1.2 Statement of the Problem

About 80% of Kenya is characterized as ASAL with livestock production as the main source of livelihood to millions of people residing in these lands (Amwata *et al*., 2015). These ASALs are characterized by high ambient temperatures and humidity; low and erratic rainfall. Livestock production systems in ASALs are predominantly characterized by extensive production under free range, pastoralism and ranching where they rely solely on prevailing pasture with limited supplementation. These pastures alone, are of low nutritional value to support robust growth of weaner calves.

Inadequate nutrition is a major constraint that impact negatively on the growth and viability of livestock farming in Kenya. The poor quality pastures leads to low ADG, high mortality and delayed age at first service. The high calf mortality among the Sahiwal and their crossbred calves after weaning is attributed to these poor quality pastures and lack/low level of concentrate feed supplementation. The calves that survive portray slow growth rate, making them take a longer time to reach maturity and, resulting in delayed attainment of market weight.

1.3 Justification

The rising affluence of Kenya's population coupled with the income growth and urbanization has caused increasing demand for food of animal origin at an unprecedented level. Kenyan cattle production suffer from various constraints that limit productivity, of which the main ones include high incidence of diseases and unpredictable weather patterns characterized by drought (Wakabi, 2006; Bett *et al*., 2009), inadequate feeding, lack of credit facilities and lack of proper breeding services (Bebe *et al*., 2003; Murage and Ilatsia 2011). Raising replacement heifers is the most challenging component of any livestock farm operationssince it requires more inputs for a longer period of time with no visible returns than any other farm operation(Heinrichs, 1993). Poor growth rate resulting in delayed age at maturity in the local dairy animals further aggravates the situation; and this could be due to underfeeding or imbalanced feeding or use of feeds deficient in nutrients (Bhatti *et al*., 2007). In the ASAL areas, calves are usually raised on prevailing fodders and pasture (for example*Themeda triandra*, *Hyparrhenia filipendula*,*Pennisetum catabasis* and *Loudetia kagerensis*) that are low in protein and energyand also with limited or no amounts of concentrates, before and after weaning. This is one of the reasons for lower ADG and delayed age of attaining puberty in heifers. Protein and energy are the most critical nutrients influencing animal productive performance under tropical/subtropical environment conditions (Shahzad *et al*., 2010).

To improve ADG and reduce mortality, it is important to identify, sample and analyze the nutrient content of the common pastures (basal diet) in the ASAL and thus formulate supplementary ration/diet using concentrates and minerals that would improve the pasture, making it suitable for the Sahiwal and their crossbred weaner calves for their growth and reproductive health. The study therefore seeked to develop a feeding technology that would enable both Sahiwal and their crossbred weaner calves in Trans-Mara sub County of Narok County, have improved nutrient intake and performance that would enhance their growth rate and survival. This would assist the livestock farmers optimize on the good attributes of the Sahiwal and their crosses in the ASALs

1.4 Objectives

1.4.1 Overall objective

To contribute to improved utilization of local forages by Sahiwal and their crossbred weaner calves for increased production under pastoral system

1.4.2 Specific objectives

i. To assess the socio-economic and nutritional factors affecting the growth performance of calves in Trans-Mara sub County.

ii. To determine the nutritive values of the forages by proximate analysis and their digestibility using *In vitro* gas production procedure.

iii. To compare growth rate of Sahiwal and Friesian x Sahiwal cross weaner calves under on station feeding using cotton seedcake and lucerne protein rations

1.5 Hypotheses

H_o1**:** There are no socio economic and nutritional factors affecting growth of weaner calves in Trans-Mara sub County.

H_a: There are socio economic and nutritional factors affecting growth of weaner calves in Trans-Mara sub County.

H_o2: There is no significant difference in the nutritive values of the forages by proximate analysis and their digestibility using *In vitro* gas production procedure.

H_a: There is significant difference in the nutritive values of the forages by proximate analysis and their digestibility using *In vitro* gas production procedure.

H_o3: There is no significant difference in thegrowth rate of Sahiwal and Friesian x Sahiwal cross weaner calves under on station feeding using cotton seedcake and lucerne protein rations.

H_a: There is significant difference in the growth rate of Sahiwal and Friesian x Sahiwal cross weaner calves under on station feeding using cotton seedcake and lucerne protein rations.

CHAPTER TWO

LITERATURE REVIEW

2.1. Pastoral cattle production systems in Kenya

2.1.1 Agro ecological zones: Climate - rainfall, temperatures, humidity, soils and vegetation

The land area in Kenya is approximately 591 958 km^2, of which 98.1% is dry land and 1.9% is water (GoK, 2010). According to FAO's agro ecological zoning system, (the main system for land resource assessment), Kenya's dry land mass is divided into six agro-ecological zones as follows; (i) Agro-Alphine - 0.1% (ii) High Potential - 9.3% (iii) Medium Potential -9.3% (iv) Semi-Arid - 8.5% (v) Arid - 52.9% (vi) Very Arid - 19.8% (Sombroek *et* al., 1982; FAO, 1996). Most of Kenya's land mass (approximately 81.2%) is classified as arid and semi-arid (ASAL), with the remaining portion being classified as medium to high potential (Republic of Kenya, 2012). These classifications are based mainly on average annual rainfall and evapo-transpiration, which are key determinants for agricultural production (Macharia, 2004).

Kenya is characterized by diverse agro climatic conditions indicated by the variation in altitude, temperature, soil conditions, and level and reliability of rainfall. The ASALs are characterized by high ambient temperature and humidity; low and erratic rainfall that is poorly distributed; and there is also significant variation in soil type, vegetation and topography (Jaetzold & Schmidt. 1982). The ASALs therefore receive rainfall of between 400 to 500 mm per annum while the potential range from 190 to 2300 mm per annum thus exceeding the annual precipitation hence resulting in water deficit. The mean annual temperature range from 22^{o} to 35^{o}C and the relative humidity from 70 to 90%(Creemers, 2019**;**Amwata *et al*., 2015). Also, dry land resources such as water, pasture, and crops may vary significantly in space and time, while the high and medium rainfall areas exhibit ample rainfall, and these areas are rich in volcanic soils.

2.1.2 Cattle breeds and production

2.1.2.1 Livestock species in Kenya

The livestock production is the main economic activity,a source of food, and cash for many pastoral families (Amwata *et al*., 2015). The majority of pastoral communities living in the ASAL keep different kinds of livestock which have different feed and water requirements, ecological adaptation, growth rates, adaptation to diseases and management requirements (Cossins, 1983). Currently the numbers of the various livestock species in the country stand at approximately17.5 million cattle, 17.1 million sheep27.7 million goats, 43,8 million chicken, 3 million camels,0.33 million pigs, 1.8 million donkeys and undetermined number of companion, game and aquatic animals; 60% of these livestock population is found in the ASAL areas mainly under pastoral production systems (MoLD, 2009; KNBS, 2010; ILRI, 2019). Livestock production as a wholecontributeapproximately 13.4%(USD 3.1 billion) to agricultural value added products – cattle being the lead contributor. In these ASAL areas the economic worth of livestock stand at USD 1.04 billion accounting for 92% of the economy (KNBS, 2017; Nyarigi & Amwata, 2019). In 2014 the country produced over 4.48 billion litres of milk valued at KES 243 billion; of this milk, 76% was from cows while the rest was from camels and dairy goats (FAO, 2017. In Kenya, beef industry is the largest contributor to agricultural GDP accounting for about 35% (Kosgey *et al*., 2011; Otieno *et al*., 2012). Livestock production therefore is an important contributor to the country’s economy in terms of value and employment (Alarcon et al., 2017), this is more so especially in the ASALs where beef production under pasture based system, is the main economic activity (Kinyamario & Ekeya, 2001; Kahi*et al*., 2006).

The local zebu cattle breeds, mainly the SEAZ and unimproved boran, are predominantly found in this system where they fulfill socio-cultural, subsistence and economic needs of the pastoral communities (Mwacharo & Drucker, 2005; Rewe *et al*., 2006; Ouma *et al*., 2007). These breeds have evolved to adapt to the harsh environmental conditions and traditional husbandry systems encountered in these areas. The production potential of these livestock is sometimes perceived to be relatively low hence producers resort to cross breeding with both exotic *Bos Taurus* and other introduced Zebu breeds in order to exploit the tradeoffs that exist in regard to production and adaptation (Muhuyi *et al*., 1999; Mwacharo & Drucker, 2005; Roessler *et al*., 2010). In this regard, Sahiwal is one of the breed of choice because of its relatively high milk production and growth potential, as well as possessing a good reproductive ability (Mwandatto, 1994; Ilatsia et al., 2007; Ilatsia *et al*., 1011). The suitability of this breed for the rangelands is based on the fact that it has evolved and been reared under almost similar harsh agro-climatic conditions in its native home in Punjab region of India and Pakistan (Meyn & Wilkins, 1974; Kimenye, 1978; Trail &Gregory, 1981; Muhuyi, 1997). In Kenya, Sahiwal breed is specifically used in an upgrading programme of the relatively well adapted SEAZ for improved milk production and growth performance under the challenging conditions encountered in the rangelands ((Meyn & Wilkins, 1974; Trail &Gregory, 1981; Muhuyi, 1999). Several generations of this up-grading programme has resulted in the development of the Kenyan Sahiwal. The breed has been utilized also in crossbreeding with European cattle breeds for both large scale and small holder dairy production, though only on a limited scale (Kahi *et al*., 2000; Bebe *et al*., 2003).

In terms of economic importance, the Sahiwal cattle is the best milk producing breed under the harsh climatic conditions of the tropics and sub-tropics(Khan *et al*., 2008). The Sahiwal breed therefore has been used for upgrading other cattle breeds (SEAZ, Dinga, Boran) to improve their milk potential (Rehman &Khan, 2012; Baharizadeh, 2012; Du *et al*., 2013). Sahiwal cattle and their crosses with Zebu and Taurine breeds play an important socio-economic role in various communities in developing countries in the tropics.

The Sahiwal breed carries unique adaptive capabilities having evolved in harsh and diverse tropical environments; this has made the breed relatively competitive in terms of production and adaptation under low input production systems (Muhuyi, 1997; Philipsson, 1999; Joshi *et al*., 2001). Among the zebu breeds of South Asia ancestry, Zebu breed has been spreading to various tropical regions and comes second after Brahman in terms of distribution in these areas (Joshi *et al*., 2001; Mulindwa *et al*., 2006; Hatungumukama & Detilleux, 2009).

2.1.2.2 Sahiwal productivity

In their home tract (Punjab province in Pakistan) the Sahiwal breed has been reported to produce between 1474±15.4 kg to 2217±10.48 kg of milk in 235 to 348 days of lactation. Dahlin (1998) gave the largest data set on lactation performance of Sahiwal cattle when he analysed 11 Sahiwal herds in Pakistan where 4069 cows contributed their lactation records. The reports indicate that the productivity of Sahiwal cattlevary both within and across countries. Dahlin *et al.* (1998) working in different Livestock Experiment Stations in Punjab, India reported a total of 1528 litres of milk per cow per lactation (of lactation length 252 ± 82 days). In other countries including Kenya, the lactation performance has been reported to be in the range of 1474 to 1550 kg of milk (Bajwa *et al*., 2004; Rehman *et al*., 2006; Ilatsia *et al*., 2011). However, Gaur &

Raheja (1996) reported higher lactation milk yield of 2177.8 ± 40.8 litres in a lactation length of 294 ± 1 day. In Kenya in particularSahiwal is capable of producing 1368 kg of milk per lactation of 282 days, and up to 1700kg by the fourth lactation (Ilatsia *et al.*, 2007). FAO (1992) has therefore prioritized the development of Sahiwal cattle through genetic improvement and proper management for use in tropical and subtropical regions.

2.1.2.3 Productivity of Sahiwal crosses

The Sahiwal and Boran breeds of cattle are thought to be suitable dual purpose dairy/beef Zebus for low potential areas (Meyn & Wilkins, 1974).Compared to most *Bos Taurus* breeds, the Sahiwal breed is considered heat tolerant(Holmes, *et al.*, 1983), hence it has been used in New Zealand to produce Sahiwal-Friesian cross bred heifers for export to subtropical and tropical countries for dairy production.

Sahiwal is an excellent grazer, able to use pastures in arid and semi-arid areas, making it a good alternative choice for farmers who are not interested in zero grazing or want to have both milk and beef. In contrast, *Bos taurus* breeds that are predominantly found in temperate countries have a high milk production potential, but poor adaptation to tropical hash environment (Roschinsky *et al.*, 2015). Therefore, crossbreeding of *B. indicus* with *B. taurus* breeds has been widely used in most African countries, including Kenya, to combine the high-production potential of exotic breeds with the adaptability of the indigenous breeds (Manzi *et al.*, 2012; 2017). Cross-breeding with Fresian, Jersey or Aryshire as breeds of choice for crossbreeding therefore increases the milk production potential of its heifer (Lakshmi, *et al.*, 2009). A Sahiwal-Friesian cow gives higher milk yields compared to a purebred Sahiwal, yet it does not eat as much as the Friesian breed. There has been attempts to improve the dairy characteristics of cattle populations through cross-breeding to combine the superior production performance of the *Bos taurus* and the heat/disease tolerance of *Bos indicus* so that the resultant progeny possessing various levels of exotic blood may mature early and produce more milk without getting disturbed and stressed by the extreme climatic conditions (Zaman*et al.*, 1983).

2.1.3 Feeding basal roughages

2.1.3.1 Basal roughage, supplementary forages, concentrates, and minerals

Farmers in the arid and semi-arid communal rangelands of Kenya rely on livestock for their livelihoods. The livestock production in these rangelands of Kenya is under a predominantly extensive system where virtually all animals (cattle and small ruminants)depend on the natural pastures and to a lesser extent on crop residues for feed.Due to low and erratic rainfall there is variable supply of fodder in these rangelands(Smith *et al*., 2010).

The natural grasses in the savannas of Kenya, constitute a significant proportion of the diet of domestic ruminants during the wet and dry seasons. In communal grazing lands, the productivity of ruminants largely depend on the quality and quantity of available forages. For pasture, the quality is related to the amount of nutrient available for the animal (Walton, 1983). Vallentine (1990) reported that the optimum nutrition of an animal is dependent on the animal nutrient requirement, nutrient content of the feedstuff consumed, digestibility of the feedstuff consumed, and the amount consumed, which are in turn affected by botanical and chemical composition of the range forage both of which vary with season: large volumes of relatively high quality forage during the normal wet season andscanty amounts of low quality forage in the dry season (Ontitism*et al.,* 2000*;*Mbatha & Ward 2010). Tefera *e al*. (2009) observed that the annual and perennial grass species in these areas grow rapidly during the rainy season and their growth rate, production and nutritive value decline as they mature towards the end of the season. For example, a summary of published nutrient contents of common grasses growing in humid Africa during the rains, show that these grasses contain on average, 25% dry matter, 10% crude protein, 6% ash, and about 43% acid detergent fibre (ADF) (Smith, 1992). These values change during the dry season with fibre levels of standing hays going much higher (60% ADF), and ash levels falling to below 3%, with a corresponding decline in essential minerals like phosphorus and sodium . With such high fibre levels and extremely low crude protein content (2%), these forages no longer ensure a functional rumen ecosystem, which requires a minimum of 7% protein. Digestibility and intake in turn fall below the minimum required for maintenance (dry matter intake and digestibility of 1.2-2% of live weight and 50-55%, respectively) (Smith, 1993). But the leaves of shrubs and trees provide supplements of protein and energy when grasses are mature and are of low nutritional value, they also provide reserve of feed that can be utilized in times of drought (Wilson, 1969). The browse foliage are often regarded as important supplemental feed resources for the grazing ruminants and therefore the browses have been incorporated into the feeding regimen to improve the nutritional status of the animals (Lusigi *et al*. 1984).

2.1.3.2 Importance of feeding roughage (pastures, fodder, crop residues) to young stock

In Kenya, like other East African countries, young stock (calves) face the same nutritional challenges as the mature cows; poor nutrition and feed shortage in the dry season that result in low protein diets (Smith & Chase, 2000). The impact of inadequate nutrition is most evident in the dry season when forage quantity decreases and other high quality feeds are either expensive and/or unavailable to farmers (Njarui *et al*., 2011; Bii, 2017). Due to these challenges, a reasonable ADG benchmark for forages in the East African region has been estimated at 400-700 g day^{-1}(Lukuyu *et al.*, 2012). Calves achieving this ADG in the first 5 months are able to experience their first calving at 27 months or less (Lukuyu *et al*., 2012).

2.1.3.3 Types of basal roughages in pastoral areas, biomass yield and nutritive value

Since animals require a continuous and adequate supply of nutritive and satisfactory feeds, most of which are in the form of grasses and other forages, the grass family therefore is one of the most important families in the world. It forms the very basis of many ecosystems and all ruminants are therefore either directly or indirectly dependent on them for survival. Livestock in sub-Saharan Africa are dependent primarily on native grasslands and crop residues as basal diet. Browse and grass species of communal grazing lands of sub-Saharan Africa are important sources of feed for smallholder ruminant production systems (Dicko & Sikena, 1991).There are several grass species available for both livestock and wild animals within the rangelands, though only four species i.e. *Hyparrhenia filipendula, Themeda triandra*,*Pennisetum catabasis*and *Loudetia kagerensis* predominate in the Trans Mara rangelands. Browse in form of fodder trees and shrubs also form an integral part feed resources, but are yet to play a strategic role in livestock feeding within these areas. A number of browse species such as *Leucaena leucocephala*, *Gliricidia sepium* and *Sesbania sesban*, grow year round, and respond positively to regular pruning. They could, therefore, be managed to provide fodder during the critical dry periods.

Under the majority of smallholder production systems, both quantity and quality of available feeds varies with season following the rainfall pattern. The most critical quality parameters that limit animal performance, especially during the dry season, are the low crude protein and high fibre contents of the feeds available then.

Supplements that correct for these deficiencies have been shown to improve efficiency of utilization of the available low quality fibrous forages and thus the performance of animals (Muia, 2000). Unfortunately, the high cost of commercial concentrates, make them unaffordable to smallholder farmers with limited resources (Ademosun, 1994). Irungu (1999) observed that in Kenya, the cost and availability of good quality supplemental feed is a major constraint to their increased utilization by smallholder farmers.

Intake of poor quality pasture grasses and cereal straws by ruminants is usually low in maintaining body weight because of their tough texture, poor digestibility and nutrient deficiency which contribute to the low level of consumption (El-Naga, 1989). These roughages are deficient in readily available energy and nitrogen, which reduces the efficiency with which they are utilized by animals. Most of these deficiencies can be corrected by supplementation with high density feeds such as oilseed cakes. However, protein sources such as oil seed cakes and those of animal origin are produced in limited quantities and are often beyond the economic reach of most farmers. It is therefore feasible and economical to use proteins from plant origin such as Lucerne and Desmodium which the farmers can grow easily.

Ruminant livestock production, according to Nurfeta (2010), is hindered by inadequacy and low quality of feed. High level of productivity cannot be obtained since the tropical grasses which are usually given to these livestock are low or deficient in protein (Kosgey & Okeyo, 2007). It has, however, been reported that when these tropical grasses are supplemented with concentrates, their intake and digestibility are improved (Nurfeta, 2010). However, such strategies are rarely adopted by smallholder livestock farmers because these farmers consider concentrates to be scarce and expensive to use. There is therefore limited prospect for using cereal grains and by-products as livestock as livestock feed by these farmers. To mitigate the problems associated with lack or limited protein there is need to identify alternative protein sources that can be easily produced at farm level without incurring additional cost.

2.1.4 Need for feed supplementation

In most of Kenyas rangelands, particularly in the grassland areas of Trans-Mara region, the basal diet of ruminants, particularly large ruminants (cattle), consists of fibrous feeds, mainly from mature pastures and to lesser extend crop residues (for example: maize stover, bean trash among others). These roughages are unbalanced in terms of nitrogen (N), mineral and vitamin content and they are also highly lignified. Consequently, their dry matter (DM) digestibility is reduced. These characteristics keep voluntary dry matter intake (DMI) and productivity low, and consequently the quantity of animal products (meat, milk) is limited or nil. Animals may sometimes barely survive, or even die during times of feed scarcity.

Browse plants, beside grasses, constitute one of the cheapest sources of feed for ruminants (Ahamefule*et al*., 2006). Their ever greenness and nutritional abundance provides for year round provision of fodder (Ibeawuchi*et al*., 2002). Almost all the browse trees and shrubs have the advantage of maintaining both their greenness and nutritive value throughout the dry season when herbaceous vegetation dry up and deteriorate both in quantity and quality. Trees and shrubs have been used for generations as multipurpose resources in many parts of the world (Smith, 1992). Moreover, the browsers may consume various parts of woody plants viz: leaves, twigs, thorns, bulbs, tubers, roots, flowers, seedpods, and fruits (le Houerou, 1980).

In areas where the dry season lasts for long time, like ASALs, trees and shrubs are a good source of supplementary nitrogen. The major use of foliage browse species is as a source of crude protein (CP). This quality of browse species is most useful during the dry season when most of the range grasses and other herbaceous annuals are no more producing the needed forage biomass (Devendra 1990). The ability of most browses to remain green for longer time is attributed to their deep roots that enable them to extract water and nutrient resources from deep in the soil profile. Moreover, leguminous browse species fix atmospheric nitrogen, and this improves soil fertility that can be utilized by the companion or subsequent crops grown in the area (Atta-Krah 1990).

2.1.4.1 Importance of Supplementary Forages

The nutrients supplied from the feed resources (natural pasture) are not enough to meet the requirements of the existing livestock population in the ASAL areas and thus resulting in low productive and under nourished livestock. To fulfill the existing nutrients demand for growing livestock population in the country, there is a need to explore alternative feed resources. Ondiek *et al*. (2000) suggested that the replacement of conventional concentrate with supplementary forages (legumes and fodder trees) would be cheaper than the conventional concentrate.

According to Baumer (1991) tree herbage is an integral part of the ruminant diets and constitutes significant source of protein, mineral and vitamins. In Kenya large varieties of tree leaves in both ASAL and high potential regions are available and are extensively used for livestock feeding. Nutritive value of some of the local tree leaves is very high and comparable to concentrates for ruminant. Lucerne (*Medicago sativa)* is a well-established leguminous fodder in the country with high CP content of 16 to 21% DM (Kariuki, 1998; Odongo *et al.,* 1999). Its annual yield is estimated at 0.9 -

1.4 T DM/ha/year (Odongo *et al*., 1999; Wanyama *et al.*, 2000). It is mainly grown in medium and large-scale farms and is fed in the form of hay as a dairy cattle supplement especially during the dry season. It is available in many parts of the country and has been shown to improve growth rate and milk production in cattle (Kariuki, 1998). However, little information is available in the country on its use as a supplement in calf production.

de Leeuw *et al.*(1991) observed that in the Maasai pastoral herds, the young stock (the calves) are weaned naturally by the dams at around the age of one year. Earlier weaning could lower pressure on the dam and re-gain lost weight quicker in addition to having calving intervals shortened. Early introduction of fodder to the calf would also enhance rumination thereby increasing the ability of the calf to fully utilize available fodder at the time of weaning. However, supplies of better quality fodder must also be secured. Early development of rumen activity can also be attained by supplementing the calf with concentrates.

2.1.4.2 Types of supplementary forages in pastoral areas and nutritive value

Semi-arid and arid rangelands are characterized by variable supply of fodder for livestock which is largely attributed to low and erratic precipitation(Smith *et al*., 2010). During normal wet seasons, most of these lands support large volumes of forage which is also of relatively high quality (Mbatha & Ward, 2010). The dry seasons, on the other hand, are characterized by scanty amounts of forage which is mostly of poor quality (Ontitism *et al*., 2000).

Nutrition is one of the major constraints to cattle production in the tropics, particularly the lack of protein during the dry season (Minson, 1990). The problem of feed supply and quality is even more aggravated in arid and semi-arid areas with erratic and unreliable rainfall. Thus, animals in these areas have to survive only on range vegetation that has low nutritive value for most part of the year. The crude protein (CP) content of range vegetation is between 8-12% of DM at the beginning of rainy seasons, but drops to 2-4% in the four to six month dry season, leading to prolonged period of under nutrition and malnutrition (Amaning-Kwarteng, 1991). Under these circumstances, the most practical supplement would be to use feed resources from locally available legume trees. The value of forages as feed supplements depends on their capacity to provide the nutrients deficient in the basal diet (Preston & Leng, 1987). For ruminants subsisting on high fibre roughages such as mature grasses and crop residues, the first limiting nutrient for microbial activity is nitrogen (N) which must not only be present in adequate quantities in the feed but must also be available to the microorganisms (Tamminga, 1989). For effective utilization of supplemental N by the rumen microorganisms a synchronous availability of energy is necessary (McDonald *etal*., 1995). On high fibre mature tropical grasses this may also constitute a limiting factor (Van Soest, 1994; McDonald *etal.*, 1995). The lower NDF and ADF content of forages, which translates to higher digestibility, would also supplement energy supply thus promote higher microbial activity (Van Soest, 1994; McDonald *et al.*, 1995).

Chemical composition is a major determinant of nutritive value of forages and could affect ruminant performance at both plant and animal levels (Minson, 1990). At the forage level, species could differ in quality and in the extent and rate of ruminal degradation and hence influence the yield of fermentable substrate (Minson, 1990). The nutritive value of forage is a function of its chemical composition, mineral content, presence of toxins or anti-nutritive factors and digestibility (Ivory, 1990).

2.1.4.3 Feeding Concentrates

Livestock diet can be exclusively forage or largely forage with concentrate supplementation. Concentrate supplementation is used to compensate nutritional deficiencies in the forage supply, increase animal performance such as milk production or at particularly challenging periods of development, for example calving (Erb *et al*., 2012; Capstaff & Miller, 2018). Concentrate supplementation is an important component of feeding programs for early weaned calves on pasture because low forage intake may limit calf performance (Arthington & Kalmbacher, 2003). A concentrate feed is a parasite-free fodder and would be good for the young calf because it does not yet possess any immunity against parasites. Galloway *et al.* (1992) indicated that moderate levels of supplement with concentrates (200–300 g kg^{-1} of diet DM) can improve nutrient intake and performance of 12-month-old cattle consuming Bermuda grass. At greater amounts, forage nutrient digestion, intake, or both, can be affected negatively. Among several theories used to explain the associative effect of concentrate on forage intake. Horn and McCollum (1987) suggested that greater consumption of readily fermentable carbohydrates decreased rumen pH and quantity of cellulolytic bacteria, and reduced forage digestibility and passage rates. Thus, associative effects make it difficult to predict the impact of feeding greater amounts of concentrate supplement.

In addition, the main problem facing livestock farmers in tropical areas is the right nutrition for their animals during the dry season when pastures, cereal residues and maize stover are limiting in nutritional quality. Usually, it is during this season that problems such as disease and weight loss due to poor dietary profile increases. It is envisaged that supplementation would also hasten growth of female calves, which will then reach sexual maturity early, thus lowering the age of first calving.

2.1.4.4 Minerals: types, nutritive value and role in young stock rearing

Nutrition obtained from the diet play significant role in any livestock development programme. The optimum expression of genetic potential for milk production in dairy cows depend on adequate supply of nutrients (Bhanderi*et al*., 2016). the minerals are inorganic elements that are needed by the animals' body for growth and maintenance of the bones, osmotic balance, muscle and nerve function, body enzymes, hormones, and body cells (Bhanderi*et al*., 2016). Underwood & Suttle, (1999) has reiterated the importance of minerals in regulating biological systems, growth, production and reproduction, however livestock in pastoral areas do not receive any mineral/vitamin supplements except for common salt. The quantities of different minerals recommended for cows are dependent partially on level of production, body size, and the environment among other dietary factors. The minerals required by the animal are usually calculated by adding up the amounts needed for each particular body function which include maintenance, milk production, growth and pregnancy. It is rare to see major mineral deficiencies' except that of milk fever, but small mineral shortages and/or imbalances that can cause health and reproductive problems that are often not immediately apparent but manifest in the long term. When production (yield) increases the mineral deficiencies become more apparent.

2.1.5 Challenges faced by farmers in pastoral areas

Given the changing global climate, coupled with expected increase in evapotranspiration due to increased temperatures, Thornton and Lipper (2014) noted that the ASALs are expected to experience frequent climatic extremes, increased aridity, increased water stress, diminished forage yields from rain-fed agriculture and increased food insecurity and malnutrition. in the tropical ASALs livestock production is constraint by myriad of factors, the major ones being feed and water scarcity, diseases, breed and breeding, limited manpower, market and infrastructure that are exacerbated by climate change. Most of these factors, impact negatively the animal productivity, the yields of forages and feed crops, animal health and biodiversity (FAO, 2017). The major feed resources are natural pastures or purposely grown forages and seasonal grasses. Fluctuations in feed quality and quantity compromise animal productivity, health and welfare (Owen *et al*., 2005; Rufino *et al*., 2006). Establishment of legumes, shrubs and fodder trees which are high in protein in agro-ecological zones that support livestock farming, would alleviate this constraint.

2.1.5.1 Inadequate feeds

Most developing countries in the tropics face critical shortage of animal feeds, particularly during the dry season (Seyoum and Zinash, 1995; Orskov, 1998; Tolera & Abebe, 2007). Climate and season greatly influence supply and quality of feeds. Unreliability of roughage production, especially during dry periods, is a major problem that limits livestock production (Baker and Gray, 2003). In smallholder systems, land for forage production is a limiting factor (Kosgey, 2004). The quality and quantity of many tropical grasses are often low and inadequate. Carles (1983), Gatenby (1986) and Charray *et al*. (1992) proposed the use of livestock genotypes that are adapted to efficiently utilize poor quality feed resources, while Baker and Rege, (1994) observed that this trait was not conventionally included amongst those used to characterize suitable breeds. Forage quality and quantity are affected by seasons and are major constraints to increased cattle productivity under most tropical livestock farming systems (de Leeuw *et al*., 1999). Forage quality is generally high in the early part of the growing season but declines dramatically for the rest of the year (Ademosun and Bosman, 1989; Mero and Uden, 1998), since they grow and mature rapidly with the onset of the rains, leading to rapid deposition of fibrous components, a decline in nitrogen and soluble carbohydrates, and increase in the stem leaf ratio of the forage, with stem containing the less digestible cell walls, thereby increasing pressure on scarce supplemental feed resources (Shem *et al*. 2001). Due to these problems, livestock farmers in the ASALs tend to feed their cattle on a variety of forages, which often have unknown nutritive values. Nutrient supply therefore, from these forages, which are the main feed resources available for livestock especially cattle, usually fall below requirements of livestock growth and acceptable performance.

2.1.5.2 Poor quality feeds

The livestock production in the ASALs of Kenya is pasture based hence depend on availability of land. Continued subdivision of land coupled with persistent droughts poses particular challenges to livestock production, especially during the dry season. This sub-division lead to shrinkage in land area available for grazing consequently affecting the productivity of the animals (Kinyaamario & Ekeya, 2001. Further, adequate nutrient supply is hindered by qualitative deficiencies resulting from peculiar growth characteristics of tropical forages: they grow and mature rapidly with the onset of rains.

2.1.5.3 Water scarcity

Water is a key natural resource need for successful livestock production, mainly used for drinking and for feed growth purposes. Water scarcity from drought therefore result in loss of livestock populations and human lives (Udmale *et al.,* 2014). Drought, a natural phenomenon, affect water resources leading to water scarcity which in turn affects the economy, social life and the environment (Martin, 2012). Wilhite et al. (2005) described drought as an insidious natural hazard that results from a deficiency of precipitation, which when it extends over a season or longer becomes insufficient to meet the demands of human activities and the environment. Water is a key factor that restricts agricultural production and income for the world‘s poor especially in rural areas (Gebregziabher and Namara, 2009). Water scarcity affects socioeconomic development and the environment and these effects limit the production and productivity of livestock and crops. Sufficient quantity and quality of water supplies are necessary for efficient livestock production; water plays major role in the physiology of livestock and it relieves the thirst of animal to increase their production and productivity (Trevor, 2007). Trevor (2007) contends that water is used for processing the livestock products and for services. Pimentel *et al*. (2004) however, acknowledged that plants use less water compared to the livestock industry. Water plays an important role in the livestock value chain as an input into the food value chain for both human and livestock. Pimentel *et al.* (2004) acknowledges that the more livestock products are needed, the more the pressure on fresh water resources. Inadequate access of these water resources will hinder efforts to meet the demand of livestock production (Pimentel *et al.*, 2004). Peden *et al.* (2008) suggest that choice of suitable animal type and breed is one of the strategies in the dry lands or water scarcity areas to cope with water crisis.

2.1.5.4 Diseases

The tropical environments are characterized by high incidences of diseases among others, which account for the reported high mortality rates (about 25%) leading to reduced livestock productivity (Herlocker, 1999; Jalang’o, 2001. This position has been associated with poor disease surveillance programmes, poor infrastructure, corruption and the poor economic condition of livestock farmers, leading to aggravated economic losses associated with these diseases. The situation is worse in the small-scale pastoral production systems where disease control measures are inadequate. The most important notifiable diseases in Kenya are Foot and Mouth Disease (FMD), Anthrax, Contagious Bovine Pleuropneumonia (CBPP), Rabies, Lumpy Skin disease, Contagious Caprine Pleuropneumonia (CCPP), New Castle Disease, East Coast Fever, Rift Valley Fever Trypanosomosis, and re-emerging diseases. More outbreaks of FMD have been reported in recent years than of the other diseases (Jalang'o, 2001). Of more significance also are the non-notifiable diseases like reproductive disorders, mastitis and scours among others that affect large number of livestock in the country and which need sustained vigilance and surveillance in order to control.

2.1.5.5 Breeds and breeding

The Short Horned Zebu represents the major genetic group of indigenous cattle in the country. The group is further divided into large and small types. The large type comprises of the Boran cluster (Orma Boran, Kenya Boran and Northern Frontier District Boran), Turkana and Karapokot, Kenya Sahiwal (exotic indicine). The small type comprises of the small East African zebu (SEAZ), such as Nandi, Kavirondo and Kikuyu. The exotic group comprises the dairy types (Friesian, Holstein, Guernsey, Jersey and Ayrshire); dual purpose types (Simmental, Red Poll, Brown Swiss); Beef types (Hereford, Santa Getrudis, Charolais, Galloway, Aberdeen Angus, Dexter), and a large genetic group of crosses (Ministry of Livestock and Fisheries Development (MLFD), 2004; Rewe *et al*., 2006; MoLD, 2009; NABP, 2009). The genotypes kept comprise the indigenous *Bos indicus* breeds (70 %), pure-bred exotic and crosses (30 %) (MLFD, 2004). These together contribute 70 % of the beef produced. About 30 % of the beef emanates from dairy herds in the form of bull calves not used for breeding, culled heifers, cows and bulls (MLFD, 2004).

The main beef cattle types in Kenya are local breeds (e.g., Zebu & Boran). These are generally considered to be relatively adapted to low-feed availability, and frequent drought and disease challenges prevalent in sub-Saharan Africa (SSA). However, local breeds also fetch low market value due to factors such as small body size/low slaughter weight, low growth rates and declining productivity (Kavoi *et al.,* 2010).

2.2 Quality and nutritive value of feed resources

2.2.1. Feed evaluation using proximate analysis, *in vitro* gas production, *in situ*, and *in vivo* approaches

The nutritive value of a ruminant feed is determined by the concentrations of its chemical components, as well as their rate and extent of digestion. Determining the digestibility of feeds *in vivo* is laborious, expensive, requires large quantities of feed and is largely unsuitable for single feedstuffs thereby making it unsuitable for routine feed evaluation. *In vitro* methods provide less expensive and more rapid alternatives (Getachew *et al*., 2004)

Whereas biomass productivity has been studied using various methods, the true benefits of the biomass in animal nutrition can only be assessed by determining whether these feeds can be consumed voluntarily, degraded, digested and metabolized by the grazers(Moreau *et al.*, 2003; Jacobs & Naiman, 2008). The quantity consumed can be inferred by relative harvest of the material from the field by the grazers but this presents an uncertainty as to which species of grazers did actually pick the material especially in free ranging grassland with several species of both large and small ruminants and pseudo-ruminants (Changwony, 2014). There are, however, several approaches in the assessment of feeds which can be applied in rangeland pastures to obtain accurate values of nutritional quality, intake and digestibility.

The rate and extent of DM fermentation in the rumen are very important determinants for the nutrients absorbed by ruminants. *In vitro* evaluation of feed involves use of laboratory techniques such as chemical analysis and artificial digestion and degradation simulating the animal situation to assess feed. These methods are at best predictive of feed value as the best arbiter in assessment is the target animal itself (Mould, 2003). *In vitro* methods always use substrate disappearance to assess degradation and rarely provide information regarding the quantity of derived end-products available to the host animal (Mould, 2003). However, in ranking feeds in terms of quality, *in vitro* evaluation is a useful and accurate tool (Sheng *et al.*, 2008). As a rapid evaluation method, *in vitro* method of feed analysis offers a fast, cheap and reliable alternative to evaluations using animals.

This method applies the premise that in the rumen, feed fermentation is associated with the evolution of gas, principally carbon dioxide and methane. On the assumption that the quantity of gas produced from *in vitro* incubation of feedstuffs with rumen fluid is closely correlated to digestibility, and therefore the energy value of feed to ruminants, recommended the gas system to evaluate feedstuffs (Menke *et al.*, 1979). In this system, the substrate is incubated (the incubation media are rumen fluid and a buffer) in a calibrated gas tight glass syringe fitted with a plunger to allow gases evolved (CH_4 and CO_2) to be retained and recorded manually over a selected time depending on the type of substrate being incubated. Based on the volume of gas gathered over time, different empirical equations are established to predict *in vivo* digestibility from chemical composition and *in vitro* gas production technique (Menke & Steingass, 1988).

An *in situ* evaluation method uses rumen degradability to assess the extent to which a feed sample is fermented by rumen microbes. It is a technique using special bags into which feed samples are weighed and incubated in the rumen. Fermentation substrates as well as soluble materials are diffused out of the bags and the disappearance is calculated to represent what was degraded within the incubation time. Often times, rumen degradation is synonymous to digestibility (Mehrez & Ørskov, 1977). The advantage of this method is its ability to estimate degradability of specific feed constituents like crude protein, organic matter and neutral detergent fibre. It is also used to assess the feed degradation kinetics (Ørskov & McDonald, 1979). This method has been used to assess various feeds though it has limitations (Melaku *et al.*, 2003; Tagliapietra *et al.*, 2011; Krizsan & Huhtanen, 2013). It only measures disappearance of feed and not the actual fermented substrate and it requires the use of rumen-canulated animals which is expensive and raises ethical issues of animal welfare (Nocek, 1988; Stern *et al.*, 1997).

In vivo methods use the whole animal system to assess feed. The animal is fed with the experimental feed which is then processed through the gastro-intestinal tract, undergoing all the natural mechanical, microbial and enzymatic action. *In vivo* evaluation therefore measures the true nutritional worth of the feed from the animal's perspective. It allows for voluntary feed intake, nitrogen balance (Adesogan *et al.*, 2002) as well as true digestibility to be measured. This method is, however, expensive as feed required should be sufficient to meet the animal's nutrient requirements. It requires frequent feed and animal handling and the choice of feed by the animal is limited by the researcher's desires. In feed evaluation, this method remains the best method to assess and rank feeds.

2.2.2 Chemical composition and nutritive values of range pastures

Nutritive value is an indication of the contribution of a feed to the nutrient content of the diet and it depends on the quantity of a feed which is digested and absorbed and the amounts of the essential nutrients (protein, fat, carbohydrate, minerals, and vitamins) it contains. It is determined by a number of factors, including composition, odour, texture and taste. This value can be affected by soil and growing conditions, handling and storage, and processing (Schneider & Flat, 1975). A number of workers have evaluated various grass species for their chemical composition and nutritive values and have reported this work for different ecological zones(Feedipedia, 2011). Species were analyzed for crude protein, crude fat, crude fibre, ash and silica contents and for the various mineral element contents. This was done on both planted and rangeland pastures but mostly on grasses. The various grass species whose analysis have been reported in greater details include *Pennisetum purpureum, Themeda triandra, Panicum maximum, Chloris gayana, Cynodon dactylon, Digitaria* spp., *Hyparrhenia* spp., *Melinis minutiflora*, *Setaria* spp. and many other range species.

The forage value of *Hyparrhenia filipendula* at the early bloom stage in Kenya has been reported to as follows: crude protein 6.6%, crude fibre 36.3%, ash 5.7%, ether extract 1.8%, and nitrogen-free extract 49.5%. Average figures are given in Table 2.1 below. Analyses on material from Malawi showed that the nutritional value of the grass decreased with the progress of the growing season: acid detergent fibre increased from 29.6% to 39.0% and finally 46.6%, neutral detergent fibre decreased from 65.6% to 55.6% and finally 47.4%, while ash remained fairly constant at 1.60%, 1.44% and 1.54%. Red oat grass *(Themeda triandra)* composition varies considerably: stage and grazing intensity are the main sources of variation (Heady, 1966). Its crude protein content declines from 8-9% DM at the early stage to 2-3% when mature. NDF content is high and increases with maturity, from 65% at the vegetative stage to 70% at maturity (Feedipedia, 2011).

Table 2. 1 Chemical content of various plants species and their parts (%)

Grass	Leaves			Whole plant		
	Crude protein	**Crude fiber**	**N free Extract**	**Crude protein**	**Crude fiber**	**N free Extract**
Hyparrhenia filipendula (Common name: fine thatching grass; Maasai name: Olperesi oyiado)	*4.53*	*34.27*	*50.38*	*2.62*	40.31	50.26
Themeda triandra (Maasai name: Olperesi orasha)	*4.89*	35.19	49.84	3.22	39.44	49.37
Loudetia kagerensis (Maasai name: Inkujit)	*4.23*	*38.04*	47.17	3.59	41.65	48.83

(Feedipedia, 2011)

Grass constitutes the nutritional basis for cattle herds in the tropics (Elizondo & Boschini, 2003). African Star Grass (*Cynodon plectostachyus*) is a forage species that has been established and has persisted in pastures around Lake Naivasha where it currently occupies a large area. Star Grass is a valued pasture in the tropics and it is part of cattle production systems in several dry tropical areas, particularly in Eastern Africa and in Central and South America. For instance, in the drylands of southeastern Kenya, *Cynodon plectostachyus* was the top-ranked pasture (sometimes above *Eragrostis superba*, *Cenchrus ciliaris* and *Megathyrsus maximus*) according to a survey of cattle farmers (Ndathi *et al*., 2012).

C. plectostachyus is a moderately nutritive grass, containing about 10% DM of protein. Grass fed during the dry season can contain less than 6% DM of protein while young grass can contain more than 15% DM of protein and more than 18% DM under Nitrogen (N) fertilization (Cecato *et al*,. 2001). *Cynodon plectostachyus* may have a similar to or lower value than other grasses available at the same period in the same area. In Kenya, the *in vitro* DM digestibility (35%) of *Cynodon plectostachyus* hay was lower than that of *Eragrostis superba* (45%) and similar to that of *Cenchrus ciliaris* and *Megathyrsus maximus* at 37 and 34%, respectively (Ndathi *et al*., 2012). In Puerto Rico, its *in vivo* DM digestibility (50%) was lower than that of *Cynodon dactylon, Cynodon nlemfuensis, Digitariaeriantha* and *Megathyrsus maximus* (54-55%) (Randel & Mendez-Cruz, 1989). In Brazil, the *in vitro* DM digestibility of *Cynodon plectostachyus* grass (63%) was found to be similar to that of Tifton 85 and *Cynodon nlemfuensis* (63%) and slightly lower than that of *Cynodon* cultivars Coast cross and Tifton 44 at 65% (Cecato *et al*., 2001). In the Philippines, giant star grass cut every 20 days had a higher *in vivo* DM digestibility in sheep (60%) than when cut every 30 or 40 days (Intong, 1998). In Cuba, the *in vivo* OM digestibility in sheep of *Cynodon plectostachyus* silage was identical to that of *Megathyrsus maximus* silage (59%), and lower than that of King Grass (*Pennisetum purpureum* × *Pennisetum glaucum*) silage at 63% (Esperance & Diaz, 1985).

2.3 Feed intake and growth performance of weaner calves

Good quality feed is crucial for higher milk/beef production and ideal reproduction. Inadequate intake of energy, protein, vitamins and minerals is associated with poor reproductive performance (Smith & Chase, 2000). Good calf management is the cornerstone of future cattle productivity. Calf management is of particular importance in countries such as Kenya where the dairy industry is expanding (Odero-Waitituh, 2017). Lukuyu *et al.* (2012) observed that nutritional management is aimed at building immunity and ensuring proper ruminal development during the early stages of a calf’s life. Post weaning, when the rumen is functional, provision of high quality forage is key to maintaining a healthy growth rate (Moran, 2005).

2.3.1 Feed palatability, its importance and the factors affecting it

Palatability usually designates those characteristics of a feed that invoke a sensory response in the animal, and is considered to be the corollary of the animal's appetite for the feed (Baumont, 1996). Thus, palatability measured as the sensory response invoked by the feed integrates its nutritive value. However, for a given nutritive value, sensory properties of the feed *per se* can stimulate or depress hedonic feeding behaviour. The role of hedonic behavior on intake may be of particular importance in choice situations and for low producing animals. In a first approach, hedonic value of the feed can be assessed by the difference between the observed intake and the predicted intake as affected by the nutritive value. Palatability of the forage is therefore an indirect measure of quality: it is the summation of the plant characteristics that determine the relish with which a forage is consumed by an animal. Livestock find some harvested forages much more acceptable than others, and low palatability may greatly reduce consumption levels or may result in animals refusing to consume even smaller amounts. Potential intake level by the ruminant animal is considered one of the two universal factors in forage quality, the other being nutritive value. Animal preferences of forages result primarily from the senses of smell and taste (Marten, 1978; Walton, 1983). Many feedstuffs of low palatability but otherwise wholesome for animal consumption are relished when sprayed with molasses or artificial sweeteners such as saccharin, indicating a high dependence on taste in dietary selection. The presence of antipalatability (bad taste) factors such as alkaloids, volatile chemical components, rancidity, moldiness, and contamination with agricultural chemicals can sharply reduce palatability. The sense of touch or feel may also be important; palatability is related to physical characteristics such as fiber content, toughness, steminess, leafiness, level of maturity, and succulence. The sense of sight apparently plays an insignificant role in determining forage preference by domestic livestock. Palatability is actually a major parameter given its strong relation with feed intake (Bobroff and Kissileff, 1986), either as a determinant or a consequence of amount eaten (Sorensen *et al*., 2003).

2.3.2 Feed intake: its importance and the factors affecting it

Feed intake is one of the most important factors for the productivity of ruminants. If the voluntary intake is too low the rate of production will be depressed, resulting in requirements for maintenance becoming a very large proportion of the metabolizable energy consumed and so giving a poor efficiency of feed conversion (Forbes, 1995). The factors affecting feed intake of ruminants can be distinguished as (i) animals, (ii) the feed characteristics or (iii) the environmental conditions (McDonald *et al*., 1995). Regulation of feed intake and dietary choices combine short-term control of feeding behaviour related to the body’s homeostatic and long-term control that depends on nutritional requirements and body reserves (Faverdin *et al.*, 1995). Feed factors act mainly on the short-term control. Feed quality and physical characteristics of forage, such as a DM content, fibre content, particle size, and resistance to fracture are known to affect ease of prehension and thus intake rate (Inoue *et al*., 1994).

The presence of competition for feed and feeding space has a major influence on feeding behaviour, rate of eating being increased when there are more animals per feeder. Insufficient feed intake occurs even in the case of a well-balanced feed available ad libitum. Many farm species show social synchrony of feeding and it is possible that some individuals cannot get to the trough during these feeding periods, sometime being excluded by dominant members of the group (Young & Lawrence, 1994).

2.3.3 The Growth rate of weaner calf and fertility

Growing calves depend on availability of feed that varies seasonally in most of the tropical areas. The ability to grow or maintain weight in separate environments during the wet or dry seasons determines how quickly an animal will reach marketweight. After weaning, the first 30 to 45 days are considered the stressful period of the calf's life, and good performance during this time can set a stage for efficient and profitable feed out, or a long and productive life in the herd. Most sicknesses and deaths from respiratory diseases occur at this time. Respiratory diseases affect one in 7 feedlot placements and are the leading cause of death loss. Recovered cattle also gain weight more slowly and have low value carcasses than healthy cattle. Also, digestive upsets that occur here may show up as founder, liver abscesses and other side effects later on. Cattle that are fed too conservatively at this stage may pass up the most potentially efficient period of their life and add extra days on feed, and cost of gain.

Average daily weight gain (ADG), body condition score (BCS), age at first calving (AFC) and body weight (BW) are some of the indices used to monitor and predict the potential of weaned calves and heifers in dairy farms (Krpálková *et al.*, 2014). The rate of calf growth, as indicated by ADG is commensurate with the quality of feeding and subsequently determines BCS and BW, which subsequently influence onset of puberty and hence AFC (Moran, 2005). Age at first calving can be regarded as an indicator of the quality of nutritional management of heifer calves. Heifers subjected to poor nutrition and with low BW at 6 months of age (therefore a slow growth rate) calved at more than 25 months of age compared to well-nourished heifers that calved at an earlier age (Cooke *et al.*, 2013).

Calves that have been allowed to suckle freely or are fed *ad libitum* ingest about 20 percent of body weight (BW) daily and can gain up to 1Kgd^{-1} (Flower & Weary, 2001). Maximum milk productivity per day of life has been observed in heifers/calves that achieve a pre pubertal ADG of 0.8850g/day and AFC of 24-27 months (Krpálková *et al*., 2014). In a study to identify the effects of these indices on milk production, a group of Holstein calves had an ADG of between 0.850 kg/day and 0.949kg/day during the ages of 5 to 14 months with a mean body weight of 412.5 kg at first calving (Krpálková *et al*., 2014).

The nutritional quality of feeds and forage can have a tremendous influence on the reproductive performance of cattle. Although reproductive failure may occur for several reasons, management and the environment are often important contributing factors. Part of the environment and management of any animal is nutrition. Nutrition is one of the most important management factors in reaching calf crop goals and in attaining a short calving season every year in beef breeding herds. The protein requirement of young growing stock and heavy-milking cows is often a limiting factor, while mature dry cows are often overfed protein. Heifers must be fed adequately from weaning to breeding if they are to calve at 2 years of age; this target is critical for herd economics, because before this point the absence of beef calf or milk for sale represents significant investment and risk (Jonathan, 2015).

While the productivity of herds depends on the reproductive performance of breeding females, mortality and growth rate of calves from birth to maturity, it is the number of calves born, their survival and growth that determines the viability of the herd (de Leeuw *et al.,* 1991). Bekure *et al.* (1991) observed that calf feeding among the Maasai pastoralists aim at avoiding losses rather than promoting fast growth. Milk off take is carefully controlled to maintain a safe balance between the needs of the calf and human consumption. During the first 3-4 days of birth, the calf is allowed to suckle almost all of the dam’s milk. Thereafter, the dams are milked once per day for several weeks while calves are allowed to suckle during and immediately after milking, before being separated from their dams. Usually, women milked the two left teats leaving the two right teats for the calf to suckle. However, in times of need the woman may strip three teats. High mortality in calves is a major cause of low productivity in Maasai pastoral systems. During drought, calf losses are much higher. Mortality rates of 60% are commonly recorded for calves less than one year old (Bekure *et al.*, 1991). Generally, mortality increased when the calves were sent out to graze and was mainly due to worms, diseases and malnutrition (de Leeuw *et al.*, 1991).

Fertility is a term used to describe the ability of an animal (dairy cow) to conceive and maintain pregnancy if served at the appropriate time in relation to ovulation. Livestock producers usually aim to breed replacement heifers by 15 months to calve at 24 months. An age at first calving (AFC) close to 2 years (23 to 25 months) is considered optimum for economic performance as it minimizes the non-productive period and maintains a seasonal calving pattern. This is rarely achieved in either dairy or beef herds, the average AFC for dairy herds usually between 26 and 30 months. Maintaining a low AFC requires good heifer management with adequate growth to ensure an appropriate BW and frame size at calving (Wathes *et al*., 2014).

The consequences of nutritional restriction from birth to weaning for subsequent growth have been reviewed by Allden (1970), Berge (1991) and Hearnshaw (1997). It is generally recognized that severe pre–weaning nutritional restriction limits the capacity of cattle to exhibit compensatory growth and achieve equivalent weight–for–age in later life. In reviewing a series of Australian studies on consequences of pre–weaning nutritional systems, Hearnshaw (1997) concluded that compensatory gain occurred most frequently when post–weaning growth rates were less than 0.6 kg/d, that compensation did not occur or was negligible at higher post–weaning growth rates and in feedlots. However, Hennessy and Morris (2003) found that calves reared slowly (0.464 kg/d) from birth to weaning were 37 kg lighter at weaning compared to those reared rapidly (0.872 kg/d), but 48 kg lighter after backgrounding and 46 kg lighter at slaughter at 17 months of age.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study sites

(a) Baseline survey study

The survey was conducted in three wards of Trans Mara sub County of Narok County (Fig. 3.1) in Kenya. The study site is situated in the western side of Narok County and it borders Kisii County to the North, Republic of Tanzania to the South, Bomet County to the East and Migori County to the West. Administratively, Trans Mara sub County has six County assembly wards namely, Kilgoris Central, Keyian, Kimintet, Ang'ata Barrikoi, Shankoe, and Lolgorian. Three wards where this study took place include Lolgorian, Keyian and Kilgoris Central. The area of study lie at approximately between East 35° 8' 0" E; north 1° 32' 51" S; North 0° 59' 56" S; West 34° 37' 57" E; with a minimum altitude of 1156 m and a maximum altitude of 2278 m. The County's climate is influenced by the altitude and physical features resulting to four agro-climatic zones namely; humid, sub-humid to arid and semi-arid (Narok DEAP, 2009-2013). The dominant vegetation includes forest land especially in the Mau area, grasslands and shrubs in the lowland areas of Suswa in Narok North, Osupuko and Loita divisions as well as the Mara sections in Transmara. This kind of vegetation makes the areas above suitable for rearing livestock and also for irrigation. Fig. 3.1 shows the map of Narok County

(b) Animal feeding study

The feeding study was conducted in Naivasha sub County of Nakuru County (Fig. 3.2). Nakuru County is one of the 47 counties in Kenya. It lies within the Great Rift Valley and borders 8 other counties, i.e. Baringo and Laikipia to the North, Kericho and Bomet to the west, Nyandarua to the east, Narok to the south west, Kajiado and Kiambu to the South. It is located between Longitude 35 º 28` and 35º 36` East and Latitude 0 º 13 and 1º 10` south and covers an area of 7,495.1 Km². The altitude and physical features within Nakuru County strongly influences the climate of the region, resulting to wet conditions that are suitable for agro-based economic activities.

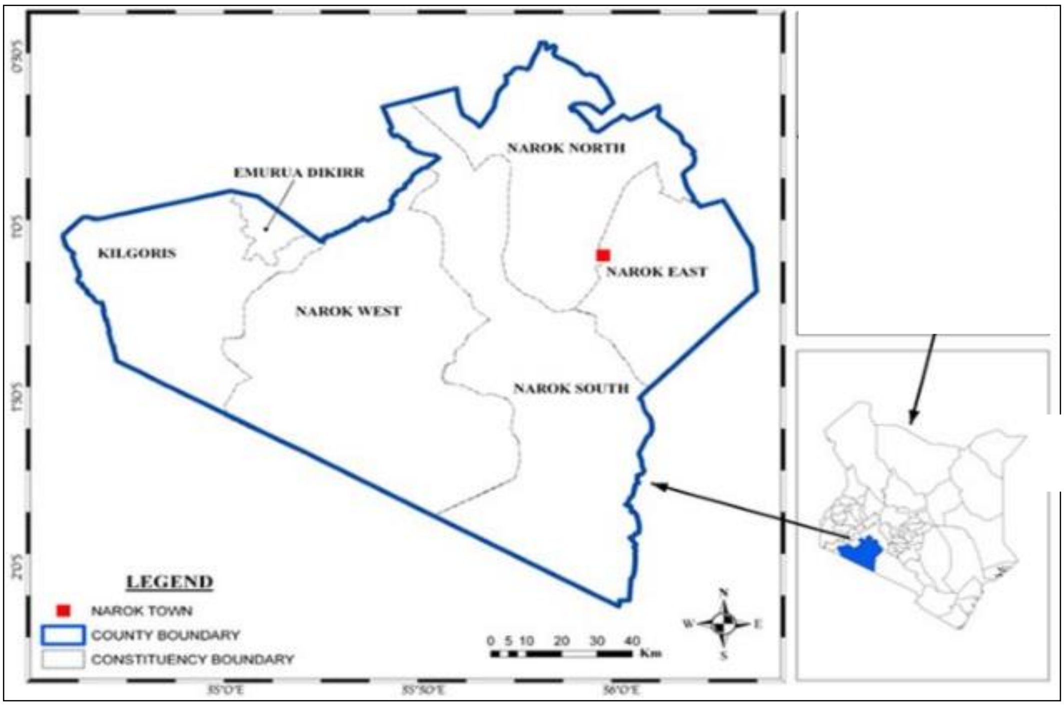

Figure 3. 1: Map of Narok County (Kamau *et al*., 2017)

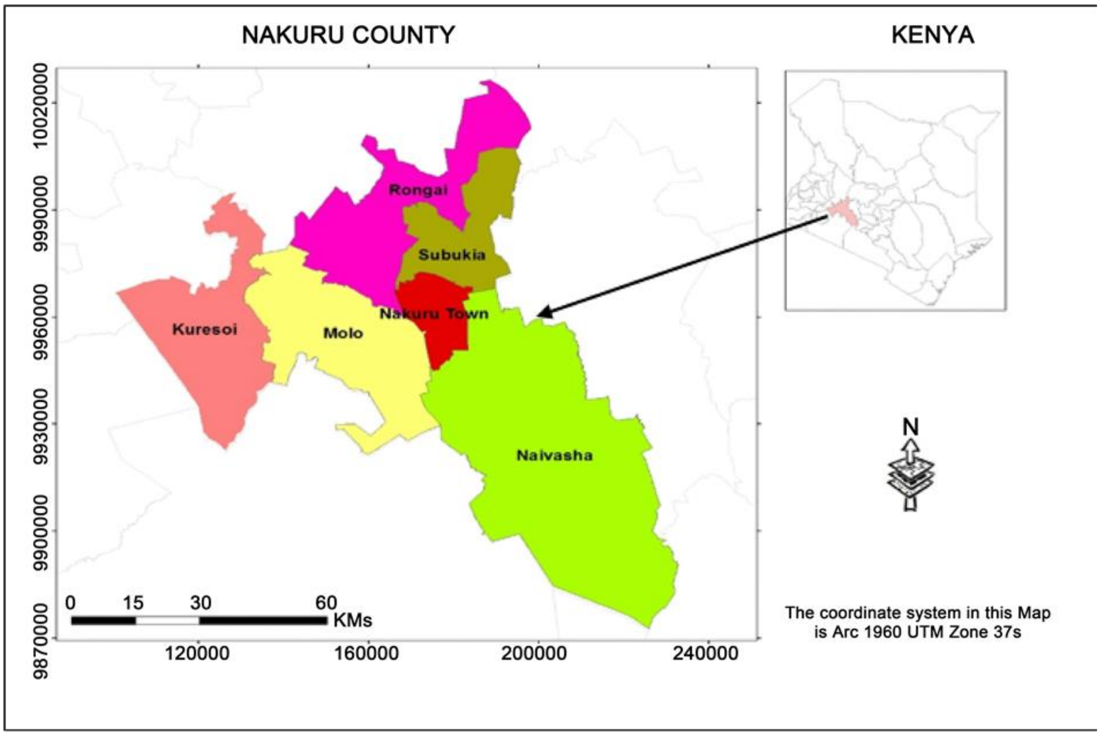

Figure 3. 2. Map of Naivasha sub County, Nakuru County (Chebole, 2015)

3.2 Baseline survey study

3.2.1 Study design and sampling method

Cross-sectional study design was used and it involved farm visitsand questionnairesadministration, with assistance from trained enumerators. Purposive sampling was conducted to farmers with Sahiwal and their crossbred cattle, resulting to 51 respondents. This was done using the Central Limit Theorem, which states that: as the number of occurrences (n) increases, the expected results move closer to the actual results and hence, any sample size that is greater than 30, is justified to infer population characteristics from the sample selected.

3.2.2 Data collection procedure

The data for the study was collected using semi-structured questionnaires (Appendix I) which were administered to livestock farmers purposively, whereby farmers with Sahiwal and their crossbred cattle were sampled. The questionnaires administered to the farmers rearing both Sahiwal and sahiwal/zebu cross bred cattle captured the following information: (i) Land tenure systems (ii) size of the farm (acres), (iii) land for grazing (acres), (iv) Number of Livestock per farmer, (v) Cattle herd structure (%), (vi) weaner calves mortality, (vii) Causes of weaner calves mortality, (viii) The grazing system practiced(%), (ix) Supplementary feeding(concentrates and minerals), (x) Forages types fed to livestock(%) and (xi) Challenges of weaner calves rearing. The available grass species were sampled randomly from the grazing fields in Trans Mara Sub County, and taken to KALRO Naivasha Laboratory for nutrient content analysis. Dry matter (DM %) analysis, crude protein (CP %) and ash contents were done using the official analytical methods (AOAC, 1990).The neutral detergent fibre (NDF %), acid detergent fibres (ADF %) and acid detergent lignin (ADL %) contents were analysed according to the methods by Van Soest *et al*., (1991).

3.3 Animal feeding experiment

The activities in here were conducted at Kenya Agricultural and Livestock Research Organization - Dairy Research Institute (KALRO-DRI), in Naivasha (Nakuru County). Twelve weaner calves were selected from the Sahiwal and Sahiwal/ Friesian crossbred herds.

3.3.1 Experimental design and sampling method

Sahiwal and their crossbred weaner calves that were set aside for experimental purpose, were randomly selected based on weight and age, totaling up to 12 calves. The selected calves were further put into three blocks based on age in the range of 8-19 months old, where block one consisted of relatively young age, block two consisting of medium age while block three consisting of older calves. Each block consisted of four calves (two Sahiwals and two crosses). They were then subjected to feed trials for a period of 12 weeks a 14-days adaptation period. Two diets (cottonseed cake or Lucerne hay based-diets) were allocated in an RCBD using a 2 x 2 factorial arrangement.The first factor was the breed with two levels (Sahiwals or Crosses) and the second one was the source of protein with two levels (Cotton seed cake or Lucerne hay). The two diets were assigned randomly to the two animals within the breeds per block.

Table 3.1 shows the physical composition of the diets whereas the experimental layout is shown in Table 3.2.

All calves were confined in the experimental stables from day 1 to 14 (2 weeks) to adapt them to the new environment and the experiment diets. Data was collected from day 15 to day 98 (12 weeks).

Table 3. 1 Physical composition of the diets.

Ingredients	**Cotton Seed Cake (Diet A) %**	**Lucerne Hay (Diet B) %**
Naivasha star grass	48	12
Cotton seed cake	12	0
Lucerne	0	36
Wheat Bran	30	42
Maize germ	5	5
Stock lick	1	1
Molasses	4	4
Total	**100**	**100**

Table 3. 2 Experimental layout of the feeding trial

BLOCK		**Calf no, breed and diet per block**			
1	Calf No	1	2	3	4
	Breed	Sahiwal	Sahiwal	Cross	Cross
	Diet	A	B	B	A
2	Calf No	5	6	7	8
	Breed	Sahiwal	Sahiwal	Cross	Cross
	Diet	B	A	B	A
3	Calf No.	9	10	11	12
	Breed	Sahiwal	Sahiwal	Cross	Cross
	Diet	A	B	A	B

Key: A = Naivasha star grass hay + cotton seed cake + wheat bran + maize germ + stock lime + Molasses (control), and B= Naivasha star grass hay + Lucerne hay + wheat bran + maize germ + stock lime + Molasses.

The calves were confined in individual feeding structures withwatering and feeding facilities. Feeding troughs were designed to minimize feed wastage while a 20-liter water bucket was well secured next to the feeding trough to avoid water spillage. The diets offered were measured daily in the morning and equal portions fed twice (08.00 hr and 18.00 hr) per animal while daily refusals were measured per animal at 07.00 hr. Daily feed allowance was adjusted to ensure that feed refusal was above 10% of the amount of feed offered to an animal the previous day. The feeding of calves allowed the consumption of all concentrates on offer and clean water made available to the animals throughout. Samples of the offered feeds and refusals were taken daily and representative samples were taken weekly for laboratory analysis. Animal feed or water intake was calculated as the difference of feed offered and feed refusals whereas the live-weight of animals was measured weekly using a digital weigh bridge. The feed conversion efficiency was derived from the determined measurements as the amount of feed required to support a kg of live-weight gain per day.

3.4 Laboratory analysis

The quality of feed offered to the calves and feed leftovers were determined through proximate analysis and Van Soest Detergent fibre method. Feed offered and refusals were also analyzed for ash content (calcium and phosphorus). The samples were analysed in triplicate. *In vitro* digestibility by gas production method was also determined. Below are detailed procedures on how the laboratory experiments were conducted.

Determination of ash content

An empty container selected to hold the feed was weighed using an electric weighing balance and the measurement recorded. The feed was then placed in the crucible and then weighed in order to get the weight of the crucible plus the feed. The weight of the feed before ashing was determinedby subtractingthe weight of the container from the total weight. The sample was then placed in a temperature controlled muffle furnace which was already turned on and preheated to 600^{o}C. The ashing process took place within 12 -18 hrs after which the temperature was held at 600^{o}C for 2 hrs. The crucible was then transferred directly to the desiccators, allowed to cool and the weights taken using an electric weighing balance. Values were presented in percentage (AOAC, 1975).

$$\% \, Ash \, content = \frac{Dry \, sample}{Original \, sample \, (Wet)} \, x \, 100\%$$

………………………………Equation 1.

Determination of crude protein

Protein analysis was done on the feed samples following the Association of Official Analytical Chemists (AOAC, 1975). This was determined by Kjeldahl method. The protein content was the protein mass expressed as a percentage of the total sample. One gram catalyst (made up of 1000g Potassium sulphate, 5g Selenium and 25g Copper sulphate mixed together thoroughly) was weighed and put in digestion tubes that were numbered. One gram of sample was put in a digestion tube and 7.5 mls concentrated Sulphuric acid (Nitrogen free) added to it. This was digested in a digester (Tecator, Sweden) for 30 minutes at 398^{o}C or until the mixture cleared. It was then removed from the digestion block and left to cool for 20-30 minutes. After cooling, 25mls of distilled water was added to the mixture then followed by addition of 25 mls NaOH which was added slowly to avoid the vigorous reaction of the acid and base. Distillation followed after addition of a base, into a conical flask with 0.1N boric acid for 4 minutes which contained bromophenol blue dye. Blue Color in boric acid changed to green upon receiving nitrogen in form of ammonia. This was then back titrated using 0.1N hydrochloric acid which changed the green color of the mixture in conical flask to blue. The titre volume was recorded and was used in the following formula for calculation of average percent protein:

$$\text{Average Protein \%} = \frac{(T_S - T_B) \text{ X N X } 14.007 \text{ X } 100 \text{ X F}}{\text{Sample weight in mgs}}$$

..............................Equation 2

Where, T_S is Titre volume in sample, T_B is Titre volume for control, N is Normality of Acid, F is Factor (6.25). The conversion factor used was 6.25 (Bradbury &Holloway, 1988).

Determination of calcium

Two grams (2g) of finely ground sample was weighed into a porcelain dish and ignited in a muffle furnace. The residue was then boiled in 40 ml HCl and a few drops of HNO_3 added. The content was then transferred to a 250 ml volumetric flask, allowed to cool and the diluted to volume before thorough mixing. Twenty five (25) ml of clear solution was then pippeted into a beaker and diluted to 100 ml mark before adding 2 drops of methyl red. NH4OH was then added drop wise until there was a visible colour change (brownish orange). Drops of HCl were added until colour changed to pink. It was the diluted to 150 ml, brought to boil and then 10 ml of hot saturated solution of $(NH_4)_2C_2O_4$ was added with constant stirring. It was left to stand overnight for the precipitate to settle then filtered through Whattman filter paper. The precipitate was then thoroughly washed with NH_4OH. The filter paper with the precipitate was then placed in the original beaker and a mixture of 125 ml of water and 5 ml of sulphuric acid added to it. Heating was done at 70^{o}C and titrated with 0.1N KMnO4. Correction for blank was done after which % Ca was calculated (AOAC, 1975).

Determination of phosphorus

Just like in calcium analysis, the sample preparation for phosphorus analysis was similar. Two grams (2g) of finely ground sample was weighed into a porcelain dish and ignited in a muffle furnace. The residue was then boiled in 40 ml HCl and a few drops of HNO_3 added. Aliquot corresponding to 2g sample for P_2O_5 content of sample < 5%; 0.2g for 5-20%; 0.1g for >20%, was pipeted into a beaker before adding 5-10 ml HNO3. NH_4OH was then added until the precipitate that was formed, dissolved slowly on stirring. It was then diluted to 75-80 ml and adjusted to 25-30 ^{o}C. Addition of 20-25 ml acidified molybdate solution was done for P2O5 content < 5%;

30-35 ml for 5-20%; and enough acidified molybdate solution to ensure complete precipitation for >20%. Stirring was done at room temperature for 30 minutes using a stirrer after which decanting was done immediately through a filter and the precipitate washed twice by decanting with 25 – 30 ml portions of water. Agitation was then done before allowing the contents to settle. The precipitate was transferred to filter and washed with cold water until filtrate from two fillings of filter yielded pink colour on adding phenolphthalein and one drop of the standard alkali. Reporting was then done as % P (AOAC, 1975).

Determination of acid detergent fibre

This was done according to the procedure of Van Soest et.al. 1991. One gram of air dried sample, ground to pass 1 mm screen was weighed into a refluxing container. Acid detergent (100 mls) solution, which was at room temperature, was then added and the contents heated to boiling in 5-10 minutes. The heat was then reduced to avoid foaming as boiling begun. Refluxing was done for 60 minutes from the onset of boiling. The container was then removed, swirled and filtered through a weighed (W_1) crucible using minimum suction. Breaking up of the filtered mat with a rod was done and the crucible filled to 2/3 full with hot (90 – 100 ^oC) water. Stirring was done before it was let to soak for 15 – 30 seconds. Drying was then done with vacuum and repeat water washing was done as well as rinsing the sides of the crucibles. Washing was also done with acetone. This was done repeatedly until no more colour was removed. All the lumps were then broken down so that solvent could wet all particles of the fibre. Residual acetone was removed with vacuum. Oven drying was then done overnight. The crucibles were then placed in the dessicator to cool before being weighed (W_2) (Van Soest et al., 1991)

$$\% \, Acid \; Detergent \; Fibre = \frac{(W2 - W1)}{S} \, x \, 100\%$$ ....Equation 3

Where, S = g sample x g oven dried matter / g air-dried or wet matter

Analysis of acid detergent lignin

To the crucible containing fibre (from the above experiment on ADF), 1 g of asbestos was added. The crucible was then placed in 50 ml beaker for support. The contents in the crucible was covered with cooled (15^{o}C) 72% sulphuric acid and stirred with glass rod to smooth paste, breaking all the lumps. The crucible was then refilled with the acid and stirred hourly as acid drained. After 3 hours, filtration was done with vacuum and the contents washed with hot water until acid free to pH paper. The side of the crucible was then rinsed off and the stirring rod removed before the crucible was let to dry in 100^{o}C forced-draft oven. Cooling was then done by placing the crucible in a desiccator over P_2O_5 and weight (W_3) thereafter. The crucible was again ignited in a 500^{o}C furnace for 2 hours. The hot crucible was then placed into a 100oC forced draft oven for 1 hour before being transferred to the desiccator to cool and the weight (W_4) taken. Asbestos blank was determined by weighing 1 g asbestos into a tared crucible. Any loss in weight on ashing (W_5) was recorded. Calculation of % acid insoluble lignin was then conducted as follows (Van Soest et al., 1991):

% Acid insoluble lignin = $(W_3 - W_4 - W_5) / S \; x \; 100\%$ ....Equation 4

Determination of neutral detergent fibre

The air dried sample was ground to pass 1 mm screen. One gram (1 g) of the sample was weighed in a crucible after which 100 ml of neutral detergent solution was added at room temperature into the crucible, together with 0.5 g of sodum sulphite and some drops of n-octanol. The contents were then heated to boiling and refluxed 60 minutes from the onset of boiling. They were then filtered and washed 3 times with boiling water then twice with cold acetone. Dring was then done for 8 hours at 105 ^{o}C and let to cool in a desiccator before the weight measurements were taken. Calculation was then done as follows (Van Soest et al., 1991) :

% NDF = (Weight loss on ashing / weight of sample) x 100% ....Equation 6

***In vitro* digestibility by gas production method**

In vitro gas production was undertaken according to the procedure described by Mauricio *et al*., (1999). Basal solution was prepared and added into the PTT bottles containing samples and three blanks and then they were placed in a water bath set at 39°C. Rumen fluid was collected from fistulated steers fed on natural pastures into a pre-warmed thermos flask. The rumen fluid was filtered and flushed with CO_2, and then mixed and CO_2 flushed rumen fluid is added to the buffered mineral solution (1:2 v/v), which is maintained in a water bath at 39°C, and combined. Samples (200 ± 10mg) of the air-dry feedstuffs were accurately weighted into syringe fitted with plungers. Incubation was conducted in 125 ml serum PTT bottles. The PTT bottles were thoroughly rinsed with distilled water and dried before each study. Prior to the addition of substrate (which was pre-dried and milled to pass a 1 mm screen), the bottles were then flushed with carbon dioxide to create anaerobic conditions. Rumen fluid (10 ml) was inoculated/injected using a 20 ml syringe fitted 21 gauge, 1.5” needle into each PTT bottles containing the substrate, and the PTT bottles were immediately placed into the water bath set at 39°C (Blummel and Ørskov, 1993). Three PTT bottles with only rumen fluid were incubated and considered as the blank. Once all the PTT bottles had been inoculated, the gas pressure was set in the bottles to zero using transducer and the incubation was terminated after recording the 96 h gas volume. Using the transducer, the pressure and gas volume in each bottle was read and recorded after 2, 4, 6, 8, 10, 12, 15, 19, 24, 30, 36, 48, 72, and 96 h of incubation. After every interval readings, the gas was released to zero. Total gas values were corrected for the blank incubation, and reported gas values was expressed per 1g of DM. Cumulative gas was expressed as milliliter of gas produced per 1g of dry matter and corrected for blanks.

3.5 Data analysis

The baseline survey data was sorted, coded and analyzed using SPSS software version 20.0, 2009. The analyzed data were presented in percentages as distribution tables while the qualitative aspects were discussed in the study.

The digestibility and feed intake data were analysed using statistical package SAS (2000). Variables for in-vitro GP, OMD, and ME, were analyzed using least square means in General Linear Model as follows:-

$Y_i = \mu + P_i + e_i$

Where,

Y_i= parameter outcome for i^{th} protein source; μ=Overall mean; P_i= effect protein source where i=CSC or LH;, and E_i=error term.

The water and feed intake, daily live-weight gain, and feed conversion efficiency variables were analyzed using repeated measures in Mixed Linear Model where experimental period (weeks) was the repeated measure, protein sources and breeds were the fixed effect and the weaner calf the random effect. Autoregressive was the covariance structure of choice because it resulted in the smallest Akaike's Corrected Information Criteria (CIC) and Bayesian Information Criteria (BIC) and the model was:-

$Y_{ijk} = \mu + W_i + B_j + P_k + (B \times P)_{jk} + e_{ijk}$

Where,

Y_{ijk}=Response variable from i^{th} week, j^{th} breed, and k^{th} protein source, μ=Overall mean; W_i=effect of week i=1,2,3,4,5,6,7,8,9,10,11 and 12; B_j=effect of breed j= Sahiwal or Friesian x Sahiwal cross; P_k=effect of protein source, k=CSC or LH; $(B \times P)_{jk}$=interactions of j^{th} breed and kth protein source; and E_{ijk}=error term

Least square means were adjusted and significant differences declared at $P < 0.05$ based on Tukey's ANOVA test.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Baseline survey data

4.1.1 Household and farmer characteristics

Table 4.1gives a summary of the respondent characteristics from the three sites of study. Majority of the interviewees were male (92.7%, 100.0% and 96.4% in Keyian, Kilgoris Central and Lolgorian respectively),with 50.0 % in Keyian, 33.3% in Kilgoris Central and 21.4% in Lolgorian of those interviewed falling in the middle aged bracket (30 to 40 years).

Table 4. 1 Percentage of respondents by Gender and age group

	n	Gender (%)		Age (%)			
Ward		**Male**	**Female**	**< 30 yrs**	**30 - 40 yrs**	**40-50 yrs**	**>50 yrs**
Keyian	14	92.86	7.14	28.57	50.00	21.43	0.00
Kilgoris Central	9	100.00	0.00	11.11	33.33	44.44	11.11
Lolgorian	28	96.43	3.57	14.29	21.43	46.43	17.86
Grand Total	**51**	**96.08**	**3.92**	**17.65**	**31.37**	**39.22**	**11.76**

The number of female respondents was dismal in Keyain and Lolgorian Wards, while there were no female respondents from Kilgoris Central (Table 4.1). From Table 4.1, the respondents were divided according to gender and age group. In the data collection more respondents were recorded from Lolgorian while the lowest number was interviewed in Kilgoris Central wards. Although the figure for Kilgoris Central Ward may not be a true reflection of the position since the ward has largest population while the number interviewed was small as it acted as a sample representative of the population (Table 4.1). Males formed a majority of the respondents with Kilgoris Central ward registering only male respondents. Activities especially on livestock issues were men dominated and hence the reason the low percentage of women being interviewed.

Generally, female respondents from all the Wards, were low in number compared to their male counterparts; a fact attributed to male dominance in livestock farming among the Maasai communities. Similar observations were made by (Mwacharo and Drucker, 2005; Ouma *et al*., 2007; Kosgey *et al*., 2008). Women were mainly restricted to duties that involved milking, taking care of the young stock and crop production which was also key in contributing to household food security.

Increase in climatic variability and human population, among other factors, have led to changes in the production systems of the region, which was predominantly a pastoral area over the years (Simotwo *et al*., 2018). Most productive assets were owned by men though other household members could access them (Alusi, 2014). Decisions on use or control of resources at the household level were directed by men (Table 4.1). Women were however, only considered if they were either widowed or when their husbands were not available.

In terms of age of respondents, majority were above 40 years (55.5% and 64.3% in Kilgoris Central and Lolgorian wards, respectively), while in Keyian Ward most of the them were below 40 years (78.6%) with most of them (50.0%) falling under the age bracket of 30 to 40 years (Table 4.1). The respondents who were above 50 years constituted 11.1% and 17.7% for Kilgoris Central and Lolgorian, respectively, while there were none for Keyian Ward (Table 4.1). This is because of the fact that in the first two wards young men had gone herding while others gone to places of work hence their absence at homes or at the market during the interview. In Keyian Ward, the visit coincided with the market dayand hence, so many young men were interviewed.

Table 4.2 shows the education level of re spondents.Most of them (78.57% in Keyian and 82.15% in Lolgorian Wards) had primary level or no formal education, while only 14.3% and 7.14% in Keyian and Lolgorian Wards completed tertiary education, respectively. In Kilgoris Central,66.67% had at least secondary education and only 11.11% had tertiary education.

Table 4. 2 Formal education level of respondents by ward

		Level of Education (%)			
Ward	**n**	**None**	**Primary**	**Secondary**	**Tertiary**
Keyian	14	28.57	50.00	7.14	14.29
Kilgoris Central	9	11.11	22.22	55.56	11.11
Lolgorian	28	39.29	42.86	10.71	7.14
Grand Total	**51**	**31.37**	**41.18**	**17.65**	**9.80**

The land tenure system, both in Keyian and Kilgoris Central were exclusively (100%) Freehold while in Lolgorian 64.3%was under communal and 32.1% under Freehold (Table 4.3). The mean farm sizes owned by farmers in the three wards, differed according to land tenure system.

Table 4. 3 Land tenure systems by ward

Ward	n	Freehold (%)	Leasehold (%)	Communal (%)
Keyian	14	100.00	0.00	0.00
Kilgoris Central	9	100.00	0.00	0.00
Lolgorian	10	32.14	3.57	64.29
Grand Total	**51**	**62.75**	**1.96**	**35.29**

The mean acreage of the farms in Keyian and Kilgoris Central Wards ranged from 50 to 65 acres and were under Freehold tenure system (Table 4.4). The two land tenure system (freehold and leasehold) exist in Lolgorian ward with the average acreage under freehold being 185 acres while that under leasehold being 48 acres per farmer. The allocation of the farms to grazing activities was similar in all wards, with more than three quarters of the farm reserved for grazing (Table 4.5)

Table 4. 4 Mean of farm size (acres) by Ward and land tenure system

Ward	N	Freehold	Leasehold	Grand Total
Keyian	14	63.43	-	63.43
Kilgoris Central	9	50.89	-	50.89
Lolgorian	10	185.00	48.00	169.78
Grand Total	**33**	**91.16**	**48.00**	**89.81**

Table 4. 5 Mean Grazing land (acres) by Ward and land tenure system

Ward	N	Freehold	Leasehold	Grand Total
Keyian	14	48.79		48.79
Kilgoris Central	9	40.00		40.00
Lolgorian	10	130.67	45.00	122.10
Grand Total	**33**	**69.34**	**45.00**	**68.61**

4.1.2 Farm enterprises and herd structure

The main livelihood enterprises in the study area were livestock and crop production. Almost all households had both livestock and crop enterprises in their farms. The livestock kept by farmers in the three wards were mainly cattle, sheep and goats. Cattle formed the biggest part of the livestock in each farm followed by sheep and goats in that order (Table 4.6). Farmers in Lolgorian ward had the biggest herd of cattle, sheep and goatscompared to their counterparts from the other two wards.

Table 4. 6 Number and species of livestock kept (%)

Ward	N	Cattle (%)	Sheep (%)	Goats (%)
		Mean	Mean	Mean
Keyian	14	73.5	24.8	14.9
Kilgoris Central	9	68.9	25.0	12.4
Lolgorian	28	86.6	28.4	19.5
Grand Total	**51**	**79.9**	**26.8**	**17.0**

Table 4.7 shows the herd structure which composed of calves, weaners and mature cattle. The weaners were further subdivided into those below one year and those between one and two years.

Table4. 7 Cattle herd structure (%)

Ward	Calves <6 months	Weaners 6-12 months	Growers 12-24 months	Mature stock >12 months
Keyian	19.9	16.0	13.7	50.4
Kilgoris Central	18.8	17.1	13.0	51.0
Lolgorian	21.3	14.4	12.7	51.7
Means	**20.6**	**15.2**	**13.0**	**51.3**

4.1.3 Livestock production and feeding systems

Extensive grazing was practiced exclusively in Keyian and Lolgorian Wards while in Kilgoris Central a negligible percentage (3.6%) practiced both semi-Zero and extensive grazing beside the extensive grazing (Table 4.8).Under extensive grazing, farmers in these wards practice rotational grazing. Farmers in Keyian (57.1%) practiced this type of grazing followed by Kilgoris Central (44.4%) and Lolgorian (7.4%) respectively (Table 4.9).

Table 4. 8 The Grazing System practiced by farmers in Trans Mara(%)

Ward	N	Zero	Pasture Extensive	Semi-Zero and Extensive pasture
			Mean	Mean
Keyian	14	0.0	100.0	0.0
Kilgoris Central	9	0.0	96.4	3.6
Lolgorian	28	0.0	100.0	0.0
Grand Total	**51**	0.0	**98.0**	**2.0**

Grazing system used was extensive because land was communal (Nyariki *et al*., 2009). At the same time people were not aware of other systems (such as zero grazing) and the pasture in the farm was natural. Rotational grazing was however practiced in some areas where land was paddocked. The crop by product used by famers, as animal feedswere maize stovers and bean husks which were fed directly to the animals in the field. Rivers were the main source of water for the livestock, while in some instances, dam water was preferred in the case where rivers were far from the farms.

Table 4. 9 Percent of farmers practicing rotational grazing per ward

Ward	N	Respondents practicing (%)
Keyian	14	57.14
Kilgoris Central	9	44.44
Lolgorian	28	7.41
Grand Total	**51**	**109**

All farmers practiced supplementary feeding by providing mineral supplements (Table 4.10). Very few farmers, particularly in Lolgorian ward (7.1%) fed concentrates to the animals during drought (Table 4.10).

Table 4. 10 Percentage respondents practicing supplementary feeding

Row Labels	N	Concentrates	Minerals
Keyian	14	0.0	100.0
Kilgoris Central	9	0.0	100.0
Lolgorian	28	7.1	100.0

Natural pastures formed a major part of the forages used by livestock as feeds in all the three wards (Table 4.11). Depending on the ward, different crop by-products existed. Sugarcane cane cut tops took the lead in Keyian, maize in Kilgoris Central and maize and bean husks in Lolgorian Ward. The average use of the by-products therefore were as follows: Keyian– 44.4%, Kilgoris Central –70.0% and Lolgorian – 50%) (Table 4.12).

Table 4. 11 Types of forages fed to livestock(%)

Ward	N	Natural pasture	Both Natural and Cultivated (fodder)
Keyian	14	85.7	14.3
Kilgoris Central	9	77.8	22.2
Lolgorian	28	96.5	3.5
Mean		**90.2**	**9.8**

Table 4. 12 Use of Crop by-products by wards

Ward	N	Crop By-product	% of Responses
Keyian	14	Bean husks	14.81
		Sugar cane cut tops	22.22
		Banana leaves	11.11
		Maize products	7.40
		Maize stovers	44.44
Kilgoris Central	9	Beans husks	10.00
		Maize products	20.00
		Maize stovers	70.00
Lolgorian	28	Bean husks	23.80
		Sugar cane cut tops	4.76
		Banana leaves	4.76
		Maize products	11.90
		Maize stovers	50.00
		None	4.76
Total	**51**		

4.1.4 Rearing weaner calves and its challenges

Several challenges were encountered by farmers when rearing calves in the three Wards. Unpacking these challenges, diseases posed a major challenge to calf rearing in each of the wards (35.1%, 47.4%, and 32.9% in Keyian, Kilgoris Central and Lolgorian respectively) (Table 4.13). The challenges enumerated by respondents includedpests and diseases, poor nutrition and management, predators, raids, high cost of inputs, lack of clean water, lack of market and lack of skills (Table 4.13).

Table 4. 13 Challenges of rearing weaners per Ward

Ward	N	Challenge	% of Responses
Keyian	14	Diseases	35.1
		Drought	21.6
		Overgrazing	5.4
		Poor management	2.7
		Predators	2.7
		Raids	8.1
		High cost of inputs	5.4
		Worms and other parasites	10.8
		Pests including tsetse fly	2.7
		Poor feeding	2.7
		Lack of skills	2.7
Kilgoris Central	9	Diseases	47.4
		Drought	21.0
		Overgrazing	5.3
		Poor management	10.5
		Poor housing	5.3
		Poor feeding	5.3
		Lack of clean water	5.3
Lolgorian	28	Diseases	32.9
		Drought	23.5
		Overgrazing	7.1
		Poor management	2.3
		Predators	11.8
		Raids	8.2
		High cost of inputs	3.5
		Worms and other parasites	3.5
		Pests including tsetse fly	1.2
		Poor housing	2.3
		Lack of Market	1.2
		Lack of clean water	2.3
Total	**51**		

The overall weaner mortality was high (over 20%) (Table 4.14) with Lolgorian leading followed by Keyian and Kilgoris Central in that order. In Keyian and Kilgoris Central wards, more than half of the causes of mortality were attributable to diseases (65.0% and 54.3% respectively) (Table 4.15). Besides the four common causes of mortality (viz: Diseases, drought, poor management and predators), Worms, tsetse fly and other parasites were common to Kilgoris Central and Lolgorian while raids and Shortage of feed and water were unique to Lolgorian ward (Table 4.15).

Table 4. 14 Mortality rate of the weaner calves

Ward	Weaner Mortality %
Keyian	20.0
Kilgoris Central	16.0
Lolgorian	27.7
Percent mean	**23.7**

Table 4. 15 Breakdown of the causes of weaner mortalities per Ward

Ward	n	Cause of Mortality	Responses (%)
Keyian	14	Disease	65.0
		Drought	20.0
		Poor management	10.0
		Predators	5.0
Kilgoris Central	9	Disease	58.3
		Drought	16.7
		Poor management	8.3
		Predators	8.3
		Worms, tsetse fly and other parasites	8.3
Lolgorian	28	Disease	41.0
		Drought	21.3
		Poor management	9.8

		Predators	18.0
		Raids	1.6
		Shortage of feed and water	1.6
		Worms, tsetse fly and other parasites	6.6
Total	**51**		

4.1.6 Farmers' ways of improving livestock in Trans Mara

As a way of improving the livestock in the area, 31.2% of the respondents suggested the use of qualitySahiwal bulls for breeding purposes (Table 4.16). Other suggested methods included parasite and disease control (through vaccination and dipping), proper feeding, land subdivision (through paddocks to facilitate rotational grazing), pasture management and also provision of clean water. At the same time, some suggested the introduction and use of A.I. services instead of bulls, for breeding (Table 4.16). Respondents in each ward prioritized differently the ways to improve production in their areas (Table 4.17).

Table 4. 16 Overall ranking by farmer on ways to improve livestock production

Suggested ways	n	% of Responses
Avail affordable and quality breeding bulls especially Sahiwal	51	31.15
parasite and Disease control - Vaccination, dipping,		17.21
Improve livestock management by proper feeding, land		13.93

subdivision, paddocking, rotational grazing, pasture carrying capacity		
Improvement of pastures including introductions		7.38
Construction of dams		6.56
Avail adequate clean water		5.74
Seek training and advisory services from KALRO and other professionals and attend seminars		5.74
Introduction and use of A.I. services		4.92
Others including security, markets and crop cultivation		2.46
Reduce cost of production		1.64
Keep pure breed Sahiwal		1.64
Reliable access to affordable animal feeds		1.64
Total		**100**

Table 4. 17 Farmer ways to improve production

Ward	N	Suggested way	Responses (%)
Keyian	14	Parasite and Disease control - Vaccination, dipping, deworming	22.22
		Introduction and use of A.I. services	3.70
		Avail affordable and quality breeding bulls especially for Sahiwal	40.74
		Improve livestock management by proper feeding, land subdivision, paddocking, rotational grazing, pasture carrying capacity	14.81
		Improvement of pastures including introductions	3.70
		Avail adequate clean water	3.70
		Seek training and advisory services from KALRO and other professionals and attend seminars	3.70
		Construction of dams	3.70
		Others including security, markets and crop cultivation	3.70
Kilgoris Central	9	Parasite and Disease control - Vaccination, dipping,	15.79
		Introduction and use of A.I. services	5.26
		Avail affordable and quality breeding bulls especially for Sahiwal	31.58
		Improve livestock management by proper feeding, land subdivision, paddocking, rotational grazing, pasture carrying capacity	5.26
		Improvement of pastures including introductions	21.05
		Avail adequate clean water	5.26

		Reliable access to affordable animal feeds	5.26
		Seek training and advisory services from KALRO and other professionals and attend seminars	5.26
		Construction of dams	5.26
Lolgorian	**28**	Parasite and Disease control - Vaccination, dipping,	15.79
		Introduction and use of A.I. services	5.26
		Avail affordable and quality breeding bulls especially for Sahiwal	27.63
		Reduce cost of production	2.63
		Improve livestock management by proper feeding, land subdivision, paddocking, rotational grazing, pasture carrying capacity	15.79
		Keep pure breed Sahiwal	2.63
		Improvement of pastures including introductions	5.26
		Avail adequate clean water	6.58
		Reliable access to affordable animal feeds	1.32
		Seek training and advisory services from KALRO and other professionals and attend seminars	6.58
		Construction of dams	7.89
		Others including security, markets and crop cultivation	2.63
Total	**51**		**100**

4.2 Quality of natural pastures

The chemical compositions of these pastures are presented in Table 4.21. The cell wall content (NDF and ADF), which represents the most important fraction of dry matter for all pastures, ranged from 70.203% to 74.500% and from 44.120% to 45.290%, respectively (Table 4.21). The crude protein (CP) of *Pennisetum catabasis* at blooming stage (BS) was considerably higher (5.975%) than in the other forages and better than CP of the same species at mature stage (MS). Also the CP for all the species sampled ranged from 4.54% to 5.98% which were thought to be low for optimum bacterial growth (11% to 14%) (Satter and offler,1975).This was mainly attributable to the grass species and their stage of growth since forage crops accumulate cell wall carbohydrates at their later stages of growth. Forages form the foundation, upon which diets for cattle are obtained, however, they have low levels of nitrogen and moderately available energy (Table 4.21) which when fed alone, may not be able to sustain growth of weaner calves.

Table 4. 18 The chemical composition of the natural pastures from Trans-Mara

	Chemical composition (%)					
Forages (growth stage)	**CP**	**DM**	**NDF**	**ADF**	**ADL**	**ASH**
Pennisetum catabasis (MS)	4.537	96.397	71.797	44. 630	5.673	10.233
Pennisetum catabasis (BS)	5.975	95.135	74.500	44.690	5.320	9.670
Themeda triandra (MS)	5.783	95.777	70.203	44.120	6.003	9.840
Hyparrhenia filipendula (MS)	5.760	96.207	70.717	45.290	7.047	8.530
Loutedia kagerensis (MS)	5.839	95.706	71.807	44.700	6.123	9.347

Key: MS= Mature stage; BS= Blooming stage; Dry Matter = DM; Crude Protein = CP; Neutral Detergent Fiber = NDF; Acid Detergent Fiber = ADF; Acid Detergent Lignin = ADL.

Maasai names for the forages respectively: *Pennisetum catabasis* – olmagutian*;* *Themeda triandra*- Olperesi orasha*;* *Hyparrhenia filipendula* - Olperesi oyiado*;* *Loutedia kagerensis* - Inkujit

4.2.1 Simulating pastures obtained from Trans-Mara sub County

Since the pasture collected from Transmara Sub County was not sufficient, Naivasha star grass was used as the basal diet through simulation for feeding the weaner calves. Naivasha star grass therefore formed the basal diet for the current study. Different feed rations were formulated and fed to weaners calves. In the laboratory the samples of the different feed ingredients were analyzed by standard proximate analysis and van Soest Detergent Fibers methods (Table 4.22)(Van Soest *et al.*, 1991).

Table 4. 19 Chemical composition of feed ingredients

Feed Ingredient	DM	Ash	CP	NDF	Ca	P	Cost (KES/Kg
			%				
Naivasha Star Grass	89.50	10.50	10.75	70.06	0.40	0.20	7.00
Lucerne Hay	89.40	8.10	18.20	44.80	1.68	0.26	23.00
Cotton Seed Cake	91.00	6.84	39.42	14.07	0.19	0.20	60.00
Wheat Bran	89.00	5.56	17.70	43.60	0.14	0.65	15.00
Maize Germ	92.50	4.84	7.57	21.51	0.10	0.50	20.00
Stock Lime	100.00	95.80	0.00	0.00	34.00	0.02	12.00
Molasses	74.00	0.00	4.20	0.00	0.90	0.10	20.00
SEM:	3.47	13.93	1.533	0.77	0.97	0.01	1.38

Standard Error of the Means. DM: Dry Matter; CP: Crude Protein; NDF: Neutral Detergent Fibre; Ca: Calcium and P: Phosphorus

The fundamental matrix of the parameters analyzed indicated differences between the feed ingredients as far as the DM, CP, NDF, Ca, P, and Ash content. The chemical composition of the five related feed ingredients chosen for use in feed formulation showed that in terms of crude protein, cotton seed cake (CSC at 39.42%) was superior followed by Lucerne hay (LH at 18.20%), Wheat Bran (17.70%), Naivasha Star Grass (10.75%) and Maize Germ (7.57%) in that order. Calcium levels in the fodders and concentrates studied ranged from 34.00 percent dry matter in lucerne hay to 0.10 percent dry matter in maize germ while phosphorus levels ranged from 0.65 percent as the highest in the wheat bran to 0.20 percent as the lowest in both Naivasha star grass and cotton seed cake (Table 4.22).

During the period of the experimentation, the ingredients attracted varying cost as portrayed in Table 4.22. The cheapest ingredient (Ksh 7.00 per Kg)was the Naivasha Star Grass which was then used as the basal ingredient in the formulation of the weaner calves feed (Table 4.22). The ingredients in Table 4.22 were then used to formulate the two rations: Cotton Seed Cake (CSCR) based and Lucerne Hay (LHR) based rations (Tables 4.23) which were fed to weaner calves with the aim of addressing the effect of protein source on growth rate of weaner calves.

Table 4. 20 Formulation of cotton seed cake based ration (CSCR) and lucerne hay based ration (LHR)

Feed resource		As fed (kg)	DM (kg)	Percentage
Forages:	Naivasha star grass hay	1.275	1.141	48.0
	Sub-total	**1.275**	**1.141**	
Concentrates:	Wheat bran	0.786	0.700	30.0
	Maize germ	0.126	0.117	5.0
	Cotton seed cake	0.328	0.298	12.0
	Stock lime	0.020	0.020	1.0
	Molasses	0.100	0.100	4.0
	Sub-total	**1.360**	**1.209**	
	Grand total	**2.635**	**2.350**	**100.00**
Forage: concentrate ratio			**49:51**	
Lucerne hay based ration (LHR)				
Forages:	Naivasha star grass hay	0.310	0.278	12.0
	Lucerne hay	0.974	0.870	36.0
	Sub-total	**1.284**	**1.148**	
Concentrates:	Wheat bran	1.118	0.995	42.0
	Maize germ	0.122	0.113	5.0
	Stock lime	0.020	0.020	1.0
	Molasses	0.100	0.100	4.0
	Sub-total	**1.360**	**1.202**	
	Grand total	**2.644**	**2.350**	**100.0**
Forage: concentrate ratio			**49:51**	

Treatment diets fed to weaner calves

Results of dry matter digestibility (DMD), organic matter digestibility (OMD), digestible organic matter in dry matter (DOMD) and total digestible nutrients (TDN)of diets are shown in Table 4.21. No differences were recorded in DM, OM digestibility among all diets fed to weaner calves. Dry Matter Digestibility relates to the portion of food which is not excreted in the faeces and so is available for use by the animal. Digestibility is not a direct measure of energy, but it does indicate overall feed quality. The greater the digestibility, the greater the benefit of that feed to the animal because the animals are able to digest and use more of the feed. The digestibility of various feed constituents can be determined, with Organic Matter Digestibility (OMD) sometimes being used to describe feed quality. The OMD is a measurement of the percentage of digestible organic matter per total dry weight. Total Digestible Nutrients (TDN) is sometimes used to describe energy available in feeds (Moran, 2005). The OMD for CSCR and LHR was 66.61% and 65.87% respectively; The DOMD (g/Kg DM) was 579.11 g/Kg DM and 572.69 g/Kg DM respectively and DMD was 63.39% and 62.62% respectively for CSCR and LHR rations, while TDN was 58.904% and 58.363% respectively (Table 4.21).

Metabolizable energy (ME) represents that portion of the feed energy that can be utilized by the animal for its metabolic activities (i.e. maintenance, activity, pregnancy, milk production, and gain in body condition) and can be calculated directly from feed digestibility. The ME content (energy density) is measured as Mega Joules of Metabolizable Energy per kilogram of dry matter (MJ ME/kg DM). The higher the energy content of a feed, the more energy is available to the animal. If a feed contains 10 MJ/kg DM, then each kilogram of dry matter of that feed contains 10 MJ of Metabolizable Energy available for use by the cow (AFRC, 1993).

Table 4. 21 Quality and cost of calf rations

Variable	Diet A: CSCR	Diet B: LHR		
	Mean	**Mean**	**Mean**	**SE**
Chemical composition (%)				
Dry matter	89.17	88.88	89.025	±0.012
Ash	8.95	7.91	8.43	±0.043
Crude protein	13.65	13.57	13.61	±0.095
Ether extract	4.95	3.21	4.08	±0.073
NDF	53.76	44.36	49.06	±0.393
Calcium	0.82	1.30	1.06	±0.020
Phosphorus	0.50	0.60	0.55	±0.004
Cost of ration (KES/Kg)				
Cost	17.21	17.58	17.395	±0.015
Digestibility of rations (%)				
OMD	66.61	65.87	66.24	±0.031
DOMD (g/ Kg DM)	579.11	572.69	575.9	±0.268
DMD	63.39	62.62	63.005	±0.032
TDN	58.904	58.363	58.633	±0.023
Metabolizable energy of rations (MJ/ Kg DM)				
ME	9.092	8.991	9.042	±0.004

Where: CSCR: Cotton Seed Cake based ration; LHR: Lucerne Hay based ration; NDF: Neutral Detergent Fiber; OMD: organic matter digestibility; DOMD: digestible organic matter in dry matter; DMD: dry matter digestibility;TDN: total digestible nutrients.

Organic matter digestibility is a measure of energy available to ruminants and is used in protein evaluation system (Gosselink *et al*., 2004). The *in-vitro* gas production method has been used to evaluate the energy value of several classes of feeds, particularly straw, agro-industrial by-products, compounds feeds and various tropical feeds (Getachew *et. al.*, 1998; Makkar andBecker, 1999; Krishna and Gunther, 1987; Aiple *et. al.*, 1996; and Krishnamoorthy *et. al*., 1995). In this study Metabolizable energy of rations (MJ/ Kg DM) was recorded as 9.092 (MJ/ Kg DM) and 8.991 (MJ/ Kg DM) for CSCR and LHR respectively, with a mean of 9.042 (MJ/ Kg DM) and SE of 0.004, (Table 4.21).

4.2.2 *In Vitro* dry matter digestibility

In vitro digestion technique has been accepted as the most accurate method available for predicting *in vivo* digestibility.It is agas production method and a suitable technique for the evaluation of the nutritive value of forages in developing countries (Calabrò *et al*., 2007; Babatoundé *et al*., 2011) where financial resources are limited. *In vitro* gas production was undertaken according to the procedure described by Mauricio *et al.* (1999). Means of CGP; Cumulative gas production, GPR; Gas Production Rate, ME; metabolizable energy and Organic Matter digestibility data by rations is shown in Table 4.22. Cumulative Gas Production by rations was 34.708% and 37.199% for CSCR and LHR respectively, with a mean of 35.954% and SE; Standard Error of 2.82. GPR; Gas Production Rate recorded 1.257 and 1.424 for CSCR and LHR respectively, with a mean of 1.340. OMD; Organic matter digestibility was 58.098% and 63.374% for with a mean of 60.736% and SE; of Standard Error of 0.307.

Table 4. 22 The means of organic matter *in Vitro* Digestibility

Variable	N	Ration CSCR	LHR	Mean	SE
CGP	42	34.708	37.199	35.954	±2.8200
GPR	42	1.257	1.424	1.340	±0.0910
ME	42	8.603	9.365	8.984	±0.0450
OMD	42	58.098	63.374	60.736	±0.3070

Where: CSCR: Cotton Seed Cake based ration, LHR: Lucerne Hay based ration, CGP; Cumulative gas production, GPR; Gas Production Rate, ME; metabolizable energy and OMD; Organic Matter digestibility

Means of CGP by ration over incubation time interval is shown in Table 4.26. At 2 hours Cumulative Gas Production was -2.107mls and -2.502mls for CSCR and LHR, respectively, with a mean of -2.305mls and SE of 0.1300. While 24 hours Cumulative Gas Production was 40.839mls and 46.773mls for CSCR and LHR with overall mean of 43.806mls and SE of 1.407. At 48 hours Cumulative Gas Production was 65.906mls and 66.147mls for CSCR and LHR respectively with and overall mean of 66.027mls and SE of 0.511.LHR had the highest CGP than CSCR at 48 hours with a difference of 0.241mls of CGP. Hour 96 recorded CGP of 78.943mls and 75.711mls for CSCR and LHR respectively with an overall mean of 77.327mls and SE of 0.917. The trends in the Means of CGP by ration over incubation time interval is shown in Figure 4.1. Cumulative gas productionshows variation is the degradability of rations and digestibility potential. There was a marked difference between the two rations from 8 hours to 48 hours and from 48 hours to 96 hours. LHR was highly degradable in the former hours (8 to 48 hours) with CGP recorded 14.905 mls, 21.405mls, 27.298mls, 33.808mls, 40.245mls, 46.773mls, 54.364mls, 60.113mls, and 66.147mls, respectively.

While CSCR was highly degradable in the later hours (48 to 96 hours) with CGP recording 73.942mls and 78.943mls at 72 hours and 96 hours respectively.

Table 4. 23 Means of CGP by ration over incubation time interval

Time	Ration		
(HRS)	CSCR	LHR	Mean
2	-2.107	-2.502	-2.305
4	2.633	2.289	2.461
6	7.688	8.203	7.946
8	12.545	14.905	13.725
10	16.728	21.405	19.066
12	20.838	27.298	24.068
15	26.561	33.808	30.184
19	33.317	40.245	36.781
24	40.839	46.773	43.806
30	50.256	54.364	52.310
36	57.829	60.113	58.971
48	65.906	66.147	66.027
72	73.942	72.029	72.986
96	78.943	75.711	77.327

Where: CSCR: Cotton Seed Cake based ration, LHR: Lucerne Hay based ration

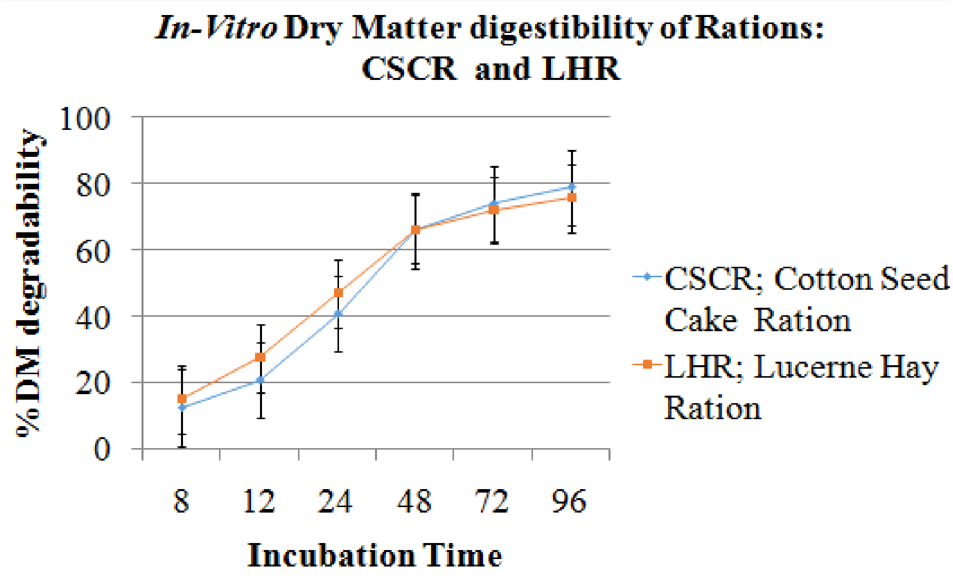

Figure 4. 1.*In-Vitro* Dry Matter degradability of Rations: CSCR; Cotton Seed Cake Ration and LHR; Lucerne Hay Ration

4.3 Effect of breed (Sahiwal and crosses) and feed ration (CSCR and LHR) on growth weaner calves

The growth of animals is influenced by so many factors such as nutritional, hormonal, managemental, biochemical, genetical and environmental. Taking these factors constant, genetics and nutrition might affect the growth rate. The average age of Sahiwal and cross bred calves are presented in Table 4.24 with the average age being 11.73±0,312 months. The average weights for the two species were recorded as 74.67±0.521 and 99.50±3.143kg in Sahiwal and cross bred calves respectively. The average live weight of the Sahiwal and Cross bred calves at the beginning of the experimental period were recorded as 84.92±2.118 and 89.25±3.156,in ‘CSCR’ and ‘LHR’ diet groups and 74.67±0.814 and 89.25±3.156, for Sahiwal and crosses respectively (Table 4.24 and 4.25). Age and weight of the steers at the start of the trial were similar across all nutritional management regimens. Although the numerical differences were found between breeds (Sahiwal and cross bred calves) and protein source (CSCR and LHR) on life weight, their differences were not significant (P> 0.05)

Table 4. 24 Initial age and weight of experimental weaner calves grouped by breed and by ration

	Breed			Ration		
Mean± SE	**Sahiwal**	**Crosses**	**Overall**	**Sahiwal**	**Crosses**	**Overall**
Age (Months)	9.77	13.69	11.73	11.47	11.99	11.73
Weight (Kg)	74.67	99.50	87.08	84.92	89.25	87.08

4.3.1 Effect of breed and feed ration on growth of weaner calves

The average weekly body weights of weaner calves (Sahiwal and SahiwalxFriesian crosses) fed with CSCR based and LHR based rations as complete feed mixture and grouped based on breed and type of ration fed are shown in Table 4.25 and 4.26. At the start of the experiment, the average body weights were 74.67±0.814 and 99.50±3.143 for Sahiwal and Sahiwal x Friesian crosses and, 84.92±2.118 and 89.25±3.156 as per diet groups (per protein source) respectively (Table 4.25 and 4.26). The average live weight of the Sahiwal and cross bred weaner calves at the end of 12 weeks of experimental period were recorded as 137.917 and 132.167kg according to the diet groups CSRC and LHR rations respectively (Table 4.26).

The total weight gain of cross bred calves was higher (57.417kg) than Sahiwal calves (38.5kg) and the daily weight gain of the same, was also higher though not significant (Table 4.25). It seemed that lack of uniformity of calves used in the present experiment as to the initial body weight, age, sex and parental breed might have caused a difficulty in obtaining statistically differences among the two groups.

Table 4. 25 Growth pattern of Sahiwal and crossbred calves by breed

WEEKS	Body weights (Kg)		Av. Daily weight gain (kg)	
	Sahiwal	Cross bred	Sahiwal	Cross bred
0	74.667	99.500	-	-
0-1	78.333	104.833	0.524	0.762
1-2	81.833	110.167	0.500	0.762
2-3	85.417	115.083	0.512	0.702
3-4	88.667	120.417	0.464	0.762
4-5	91.667	125.333	0.429	0.702
5-6	94.833	129.667	0.452	0.619
6-7	97.917	134.500	0.440	0.690
7-8	101.000	139.167	0.440	0.667
8-9	104.167	143.917	0.452	0.679
9-10	107.333	148.417	0.452	0.643
10-11	110.500	152.917	0.452	0.643
11-12	113.167	156.917	0.381	0.571

Table 4. 26 Growth pattern of Sahiwal and crossbred calves by ration

	Body weights (Kg)		Av. Daily weight gain (kg)	
Weeks	**CSCR**	**LHR**	**CSCR**	**LHR**
0	89.250	84.917	-	-
0-1	93.750	89.417	0.643	0.643
1-2	98.167	93.833	0.631	0.631
2-3	102.583	97.917	0.631	0.583
3-4	107.083	102.000	0.643	0.583
4-5	111.000	106.000	0.560	0.571
5-6	115.000	109.500	0.571	0.500
6-7	119.000	113.417	0.571	0.560
7-8	123.000	117.167	0.571	0.536
8-9	126.917	121.167	0.560	0.571
9-10	130.750	125.000	0.548	0.548
10-11	134.583	128.833	0.548	0.548
11-12	137.917	132.167	0.476	0.476

Based on breed, the average daily gain (ADG) of crossbred calves at 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 weeks ranged from 762 grams in the first week to 571grams/day in the 12th week while for Sahiwal weaner calves it ranged from 524grams/day in the first week to 381grams in the 12th week. The maximum ADG of 762g/day was observed on week 1, 2 and 4 for crossbred weaner calves while the maximum average daily gain (of 524grams) for Sahiwal was observed in week one while the mode ADG for these weaner calves (of 452grams/day) was observed in weeks 3, 6, 9, 10 and 11 (Table 4.27). The average daily gains of Sahiwal and cross bred calves in the present study revealed that the ADG through the 12 weeks of experimentation, was higher in crossbred weaner calves than in that of Sahiwal weaner calves.

Also the average daily gains were observed to be higher ($P<0.05$) in cross weaner calves (684g/day) as compared to Sahiwal weaner calves (458g/day) (Table 4.27). On the other hand there was no difference ($P<0.05$) when the protein source was considered. The calf live-weight gain per day when fed CSCR (580g/day) was slightly higher but not different ($P >0.05$) from when fed LHR (563g/day) (Table 4.27). Overall, the cross bred weaner calves gained more weight ($P < 0.05$) per week compared to sahiwal weaner calves during the same period (Table 4.27).

Table 4. 27 The effect of breed and ration on average weekly gain (AWG) (g/week) and average daily gain (ADG) (g/day)

	Breed		**Ration**		**Overall**	
Variable	**Cross**	**Sahiwal**	**CSCR**	**LHR**	**Mean**	**RMSE**
N	72	72	72	72	114	
AWG	4.785	3.208	4.056	3.938	3.997	±0.4081
ADG	0.684	0.458	0.580	0.563	0.571	±0.0583

Where: CSCR: Cotton Seed Cake based ration, LHR: Lucerne Hay based ration

There was only significant interaction between breed and ration when calf live-weight was taken at end of each week after feeding crossbred weaner calves with the two rations (Table 4.28).

Table 4. 28 Effect of Breed*ration interactions on AWG and ADG

Variable	Cross		Sahiwal		Overall	
	CSCR	LHR	CSCR	LHR	Mean	RMSE
n	36	36	36	36	144	
AWG	4.847[a]	4.722[a]	3.264[b]	3.153[b]	3.997	±0.4081
ADG	0.693[a]	0.675[a]	0.466[b]	0.450[b]	0.571	±0.0583

Means bearing different superscripts within a row are significantly different ($P < 0.05$); CSCR, cotton seed cake ration; LHR, Lucerne hay ration

4.3.2 Effect of breed and feed ration on voluntary feed and water intake, productive performance and percent feed efficiency

4.3.2.1 Dry matter intake

Dry matter and water intake can be affected by feeding management in weaner calves. Results of the daily feed intake of CSCR and LHR on total dry matter intake (DMI), and Dry matter intake efficiency (DMIE) of Sahiwal and cross bred calves shown in Table 4.29. The highest dry matter intake (DMI) of the basal diet was recorded with CSCR followed by LHR. The higher intake of the total dry matter of the basal diet supplemented with CSCR may be attributed to its high protein content of cotton seed cake (Table 4.22) and its bulky nature or may be a good appetizer as compared to LHR. Most of the straw based basal feed are usually low in nitrogen, digestible nutrients and minerals matter (Preston and Leng, 1984; Ondiek *et al*., 2000; Patra *et al*., 2003). Therefore, an ideal supplement to such feed not only compensate for the nutrient deficiency but also boost up the intake of the basal diet of the animals as happened with the basal diet supplemented in the present experiment. Improvement in intake of low quality forages may also be attributed to an increased rate of forage digestion and passage as a result of supplementation (Ellis, 1978).

Table 4. 29 The effect of breed (Sahiwal and crosses) and feed ration (CSCR and LHR) on DMI and DMIE

	Sahiwal		CROSSES		CSCR	LHR
Week	**DMI**	**DMIE**	**DMI**	**DMIE**	**DMI**	**DMI**
1	2.403	4.602	3.522	4.665	2.942	2.983
2	2.651	5.320	3.488	4.620	3.092	3.047
3	2.522	4.888	3.646	5.633	3.058	3.110
4	2.680	6.109	3.529	4.661	3.101	3.108
5	2.809	6.616	3.596	5.137	3.058	3.347
6	2.590	5.729	3.644	6.409	2.995	3.239
7	2.456	5.534	3.747	5.451	3.042	3.161
8	2.755	6.233	3.778	5.714	3.186	3.347
9	3.155	6.964	3.540	5.229	3.275	3.420
10	3.337	7.392	4.049	6.299	3.942	3.444
11	3.277	7.266	4.247	6.606	3.802	3.722
12	3.482	9.188	4.168	7.294	3.889	3.762

Where: CSCR, cotton seed cake based ration; LHR, lucerne hay based ration; DMI, dry matter intake; DMI, Dry matter intake; DMIE, Dry matter intake efficiency

Dry matter intake (DMI) in Sahiwal weaner calves fed on CSCR was not different ($P>0.05$) and values of DMI ranged from 2.403 to 3.482, but lower than for crossbred calves whose values ranged from 3.522 to 4.247. Also the DMI of the weaner calves irrespective of the breed were similar between the rations. When the calves were fed

CSCR the DMI ranged from 2.942kg to 3.942kg while when fed LHR it ranged from 2.983kg to 3.762kg (Table 4.29). Overall, the crossbred weaner calves recorded significantly (P<0.05) higher dry matter intake and dry matter intake per metabolic weight, while in terms of ration, LHR recorded high (P<0.05) dry matter intake per metabolic weight.

Table 4. 30 The effect of breed (Sahiwal and crosses) and feed ration (CSCR and LHR) on DMI and WI

Variable	Breed		Ration		Overall	
	Cross	Sahiwal	CSCR	LHR	Mean	RMSE
N	72	72	72	72	144	
DMI	3.746	2.843	3.282	3.307	3.295	±0.3885
WI	21.078	18.021	19.535	19.564	19.55	±0.3539

Where: CSCR, cotton seed cake based ration; LHR, lucerne hay based ration; DMI, dry matter intake; WI, water intake

4.3.3.2 Water intake by weaner calves

Water is essential for all living animals and it is a good practice to provide calves with ad lib fresh, clean water. Weaned calves can drink 10–15 L/day and up to 25 L/day on hot days. For optimum feed efficiency, milk-fed calves are required to drink 4 L of water for every kilogram calf concentrate they eat. Average weekly water consumption per calf for Sahiwal and its crossbred weaner calves is shown by weeks up to three months after commencement of the trial in table 4.31.

Table 4. 31 The effect of breed (Sahiwal and Sahiwal crosses) and feed ration (CSCR and LHR) on Changes in WI

Week	Breed			Ration		
	Cross	**Sahiwal**	**Mean**	**CSCR**	**LHR**	**Mean**
1	15.555	12.452	14.004	14.1119	13.8952	14.004
2	16.548	13.417	14.982	14.9429	15.0214	14.982
3	17.693	14.807	16.250	15.9524	16.5476	16.250
4	18.800	15.526	17.163	17.2143	17.1119	17.163
5	19.605	16.288	17.946	17.9071	17.9857	17.946
6	20.648	17.421	19.035	19.0571	19.0119	19.035
7	21.505	18.657	20.081	20.0857	20.0762	20.081
8	22.431	19.650	21.040	21.1071	20.9738	21.040
9	23.574	20.543	22.058	22.0214	22.0952	22.058
10	24.479	21.514	22.996	22.9071	23.0857	22.996
11	25.629	22.450	24.039	24.15	23.9286	24.039
12	26.476	23.521	24.999	24.9643	25.0333	24.999

Where: CSCR: Cotton Seed Cake based ration; LHR: Lucerne Hay based ration;

The WI by the cross bred weaner calves was significantly ($P<0.05$) higher than for Sahiwal calves, but no difference ($P<0.05$) was recorded when the weaner calves were fed either CSCR or LHR (Table 4.35).But weaner calves fed LHR portrayed a significant ($P<0.05$) water intake per metabolic weight as compared to those fed CSCR (Table 4.32).

Table 4. 32 The effect of Breed*ration interactions on DMI and WI

Variable	Cross		Sahiwal		Overall	
	CSCR	**LHR**	**CSCR**	**LHR**	**Mean**	**RMSE**
N	36	36	36	36	144	
DMI	3.760^{a}	3.732^{a}	2.803^{b}	2.883^{b}	3.295	±0.3885
WI	21.068^{a}	21.089^{a}	18.002^{b}	18.039^{b}	19.55	±0.3539

Where: CSCR, cotton seed cake based ration; LHR, lucerne hay based ration; DMI, dry matter intake; WI, water intake. Means bearing different superscripts within a row are significantly different ($P < 0.05$)

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

i. Farmers with low education levels lacked adequate skills and knowledge on feed production and feeding. In addition, the forages grazed by livestock at Transmara had low CP but high ADF & ADL.These factors cannot promote the fast growth of weaner calves at Transmara Sub-County

ii. There was high growth rate of Sahiwal crossbred calves than Sahiwal calves as observed in the study. The trend manifested itself right from the onset of the trial

iii. The formulated diets (with both CSC & Lucerne), used in the feeding trial had sufficient nutrient contents and were moderately digestible for use among growing Sahiwal and crossbred weaner calves.

5.2 Recommendations

i. Farmers should be trained on feed production and feeding.

ii. Feed supplementation needs to be done because forages in the fields are poor in terms of nutritional content. Farmers should be encouraged to grow cheap protein forages to continue with the supplementation.

iii. Farmers are encouraged to keep Sahiwal crosses as they perform better than Sahiwals.

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APPENDICES

APPENDIX 1. QUESTIONAIRE FOR PASTORAL LIVESTOCK FARMERS

The aim of the study was to determine feed resources available in transmara: pasture for weaner calves

Questionnaire No……………………………………..

1.0 ENUMERATOR INFORMATION

1.1 Full Name ………………………………………………………….

1.2 **Gender (tick)**. (1) Male (2) Female

1.3 Date (of interview/questionnaire administration)

…………………………………………

2.0 GENERAL FARMER INFORMATION

2.1 Name (farm/household head) …………………………2.2 Gender (tick) (1) Male (2) Female

2.3 Age (years)……………..2.4 Education level (tick) 1=none (illiterate), 2=primary (1-8), 3=secondary, 4=tertiary (post-secondary)

2.5 Location………………………………..2.6Ward………………..………………..

2.7 Division………………………………..2.8 District………………………………

2.9 County…………………………………2.10 Ecozone……………………………

3.0 TYPES OF FARM ENTERPRISES:

Enterprise	Allocated Land (Acres)/Communal)
(i)	
(ii)	
(iii)	
(iv)	

3.1 Source of labour **(**tick**)** (1) Family (2) Hired labour (3) Exchange

4.0 LAND USE

4.1 Land Tenure (tick) (1) Freehold (2) Leasehold (3) Communal (4) Others, specify……………

4.2What is the size of your land**?** …………………… acres

4.3 How much land is available for cattle rearing? …………………… acres

4.4 Is your land paddocked? (tick) (1) Yes (2) No

4.5 If yes what are the paddock sizes? ………………….acres

5.0 HERD STRUCTURE AND HERD SIZE

Class		**Type of Breeds**				**Total**
		Zebu	**Sahiwal**	**Z x S Crosses**	**Others**	
Calves	Male					
	Female					
Weaners	Male					

	Female					
12 – 24 months	Male					
	Female					
Mature female stocks	Lactating					
	Dry					
Mature female stocks	Bulls					
	Steers					

6.0 FEEDING

6.1 What grazing system do you use? (tick) (1) Extensive, (2) Semi-Zero, (3) Zero-grazing, (4) Tethering

6.2 What type of pasture and fodders do you have in your farm? (Enumerator observation)

Pastures	**Fodders**
(i)	(i)
(ii)	(ii)
(iii)	(iii)
(iv)	(iv)

6.3 What type of crop by-products and forage supplements do you have in your farm? (Enumerator observation)

Crop by-products	**Forage Supplements (legumes, fodder trees)**
(i)	(i)
(ii)	(ii)
(iii)	(iii)
(iv)	(iv)

7.0 LIVESTOCK PRODUCTION SYSTEMS

7.1 How do you feed the weaners with the above mentioned forages? :

Pastures	**Fodders**	**Crop by-products**	**Forage Supplements**

7.2 Do you practice rotational grazing? (1) Yes, (2) No

7.3 If yes, how long do animals spend in one paddock?........................ (Weeks)

7.4 How many animals per paddock?..

8.0 CONCENTRATE SUPPLEMENTATION

8.1 Types of home-made rations (concentrates)

8.2 Ration 1

(i) Ingredients used………………………………………………………………………

(ii) Mixing method (tick) (1) manual (2) others, specify…………………….…………….

(iii) Quantity fed ………….. (Kg/weaner/day)

(iv) Frequency of feeding (tick) (1) once (2) twice (3) thrice per day

8.3 Ration 2

(i) Ingredients used…………………………………………………………….………..

(ii) Mixing method (tick) (1) manual (2) others, specify………………………………..…

(iii) Quantity fed ………….. (Kg/weaner/day))

(iv) Frequency of feeding (tick) (1) once (2) twice (3) thrice per day

8.4 Types of commercial concentrates used

No.	Quantity (kg/weaner/day)	Daily frequency
(i)		
(ii)		
(iii)		
(iv)		

8.5 Types of mineral salts used

No.	Quantity (g/weaner/day)	Daily frequency
(i)		
(ii)		
(iii)		
(iv)		

8.6 Source of water for your calves (tick)(1) tap (2) dam (3) river (4) well (5) others (specify)……………………………………………………………………………………

8.7 Quantity of water offered………. (Kg/weaner/day)

8.8 Daily frequency of water offered (tick) (1) free access/ad libidum (2) once (3) twice per day

APPENDIX II: CHECKLIST

TRANS MARA DISTRICT

1.0 DOCUMNT FEEDING PRACTICES IN 3 WARDS

1.1 Selected few farmers in each ward

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

1.2 Document livestock management practices

(i) Feeding practices

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

(ii) Challenges encountered by livestock farmers per ward

………………………………………………………………………………………

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(iii) Forages fed to weaners per ward

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………………………………………………………………………………………

(iv) Pastures fed to weaners per ward

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…………………………………………………………………………………………

(v) Supplements for weaners per ward

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1.3 Document mortalities (%) of weaner calves per ward

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…………………………………………………………………………………………….

1.4 Get the farmer' opinion on the mortalities (what do they think is the cause of the deaths?)

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…………………………………………………………………………………………………

…………………………………………………………………………………………………

1.5 Existing livestock production system per ward

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………………

1.6 Age at 1st calving per ward (Months)

………………………………………………………………………………………………

………………………………………………………………………………………………

1.7 daily milk production level (kg) of (1) sahiwals …………..(2) zebu…………… (3) Crosses…………….. (4) Others (name)…………………………………………………

1.8 Document major grasses in the 3 wards and collect samples for analysis

(i) Date samples

(ii) Sample type

(iii) Location

(iv) Farmer's name

(v) Detail of grass (use the most common name to label the sp)

……………………………………………………………………………………

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……………………………………………………………………………………

……………………………………………………………………………………

(vi) Indicate the growth stage of grass when samples were taken……….. (1) juvenile stage (2)flowering stage (3) maturity stage (4) dry stage

(vii) Approximate the percentage of the grass sampled in the area……….(1) less than 10% (2) 10-30% (3) 30-50% (4) more than 50%

(viii) Indicate analysis to be done in the laboratory

(ix) Farmers' opinion of the grass sampled

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………….

2.0 DOCUMENT LITERATURE RELATED TO THE GRASSES

2.1 Nutritive (quality) values of the various grasses

2.2 Feed intake, digestibility, live-weight gains

2.3 Supplementation of weaners (if any)

(i) Supplementation type …………………………………………………………..

(ii) Sahiwal ……………………………………………………………………………

(iii) Zebu…………………………………………………………………………….

(iv) Crosses …………………………………………………………………...

(v) All ……………………………………………………………………...….

2.4 Wish of the farmers and their suggestion on ways of improvement

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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…………………………………………………………………………………………………

Challenges farmers face in raising the weaners

(i) Sahiwal……………………………………………………………………….

………………………………………………………………………………

………………………………………………………………………………

(ii) Zebu………………………………………………………………………….

………………………………………………………………………………

………………………………………………………………………………

(iii) Crosses

………………………………………………………………………………………

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(iv) Others

………………………………………………………………………………………

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APPENDIX III: SIMILARITY REPORT

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