PERFORMANCE OF CAMEL CALVES IN KENYA FED ON MILK SUBSTITUTE FORMULATED FROM LOCALLY AVAILABLE FEED INGREDIENTS

TURA ISAKO

A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Doctor of Philosophy Degree in Animal Science of Egerton University

EGERTON UNIVERSITY

APRIL, 2023

DECLARATION AND RECOMMENDATION

Declaration

I declare that this thesis is my original work and has not been previously presented in this or any other University known to me for the award of any degree.

Signature _ ___________________ Date 15th March, 2023

Tura Isako

KD11/13004/17

Recommendation

This thesis has been submitted with our approval as University supervisors.

Signature __ __ Date 15th March, 2023

Prof. Anthony M. Kingori.

Department of Animal Sciences, Egerton University.

Signature _ Date 15th March, 2023

Prof. James O. Ondiek.

Department of Animal Sciences, Egerton University.

Signature _ __ Date 15th March, 2023

Dr. Paul A. Onjoro, Ph.D.

Department of Animal Sciences, Egerton University.

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DEDICATION

I dedicate this thesis to my dear wife, Sakina Isako and our sons, Ali, Abdub, and Guyo.

ACKNOWLEDGEMENTS

I want to give thanks to the All-Powerful God who has given me the health, stamina, and fortitude to travel this path. I gratefully thank all the organizations and people that helped to make the completion of this thesis possible.

I wish to acknowledge funding for this study from the Kenya Climate smart agricultural project (KCSAP), with research grant **"Performance of camel calve in Kenya fed on milk substitute formulated from locally available feed ingredients"**. My employer, Kenya Agricultural and Livestock Research Organization (KALRO). I would like to thank KALRO-Muguga South, Coffee Research Institute, Tea Research Institute and Egerton University for the support of laboratory sample analysis.

To my supervisors, Prof. Anthony M. Kingori, Prof. James O. Ondiek, and Dr. Paul A. Onjoro, I would like to convey my gratitude for their dedication, helpful supervision, and insightful comments that helped the thesis.

I really appreciate all the camel herders in Karare, Kamboi, Kargi, Korr, and Ngurunit who took part in focus group discussions (FGDs) and sample collection. My special thanks go to the Korkora camel farm that provided the site and calves for feeding trials. Many thanks to all the enumerators during the surveys and during feeding trials. Also, I would want to thank my fellow animal sciences department students who were constantly encouraging when I was writing my thesis and working on my coursework. Finally, to my parents and family for their prayers and support.

ABSTRACT

Poor nutrition is one of the biggest problems in raising camel calves in Kenya. A study was conducted in Marsabit County among rendille camel keeping community with a view to improve camel calf performance through improved nutrition. The study had four specific objectives; 1) To evaluate existing indigenous knowledge and practices on camel milk substitutes in rearing camel calves 2) To determine the proximate composition of common locally available feed resources used as substitutes to camel milk 3) To evaluate the effects of feeding a commercial (CMS) and plant-based locally formulated milk substitute (PBMS) and 4) To compute the cost /benefit analysis of feeding commercial and a calf milk substitute formulated from locally available feed resources. Key informant questionnaires (KI) and focus group discussions (FGDs) were used to collect data for evaluation of existing knowledge and practices on camel milk substitutes. Data was analysed using the SPSS (Version, 2019). Proximate composition, fibre and tannins data were analysed using ANOVA by the GLM procedures of SAS. Data on evaluation of effects of feeding CMS and PBMS, Average Daily Gain (ADG), Feed Conversion Ratio (FCR) and Dry Matter Intake (DMI) were collected and analysed using SAS. Economic costs and gains for feeding the milk substitutes were computed in a Cost Benefit Analysis whereby, Net Present Values were calculated. The results showed that mortality rates were 35.2 and 4.3% in pastoral and peri-urban system, respectively. Diseases, drought, predation, parasites and competition for milk were the five major causes of calf mortality and retarded growth. Pastoralists use locally available feed resources such as forages, animal fats, camel blood and maize meal as substitute to milk feeding. Crude Protein, Dry Matter and Metabolizable Energy were highly variable, with significant ($P<0.05$) differences among the local feed resources used by camel keepers. Calves on CMS and PBMS had a higher ADG, 0.7614 Kg and 0.5663 Kg respectively compared to calves on pastoral management regime at 0.4537 Kg. It was more economical to feed calves using PBMS (5) compared to CMS (3) or pastoral feeding regime (3). It was concluded that pastoralists supplement calves with plants, animal fats and camel blood at times of feed deficit. Local feed resources have a great potential as ingredients for formulation of camel calves' plant-based milk substitute. Use of PBMS would contribute to improved calf performance and economic empowerment of the pastoral communities.

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LIST OF ABBREVIATIONS AND ACRONYMS

AAS	Atomic absorption spectrophotometer
ADF	Acid detergent fibre
ADG	Average daily gains
ADL	Acid detergent lignin
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
ASALs	Arid and semiarid lands
BAMN	Bovine Alliance on Management Nutrition
BSE	Bovine Spongiform Encephalopathy/Mad cow Disease
CAMASEPRO	Camel Manual for Service Providers
CG	County Government
CP	Crude Protein
CRD	Completely Randomised Design
DHB	Domestic herbivore biomass
DM	Dry Matter
DMI	Dry Matter Intake
DMRT	Duncan's New Multiple Range Test
DSA	Daily Subsistence Allowance
EE	Ether extract
FAC	Future Agricultures
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Statistics
FGD	Focus group discussions
HSD	Honestly Significant Difference Test
HH	Household interviews
IgG	Immunoglobin G
IgM	Immunoglobulin M
ILCA	International Livestock Centre for Africa
KCA	Kenya Camel Association
KES	Kenya Shillings
KI	Key Informant questionnaire

KNBS	Kenya National Bureau of Statistics
ME	Metabolisable energy
MLFD	Ministry of Livestock and Fisheries Development
MoLD	Ministry of Livestock Development
MS	Milk substitute
NDF	Neutral detergent fibre
NPV	Net present value
NRC	National Research Council
OM	Organic matter
PCV	Packed cell volume
PLP	Pastoral Livestock Production
SAS	Statistical Analysis Software
SF	Starter feed
SPSS	Statistical Package for Social Sciences
TDN	Total digestible nutrients
UAE	United Arab Emirates
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USD	United States Dollar

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background Information

Camels (*Camelus dromedarius*) are well adapted to arid and semi-arid regions due to their unique characteristics. These attributes include physiological, anatomical, and behavioral adaptation mechanisms (Fesseha & Desta, 2020). Physiologically, for instance, the camel can stay for long periods without water and tolerate loss of large amounts of water and has a good body temperature regulation whereby the body temperatures can rise to 41ºC when the camel is dehydrated (Asres & Amha, 2014). The camel's huge body size, height, and broad foot pad are anatomical adaptations that make it easier for it to move around in arid environments (Gallacher & Hill, 2006). The camel also has a feeding, drinking and sexual behavior that enables it to survive in areas with feed and water scarcity (Ouajd & Kamel, 2009; Zarrouk et al., 2003). It can take large quantities of water at one instance and breeds seasonally to facilitate survival of the calves because of parturition occurring during favourable seasons of the year (Fesseha & Desta, 2020). These traits give the camel the ability to survive and reproduce in very hot climatic conditions (Fesseha & Desta, 2020).

Most of the people who live in the Arid and Semi-Arid Lands (ASAL) are pastoralists who depend on camels for food, transportation, income, and important cultural reasons (Guliye et al., 2007; Mahmoud, 2010). The importance of camels in providing livestock farmers in northern Kenya with food will increase due to global warming and climate change (Ndikumana et al., 2000). A total of 4.6 million one-humped camels are kept by these pastoral communities in Kenya (KNBS, 2019). Production systems have always been extensive and very mobile. But camel farming in outskirts of cities (peri-urban) to feed the growing number of people in cities with milk and meat is becoming a new way to make money (Noor et al., 2013).

In Kenya, camels constitute 25% and 6% of the ASALs and total national Domestic Herbivore Biomass, respectively (Schwartz & Dioli, 1992). According to Anderson et al. (2012), pastoralism contributes 16% of Kenya's Gross Domestic Product (GDP). The sale of live camels and camel products, such as milk, have also gained popularity. Milk from camels has shifted from being for subsistence consumption only to commercialization due to factors such as urbanization (Anderson et al., 2012). Camel milk has been processed to produce yoghurt, whole processed milk, and low-fat boiled milk (Muloi et al., 2018). This has contributed to the economic empowerment of pastoral communities and other stakeholders in the camel milk value chain (Anderson et al., 2012). The cash which is obtained from the sale of live animals is used for purposes such as purchase of food and clothing and a source of capital where the pastoralists want to invest (Noor et al., 2013). Despite its importance, the camel population remains low to allow large scale production and marketing purposes.

Late maturation of camels and high calve mortality are the main factors hindering the growth of camel populations. Mortality rates of up to 62% have been reported in calves from birth to weaning (Kaufmann, 1998; Njanja, 2007). This has slowed the growth of pastoral camel herds. Compared with pastoral production systems, camel calf mortality rates as low as 0-25% have been reported on commercial farms in Kenya (Browne & Deem, 2012; Wilson, 1986). In commercial ranches small numbers of camels are integrated with beef production. Camels were introduced in Kenyan ranches as bush breakers and for eco-tourism purposes. Under ranching conditions browses are plenty and milk competition with calves is minimal if any.

Wild pastures are the only diet for camels in pastoral systems where natural vegetation is often of poor quality. This dependence poses a major challenge in terms of food shortages, especially during periods of drought. Camel farming in traditional pastoral production systems faces a number of challenges that lead to high mortality rates. Research by Kuria et al. (2011) reported difficulties in camel management among camel breeding communities in the areas of feeding, watering and health management. This is attributed to a lack of knowledge by breeders on how they can address these challenges and poor animal health service delivery. In addition, water intake points in these areas are often far from grazing areas and often require many days of walking (Dioli, 2022). Even though Kenya is among major camel keeping Countries, very little has been done on improvement of the calf feeding to minimize mortality because camels are mainly reared in the marginal Counties in Kenya.

Milk substitutes are alternatives to dam milk that support the young calf's demands for development and growth. Faster calf growth could lead to higher long-term growth rates, better hormone response, enhanced milk production, immune system enhancement, and improved gain effectiveness (Kertz et al., 2017). Some circumstances, like chilly temperatures, call for a larger energy consumption. The metabolic energy (ME) content of milk alternatives is primarily influenced by their fat and carbohydrate content (Kertz et al., 2017).

When the demand for human milk is high, milk substitutes or dairy by-products are frequently fed to calves. From birth to three weeks, ruminants are fed liquid foods consisting of whole milk or milk substitutes made from milk by products. After which, a significant portion of milk protein may be replaced with alternative plant protein sources in milk substitute formulas. After three weeks, rumen fermentation commences, at which point highly digestible solids may be offered as an alternative to whole milk (Kertz et al., 1984). The components of milk substitutes can vary greatly and are typically obtained from plants or dairy. Plant formulations, which are often soy-based and less expensive, are unavailable in Kenya's camel keeping areas. Young calves can digest milk proteins far more easily than plant proteins (Erickson & Kalscheur, 2020). Dairy ingredients such as whey powder, milk protein concentrate, skimmed milk powder, butter milk powder, casein, and lactose-free whey are also uncommon in Kenya.

Non-dairy proteins have been shown to be able to replace skimmed milk or whey protein in milk substitutes (Kertz et al., 2017). Montagne et al. (2000) reported that mucin, among other endogenous intestinal secretions, was elevated more in calves fed a milk substitute containing partially hydrolyzed soy protein concentrate or soy protein isolate than in calves fed a milk substitute containing skimmed milk protein isolate. These data illustrate the significance of mucins as an endogenous nitrogen source as well as the influence of dietary protein content and origin on this flow. Hill et al. (2008) conducted a study that demonstrated the significance of lysine and methionine supplementation when utilizing protein sources other than milk protein.

In Kenya, commercial milk substitutes are expensive and not readily available in camel keeping areas. Introduction of formulated low-cost milk substitute from locally available feed resources used by pastoralists to feed calves will be a first step towards improving camel calf nutrition.

1.2 Statement of the Problem

Camels in Kenya are mainly reared under extensive pastoral production system. This system is characterized by large herds which are grazed on extensive rangelands with low inputs of production. In the extensive production system, there is high pre-weaning calf mortality (62%), slow calf growth rate and late reproductive maturity in pastoral camel production system in Kenya. This mainly emanates from inadequate feeds due to frequent drought and high competition for milk from households for food and income. Suppressed nutrition of young calves at early age leads to slow growth rate, low survival rates, poor health and delayed reproductive maturity. To ensure that calves are adequately fed, milk substitute of plant and milk origin have been used to supplement milk feeding. Plant-based milk substitute has been used in cattle calves for survival, faster growth and early reproductive maturity. Although plants that may be used to formulate milk substitute can be found in camel keeping areas, little is known about their nutritional composition and their effectiveness to formulate a substitute for camel milk in improving camel calf nutrition.

1.3 Objectives

1.3.1 Overall Objective

To contribute to sustainable camel production for alleviation of poverty, food security, promote sustainable agriculture and combat climate change in Kenya's ASALs through improved calf nutrition by utilization of selected locally available feed resources.

1.3.2 Specific Objectives

i) To evaluate existing indigenous knowledge and practices on camel milk substitutes in feeding camel calves under extensive and peri-urban camel production systems.

ii) To determine the proximate composition of identified common locally available feed resources used as substitutes to camel milk.

iii) To compare the effects of feeding a commercial and milk substitute formulated from locally available plant feed resources on feed intake (FI), average daily gain (ADG), and feed conversion ratio (FCR).

iv) To compute the cost /benefit analysis of feeding commercial and a calf milk substitute formulated from locally available feed resources.

1.4 Hypotheses/Research Question

i) There are no existing indigenous knowledge and practices on camel milk substitutes in rearing camel calves under extensive and peri-urban camel production systems.

ii) There are no significant differences in the proximate composition of identified common locally available feed resources used as substitute to milk.

iii) There is no significant difference in the performance (ADG, FI and FCR) of camel calves fed on commercial cow calf milk substitute and milk substitute formulated from locally available plant feed resources.

iv) What are the economic benefits of using locally formulated plant-based milk substitute and commercial milk substitute for feeding camel calves?

1.5 Justification

Camel milk is preferred over milk from other animals due to taste, nutritional value, health reasons and cultural perceptions. Such perceptions include the belief that it suppresses thirst even during long walks. Due to these perceived benefits, there is a high demand for camel milk which currently is not met by production levels.

The available milk is mainly sold or used for domestic consumption with very little left for calf consumption. The reduced milk intake by calves lowers calf growth and survival rates. The reduced milk intake by the calves before attaining full rumination affects their growth and survival rates due to their high dependency on nutrients from milk. Thus, there is need for research on a camel milk substitute to improve calf growth rates and reduce mortality in pastoral production systems.

Despite Kenya being among the major camel keeping Countries, very little research has been done on the improvement of the nutrition of the calf. There are locally available feed resources whose potential as ingredients of milk substitute have not been evaluated and thus the need for this study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and Domestication of Camels

Camels are in the Artiodactyla order and are in the Camel family. Camelids from the old world and llamas from the new world make up the two genera (Gauthier-Pilters & Dagg, 1981). (Gauthier-Pilters & Dagg, 1981*)*. *Camelus dromedarius* (one hump) and *Camelus bactrianus* (two hump) are two species of camel. *Camelus dromedarius* live in the hot deserts of Africa, while Bactrian camels live in the cold deserts of Asia. Lalamoids comprise species; Guanaco (*Lama guanacoe*), vicuna (Vicugna vicugna), llama (*Lama glama*) and alpaca (*Lama pacos*), which are all found in South America.

Evidence from fossils shows that camels and their direct ancestors came from North America during the Late Eocene, Tertiary and Pelcitocin periods, which happened about 40 million years ago. They used to be the size of a small rabbit, but now they are over 2 metres tall (Mikesell, 1955). From North America, camels moved to other parts of the world, where they changed into the camels we know today (McKnight, 1969). Mikesell (1955) found camel bones in Algeria that are thought to be from the ancient species, but they were given the name Dromedarius.

There are two ideas about how the humped camel became domesticated. One theory says that it was first tamed in the southern Arabian Peninsula (Epstein, 1971), where copper miners needed animals to carry the metal to the seashore. Also, they were used to carry salt and spices (Almathen et al., 2016) in a town built around 2700 B.C. On the island of Umm an-Nar (Oman), off the coast of Abu Dhabi, there are many camel skeletons with age records that point to the beginning of domestication (Kohler-Rollefson, 2000). The second theory says that camels were first tamed to produce milk in southern Arabia (Bulliet, 1975). Wilson (1984) said that camels were mostly used for work and transportation, but Bulliet (1975) and Yagil (1994) say that they were probably kept as pets for their meat and milk. But archaeological evidence doesn't back up this idea. In 3000 BCE, the Bactrian camel was first domesticated in southern Turkmenistan, according to early domestication evidence. Clay figures show that it was first used to pull carts (Bulliet, 1975). Currently, however, just a few wild Bactrian herds exist in the Gobi Desert and the highlands of China and Mongolia (Sala, 2023).

Recent worldwide sequencing of modern and ancient mitochondrial Deoxyribonucleic Acid (DNA) using nuclear microsatellite and mitochondrial genotype data suggests that camels were domesticated for the first time in the Southeast Arabian Peninsula (Almathen et al., 2016; Ming et al., 2020). According to Almathen et al. (2016), Arabian dromedaries were introduced to Africa from Arabian Peninsula via Sinai after which they spread to the whole of northern Africa. In another study (Cherifi et al., 2017), it is recorded that dromedaries were introduced to Africa through several routes. One route is a sea route through Somali and another land route through Egypt. The dromedaries in East Africa have been found to have a great genetic distinction from other parts of Africa which could be due physiological, geographical, and cultural limitations (Almathen et al., 2016). According to Orlando (2016), the dromedaries could have been introduced from South Arabia to East Africa through the Red Sea using boats (Orlando, 2016). This is because a minimal genetic distance has been observed between Dromedarius between East Africa and South Arabia and not North Arabia (Orlando, 2016; Teka, 1991).

It is generally believed that the modern dromedary or one-humped camel evolved from two species of humped Bactrians. This theory is supported in part by embryological evidence indicating that foetuses of dromedary camels have two humps during prenatal development (De Latour, 1971), whereas adult camels have prehistoric humps. Williamson and Payne (1978), speculate that the one-humped species probably evolved in one of the hotter and more arid areas of western Asia. Today, the two species can and often do interbreed, and on the basis of the fertility of the hybrids some authors have advocated amalgamating them into one species with two varieties. In areas of bordering distribution, such as north Punjab, Persia and Afghanistan, the phenotypic differences between the two types tend to diminish as a result of the crossbreeding between them (Mukasa-Mugerwa, 1981).

2.2 Overview of Camel Population and Distribution in the World

It is difficult to exactly determine the number of camels in the world due to some reasons. First, it is mainly an animal of nomadic people and pastoralists who move frequently. Secondly, camels are not usually subjected to obligatory vaccination like other domesticated ruminants. An exhaustive census for the camels is therefore quite difficult. Officially, the total number of camels in the world was around 27 million heads (FAOSTAT, 2014). This number is probably underestimated particularly, in the Sahelian Countries (Mauritania, Mali, Niger, Chad, Sudan, Ethiopia) when the number of camel heads was adjusted after appropriate census (Faye, 2014).

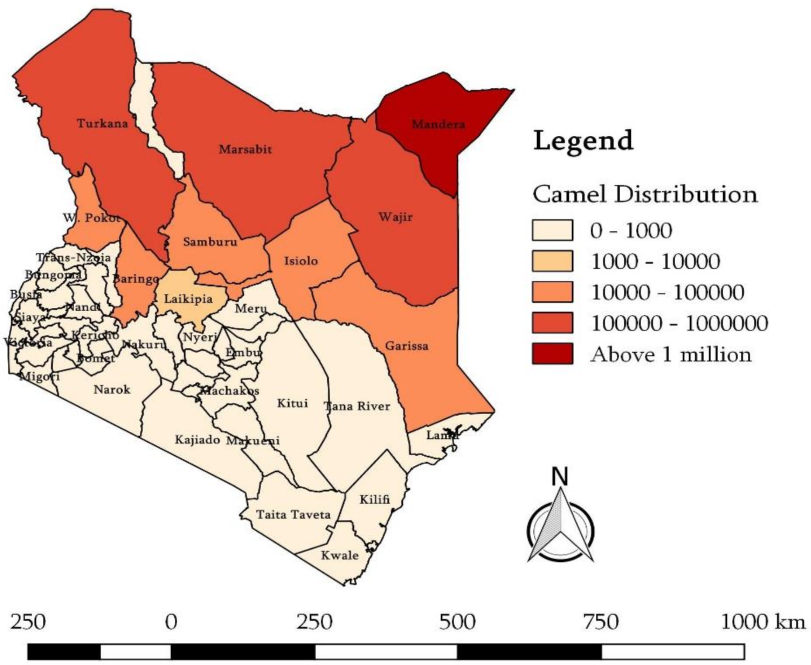
According to FAOSTAT (2019), the global estimate of camels in 2017 was 34.8 million, of which 30.1 million are found in Africa and 4.7 million in Asia. Kenya has the fourth largest camel herd in the world (Table 2.1) estimated at 3,338,757 after Chad, Somalia and Sudan.

Table 2. 1 Estimated camel populations of Africa and the world in 2017

Country	**Camel population**	**Country**	**Camel population**
Africa			
Chad	7,285,309	Nigeria	282,000
Somalia	7,222,181	Tunisia	237,005
Sudan	4,849,003	Egypt	149,224
Kenya	3,338,757	Western Sahara	111,329
Niger	1,788,149	Djibouti	70,965
Mauritania	1,479,648	Libya	64,469
Ethiopia	1,210,663	Morocco	59,000
Mali	1,192,900	Burkina Faso	19,475
Algeria	381,882	Senegal	4,765
Eritrea	379,189	Namibia	90
Other areas			
Mongolia	434,096	Iraq	78,196
India	325,155	Syria	66,390
China, mainland	323,000	Qatar	40,843
Oman	262,870	Uzbekistan	17,685
Kazakhstan	193,124	Jordan	14,322
Afghanistan	172,000	Kuwait	9,389
Iran	141,052	Europe	7,163

***Source*:** FAOSTAT (2019)

Of the projected world population, 31.1 million are one-humped dromedary camels (*Camelus dromedarius*) and 3.7 million two-humped (Tura & Kimindu, 2019). Approximately 20.1 million dromedaries, representing two thirds of the world's camel population, are in North Eastern Africa, i.e. Somalia, Sudan, Ethiopia and Kenya. In Kenya, camel population density increases with aridity as shown in Figure 2.1.

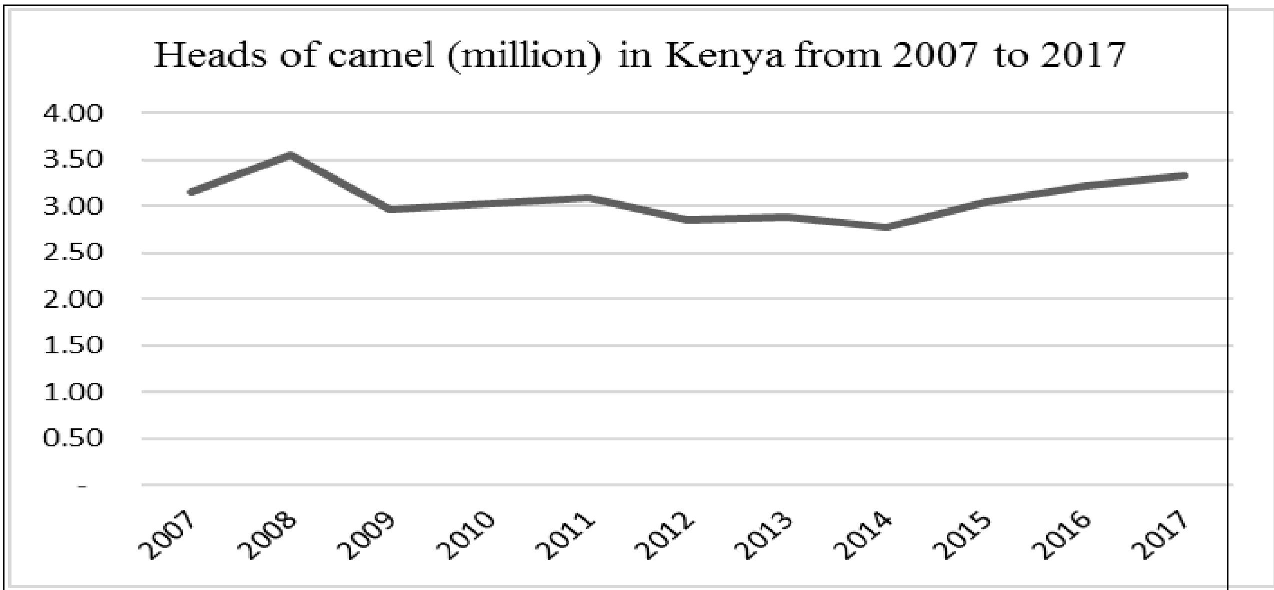


Source: Compiled from various County Governments Integrated Development Plans 2018-2022 (2018)

Figure 2. 1 Map of Camel Population Distribution in Kenya

The Counties leading with the highest camel populations are Mandera with 1,016,970 (Mandera CG, 2018), Turkana with 832,462 (Turkana CG, 2013), Wajir with 533,651 (Wajir CG, 2015), Garissa with 486,000 (Garissa CG, 2018) and Marsabit with 217,360 (Marsabit CG, 2018). All these Counties are predominantly arid areas. They are distantly followed by Samburu with 60,000 (Samburu CG, 2013), Isiolo with 40,460 (Musinga et al., 2008), West Pokot with 35,271 (West Pokot CG, 2018), Baringo with 10,189 (Baringo CG, 2013) and Laikipia with 9800 camels (Laikipia CG, 2018). These latter Counties fall between arid and semi-arid zones with 30-84% aridity.

In the past two decades, the national livestock population has been on a decline, reasons being attributed to climate change as evidenced by more frequent droughts (UNDP, 2005), yearly decline in long-season rainfall and the significant warming in temperature (USAID, 2010). However, camel population has somewhat stabilized in the past decade (Figure 2.2) and this has been attributed to its better adaptation to the changing climate (Hülsebusch & Kaufmann, 2002).



Source: FAOSTAT (2019)

Figure 2. 2 Camel population trends in Kenya between 2007 and 2017.

2.3 Breeds of Camels in Kenya

The camels found in Kenya may be broadly divided into three types according to habitat. The Somali camel is found in the northeastern province and is probably the same as the Benadir type found in Somalia, which also shows some affinity with the Anafi of Sudan (Mukasa-Mugerwa, 1981). It is suitable only for light work, e.g., water carriage and transportation of camp equipment, but is little used as a riding animal. The Rendille or Gabra is bred by the Rendille and Gabra people, who are extensively discussed by Spencer (1973). It is a smaller but more robust animal of the semi-desert areas. The Turkana is a small breed adapted to the bush and stony hill areas west of Lake Turkana (Mukasa-Mugerwa, 1981). Besides the Somali, Rendille and Gabra peoples, who raise camels in large numbers, the Turkana, Samburu, Borana and Pokot also keep them to a lesser extent (Mukasa-Mugerwa, 1981).

Camel populations are traditionally named after the different pastoral communities that keep them. Camels in Kenya are mainly kept by the Somali people in Mandera, Wajir and Garissa Counties and Gabra and Rendille communities in Marsabit County of Kenya. The Turkana are believed to have acquired camels from Gabra and Rendille through rustling (Njeru, 2011). These communities clearly distinguish their different camel populations, and these have often been referred to as breeds. Results from previous studies indicate that genotypic **(**Mburu et al., 2003) and phenotypic differences (Hülsebusch & Kaufmann, 2002) exist between these types of camels. A few Pakistani camels (imported from Pakistan within the last decades) are also found in Kenya though confined in commercial ranches in Laikipia County.

Somali breeds are generally much larger than other breeds in the Country with adult females weighing between 500 – 600 kg and males 600 – 800 kg (Kadim & Mahgoub, 2014). The Somali breed has the highest milk yield estimated at 5 – 8 litres per day (Farah et al., 2004a). Camels kept by the Gabra and Rendille are referred as Gabra/Rendille (G/R) breed and are generally smaller than the Somali breed with adult females weighing 350 – 450 kg and males 400 – 500 kg. Milk yield is also lower averaging 3 - 4 litres per day for a lactation period of 12 months. The Turkana breed is the smallest camel found in Kenya averaging 350 kg for females and 400 – 450 kg for males. Milk yields are also much lower with yields averaging 2 – 3 litres per day over a lactation period of 9 to 10 months. Besides these three main traditional breeds found in Kenya, some ranches have introduced Pakistani dromedaries in order to improve milk production through crossbreeding and these crossbreeds are now also found among some pastoral communities (Muli et al., 2008).

2.4 Camel Production Systems and Constraints in Kenya

Camels in Kenya are mainly reared under extensive pastoral production system. This system is characterized by large herds which are grazed on extensive rangelands with low inputs of production (Noor et al., 2013). There has been an emergence of a peri-urban production system however, whereby milking herds are grazed in areas close to urban markets for supply of milk, stock and meat. The peri-urban systems provide opportunities of value addition to the meat and milk produced by the camels. Various constraints are experienced in these production systems which include diseases, insecurity, limited markets and low productivity levels of the animals (Kagunyu & Wanjohi, 2014).

2.4.1 Extensive Pastoral Production System

The dominant land use system practiced by the pastoralists in the ASALs of Kenya is extensive livestock production. Camels are traditionally reared under pastoral system, usually in communally owned rangelands, mainly by subsistence pastoralists (Noor et al., 2012). This system is characterized by low production inputs/investments, low productivity/output, seasonal migration as well as herd and household mobility in search of pastures, water and mineral licks, or when other conditions (e.g., inter clan feuds) necessitate movements. The mobility enables pastoralists to utilize rangeland resources more efficiently (Guliye et al., 2007; Noor, 2013).

The most common strategy by pastoralists to cope with drought is herd mobility which aims at making use of spatially different vegetation type and productivity in variant places (Mworia & Kinyamario, 2008). The access to different vegetation species and productivity ensures maintenance of livestock population stability and body condition (Ellis & Swift, 1988) and maximizes use on available feed resource in the range.

Pastoral resource use pattern is predicated upon risk spreading and highly flexible mechanisms such as mobility, communal land ownership (a prerequisite for mobility and, therefore nomadism), large herd sizes that are diversified, and herd separation and splitting (Farah, 1996). Camel producers in northern Kenya adopt herd splitting as a risk spreading strategy. They split their herds into home-based herds (usually lactating) and nomadic herds (mostly dry) (Farah et al., 2004b). Nomadic camels are normally moved and cover long distances looking for browse forages and water.

The usual habitat of the camel is characterized by high temperatures and scarcity of water. Because of these environmental conditions, these areas are also characterised by considerable seasonal variations in available forage quantity and quality (Schwartz & Dioli, 1992). However, proper husbandry and sound management techniques are the reasons for the success of camel pastoralists in an environment characterized by erratic rainfall and frequent droughts (Farah et al., 2004b).

2.4.2 Peri-Urban Pastoral Production System

In northern Kenya, in the last two decades, high prices of camel products and other strong incentives are attracting more and more pastoralists into the market economy (Farah et al., 2004a). Urban market demand for camel products is also expanding in major Kenyan cities, particularly Nairobi (Guliye et al., 2007), where many communities of pastoral background have migrated in search of business and employment opportunities (Simpkin et al., 1996).

Many nomads now wish for themselves or their children the benefits provided by urban cities, including medical services and education (Wilson, 1998; Yagil, 1994). Herders are becoming more and more attached to semi-permanent settlements. The resulting short-range management system differs from the traditional long-range mobility patterns, which is used to balance the feed budgets of the herds (Hashi et al., 1995). The emergence of peri-urban camel production may have been initiated by market-oriented entrepreneurs taking advantage of available market opportunities for camel products e.g., milk.

2.5 Importance of Camels

The role of the camel in the modern world is changing. As pastoral societies evolve or decline, traditional uses of the camel, for example for transport, diminish (Faye, 2015). Yet the productive potential of this species and the manifold purposes which it may serve, combined with its ability to perform efficiently in harsh environments, are compelling reasons for understanding how to make better and more systematic use of this animal resource (Köhler-Rollefson, 2000).

The camel is considered to be potentially the most important animal source of food in pastoral areas (Schwartz & Dioli, 1992). Unique physiological, anatomical and ecological adaptations enable the camel to produce and supply milk to pastoral households throughout the year (Farah, 1996). During prolonged drought, milk production in cattle and goats ceases at higher proportions (52% and 75%, respectively) than camels (22%) (Herren, 1990). During such times, camel milk may contribute up to 50% of total nutrient intake of some pastoralist's groups. While a camel has the potential to produce 5-10 times as much milk per lactation as a cow in a similar environment (Farah, 1996), the total amount of protein and energy produced annually by camels under traditional management is about 2½ times the quantity produced by cattle (Dell'Orto et al., 1999).

The other global uses of the camel include meat, blood, recreation (camel rides, safari treks, and entertainments e.g., wrestling), racing, wool and fibre production, draught and transport, leather production, dung for fuel, urine as disinfectant and bones for manufacture of jewelry (Kuria, 2004). Camels also have cultural and religious significance among the communities keeping them (Köhler-Rollefson, 2000).

2.6 Reproductive Performance in Camels

Camel reproductive rate has been described as low by Novoa (1970). Compared to other livestock species, a camel has low reproductive performance due to late maturity (Zafar, 2000). Female camels attain sexual maturity at the age of 3 years but are usually not mated until they are 4 to 5 years old (Tefera & Gebreah, 2001). Breeding activity in the male dromedary camels in nomadic herds starts at 5 – 6 years of age and continues until 14 – 15 years with some minor differences according to breed and geographical location (El-Wishy, 1990). Camels are seasonal breeders (Yagil & Etzion, 1980), mating during the rainy or cold season. The male dromedary can serve 50 to 80 females in a season when in good condition (Yasin & Wahid, 1957). The fertilization rate of dromedary camels in pastoral herds is considered low and unlikely to be higher than 50% mainly due to low levels of management

(Mukasa-Mugerwa, 1981). However, under intensive management, 80-90% fertilization has been reported (Abdel-Rahim & El Nazier, 1990). Abortion rate of 26% and a calving rate of 21% have been reported in Kenya (Simpkin & Guturo, 1995). The gestation period of a dromedary female is 365 to 395 days (Simpkin & Guturo, 1995). The camel has an average calving interval of 2 years (Tefera & Gebreah, 2001) and produces about 8 calves in a lifetime (Yasin & Wahid, 1957). Depending on the level of demand, these factors can limit the volume and or quantity of camel products available for sale.

When pastoralists allow closely related camels to mate, this can result in inbreeding whereby abnormalities such as deformed legs, short ears, cryptorchidism and infertility can occur (Peter, 2010). The generation interval in camels which is already long because of their gestation period of 370 to 400 days (Evans & Powys, 1979; Kuria, 2004; Simpkin & Guturo, 1995; Wilson, 1998; Yasin & Wahid, 1957) can be further lengthened if sub-fertility occurs in either bulls or dams. In such situations genes for abnormalities take long before they are discovered. If decisions have to be made, then they are delayed resulting in an economic loss to the pastoralists.

2.7 Camel Products

Demand for livestock products has been steadily increasing as shown in Table 2.2 on trends in consumption and projected future demand. In developing countries, per capita consumption of meat has doubled from 14 kg in 1980 to 29 kg in 2002 and total meat supply has tripled from 47 million tonnes to 139 million tonnes. Most of the expansion in supply comes from increased production, and only a relatively small part from imports (Steinfeld et al., 2006). A combination of high population growth and growing income in many developing countries has led to a dramatic increase in demand for livestock products, and this trend is expected to continue for another 20 years (Delgado et al., 1999).

Table 2. 2 Past and projected trends in consumption of meat and milk in developing and developed countries

	Developing countries					Developed countries				
	1980	1990	2002	2015	2030	1980	1990	2002	2015	2030
Annual per capita meat consumption (kg)	14	18	29	32	37	73	80	78	83	89
Annual per capita milk consumption (kg)	34	38	46	55	66	195	200	202	203	209
Total meat consumption (million tonnes)	47	73	139	184	252	86	100	102	112	121
Total milk consumption (million tonnes)	114	152	222	323	452	228	251	265	273	284

Source: Steinfeld et al. (2006)

2.7.1 Camel Milk

Camels have the potential to produce milk, especially when raised in harsh environmental conditions. Lactation in camels continues during the dry seasons and only rarely ends, even during prolonged droughts. This allows camels to produce more milk than cattle and small herds would under the same harsh environmental conditions. To a greater extent than with milk from other livestock, camel milk is prized for its flavour, the quality of the nutrients it contains, and the positive effects it has on one's health. Additionally, it is believed that drinking camel milk while travelling long distances may assist in warding off thirst (Kaufmann & Binder, 2002). Community members can potentially sell excess camel milk for cash depending on market access (Kaufman & Binder, 2002).

When milk is in excess, preservation technologies such as milk condensation may be applied to improve the shelf life of the product and improve food security at the household level. According to Simpkin (1993) and Farah et al. (1995), when 250 g of sugar added to a liter of milk and boiled until only 0.5 kg or 500 ml remains, the shelf life of milk is extended to over six months. This condensed milk can be used by the pastoralists during the dry period.

Camel Milk Production

The data on milk production of camels are not very precise when used for the purpose of measuring the production potential because, among other things, it is difficult to estimate the amount of milk that is suckled by the calf (Farah et al., 2004a). Good milkers can yield 20 to 30 litres per day (Wernery, 2003). According to reports, the Somali breed camels produce 5 to 8 litres of milk on average each day (Bekele et al., 2002; Farah et al., 2004a; Farah et al., 2004b). During the height of their lactation, Somali camels may be able to produce more than 15 liters of milk per day under extraordinarily favorable circumstances (Farah et al., 2004a). Camels can produce up to 12 to 20 litres per day under more intense systems, according to Ramet (2001).

Several camel milk yield estimates per day under conventional pastoral management systems have been recorded in Kenya. Simpkin (1993), for instance, provided a range of 2.4 to 4 litres per day, while Simpkin et al. (1996) estimated the yield to be between 3 and 7 litres per day. According to Onjoro (2004), with proper feeding, the production can increase to over 10 litres per day. A camel's ability to give milk is influenced by a variety of circumstances. These include diet, lactation stage, season of the year and milking interval (Igge et al., 2020). In a study done in Egypt, other factors such as management systems and parity were found to have a significant effect on milk yield of camels (Mostafa et al., 2018).

According to Bekele et al. (2002), the average daily output for camels kept as herd animals in semi-arid eastern Ethiopia is 4.14 litres. In Eastern Ethiopia, according to Baars (2000), camels produce between 3.6 and 6.5 liters of milk per day. Camels have also been found to produce 2-6 litres of milk per day when milked either twice or three times daily in Afar area in Ethiopia (Gebremichael et al., 2019). In this region, a few farmers believed that milking thrice resulted in more milk as compared to milking two times per day. An average milk yield of 5.2 litres daily has also been observed where farmers indicated that they milked their camels up to even five times in a day (Kebede et al., 2015). In Somalia (Issack, 2021), peri-urban camels were reported to produce an average of 5.8, 4.7 and 4.7 litres in large, medium and small-scale producers in early lactation stages respectively.

Most of the milk is produced in the first seven months of a dromedary camel's lactation, which can extend from nine to eighteen months (Yagil, 2000). In northern Kenya, a year-long lactation period has been reported with a lactation yield of 1897 kg (Field, 1979).

Simpkin (1998) reported milk production from 677 to 2813 liters for different camel breeds in Kenya while Kuria et al. (2005) reported a total yield of 387 liters after 160 days of lactation. The production of camel milk is highly variable from one region to another, depending on factors such as the breed of camel, the number of times it is milked, the disease burden, and the camel's physiological state. Some of these factors include the feed quality and quantity, the water source, and the number of times it is milked (Simpkin, 1996).

Camels can produce and supply milk to pastoral households due to their special adaptations (Farah, 1996). According to Kaufmann and Binder (2002), about 44% of the adult females (47% of the national herd of 830,000 heads) are lactating at any one time i.e., 171,644 camels. Using an average of 2 liters per camel per day (Kuria et al., 2005) throughout a 12-month lactation, then the annual yield from all camels in Kenya is estimated as follows: 2077636 x 2 x 365 = 1.516 billion liters per annum. At current prices of about 100/- per liter, this milk is estimated to be worth KES 151.7 billion.

Camel Milk Marketing

There are currently three primary entry points for camel milk onto the market. The first is a covert channel through which most informal traders transport the fresh milk of large and small camel breeders. A diminishing but rising amount is sent to other areas of Nairobi and as far as Kampala, Uganda, from Nairobi. The primarily Somali urban consumer of the expanding Eastleigh real estate (and shopping mall), where it is purchased predominantly by households and restaurants. With fresh milk delivered to customers in Nairobi within two days at a competitive price of KES 80 per liter compared to on-farm costs of KES 25-30, the distribution channel is quite effective at handling approximately 70% of peanut milk. This is due to the fact that fresh milk is delivered to customers in Nairobi at a price of KES 80 per liter.

According to calculations, this route (which currently manages around 4,000 liters per day) can only satisfy 20-25% of the demand that is currently being placed on it. Even without further development, the existing market has the capacity to drink 20,000 liters of fresh milk every single day (Noor et al., 2013). This company is worth 1.6 million Kenyan shillings every day, which is equivalent to 0.6 billion Kenyan shillings per year, and the value of this enterprise has the potential to increase many times over because of our development activities. Well-targeted market development seems high. In a study conducted by Noor et al. (2013) in Isiolo County, it was found that once milk reaches Nairobi County, a litre of processed milk can cost up to KES 240. This milk is primarily purchased by consumers who desire processed milk and who place a premium on hygiene standards. In Isiolo County, milk that has been produced in the peri-urban areas is mostly transported to Isiolo town using donkeys and pick-ups and is sold through informal agreements that have been made between traders and farmers (Noor et al., 2013).

The second distribution channel offers high-quality pasteurized camel milk that is produced by quality-conscious large and small producers, primarily in the Laikipia district. This milk is subsequently processed at Vital Camel Milk Limited's only camel milk processing factory in Kenya, which is located in Nanyuki. The upmarket urban consumer in Kenya and abroad is the target market for this milk. Despite the fact that this is the least major distribution channel, accounting for less than 5% of camel milk delivered in and around Isiolo (Anderson, 2012), it has the greatest potential for expansion and effect. Camel milk's growing international recognition as a natural health product for the treatment of diabetes and other diseases has contributed to an increase in projected demand. It is predicted that this will be much more than the Country's present yearly production of camel milk, which is measured in liters and totals 300 million (Mohan, 2020). It appears that Kenyan camel milk will be able to effectively penetrate the international medical market if the market is developed properly, turning it into a high-value product with returns sufficiently to justify the investments necessary for the expansion of the subfield industry. All indications point to this being the case, and everything indicates that it will be possible. It has been stated that self-help groups and co-operative societies in the town of Isiolo are also involved in the marketing of camel milk (Anderson et al., 2010; Mwaura et al., 2015).

The third channel is a raw milk rural consumer channel, wherein farmers supply raw milk to rural homes and restaurants directly or via middlemen. Most of the time, this milk is marketed to non-pastoralists in these areas, notably to civil workers like the police and teachers (Mwaura et al., 2015). According to estimates, the present volume handled through this channel accounts for around 25% of the milk marketed in Isiolo County. This channel's growth prospects are likewise promising, albeit lower than those of the other two channels (Muli et al., 2008). In a study done by Gebremichael (2019), in Ethiopia, the milk produced was mainly sold on the roadsides (58.5%) and at the farmers’ gate (18.3%). In this study, the farmers who owned the camels were observed to gain more income when they sold the milk directly to the consumers as compared to when sold to the middlemen.

Characteristics and Composition of Camel Milk

The quality of camel milk is similar to cow's milk in many ways. However, fundamental differences exist in the fat, vitamin C and protein content. The fat in camel milk (3.7%) is lower than in cow's milk (5.7%) and is not easily separated (Yagil, 1982). In addition, camel milk also contains protein (2.5-4.5), SNF (9.9-14.3), water (86.3-88.5), ash (0.35-0.95).) and lactose (2.9-5.8) (Ali et al., 2020). Milk is rich in vitamin C, ranging from 5.7 to 9.8 mg/l, which is about three times more than cow's milk (Farah et al., 2004b). This is important in ASAL areas where fruits and vegetables are not readily available as a source of vitamins for livestock farmers.

Camel milk is gaining more and more attention because cattle-raising tribes believe it has medicinal properties (Muloi et al., 2018; Wernery & Wernery, 2010). In addition, it has antibacterial properties (Bakry et al., 2021; El-Agamy et al., 1992). Studying the potential of camel milk to inhibit the growth of pathogenic bacteria, Barbour et al. (1984) found that four out of six pathogenic bacteria were inhibited. Faye (2008) revealed that camel milk is a known remedy for diabetes, tuberculosis, peptic ulcers, gastroenteritis and cancer in the Rift Valley of Africa and Asia. This review was performed to establish evidence for the antibacterial activity of camel milk. Through the research report on camel milk, the author discovered some indications of some medicinal potential. Camel milk contains about 10 times more protein lactoferrin than cow's milk. Camel milk has powerful healing properties against viral and bacterial diseases in humans, such as diabetes, tuberculosis, stomach ulcers, gastroenteritis, anemia, hemorrhoids, arthritis and cancer (Faraz et al., 2019a; Köhler-Rollefson 2000). Camel milk also contains the protein lactoferrin and vitamin C. An Indian study provided evidence to support this claim (Agarwal et al., 2002).

According to Mudgil et al. (2018), camel milk does not cause allergies in humans because contrary to cow milk, it has lacto-albumin of whey protein and a pure form of β-casein. Because of this quality, it is recommended for infants who have allergic reactions to cow milk (Solanki et al., 2017). In a study on how camel milk can be used in management of diabetic patients Aqib et al. (2019), concluded that there was a favourable effect in insulin production and regulation which assisted in improvement of cholesterol and blood glucose in diabetic patients, leading to a reduction of complications that arises from diabetes. Camel milk has also been proposed as a positive contributor to healing of wounds by promotion of some processes such as extra-cellular re-modulation and angiogenesis (Aqib et al., 2019). In Ethiopia, the possibility of camel milk in management of conditions was tested by Muleta et al. (2021) who reported that children who took camel milk as opposed to cow milk were observed to have lower anaemia.

Challenges in Camel Milk Marketing

Unhygienic handling procedures in traditional camel milk production and the informal camel milk trade pose significant obstacles to the implementation of modern milk processing and marketing (Younan & Abdurahman, 2004). The maintenance of milk quality during production, transport, processing, and marketing will be crucial to the effective adaptation of pastoral subsistence agriculture to the demands of an improved camel milk production and marketing system. Owing to the lack of potable water, it remains challenging to adapt hygiene principles and practices to pastoral settings. The marketing of raw milk in Garissa, Kenya faces numerous obstacles, such as low milk production, poor hygiene (dirty plastic containers and poor milk handling), transportation due to a poor transportation network, a lack of suitable packaging, and low demand during the period of milk surplus due to traditional consumer trust and a lack of consumer awareness (Dirie, 1999). In other pastoral regions, the marketing of fresh camel milk faces similar obstacles.

In a study by Noor et al. (2013), farmers in pastoral production systems cited poor road conditions and long distances to the market places as some of the reasons they were not able to sell their milk. During transportation, the milk is exposed to high temperatures for a long time before reaching the market and then pooled without carrying out tests which leads to milk spoilage (Machan et al., 2020; Nato et al., 2018). In Ethiopia, a study was done to determine the distance that respondents travelled to sell their milk. Majority of farmers were found to travel between 10-15 KM (38%), and 5-10 KM (27.5%) to reach to the market. The other challenge was differences in pricing during the seasons of the year. According to Tura and Kimindu (2019), milk prices are highly variable depending on location and season whereby there is limited supply of camel milk during the dry seasons.

2.7.2 Camel Meat

Evaluation of the camel's ability to produce meat is hampered most by a dearth of correlated data (Wilson, 1984). According to the available research, camel meat is comparable in quality and carcass composition to other red meats (beef, lamb, and goat) (Alkahal, 1994). However, camel meat has a lower fat content, a higher concentration of inorganic minerals, and a higher moisture content when compared to beef (Alkahal, 1994). El-Magoli et al. (1973) found out that camel meat has lower cholesterol levels than beef tenderloin (50 mg/100 g vs. 65 mg/100 g), making it a healthier option. The nutritional composition of camel meat, lamb, beef, and poultry was directly compared by Mohamad et al. (2020). Four meats were analyzed for their moisture, fat, crude protein, and vitamins. According to this study, camel meat contains more water, vitamins, minerals, and amino acids. Depending on how the meat was handled during slaughter and storage, camel meat contains less fat, cholesterol, and bacteria than other meats. It has also been reported that camel meat is low in fat (Eskandari et al., 2013).

In a study conducted by Baba et al. (2021), camel meat was found to contain 19% protein, 78% water, 3% fat and 1.2% ash. In another study in Iran, Ebadi and Sarrhadi (2019) evaluated fatty acids and functional properties of meat from leg, shoulder, loin, and neck parts from *Camelus dromedarius* and their crosses with two humped camels. From the results, the pH of the meat was affected by the camel breed, the cooking loss percentage and water binding capacity was lower in the crossbred as compared to the dromedaries. For meat toughness, the loin part of the crossbred had an increased toughness. Sex was found to having no effect on all the meat properties except for pH.

Up until the age of five, camel meat is comparable to beef; after that point, however, it can become stringy (Field, 2005). Because fats are stored in the hump, it has a high-water content, a protein content of 22%, and only 1% fat. Additionally, it has a low cholesterol content. Fats have a high melting point and can be kept in the pantry for at least a year without going rancid, and they don't impart an off flavor or smell either (Okparanta, 2018). Because of their large size, camels were traditionally only slaughtered rarely for the purpose of domestic consumption (Field, 2005).

According to estimates, a camel population might lose up to 7.5% of its animals per year to slaughter or export without their being a long-term loss (Wilson, 1984). Heath (1992) estimated that an annual off take of about 6000 camels would be possible in Kenya although there was a large surplus at the time, mostly among Somali camels in Northeastern province. With an average live weight of 500 kg and a 50% carcass, they would yield 1.5 million kg of carcass, valued at KES 120 million. It is recommended that males between 1 to 3 years should be slaughtered because their meat is tender at this age (Kadim et al., 2018).

An extension of the shelf life of the camel meat can be achieved by several ways. Djenane et al. (2020), recommends that treatment of camel meat with plant leaves such as wild olive oil tree leaves that have been ground into powder can be used for inhibition of microbial growth and therefore prolong its shelf life. Addition of specific oils to minced camel meat can also be used to extend its shelf life (Shahbazi et al., 2017). Baba et al. (2021), discussed a number of methods that can be used to preserve and also improve the quality of camel meat among them low temperature storage and aging. The quality of the meat is achieved through colour retention, reducing microbial load, and peroxidation of lipids among other ways. Use of garlic has also been reported to decrease lipid oxidation for a period of 14 days by Gheisari and Motamedi (2010).

The annual off take is very variable, making it difficult to estimate the average camel meat consumption. Off take in a drought year in rural areas is estimated at 20,000 heads with about 5 camels slaughtered in the ASAL towns daily down to very few under good conditions. Estimated off take based on mainly male and barren cull females is in the range of 13-18,000 heads, or an average in the range of 1.4 to 2% for the national herd. With an average live weight of 600 kg and killing out percentage of 55 (Staatz, 1979), this gives a dead carcass weight of 330 kg which translates to a total consumption ranging from 4,300 to 6,000 metric tons per annum. Agriconsortium (2003) estimated camel meat consumption in Kenya at 5,000 metric tons.

Live Camel Trade in Kenya

The professional marketing of live camels has only just begun to take shape. The offtake of live camels is estimated to be between 1% and 5% (Simpkin, 1993). Kenyans regularly sell live camels for slaughter, usually males and unproductive females, and there are now a rising number of camel butcheries in several urban areas (Farah et al., 2004a). These sales of live animals provide cash for purchase of food and clothing and a source of capital where the pastoralists want to invest (Noor et al., 2013).

As a direct result of the opening of the camel export corridor in Ethiopia, camel prices in northern Kenya have increased by a factor of ten over the course of the past three years (Gitao, 2021). When compared to the price of a camel on the Moyale camel market approximately three years ago, the current average price of a camel is $1,400. As a result of Ethiopia opening its market to the export of camels for meat and live animals, primarily to Middle Eastern Countries, the Country's farmers have been able to find better prices. Kenya, Somalia, Ethiopia, and Sudan are among the Countries that the market serves (Mahmoud, 2010).

A study was conducted to determine the revenue gained from sale of Somali camel breed in Isiolo and Marsabit Counties in Kenya by Kuria et al. (2016). It was observed that camels are sold at different prices depending on age and sex with females being sold at higher prices compared to the males due to higher demand for the former. Moreover, the prices were higher in Isiolo as compared to Marsabit which was attributed to Isiolo being more accessible and presence of more people who take camel meat in comparison to Marsabit. Based on age, mature camels which were more than three years old were sold at the highest price while calves whose age was less than one year were found to be sold at the lowest prices compared to camels above one year of age. Noor et al. (2013) carried out a study in Isiolo County to assess marketing of live animals and milk under peri-urban and pastoral system and reported that the number of steers sold were 2.4 times more in peri-urban in comparison to pastoral system. In another study, there were differences in prices for castrated and uncastrated males in Turkana, Kenya (Arasio, 2004). In Ethiopia, it was observed that camels were sold and bought in the same market where pastoralists and traders met (Mehari et al., 2007) with the average age of the camels bought being 24 and 29 months. The average price of sale was 2011 and 1784 birr in the year 2004 and 2005. Like Kenya scenario, the age at which the camels were bought was a significant factor in determining the selling price.

The export of camels to Egypt is via the Moyale-Nazareth-Djibout route and Egypt, or via the Nazareth-Hamara (Ethiopia) and Sudan route. Sudanese traders preferred the Djibouti route because of less risk and fewer dead camels (Gikonyo, 2018). The Future of Agriculture (FAC) study highlights several reasons why camels from Moyale are preferred over camels from Sudan (which also explains the increase in exports to the Middle East): Traders in Sudan are looking for cheaper animals elsewhere in the region as the price of camels in Sudan has increased significantly in recent years, which has made their business more difficult (Mahmoud, 2010). The camel market in Darfur was closed due to the war and for this reason, Middle Eastern Countries are looking for camels from Ethiopia to fill the gap caused. In the Middle East, there has been a sharp increase in the demand for low-cost sources of protein, which has led to an increase in exports of this commodity from the Horn of Africa. Egypt eats a significant amount of camel meat imported from Ethiopia, Eritrea, and Sudan; however, the majority of camels labeled as being from Ethiopia are actually from Kenya and Somalia (Mahmoud, 2010).

Challenges to Camel Marketing

When it comes to trying to sell their animals, producers in northern Kenya face a number of challenges. There is a lack of uniform livestock marketing policies, which leads to a reliance on individual dealers. In addition, the roads are in poor condition, there is a dearth of reliable market information, there is widespread insecurity, and thieves steal livestock (Chabari & Njiru, 1991). According to Melketo et al. (2021), marketing of livestock was severely impacted by lengthy distances to the market because pastoralists who are closer to the markets tend to sell their animals for more money because they are more aware of the going rates in the markets. Another major challenge is that pastoralists mainly market their camels based on visual appearance of the animal which sometimes leads to exploitation by middlemen (Kuria et al., 2016). When comparing knowledge of farmers about market prices, Kuria et al. (2016) reported that farmers in Isiolo in Kenya were more aware of giving market value to their animals as compared to farmers in Marsabit County. In pastoral communities in Ethiopia, farmers were found to experience similar marketing problems for their livestock such as lack of market knowledge, poor infrastructure, middlemen exploitation among others (Melketo et al., 2021). In other areas such a South Sudan factors such as communal conflicts have been found to destabilize livestock markets by negatively affecting supply of animals to the markets (Aklilu et al., 2016; Catley, 2018).

Marketed Camel Meat Products

Although Bruntse (2003) did establish that the sales value of a camel partially processed and partially sold fresh could be three times the purchase price, most of the camel meat sold in Kenya is not processed. Traditionally, the Gabbra and Borana communities of Marsabit district made *Nyirinyiri* (fried meat in oil) from beef, goat or camel for their own consumption with the latter being preferred (Dabasso, 2019). It was given to a husband or friend as a delicacy or was made as part of a girl's dowry. However, among the Somali pastoral community of northeastern province, this product is unofficially exported all over the world and there is a high demand for it wherever Somalis live (Field, 2005). A report by Lemunyete (2003) indicated that the Salato Women Group in Ngurunit, Marsabit district made the following camel meat products for sale; *Nyirinyiri* in vegetable oil (traditional), *Nyirinyiri* in camel fat, Sirikan (brine treated, sun dried meat) and *Lakuli* (fried Sirikan), vacuum-sealed meat dishes, canned meat and processed camel fat. The Women Group sold 250 g can/jar of *Nyirinyiri* for KES 150. This price was arrived at based on the production economics (Wayua, 2001), which indicated that with 8.475 kg of fresh camel meat, one could make 4.88 kg of the product, reflecting a 50% weight loss. The selling price of 100 g sachet of Sirikan is a minimum of KES 60. A study was done by Werikhe et al. (2019) to assess the processing of a camel meat product called *koche* in Isiolo and Marsabit Counties in Kenya for sale. It was concluded from this study that making *koche* is profitable and therefore can be considered as a good area for investment.

According to Maqsood et al. (2016), camel meat being tough in texture and having an off odor are some of the concerns lowering consumption of this meat. Presence of off-odor is attributed to polyunsaturated fatty acids and microbial storage which can be removed by use of antioxidants (Dawood & Alkanhal, 1995). Preparation of other products other than the fresh meat is one of the strategies that is used to encourage people to consume camel meat (Maqsood et al., 2016). This is usually done through processing the meat to make products such as sausages and burgers (Maqsood et al., 2016). In some areas such as Tunisia and Australia, preparation of camel meat products such as sausages has been reported (Adab et al., 2020; Kadim, 2012). A study by Abdel-naeem and Mohamed (2016) was carried out a study in Egypt to evaluate how sensory characteristics of burger patties can be improved through addition of some spices. This study concluded that addition of tenderizing agents can improve sensory and physico-chemical characteristics in burgers preparation. This shows that there is a demand and consumption of many camel meat products globally, especially in regions where camels are found.

Other value-added products made from camel meat have come on the market in Kenya (Allport, 1999). The most popular of these products, especially among tourists are hamburgers, frankfurters, and kebabs. These have all been manufactured at an abattoir at Ol-Maisor private ranch near Rumuruti, which is also accessible to area camel pastoralists. The main processes involve mincing, adding herbs and spices, curing, corning, cooking, and smoking (Okoth, 1998). There is significant exportation of these products to destinations with particularly emigrants and refugees from Kenya and the horn of Africa. For example, there were about 60,000 people of Somali origin living in Toronto, Canada and a great deal of this product reaches them through unofficial channels (Field, 2000).

2.8 Camel Nutrition

Camels graze on a wide range of desert and semiarid forage plants, including trees, bushes, bitters, thorns, and halophytes (salty) (Coppock et al., 1986; Field, 1995; Wilson, 1989). Camels can eat spines up to one centimeter long. The amount of green matter absorbed by these plants is roughly 5 kilogram per day, as opposed to the average 30-40 kg for immature forages (Gauthier-Pilters, 1974). Gauthier-Pilters (1974) discovered that a desert camel consumes between 2 and 4 tons of DM per year during a 221-day research in the Sahara.

2.8.1 Water Requirements

Camel herders place a higher value on the animals because of their resilience in difficult conditions, capacity to withstand protracted droughts, and, most crucially, ability to transform scarce desert resources into milk and meat. The camel (Camelus dromedarius) has adapted mechanisms that allow it to survive when there is a lack of water, particularly high heat loads, and to survive when food sources are scarce or inadequate. These mechanisms allow the camel to withstand prolonged water shortages, particularly high heat loads (Gaughan, 2011). They are able to survive in severe desert habitats, which are characterized by a lack of water and seasonal flora in addition to high ambient temperatures and other environmental pressures. These animals have adapted successfully to survive in these conditions (Gaughan, 2011). Camels, both physically and physiologically, are outfitted with adaptable homeostatic systems, which enable them to live, produce, and reproduce in environments that also support human life. This is possible because camels have these mechanisms. These camels are an abundant supply of meat and milk, especially in locations where climates restrict the performance of other livestock. In particular, these camels are useful in regions that are parched (Gebreyohanes & Assen, 2017).

Camels that have been modified to live in desert environments have undergone physiological changes that either decrease the amount of water they lose or allow them to endure considerable amounts of water loss. Camels can endure several months without needing to drink water if they live in climates that are temperate (Fesseha, 2020). Camels are able to go without drinking water for extended periods of time throughout the winter and colder seasons of the year (Bornstein, 1990), notwithstanding the availability of water. Camels can only drink once every 8 to 10 days when the temperature is extremely high, and as a result, they can lose up to 30 percent of their total weight owing to dehydration (Bornstein, 1990). Camels may go 10–15 days without drinking water when the average temperature is between 30 and 35 degrees Celsius, but when the temperature is higher than 40 degrees Celsius, it is necessary to hydrate them more frequently. Both the digestive and urinary systems have evolved to be very sophisticated in their ability to conserve water. Whereas cattle lose between 20 and 40 liters of fluid through their excrement each day, camels only lose about 1.3 liters (Fesseha, 2020). This is a main strategy that is utilized in the fight against water scarcity in dry areas. The absorption of liquid occurs at the very end of the intestine, near the site where feces are formed (Ouajd & Kamel, 2009).

The camel's body is able to survive the loss of more than 30 percent of its weight, in contrast to the majority of other mammals (Fesseha, 2020). After some time has passed, they should be rehydrated since animals cannot survive for long without water. A camel can take in more than one-third of its total body weight in water while it is trying to rehydrate itself (Schmidt-Nielsen, 1997). According to some reports, a camel can drink the equivalent of nearly 110 liters of water in just ten minutes (Denton, 1996). When performed on other species, rehydrating to these levels causes overhydration, which ultimately results in death. It is possible for camels to do this because their intestines have the capacity to hold significant volumes of water for up to 24 hours, which prevents their blood from becoming diluted too quickly (Gaughan, 2011).

2.8.2 Feeding Habit and Camel Habitat

In 1979, Field published a study that examined the ecology of camels as well as the management practices of the Gabra and Rendille tribes in northern Kenya. Following the collection of 17,500 plant availability profiles over the course of 10,000 minutes of feeding, it was determined that the typical diet of a camel consists of dwarf shrubs (47.5%), trees (29.9%), herbs (11.2%), other herbs (10.2%) and vines (1.2%). However, within each category, there are significant differences in the types of plants that grow there and also between the wet and dry seasons. According to a calculation made by Field (2005), the typical diet of camels consists of the following ingredients: trees (25%), dwarf shrubs (50%), herbs (14%), and grass (11%). This information was obtained from a thorough collection of feeding observations made across five distinct types of rangelands in Marsabit County, which is located in northern Kenya. The camel is therefore primarily a herbivore, although it also eats young, tall and succulent grass. Somali camels are an exception, believed to eat more grass than browse. Somali camels brought to the farm in Laikipia, Kenya have been reported to prefer to graze rather than browse, specifically, during the first three hours of the morning (Schwartz et al., 1983).

The primary forage species that camels feed in northern Kenya are *Cordia, Acacia, Euphorbia, Duosperma, Grewia, Indigofera,* and *Salvadora* (Evans et al., 1995; Onjoro, 2004; Schwartz et al., 1983; Wilson, 1998). According to seasonal fluctuations reported by Field (1995), camel diets during the wet season were dominated by trees, shrubs, and dwarf shrubs, whereas during the dry season, when most of these species lost their leaves, the proportion of trees and shrubs dramatically decreased. Camel herds have a propensity to concentrate on evergreen trees and shrubs during times of drought, including *Dobera glabra, Salvadora persica*, and some species of *Euphorbia* (Field, 1995; Yagil, 1994). In addition, important range browse species preferred by camels are detailed in the Table 2.3 below.

Table 2. 3 Important range browse species fed on by camels as identified by scientific and local names

Scientific name	**Growth form**	**Somali**	**Rendile**	***Turkana***	***Samburu***	**Gabra**
Acacia tortilis	Tree	Abuk Abak	Dahar	*Etir Ewoi*	*Ltepes*	Dadacha
Acacia nilotica	Tree	Bili Madow	Gillorit	*Ekalapelimet*	*Ilkiloriti*	Burquqe
Indigofera spinosa	Dwarf shrub	Rufile Maratel	Khoro	*Emakwi*	*Lkitagesi*	Korotegala Kiltipe
Salsola dendroides	Dwarf shrub	Darran-ad	Hadum	-	*Aduung*	Hadum
Boscia coriacea	Shrub	Ghalangal Dakkiyah	Yoror	*Erdung*	*Serichoi*	Galgacha
Balanites	Tree	Kullen Kidthi	Kulum	*Eroronyit*	*Sarai Ilbulei*	Badhan Baddana
Salvadora persica	Shrub	Adde Athei	Hayei	*Esekon*	*Sokotei*	Aadhe
Euphorbia tirucalli	Shrub	-	-	*Elila*	*Loile*	Anno
Cordia sinensis	Shrub	Mared Maeer	Gaer	*Edome*	*Ilgoita*	Madeera

Barleria Spp	Herb	Gamaadiis Odarol	Geidow Sucha	-	*Lkurumbule Sucha*	Maadek Shiisha
Blepharis linarifolia	Herb	Quarda Yumarook	Lemaruk Harja	-	*Emarak*	Kutumbule Baraata
Sueda monoica	Shrub	-	-	-	-	Duurte

Source: Kenya Camel Association (2010)

In spite of forage diversity in the rangelands, feed availability fluctuations minimize camels feed choices causing them to turn to poisonous plants such as *Capparis tomentosa*. The plant is always green and is commonly found along riverine where camels feed from during the dry spells. The plant fruits and flowers are known to cause paralysis in camels (Schwartz & Dioli, 1992). The antidote is known though the pastoralists administer concoction of ground charcoal and fat of lamb to affected camels. The shrub can be reached by the camel calves which are more vulnerable than the adults. The plant is not easy to eradicate but pastoralists attempt through cutting (Peter, 2010).

2.8.3 Daily Feed Intake

Even when permitted to graze freely, it is still largely unknown how much feed camels consume. Despite the fact that published data are rather conflicting, it does appear that feed intakes per unit of body weight are moderate when compared to those of other domestic species (Field, 1995; Wilson, 1998). There may be a connection between camels' slower metabolic rate and their more nutrient-rich diet and the reported disparities in food intake between them and other livestock (Field, 1995). The amount of water in the fodder determines how much camel eats. The amount of dry matter consumed by a camel when it consumes 30–40 kg of fresh grass with an 80% water content is only 6–8 kg (Yagil, 1994). The amount of feed consumed by camel also depends on how carefully it feeds on a range of flora and various, varying-quality sections of browse (Hashi et al., 1995; Wilson, 1989). When favored or chosen browse is readily available, ingestion rates might be quick, whereas they are significantly slower for prickly species with few leaves. According to Kassily (2010), camels' feeding activity patterns are influenced by the quality of their fodder, and under unfavorable pasture circumstances, the amount of time they must graze would be a limiting factor for their total intake of dry matter and nutrients.

The small-bodied Rendille/Gabra camels in the arid regions of northern Kenya ingest 1.67% of their body weight each day, according to thorough nutritional research. As a result, 5.02 kg were obtained as the daily dry matter intake (DMI) by multiplying this number by the actual mean live weight (Field, 2005). The DMI calculation for camels should be adjusted by 10% to account for production costs, giving 5.52 kg per day (Field, 2005). Wilson (1989) claims that a camel's daily total dry matter consumption should be around 4% of its body weight, and that this can be achieved by feeding the animal for up to 15 hours a day. An adult camel weighing 650 kg would therefore need roughly 26 kg of dry matter, which might equal 80–100 kg of total food consumption from plants with high moisture levels.

2.8.4 Mineral Requirements and Sources in Camels

Minerals are required for the proper functioning of animal body systems because they participate in a wide range of enzymatic and hormonal activities, acid-base balance, food digestion, metabolism, and cellular absorption (McDowell et al., 1997), among others. Fifteen (15) mineral elements are considered essential and have practical significance in animal nutrition (Underwood, 1981). This includes 7 major elements and 8 trace elements. Ca, P, K, Cl, Mg, and S are the key elements. The trace elements are Fe, Zn, Cu, Mn, Co, Se and Mo. Structure, physiology, catalysis, and regulation are the four functions of minerals in the animal body (Underwood & Suttle, 1999).

Minerals are essential for the proper functioning of animal body systems, as they are involved in a variety of enzymatic and hormonal activities, acid-base balance, food digestion, metabolism, and cellular absorption (Kauffmann, 1998). Under natural grazing circumstances, camels prefer forage crops over grass (Ikanya et al., 2022). Leaves typically contain more minerals than grasses (Basmaeil et al., 1989; Field, 1995). It has been demonstrated that Rendille-selected forage (primarily shrubs) contains the recommended concentrations of essential mineral elements and can satisfy the mineral requirements of camels. In addition to consuming vegetation, camels obtain minerals from water, soil, and table salt.

Faye and Bengeumi (1994) observed that the exact mineral requirements of camels are unknown. However, it has been demonstrated that camel needs vary based on breed, location, age, sex, nutrition, and health status (Abdallah et al., 1988; Nagpal et al. 1997). Also known to affect bioavailability and, consequently, the dietary mineral requirements of animals, including camels, are mineral interactions (Church & Pond, 1988).

According to Wilson (1998), the salt (Nacl) requirement for camel body maintenance is six to eight times that of other livestock. Additionally, the author observed that camels can tolerate extremely high salt concentrations in their food and water (physiological adaptation to arid environments). The recommended daily allowance ranges from 120 to 140 grams. Garden believes a lower intake of 57 to 112 gd-1 is adequate (1971). Camel intakes between 30 and 60 gd-1 are associated with arthritis-associated deficiency syndrome (Wilson, 1984). This author observed an immediate improvement in the patient's condition after administering 140 gd-1. According to Kuria (2004), camel breeders in Rendille were aware of the importance of minerals and referred their animals to natural sources or mineral supplements (Table 2.4).

Table 2. 4 Rendille pastoralists' perception of effects of mineral supplementation on camel performance

Category of changes	Perceived effects	Percentage of responses		
		Korr (*n)	Kargi	Ngurunit
Production	Higher milk yield	34.7	29.1	33.3
	Stronger calves	0.0	9.3	0.0
	Better milk and meat taste	1.7	7.0	0.0
	Higher conception rate	0.8	4.1	3.0
	Tasty body fat	0.0	2.3	0.0
Physiological	Better feeding appetite	13.6	4.7	19.3
	Better dehydration resistance	1.7	4.7	0.7
Physical appearance	Bigger camels of better body condition	38.1	28.5	33.3
	Cleaner and shiny hair coat	1.7	1.7	3.7
Behavior	Better mothering	0.0	0.6	0.0
Others	Higher disease resistance	6.8	5.2	2.2
	Fewer external parasites and occurrence of skin diseases	0.0	2.3	0.7
	Lower worm load	0.8	0.6	3.7

*n-Sum of dry and wet season responses in a site (Korr=118, Kargi=172, Ngurunit=135)

Source: Kuria et al. (2005)

Problems related to mineral deficiencies are not easily conceptualized by camel keepers unless at advanced stages (Kuria et al., 2004). The concentration of minerals in forage also varies quite a bit and is determined by a wide range of factors, such as the species present, the mineral content of the soil, the prevailing weather conditions, and the time of year (Kuria et al., 2004). The requirement for camels varies with season (Faye et al., 1990) due to seasonal variation in vegetation quality (Kuria et al., 2004; Wardeh, 1991). However, the reasons for not supplementing camels with the right type of mineral salt are numerous, namely, limited extension services to camel keepers, low purchasing power due to prevailing poverty and availability due to long distances to the shopping centers where agro- shops are located (Peter, 2010).

2.9 Camel Calf Management

Culturally relevant behaviors, information, and beliefs that have been passed down through the generations serve as the basis for camel husbandry in Kenya (CAMASEPRO, 2012). For instance, early colostrum restriction by most camel farmers to prevent diarrhea in calves is considered detrimental to calves' survival (Megersa, 2014). Compared to other domesticated animals, camels require significantly less assistance during the parturation process. It has been reported that a normal camel birth occurs after a labor period of approximately 30 hours, with the "front" (head and front legs) and "back legs" (two legs) appearing normally (CAMASEPRO, 2012). However, Tadesse et al. (2017) found that nonspecific reasons, which accounted for 3.14 percent of calf deaths in Ethiopian camel farms, were followed by stillbirth, which accounted for 1.56 percent. This highlights the significance of monitoring and caring for the pregnant mother.

Megersa (2014) also observed that diarrhea and calf mortality were prevalent among camel farmers in southern Ethiopia. This is the case of observations made by native Kenyan keepers. It was reported that diarrhea in calves was common in second calves/calving and that these calves were valued differently than other calves over a three-week period. In Somalia, diarrhea is the leading cause of death (73%), according to Farah et al. (2007). Ahmed and Hedge (2007) reported high calf mortality (49% in the first three months and 19% up to one year) whereas Farah et al. (2007) reported that diarrhea is the leading cause of death (73%). Good calf management is a prerequisite for the advancement of any camel herd and is of the utmost importance.

2.9.1 Pregnant Dam and Neonate Management

The calfing house or Boma should be kept in good condition, clean, and free of or nearly free of dust, deep soil, and mud (CAMASEPRO, 2012). In a similar vein, it is recommended that all pregnant camels be vaccinated against tetanus and *Clostridium perfringens* (types C and D) to ensure that the newborns have sufficient levels of colostriadian antibodies. To prevent infection of the umbilicus after delivery, the umbilical cord needs to be tied and then soaked in a tincture of iodine containing 7% (Tibary & Anouassi, 2001).

Early diagnosis of respiratory and cardiovascular functioning issues in newborn calves and prevention of additional complications from exposure to environmental physical and viral variables increase the likelihood that the calves will survive. As a result, it is essential to conduct assessments and offer primary medical care to newborn camels in order to lower the mortality rate (Tibary & Anouassi, 2001).

When evaluating calves, the most important parameters to look for are birth weight, heart rate, respiratory pattern and rate, as well as body temperature. Dromedary camels typically have a mean normal birth weight of around 30 kilograms. According to Kuria (2004), the average birth weight of Rendille camels in Marsabit, Kenya was 35 kilograms, while the average birth weight of camels in Samburu, Kenya was 47.14 kilograms (Peter, 2010). A healthy heart rate ranges from 80 to 120 beats per minute, but this should be accompanied by a regular breathing rate of between 20 and 30 beats per minute (Tibary & Anouassi, 2001). Breathing with the mouth open, breathing that is difficult as a result of collapsed lungs, and fluid in the common bile duct or a narrowing of the duct are all indicators of dyspnea (Walker, 2022).

In addition, all newborns should have their eyes, ears, nose, mouth, and reflexes evaluated to determine whether or not they have any abnormalities. Abnormal limb growth, anal stenosis, cleft palate, and abnormal reflexes are some of the most common types of birth defects. All camels are born at a relatively advanced developmental stage, so within a few minutes to an hour of birth, they should be able to stand, nurse, and walk on their own. Camels are the only mammals that give birth to their young at this relatively advanced stage of development (Tibary & Anouassi, 2001).

2.9.2 Camel Calf Suckling Management

In the future, optimal nutrient levels at a young age will result in faster growth, earlier maturity, and optimal milk and carcass yields (Kertz et al., 2017). In recent years, however, research into camel nutrition has received scant attention. A review of articles published in the Journal of Camel Research and Practice between 2013 and 2017 reveals a greater emphasis on camel physiology (11.1%), camel milk and pathology (10.3% each), parasitology (9.2%), diseases (8.8%), immunology (5.8%), microbiology (5.4%), reproductive (5..08%), and anatomy, anatomy, and nutrition (4.6%). Other areas of study include anesthesia (4.2%), manufacturing (3.5%), imaging and pharmacology (3.1% each), meat (2.7%), genetics and breeding (2.3%), and serology/vaccine (1.5%). (Gahlot, 2018). It is discussed that colostrum feeding, whole milk/milk substitute feeding, and weaning are among the most important aspects of calf feeding.

2.9.3 Colostrum Feeding

Camels, like all other camelids, are born with agammaglobulinaemia, which prevents placental immunoglobulin transport (Gebru, 2017). Throughout the first weeks of life, infants rely entirely on passive immunity from their mother's colostrum for immunity (Tibary & Anouassi, 2001). Within twenty-four hours of birth, there is an increase in total protein and serum IgG and IgM levels, indicating the importance of colostrum feeding in newborn camels (Tibary & Anouassi, 2001). Colostrum contains a variety of endocrine system hormones and growth factors that interact with gut cells to program and activate the digestive system and muscles, according to recent cattle research (Ontsouka et al., 2016).

Colostrum is high in protein, energy, minerals, and vitamins and should be given to newborn calves as soon as possible after birth to build their immune systems and provide them with critical nutrients. Ascorbic acid (vitamin C) is one of the most important vitamins found in colostrum, and Al-Sultan (2008) demonstrated that ascorbic acid injection effectively increased lysosome concentrations. According to research, vitamin C can boost the immune system of newborn camels. Like other animals, control camels are born with antibodies and active immunoglobulin synthesis, which begins at two weeks of age and reaches protective levels between three and four months of age (Kaufmann, 2003). According to Tibary and Anouassi (2001), newborn camel calves should be given 10% of their body weight in colostrum within the first 12 hours of birth, with half of this amount given within the first six hours. If calves are unable to suckle within three hours of birth, colostrum should be expressed and calves bottle or hand fed. If the calf's sucking reflex is impaired, colostrum must be administered via intubation.

2.9.4 Handling of Colostrum for Bottle Feeding

As a result of unsanitary conditions on farms, the colostrum of a variety of animal species is extremely vulnerable to bacterial contamination (Steward et al., 2005). Colostrum has a high protein content, which makes it difficult to pasteurize because heating causes an increase in viscosity and coagulation. However, recent advances have made this possible. Godden et al. (2003) described a time-temperature condition of sixty minutes at sixty degrees Celsius as necessary for the successful pasteurization of colostrum. This time-temperature condition will reduce bacterial counts in colostrum while also reducing damage to immunoglobulin, vitamins A and E and beta-carotene (Donahue et al., 2012).

Calves fed heat-treated colostrum are reported to have less diarrhea, more bifidobacteria, and less E. coli than calves fed untreated colostrum (Godden et al., 2012). The use of heat to treat animals (Malmuthuge et al., 2015) suggests a potential cause for improved intestinal health. Therefore, it is essential that camel farmers in Kenya improve milking hygiene. Before bottle-feeding camel calves, commercial camel milk facilities should also consider rapid cooling of colostrum for proper storage and cleaning of feeding equipment.

2.9.5 Suckling Whole Milk

The survival of the calves during their first eight weeks of life is critical; if the mother rejects them or dies, the calves will barely not make it (CAMASEPRO, 2012). A sufficient milk supply is essential for the survival, development, and vitality of newborn calves. Calves depend on milk until the rumen begins to function, typically at three months of age (Wilson, 1984).

Field (1979) reported growth rates ranging from 378 g/d to 655 g/d when calves obtained up to 75% of their mother's milk production during the dry and wet seasons. The growth rates were 222 g/d and 255 g/d during the dry and wet seasons, respectively, in the same environment but on a range where there is intense competition for milk. Peter (2010) reported that male and female calf growth rates in the pastoral system of Samburu County were 281 g/day and 168 g/day, respectively, with an average of 212 g/day. Camel milk is an important pre-weaning food for calves, as is the milk of other animals. It determines the newborn calf's viability, growth rate, and vitality. Calves rely on milk until the rumen begins to function, typically between three and four months of age in camels (Wilson, 1984).

2.9.6 Composition of Camel milk

The milk contains the important feed components such as proteins, sugars, minerals and vitamins (Table 2.5).

Table 2. 5 A comparison of the composition of camel and cow milk

Parameter	Camel milk	Cow milk
Proximate (%)		
Dry matter	12.63	12.80
Lactose	4.62	4.80
Fat	3.70	3.70
Protein	3.45	3.50
Ash	0.74	0.80
Vitamin (µg /100g)		
Pantothenic acid	88.00	350.00
Vitamin A	15.00	45.00
Vitamin C	2370	2000
Thiamin	33.00	45.00
Riboflavin	41.00	150.0
Vitamin B6	52.00	35.00
Vitamin B12	0.15	0.30
Niacin	461.0	93.00
Folic acid	0.41	5.90
Minerals (mg/100g)		
Ca	116	125
P	67	96
Mn	33	58
K	99	140
Mg	11	12

Source: Ramet (2001)

Table 2.5 shows that camel milk is higher in vitamin C than cow milk. Generally, proportion of vitamin C is much higher in the milk of cow and camel than the other vitamins that may explain the role of ascorbic acid in immunity of animals. Ca mineral content in camel milk is generally low when compared to cow milk, as shown in Table 2.5 and the gross composition of camel milk in Table 2.6.

Camel milk marketing, while a source of income for the household, exacerbated the calf's milk availability constraints. This scenario worsened during dry season, negatively affecting the growth and survival of young calves solely depending on milk. During the rainy season milk production increased and there was complementation from other livestock which return from satellite manyattas.

Table 2. 6 Gross compositions of camel and cow milk (%) from various sources

Composition	Range	Source
Fat	2.90 - 5.40	Farah (2004b)
Fat	2.90 - 5.38	Yagil (1982)
Fat	1.95 - 2.99	Mal and Sena (2007)
Fat	2.37 - 3.24	Mal (2000)
Protein	3.00 - 3.90	Farah (2004b)
Protein	3.37 - 4.22	Mal and Sena (2007)
Protein	3.64 - 4.03	Mal (2000)
SNF	7.01 - 10.36	Yagil (1982)
SNF	6.97 - 7.94	Mal and Sena (2007)
SNF	7.45 - 8.85	Mal (2000)
Density	26.00 - 35.00	Farah (2004b)

Source: Ramet (2001)

2.9.7 Calf Growth Rate

Growth rates depend on management and milk availability to the calf. Reduced milk competition allows the calf to access more milk and the growth rate is expected to increase. The reproductive age maturity would relatively be reduced. The productivity of camels in pastoral production system is reduced by slow growth rate of calves, long gestation period, a long calving interval and low survival rate of camel calves (Kaufmann, 2005). According to Field (1979), Gabra and Rendille calves in Marsabit district of Northern Kenya gained 222 g/day in the dry period of the year and showed little improvement in the wet season to 255 g/day. In the same area but under experimental condition, gains were as high as 655 g/d. Faye (2004) reported that in traditional systems the daily growth rate of the camel calf up to one year is 190-310 g/d. In more intensive production system this can be increased to 440-580 g/day and in Austral maximum of 1100 g was reported (Faye, 2008). Other factors influencing growth are environment and general climatic and vegetational conditions, during the growing period (Wilson, 1984).

Female camels mature earlier than males and attain sexual maturity at the age of 3 years but are not bred until at 4 to 5 years of age (Kuria et al., 2004; Simpkin & Guturo, l995;

Tefera & Gebreah, 2001). The males start showing rutting signs at the age of 5 to 6 years (Kuria et al., 2004) but are fully sexually active at 6-9 years and will continue to serve up to 14 to 15 years (Tefera & Gebreah, 2001). Camels are seasonal breeders but in warm regions this is triggered by nutritional status and tends to mate during rainy seasons (Yagil & Etzion, 1980). Consequently, the calves are born in the rainy season when feeds are plenty enhancing their survival and growth. Simpkin and Guturo (1995) reported an abortion of 26% and a calving rate of 21% in Kenya, lower than 50% calving rate in Ethiopia (Tefera & Gebreah, 2001).

Most of the camels in Kenya are kept in the pastoral systems where accurate record keeping is almost non-existent. However, the camel is reported to maintain a longer lactation period than cattle (Kuria et al., 2004). In Dromedaries the lactation period varies from 9 to 18 months, with peak production on the 7 month (Yagil, 2000). A lactation of one year was recorded in Northern Kenya with a milk yield of 1897 kg (Field, 1979).

2.9.8 Effect of Vegetation on Calf Growth

Feed availability and vegetation condition fluctuates seasonally indirectly affecting the calf growth. This is because vegetation condition determines the nutrients available to the dam hence the amount of milk it produces. For a camel calf, the rumen doesn't normally start working until the calf is 3 to 4 months old (Wilson, 1984). Peter (2010), classified calves based on age in days into very young (1 - 100 days), fairly young (100- 300 days) and post-weaned (300 - 400 days). The general expectation for the study was for the average weight of the three categories of camel calf to decrease with deterioration of vegetation conditions. However, the calves reported to be born during the excellent vegetation condition deviated from the expected results. Also defying this trend was the post-weaned group calves all of which had similar weight in spite of vegetation condition at their birth varying from good to poor. This may be attributed to errors associated with recall information.

Interpretation of vegetation condition classification such as the difference between excellent and good, would also vary among the respondents would have contribute to the errors. However, the fairly young and very young calf groups exhibited trend towards decreasing weight as the vegetation condition changed from good to poor. This was especially, pronounced for the youngest calves. This disparity in response to vegetation condition at the time of birth among calf age groups may be explained by the capacity of animal recover from periods of nutritional stress (Kellems & Church, 2002; Martinez-Ramirez et al., 2008; Read & Tudor, 2004; Summers & Spratt, 2000). The old calves would have had adequate time to recover from any earlier growth checks due to nutritional inadequacy.

The average weights of young calves in excellent and good vegetation condition were 65 Kg and 87.8 Kg while in the fair and poor vegetation condition this is 39.3 Kg and 38 Kg. The average weight of the very young calves born when vegetation condition was excellent would expect to be higher than for those born when vegetation was described as good. This discrepancy may be due to inaccuracies of the recall information on vegetation condition. The difference in average weight for the very young calves and young calves was significant as the vegetation condition deteriorated. The variation in average weight of post-weaned calves with vegetation condition was insignificant due to their ability to browse and make up for a nutrient deficiency because their rumen is then functional (Ørskov & Ryle, 1990). The variation in feed condition affected camel milk production and therefore the calf growth. The average calf body condition followed the trend of fluctuating feed availability (Peter, 2010).

2.9.9 Feeding Orphaned Camel Calves

Unless they are fed colostrum and given assistance standing, orphaned camel calves are thought to have a dismal survival chance. A healthy camel can stand and nurse within two hours of birth, and the majority can walk and follow their mother within five hours of birth (Coventry, 2002). If the "new" smell of the calves has not yet been adopted by the mother and the calf is free to drink milk from the mother's udder, or if the adoptive mother is left alone with orphaned calves for one day, the adoptive mother adopts an orphan, orphan feeding on a lactating camel can be effective.

Coventry (2002) further suggested that after unsuccessful foster care, breast-fed or bottle-fed infants could be fed using camel, goat or cow colostrum obtained during the first three days of the cycle. During lactation, milk is obtained from camels, goats, and cattle. Table 2.7 presents the suckling regime of orphaned calves until complete rumination. Recommended personalized camel calves milk or colostrum substitutes include GROBER® and LAND O LAKES® PRONURSE®.

Table 2. 7 Guide to the amount of milk to feed to orphan camel calves

Calf age	Approximate calf weight	Number of feeds per day	Maximum amount per feed
up to 1 week	40 kg	up to 8 (initially colostrum, 2-hourly)	¾ litre
2 to 4 weeks	50 kg	6 (4-hourly)	2 litres
up to 2 months	70 kg	4 (6-hourly)	3½ litres
up to 3 months	90 kg	3 (8-hourly)	4½ litres
up to 4 months	110 kg	2 (12-hourly)	3½ litres
up to 5 months	130 kg	1 (24-hourly)	3½ litres

Source: Coventry (2010)

2.9.10 Weaning with Good Quality Forage

The age at which a camel calf is weaned is determined by environmental and genetic variables (Lasley, 1987). It may also be affected by the calf's health and production goals. Camel calves may be weaned early to allow early conception of the dam or delayed to extend nursing if the goal is to grow the herd (Kaufmann, 2005). Environmental considerations include the feeding of the embryo in pregnancy and after birth via the dam's milk supply (Noor, 1999). In typical circumstances, the calf weaning age is 6 to 12 months (Noor, 1999). The Somali calf weaning age ranges from 8 to 18 months (Farah et al., 2004a), while the Samburu ranges from 8 to 12 months (Peter, 2010). Weaning age is vital for defining the economic efficiency of a production system (Wilson, 1998), whereas weaning weight influences the herd's reproduction efficiency. Hence, an efficient system is likely to have a high calves' growth rate, meaning that calves will mature swiftly and be weaned at a young age.

At 12 months, camel calves can be weaned onto premium diet such lucerne hay. While camels are typically raised in large, open-range environments, the idea of using planted forages to feed camels is not used in Kenya. However, what is practical is the management of the natural forages to promote growth of high quality and palatable shrubs that camels prefer. Some important range forage species include shrubs like *Salvadora persica*, *Acacia tortilis, Tinnospora caffra*, *Euphorbia tirucalli*, and *Balanites aegyptiaca* and herbs like *Barleria* spp. and *Blepharis linarifoloia*.

The nomadic system, which camel herders used for millennia, is no longer an efficient strategy for camel production and is being replaced by sedentary systems in many parts of the world's camel rearing regions (Schillhorn Van Veen & Leoffler, 1990). As a result, the diverse range of forages that used to provide decent camel feed has declined. This has resulted in a decrease in the number of nutritious range species and an insufficient supply of feed in terms of biomass and quality. As a result, feed becomes the single most critical factor influencing camel productivity (Yagil, 1994). As a result, camel husbandry in general, and feeding in particular, must be altered to adapt to the changing environmental and socioeconomic situation of the pastoral system in order to maximize the benefits that camels can provide. Under such changing conditions, optimal feeding of camels may entail supplementation of locally available nutrients to increase the animal's output (Arimi et al., 2022).

Young camel calves are occasionally separated from their mothers during the day to control suckling to avail milk for household consumption which require some supplementation (Simpkin, 1998). The watering frequency is affected by factors such as feed succulence, ambient temperature and water availability (Evans et al., 1995). The distance to natural salts licks range between 20-60 Km in Samburu County and very young camel calves cannot walk for such long distances for saltlick and yet are at a critical stage for mineral requirements (Peter, 2010). Mineral salt is crucial for bone development and other physiological functions. Lack of essential mineral elements can lead to poor calf growth, weak bones which can break easily (Perdrizet et al., 2020), diarrhea, anaemia, infertility and poor reproduction (Perdrizet et al., 2020).

2.9.11 Camel Calf Health and Diseases

Camel health management has emerged as a major issue in pastoral communities (CAMASEPRO, 2012). Despite the camel's hardiness and resistance to most livestock diseases, such as Foot and Mouth Disease, East Coast Fever, Rinderpest, Contagious Bovine Pleuro-Pneumonia and Lumpy Skin Disease (CAMASEPRO, 2012), camels have been shown to be susceptible to a variety of pathogenic agents (Al-Ruwaili et al., 2012). Because the calf is most susceptible to diseases in the early stages of life due to low immunity; feeding, handling, and housing are critical at this time due to risk factors (Dioli et al., 1992; Tibary & Anouassi, 2001).

The prevention of calf diseases is critical to increasing the survival rate of calves and sustaining the growth of camel generations. Pastoralists have local medicines to cure practically all animal health problems, showing that indigenous knowledge about diseases and therapies is vast (Wanyama, 1997). There are a lot of plants used for medicinal purposes by the Samburu (Wanyama, 1997). Use of these local remedies results in variations of quantities administered resulting to overdose or under dose which has consequences of either killing the animal or causing the resistance. For instance, when a calf was infested with ticks or mange, old engine oil was applied with or without acaricide which may have had some negative effect on calves as pheromones are masked off and more often than not resulted to calf rejection (Fraser & Broom, 1997) and caused heat problem as well. The pastoralists are then in a dilemma yet ticks are known to cause paralysis to young calves (Schwartz & Dioli, 1992). Ticks find a habitat in the fur along the spine and suck blood from the calf affecting its health status and they may cause tick borne diseases, anaemia or calf paralysis (Jackson & Cockcroft, 2008).

Sarcoptic mange (47.9%), ticks (25.6%), infectious skin necrosis (15.8%), abscess (19.2%), contagious ecthyma (9.4%), camel pox (6.5%), diarrhea (5.1%), and respiratory infections (4.5%) were the most common camel calve disorders in Borana Ethiopia, according to Megersa (2014). Mange mites were more prevalent during dry periods than wet, and contagious ecthyma, pox, respiratory infection, and dermatophytosis were more prevalent during wet seasons. In the same study, calves (nearly 70%) tested positive for endo-parasites such as Stronglyles, Strongyloides papillosus, Monezia expansa, and Eimeria tenella species, indicating the importance of parasitic load. The leading causes of calf death were septicemic diseases (35%), respiratory infections (22%), sunken eye or Elgof (11%), and calf diarrhea (11%). The wet season had significantly higher mortality than the dry season, and it decreased with age.

Furthermore, the common practice of pastoralists reducing colostrum intake, as well as poor veterinary care, may play a role in the increased early death of camel calves, necessitating reforms. In a field technical manual on camel diseases in Wajir County by Gitonga et al. (2018), priority diseases that affect camels were identified which included haemorrhagic septicaemia, Trypanosomiasis and contagious skin necrosis which were reported to affect all age groups. For Haemorrhagic septicaemia, the predisposing factors were identified as rainy seasons and poor body condition. Trypanosomiasis incidences were reported to occur a short period after weaning of camel calves, contagious skin necrosis was found to be prevalent during the hot months of the year and more incidences were reported in camels less than five years. Additionally, brucellosis which is a zoonotic disease was also reported whereby vaccination of calves 4-8 months was stated as one of the preventive measures.

2.9.12 Milk Substitutes

When mother's milk is unavailable, a milk substitute which is a liquid nourishment with nutritional properties equal to mother's milk needs to be provided to young animals (Verduci et al., 2019). It is a steady quality feed that will help the young calf grow and thrive. Calf growth acceleration may result in a higher long-term growth rate, improved hormone response, increased milk production, immune system enhancement, and improved gain efficiency (Drackley, 2004). Protein levels, protein/energy ratios, and protein sources are all factors that influence calf growth and performance. Because daily protein and energy intake regulates growth, varying feeding amounts will also have an impact on performance. Some circumstances, such as cold weather, necessitate feeding at a higher energy level. The ME content of milk substitutes is primarily influenced by the fat and carbohydrate contents, which indicate the intended use of the milk substitute (Kertz et al., 2017).

Where there is a high demand for milk for human consumption or where milk by-products are put to good use, milk substitutes are frequently used for cattle calves (Khan et al., 2012). Pre-ruminants are given liquid nutrition in the form of whole milk or milk substitutes made from milk by-products from birth to 3 weeks. Later in life, milk substitute formulas may contain alternative protein sources derived from feed that replace a significant portion of the milk proteins. After three weeks, rumen fermentation begins, and prepared solid foods with improved digestibility can be administered as a replacement for whole milk (Kertz et al., 1984). Although the ingredients in milk substitutes might vary widely, they are usually made from milk or plants. Often made of soy or wheat, plant-based formulas are less expensive, but milk proteins are much simpler for young calves to digest (Drackley, 2008). Dried whey, dried skim milk, milk protein concentrate, dry buttermilk, casein, and delactosed whey are examples of milk-based ingredients (Kertz et al., 2017). While dam's milk substitutes can be made from by-products of milk and feed materials that are not suitable for human consumption, many underdeveloped countries lack understanding of such alternatives. As a result, popularizing the production and feeding of milk substitutes made from locally available substances benefits calves' survival and growth (Kertz et al., 1984).

In Kenya, there are no known company formulating camel milk substitutes, and most of them import formulated cow calf milk substitutes from Europe which are sold in the

Country at higher prices. For instance, Osho Company imports cow calf milk substitutes from Netherlands and 1kg retails at KES. 345. The milk substitutes are not known to camel keepers and generally in pastoral production system. Therefore, an endeavor towards development of milk substitute from locally available feed resources is great step towards improvement of camel calf nutrition.

Choosing and Evaluating of Milk Substitute

The feed tag contains information about the milk substitute's ingredients and medication, as well as the intended use. Protein, fat (energy), carbohydrates, vitamins, and minerals are the primary nutrients of milk substitute. Table 2.8 shows the effect in bovine calves of mineral concentrations in milk substitutes. When evaluating which milk substitute to use, the followings are important considerations:

a) The age of the calf you are feeding. Calves less than three weeks of age cannot digest the same ingredients as older animals.
b) How is the milk substitute manufactured?
c) How much hot water you have available.
d) The ingredients. A good quality milk substitute will have the list of ingredients on the tag listed in order from highest to lowest.

The requirements for formulated calf milk substitute are: -

a) Easily soluble.
b) Stable in solution (No sediments).
c) Constant in composition.
d) Slightly acidified depending on hygiene.
e) Nutritional value (Vitamins and Minerals.
f) Easily digestible (BAMN, 2008)

Table 2. 8 Effect in bovine calves of mineral concentrations in milk substitutes

Mineral	Mineral concentration in milk substitute	Effect of mineral in calves
Magnesium	0.25 or 0.75% Mg	Adequate
	>1% Mg in calf diet	Toxicity (Reduced feed intake, diarrhea) in calves
Iron	5,000 mg/kg of Fe	Reduced feed intake and weight gain of pre-ruminant calves
Manganese	1,000 mg/kg of Mn	Manganese reduced feed intake and weight gain of calves
	5,000 mg/kg of Mn	Toxicity and death of calves
Zinc	500 mg/kg of Zn	Reduced feed intake and weight gain
	40 mg/kg of Zn	Adequate
Copper	1,000 mg/kg of Cu	Toxicity of calves
	50 mg/kg of Cu	Adequate; safe upper limit

Source: BAMN (2008)

Protein

Milk substitutes should have a protein concentration of 20 to 30% (Diaz et al., 2001). Calves under the age of three weeks should be given a protein milk substitute produced from milk. Non-milk sources can lower the available protein in the calf and produce diarrhoea. Non-milk replacements are permissible for calves over three weeks old. Milk substitutes include soy protein, soy flour, wheat proteins (glutens or isolates), potato, and animal plasma protein. The digestibility and amino acid content of soy protein are both low. It can produce an allergic reaction in the stomach tissue, a decrease in the amount of protein accessible to the calf, and diarrhoea. Calves older than three weeks should take this protein source. The carbohydrate fraction (fibre) was removed from potato protein isolates using specialised processing. This also removes allergies, inhibitors, and other anti-nutritional elements often associated with plant proteins. They have less fibre and are less expensive per pound of protein than milk proteins, making them an effective milk alternative (BAMN, 2008).

Because it contains both active albumin and globulin proteins, cow plasma protein is a distinctive source of protein. Its nutritional value and amino acid composition are identical to those of casein and non-fat dry (skim) milk. Centrifuging whole blood into its main components, plasma, and blood cells, yields animal plasma. The two most frequent forms of animal plasma are bovine (ruminant) and porcine plasma (swine). It is, however, fairly expensive, and with the discovery of Bovine Spongiform Encephalopathy (BSE) in Canada, customers have become increasingly apprehensive about this sort of protein source (BAMN, 2008).

Energy

Energy is the level of fat in the milk substitute. Dry whole milk has a fat content of 30%. Milk substitutes should have 10 to 25% crude fat. Non-milk fats are not digested as well as milk fats by calves under two weeks old, so milk substitutes high in milk fat reduce the risk of diarrhea. Color, melting point, odor, and fatty acid profile are all tested for in fats and oils. Tallow, lard, and coconut oil are common fats used (BAMN, 2008).

Fibre

The amount of plant protein in a product is indicated by its fibre content. The more fibre added, the higher the level of plant protein. Calves under three weeks of age should consume less than 5% crude fibre. Formerly, the crude fibre content of milk replacements was employed to determine product quality. This is no longer an acceptable criterion for evaluating milk alternatives. Crude fibre levels above 0.15% indicate the existence of a plant protein source, whilst levels below 0.15% do not always indicate the lack of plant protein. The ingredient list should be examined twice (BAMN, 2008).

Medicated Substitutes

It is not advisable to use medicated milk substitutes in place of proper management and hygienic practices. The health of the animals and their level of stress (from transportation, bad weather, subparb housing, and low birth weight) should be taken into consideration when deciding whether to feed medicated or non-medicated milk substitute and which drug to utilize. When relevant, withdrawal periods should be adhered to in accordance with the manufacturer's instructions. (BAMN, 2008).

Tannins in Plant Based Feeds

Tannins are polyphenols that are widely present in foods made from plants. They are thought to be an essential component of a plant's defense mechanism against environmental stresses (Zhang et al., 2022). Animals are affected by tannins in a variety of ways, including slowing down their growth and inhibiting their digestive enzymes. Humans are also affected by tannins; for instance, byssinosis is a disorder brought on by exposure to airborne tannin. (Bennick, 2002). Their biological impact is connected to tannins' high protein precipitation efficiency, which results from an interplay between hydrophobic forces and hydrogen bonds. There is evidence that proline-rich proteins, at the very least, operate as a first line of defence against tannins, possibly by precipitating tannins in food and inhibiting their absorption via the alimentary canal. Proline-rich proteins and histatins are two salivary protein families that are powerful tannin precipitators. The interaction of proline-rich proteins with tannins is greatly influenced by proline. Histatins, on the other hand, are mostly mediated by basic residues in their binding to tannin (Hagerman and colleagues, 1998). It is becoming more and more obvious that tannins play a variety of vital roles in plant life. Because of the astringent qualities of tannin, plant leaves may be protected by deterring browsing animals and defoliating insects from eating them, and herbivores will avoid unripe fruit until the time comes for the seeds to germinate. The ability of tannins to precipitate plant proteins and to block digestive enzymes, so decreasing the digestibility of plant proteins, has been assigned as the chemical basis for the protective role of tannins (Zucker, 1983).

According to research carried out by Mauricio and Margret (1997), phenolic chemicals present in the leaves influenced the degree to which carbohydrates and proteins might be fermented. The effect was more pronounced with carbohydrates whose fermentability ranged from medium to poor. On the other hand, it was demonstrated that they reacted with both soluble and insoluble forms of protein. The condensed tannins in the leaves had the impact of lowering the fermentability of their mixes with carbohydrates, which was the result that we observed. This depression was much more pronounced in mixes that had a limited fermentability. Both favorable and negative effects were seen with forages containing phenolic chemicals. There is a possibility that synchrony or asynchrony in the release of protein was the cause of these effects.

2.9.13 Camel Milk Substitute

There have been few publications on camel calf nutrition, despite the fact that their need for milk is likely to be as great as that of other ruminant species, and the calves are generally competing with humans for milk (Wilson, 1984). As a result, hand feeding of milk or milk substitute to camel pre-ruminants may be necessary. Orphan camel calves are frequently fed very dilute milk to avoid dyspepsia caused by overfeeding (Wilson, 1984). The number of feedings per day should be 6 to 8 up to 4 weeks of age, and this can be reduced to 3 to 4 up to 3 months of age, and 1 to 2 from 4 to 5 months of age (Coventry, 2010). Although milk substitutes are commonly used in cattle but not in other animal species' pre-ruminants in developed countries, this is not the case in developing countries (Wilson, 1984).

Whole milk or milk substitute feeding in cattle has traditionally followed a complex scheme in which the appropriate amount supplied to each calf is determined as a constantly increasing proportion of body weight. For the first three days, the amount of whole milk is 6 to 8% of birth weight, then gradually increased to 10% of body weight, then gradually reduced (5-6%) after 3 weeks of age until weaning. This method of calculating the amount of whole milk or milk substitute requires more time and labor for record keeping (Coventry, 2010). According to the studies, feeding the same amount once the pre-ruminant learns to drink until weaning can be just as beneficial as a sophisticated plan (Miller, 2012). The amount fed during the first few days should be moderate to avoid diarrhea. According to the previous study, research on the use of milk substitutes as alternatives for whole milk in developing Countries appears to be limited and confined primarily to restricted whole milk feeding with the addition of starter feed rather than a total replacement of whole milk. Nonetheless, attempts have been made to create whole milk substitutes. The literature on milk substitute formulation and feeding published in developed countries contains a wealth of intriguing data, the principles of which can be applied to make milk substitutes using locally available ingredients (NRC, 2001) (Table 2.9).

Table 2. 9 Recommended energy, protein, fibre, calcium, and phosphorus in milk substitute (MR) and starter feed (SF) in pre-ruminant animals

Species	**Feed**	**ME (MJ/kg DM)**	**CP (%)**	**EE (%)**	**ADF (%)**	**NDF (%)**	**Ca (%)**	**P (%)**
Cattle*	MR	15.8-20.1	18-22	10-20	-	-	1.0	0.7
	SF	13.0-14.6	16-18	3-5	4-8	12-18	0.6-0.7	0.4-0.5
	SF	13.0-14.6	16-18	3-5	4-8	12-18	0.8-0.9	0.6-0.7
Sheep	MR	20.0-21-0	20-24	20-30	-	-	1.2	0.9
	SF	13.0-14.6	18-20	5	2-4	8-12	0.8-0.9	0.6-0.7
Goat	MR	15.8-20.1	18-22	10-20	-	-	1.0	0.7
	SF	13.0-14.6	16-18	3-5	2-4	8-12	0.6-0.7	0.4-0.5
Camel**	MR	15.0-20.0	20-24	10	-	-	1.0	0.7

NDF, neutral detergent fibre; ADF, acid detergent fibre; Ca, Calcium; CP, crude protein; EE, ether extract; P, Phosphorus; ME, metabolizable energy
Source: *NRC (2001), **Coventry (2010).

There was a time when almost all milk substitutes were made with protein derived from animal sources, primarily milk. Whey and whey protein concentrate, which are derived from milk, are often found in commercial milk substitutes today. Casein and even skim milk may be included in some products. Other high-quality animal protein sources, such as blood cells and plasma, are occasionally used as milk substitutes. Yet, as the cost of protein from animal sources has risen, producers have looked for alternatives. The use of proteins derived from plants, such as soy, wheat, and potato, has helped to reduce the cost of milk substitutes. Table 2.10 gives an indication on different ingredients used in formulation of milk replaces and their processing methods (BAMN, 2008).

Table 2. 10 Common milk substitute ingredients

Ingredients	Processing methods
Animal Fat and Vegetable Oil	Fats and oils obtained by removing lipid portion of animal and vegetable tissue
Animal Plasma	A concentrated source of protein obtained by removing the red and white blood cells from fresh whole blood. The resulting plasma is dried (78% protein)
Casein (Dried Milk Protein)	Primary protein in skimmed milk. Concentrated by coagulating milk (85% protein)
Soy Protein Concentrate (SPC)	Protein portion of soybeans concentrated by removal of soluble carbohydrates. Contains fiber (66% protein)
Lecithin	Emulsifier. Aids in dispersal of fat in solution and enhances digestion of fat
L-Lysine and DL-Methionine	Essential amino acids necessary for calf growth
Polyoxyethylene Glycol (400) Mono and Dioleates (PEG 400)	Emulsifier. Aids in dispersal of fat in solution
Vitamin and Mineral Supplements	Many vitamins and minerals are supplemented to provide for normal health, growth and maintenance of calves

Source: BAMN (2008)

The literature review identified gaps in camel calf nutrition research and proposes that camel calf nutrition research focus on techniques to maximize survival, growth, and development using epigenetics. By combining camel calf care with nutrition and management, calves will be more comfortable and prosper. Calves will be fed and managed in order to include knowledge of how to boost calf immunity. It is necessary to find methods for increasing the usage of non-milk protein in camel calf liquid or solid diets. Calf feeding and management will become increasingly attuned to best feeding and management methods and protocols as herds grow in size.

CHAPTER THREE

EVALUATION OF EXISTING INDIGENOUS KNOWLEDGE AND PRACTICES ON CAMEL MILK SUBSTITUTES IN REARING CALVES UNDER EXTENSIVE AND PERI-URBAN PRODUCTION SYSTEMS IN KENYA

Abstract

Mortality rates, the causes, calf retardation and evaluation of existing indigenous knowledge and practices on milk substitutes in rearing camel calves were evaluated in extensive and peri-urban camel production systems in Marsabit County, Kenya. The study used key informant questionnaires (KI) and focus group discussions (FGDs) methods to collect the data. Simple systematic random sampling survey method was used to collect key informants' data. FGDs comprising of 12 camel keepers were purposefully selected and conducted per study site based on their knowledge in camel husbandry. The key informant data was entered and analyzed using Statistical Package for Social Sciences (SPSS, 2019). Data collected using focus group discussions (FGDs) from different sites were analyzed using constant comparison analysis method. The study established that mortality rates were 35.2 and 4.3% in pastoral and peri-urban production system, respectively. Disease, drought, predation and parasites were the four major causes of camel calf mortality. The study also established that diseases, drought and competition for milk between the calf and households for trade and human consumption were major factors responsible for camel calves retarded growth. This study concluded that pastoralists did not have any substitute to milk feeding for camel calves, However, when the dam dries early due to pregnancy, sudden death of dams and during dry/drought period they supplement the calves with locally available feed resources such as camel blood, animal fat, *acacia tortilis* pods, *Merremia ampelophylia, Tinnospora caffra, Cordia sinensis* and grasses such as *Cenchrus ciliaris* among other forages.

Key words: camel calves, mortality rates, pastoral production systems, retarded growth, substitute to milk

3.1 Introduction

Camel production is increasingly being recognized as a significant economic activity in Kenya's pastoral production system in arid and semi-arid lands (ASALs). Cattle-keeping communities have traditionally begun to adopt camel husbandry as a means of coping with the challenges of climate change (Watson et al., 2016). This is due to the fact that camels are better adapted to water and feed scarcity than any other livestock species, and they provide milk and income to households during drought seasons, when other livestock species migrate in search of pasture and water (King, 1983). Furthermore, camel rearing in peri-urban areas to supply milk and meat to the growing human population in ASAL major town centers is emerging as a new production system in Kenya (Noor, 2013).

The camel's contribution to providing food for pastoralists in northern Kenya is becoming increasingly important in the face of global warming and climate change. Kenya has approximately 4.64 million *Camelus dromedarius* (KNBS, 2019). Despite their importance, the camel population is still low (4.64 million) for large scale production and marketing purposes compared to other livestock species kept in Kenya. The camels' delayed reproductive maturity and high calf mortality are the key factors hindering its population growth.

Historically camels are kept by only four pastoral communities in northern Kenya, namely Somali, Gabra, Rendille and Turkana in Mandera, Wajir, Garissa, Marsabit, Isiolo and Turkana Counties. However, the trend has changed, and camels have spread to 27 other Counties of Kenya as a livelihood option in the face of climate change and for eco-tourism purposes (Table 3.1).

Table 3. 1 Counties of Kenya with their camel Population

S/No.	County	Camel population
1	Mombasa	58
2	Elgeyo Marakwet	89
3	Tharaka - Nithi	124
4	Lamu	125
5	Uasin Gishu	148
6	Embu	228
7	Nakuru	388
8	Makueni	1,111
9	Machakos	1,473
10	Narok	1,619
11	Taita Taveta	2,630
12	Kajiado	3,584
13	Kitui	5,202

14	Meru	5,732
15	Laikipia	7,827
16	West Pokot	19,389
17	Baringo	38,500
18	Samburu	48,172
19	Tana River	53,298
20	Isiolo	148,859
21	Marsabit	215,234
22	Turkana	261,923
23	Garissa	816,057
24	Wajir	1,176,532
25	Mandera	1,828,665
	TOTAL	**4,636,967**

Source: KNBS (2019)

Natural browse constitutes the sole diet of camels under pastoral production system where the natural vegetation is often of poor quality and limited in quantities (Gupta, 2021). Rearing of camel calves under traditional pastoral production systems is constrained by fluctuating availability of feeds and water in the communally owned rangelands. Competition for milk by pastoralists for household consumption and trade is also a major cause of calves' retarded growth and death under extreme condition. Mortality rates of up to 62% have been reported in calves between birth and weaning (Kaufmann, 1998; Njanja, 2007).

This study was conducted with the aim to collect data on camel calves' mortality rates, causes of mortality, factors responsible for retarding growth rates and information on any indigenous knowledge for milk substitute in rearing camel calves in extensive and peri-urban production systems in Kenya.

3.2 Materials and Methods

3.2.1 The Study Site

The study was conducted in southern rangelands of Marsabit County among the Rendille camel keeping community. The experiment was conducted in Karare (Figure 3.1) under controlled conditions. The site was identified on the basis of a willing pastoralist (one herder) with enough calves for the experiment. The researcher and the camel keeper signed an agreement for the period of the study (Two and half months). All calves were released to the owner after the experiment.

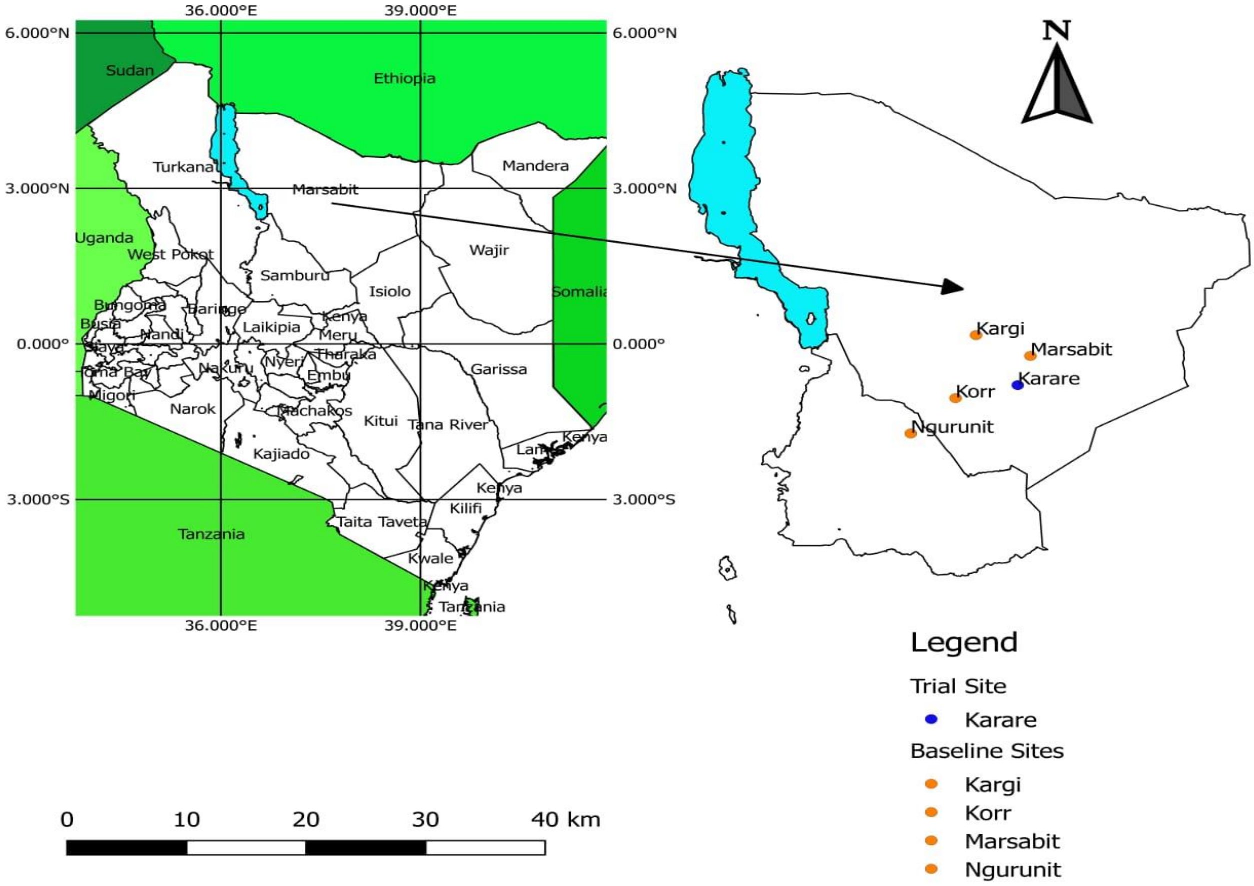


Figure 3. 1 Map of Kenya showing the study areas

Source: Google map (2021)

3.2.2 Data Collection and Analysis

Four Focus group discussions (FGDs) comprising of 12 persons per discussion was conducted in the main camel keeping areas among Rendille community in the southern rangelands of Marsabit County: Karare/Kamboi, Kargi, Korr and Ngurunit. The visits were made to the community meeting places usually referred to as 'trees of men' where men sitting under the shade of trees, discuss their daily issues affecting their livestock. The objective of the visits was explained to the elders and those to be involved in FGDs were purposefully selected based on their knowledge of camel husbandry. The selected elders were then moved to a next shade for the FGDs. Plate 3.1 was taken in Korr during one of the meetings in the study area. Open ended questions were used to guide the discussions and all responses recorded in notebook and audio.

Plate 3. 1 Focus group discussion (FDGs) in Korr, Marsabit County

Focus group discussions (FGDs) are a way to find out what people in a community think and feel. In an interactive setting, participants were asked open-ended questions and encouraged to talk freely with other participants. FGDs are the best way to find out what people in a certain area know and think in order to make changes or make products or services for a key customer group (Leech & Onwuegbuzie, 2008). Constant comparison analysis (Leech & Onwuegbuzie, 2008), also known as the method of constant comparison, was used to look at data from four different sites that was collected through focus group discussions (FGDs).

The constant comparison analysis was made up of three main stages. During the first stage, the data were coded in an open way. Then, the data were broken up into small pieces. Each unit of data was given a code or description afterward. Then, during the second stage, codes were put into categories using axial coding. In the third and final stage, data was coded selectively, and themes were made that explained what each group was about (Leech & Onwuegbuzie, 2008). All of the sites' data were put into thematic groups and reported in an objective way.

Household (HH) interviews were done with the help of questionnaires given to key informants (KI) as part of a baseline survey. Mugenda and Mugenda (2013) say that a sample size of between 10 and 30% is a good representation of the target population when the study population is less than 10,000. This means that a sample size of 10% is enough for analysis (500 x 0.1). Each site had 500 households that kept camels, and 10% of those households, or 50 per site, were interviewed. This means that a total of 200 households were interviewed. The number of households (HH) in the villages that were on the list of people who got food aid and was kept by the community and held by the area chief was used as the sampling frame for the study. The HH that was chosen for the survey was the unit of analysis for the study. Simple systematic random sampling was used to pick the nth household to be interviewed for the study. The study used a simple, clear, and easy-to-carry-out random sampling method. This is because there is a list of all the villages in the study areas that are on the relief food/hunger safety net cash transfer list. All of the answers were given codes to make data entry and management easier. The Statistical Package for Social Sciences (SPSS, 2019) was used to do the analysis.

3.3 Results and Discussion

3.3.1 Mortality Rate

The calf is the foundation of a camel herd. Calves are the replacement stock for the herd. Without them, the herd can't grow and the people who keep camels wouldn't be able to get milk (Kuria, 2011). Traditional systems for raising camel calves, on the other hand, have a number of problems that lead to a high death rate among the calves (Chimsa, 2013). The main reason African camel calves die is because they don't get enough food. This is because calf and camel keepers compete for milk (Yesihak & Bekele, 2004). Previous studies in Kenya have reported high camel calf mortality up to 62% in extensive camel production system (Kaufmann, 1998; Njanja, 2007).

This study captured from recall data of camel calf mortality rates for four years in both extensive and peri-urban production systems. The mortality rate in the study areas for pastoral production system was 35.2 and in peri-urban site of Karare was 4.3% (Figure 3.3). Karare which represents the peri-urban system had the lowest calf mortality rate that ranged from 1.6-7.6% during four years when data was captured. The mortality rate was high in extensive camel production system where Korr had a rate of up to 56.6%, with Kargi and Ngurunit having 33 and 25.5%, respectively (Figure 3.2). Korr and Kargi rangelands are classified as arid, and the rangelands are degraded compared to the hilly and Mountainous rangelands of Karare and Ngurunit which have diverse and sufficient camel browses.

Traditionally, camel keepers avoid hilly and mountainous areas for keeping camels. Pastoralists associate these areas with high tick load, camel skin diseases, cough and biting flies. Despite the facts that their observations could be true and valid, with modern veterinary drugs, ticks, worms and camel skin diseases and conditions could be easily managed. Therefore, hilly and mountainous rangelands with better browses for camels could be utilized for camel production in ASALs of Kenya.

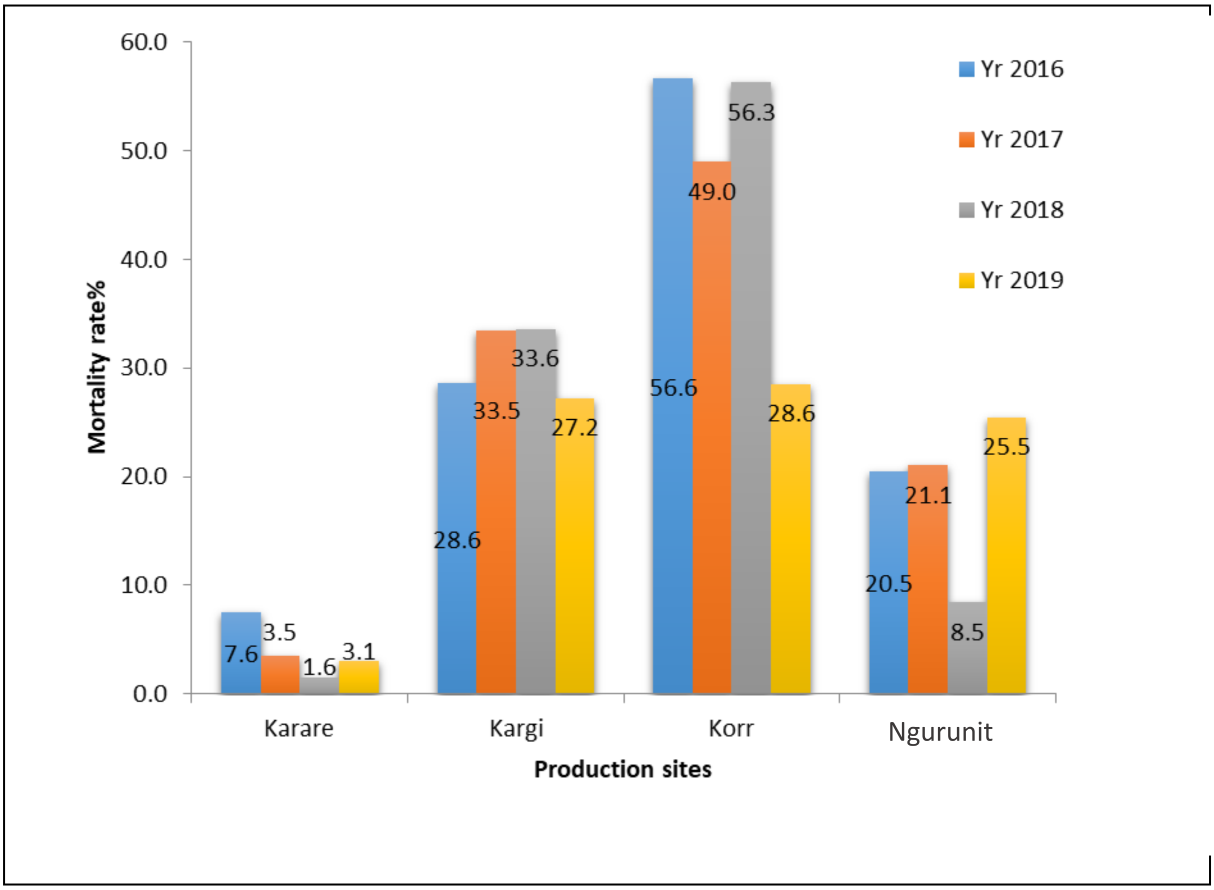


Figure 3. 2 Mortality rate of camel calves in the period (2016-2019)

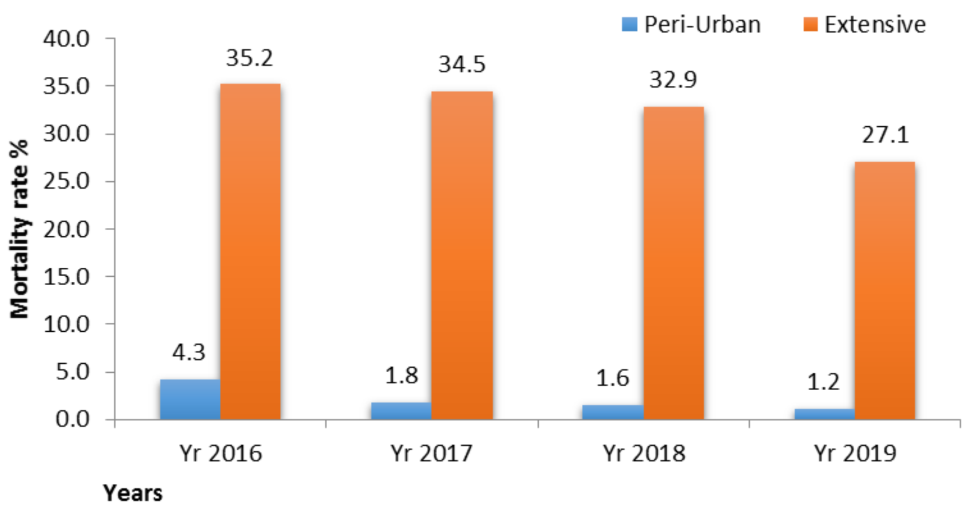


Figure 3. 3 Mortality rate of camel calves under extensive and peri-urban production systems (2016-2019)

3.3.2 Major Causes of Camel Calf Mortality

The major causes of camel calf mortality in the study area are shown in Fig 3.4. Diseases, drought, predation and parasites were the four major causes in both pastoral and peri-urban camel production systems. Diseases were the cause of death of camel calves in both extensive and peri-urban camel production systems in Kenya (Figure 3.5). Common diseases that cause camel calves' mortality as reported by pastoral keepers are cough/pneumonia *(Rendille-Yaahr),* diarrhoea *(Rendille-Harr),* sarcoptic mange *(Rendille-nabahar)* and camel pox (Rendille-*Hado)* among others. Kargi and Korr had the highest diseases and drought related mortalities. This was attributed to degraded rangelands which had fewer browses for calves before and after releasing for free range browsing compared to hilly areas of Karare and Ngurunit. Well-fed calves have high immunity to withstand any disease and succumb less to the droughts (Ericksen, 2020).

Malnutrition emanating from droughts and limited milk suckling are a common phenomenon in the ASALs of Kenya. During dry periods, there is scarcity of forage and water for calves and lactating dams which results to dams producing less milk to sustain the calves. Long distance trekking for forage and water are common causes of mortality during dry/drought seasons especially in pastoral production system. Camel herds trek for up to 300 km for watering and return to foraging areas after every 12-14 days and 15-20 km radius in search of forage daily. In addition, competition for milk for household consumption and trade is a common practice which also significantly contributes to mortality of calves. Mortality also occurs when the dam conceives and dry earlier than one year after calving. Parasites, mainly ticks and worms' infestation were reported by respondents across all study sites. Tick infestation causes paralysis of young calves and can lead to death if the tick load is high. Paralyzed calves are washed with acaricide and given milk remedy which according to the keepers results to quick recovery.

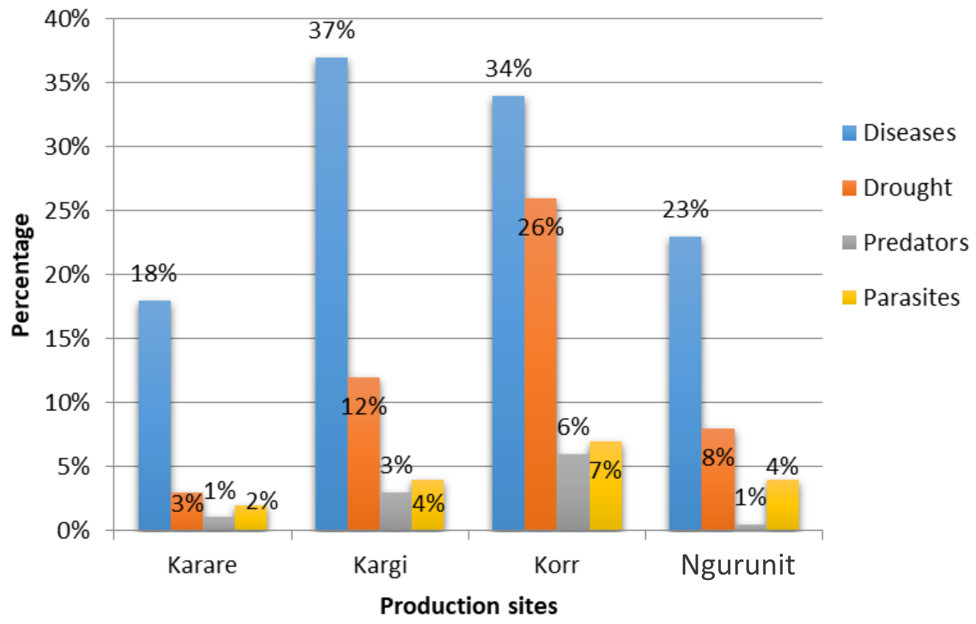


Figure 3. 4 Major causes of camel calf mortality

Predations by hyenas and leopards were reported across study sites. Camel calves are mainly vulnerable to predators when they are released for free range grazing at early stage of life (Rirash et al., 2017). The predation commonly occurs when calves stray from homesteads and occasionally at night. Pastoralists enclose calves and dams (protects them from predators) together at night to avoid predation.

Four major causes of calf mortalities were compared in different production systems, Karare represented the peri-urban production system, Korr, Kargi and Ngurunit represented the extensive pastoral production system. Drought was a major cause of mortality contributing up to 53%, diseases 15%, parasites 17% and predation 15% in the extensive camel production systems. In the peri-urban production system, the causes of calf mortality were diseases 49%, drought 33%, parasites 16% and predation 2% (Figure 3.5).

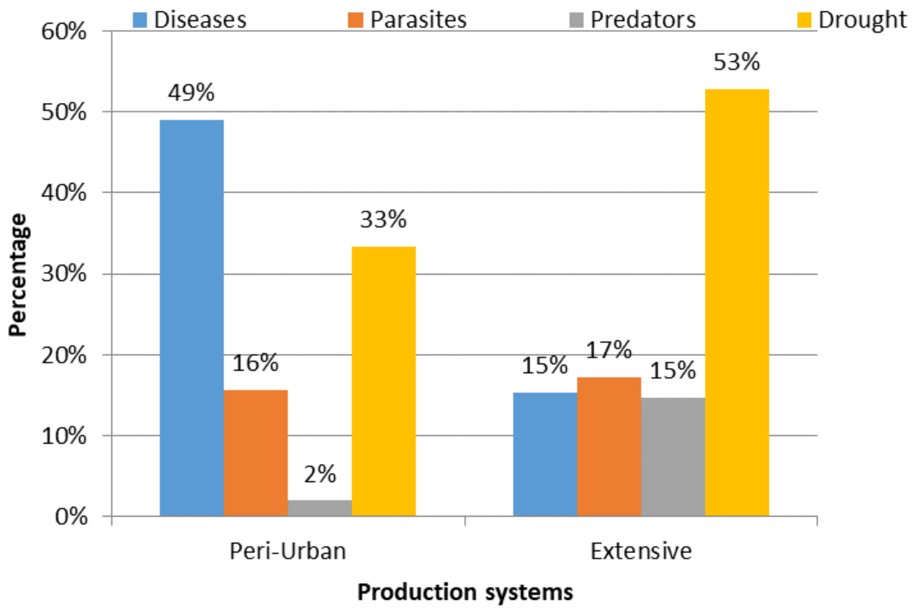


Figure 3. 5 Causes of mortality under different production systems

The study further revealed that about 40% of mortality of calves mostly occurred in the early stage of life, mainly at the age of 1-3 months. Common causes of death at this stage were diarrhoea, deprivation of colostrum, and hereditary conditions like navel bleeding (Rendille term it as *gulor*). Other common causes of death at this stage were accidental death caused by dams trampling on neonate and little attention given to individual calf by owners when many calves are born at the same time.

Pastoralists also observed that calves born after prolonged drought are generally born weak due to malnourishment of dams and foetus. Pastoralists further observed that in-calf dams supplemented with mineral salts or drunk water with natural salts licks i.e., oasis and shallow wells, produced calves that tended to be healthier at birth compared to calves from dams that were watered at boreholes or not supplemented with mineral salts at all.

About 10% of deaths occurred during 4-6 months of age mainly due to diseases like cough/pneumonia, orf as well as predation. Deaths also (30%) occurred between 7-8 months when calves started foraging and watering. These were attributed to trekking long distances (between 70-150km for water and 15-20km for foraging) daily. Other causes of mortality (10%) of calves between 7-8 months of age were predation by hyenas and leopards. About 10% deaths occurred between 8-12 months of age due to starvation and diseases like cough/pneumonia.

3.3.3 Causes of Retardation of Camel Calves

Pastoralists ranked three major causes of camel calf retardation before weaning as: diseases, droughts (limited forage and water) and limited milk due to competition for milk for trade and human consumption (Figure 3.6). Since milk is the major source of food for pastoralists, other alternative sources of feeds for the calves should be considered (Chimsa et al., 2013). In Karare, which has a peri-urban production system, diseases accounted for the highest percentage as a cause of calf retardation at 63%, droughts at 29% and competition for milk at 8% (Figure 3.6). In pastoral production system i.e., Korr, Kargi and Ngurunit, drought was ranked as main cause for retardation with 40%, competition for milk competition 32% and diseases 28% (Figure 3.7).

There is high dependency on camel milk for household use and income by pastoralists, especially among home based milking herds around permanent settlements in the pastoral production system. Camel is the only livestock species that can be found around homesteads and has the ability to constantly supply milk to households throughout the year due to its adaptability to utilize poor feeds, browsing ability on taller acacia species and ability to withstand harsh climatic conditions. Other livestock species namely cattle, sheep and goats are mostly away from home in search of pasture and water during dry/drought seasons which occupy most part of the year Ihuthia (2010).

Pastoralists observed that early separation of calf from the dam for milking purposes resulted in depressed growth and even eventual death. Therefore, calves should only be separated at about 1.5-2 months of age when they have started foraging and drinking water. Over harvesting of milk is usually done among high yielding dams (*Rendille-Hawen)* while low yielders (*Rendille-Godan)* are mostly left with their calves to suckle. Other causes of retarded growth related to milk feeding is early drying of dam due to pregnancy. Worm infestation and infection by diseases such as sarcoptic mange, orf and ring worms were also reported as other causes of camel calves' retardation.

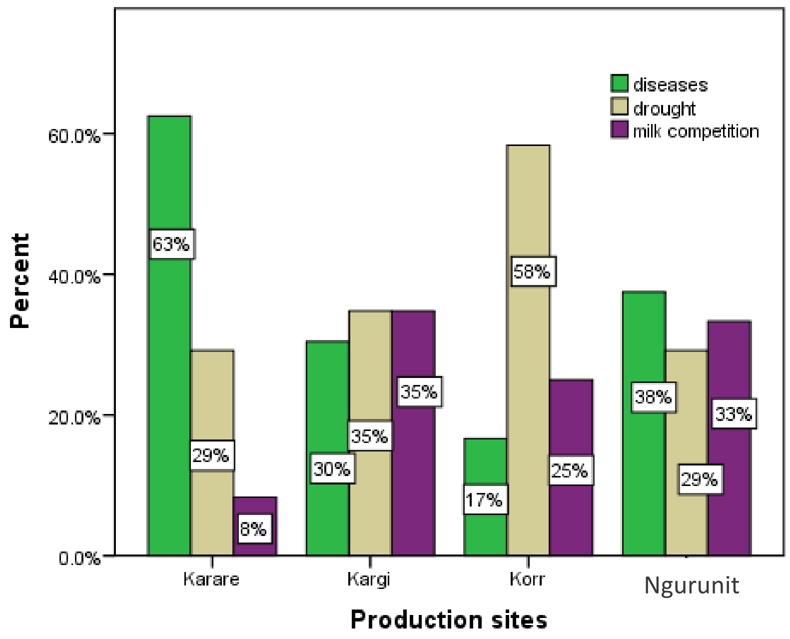


Figure 3. 6 Major factors responsible for retardation of camel calf growth by location

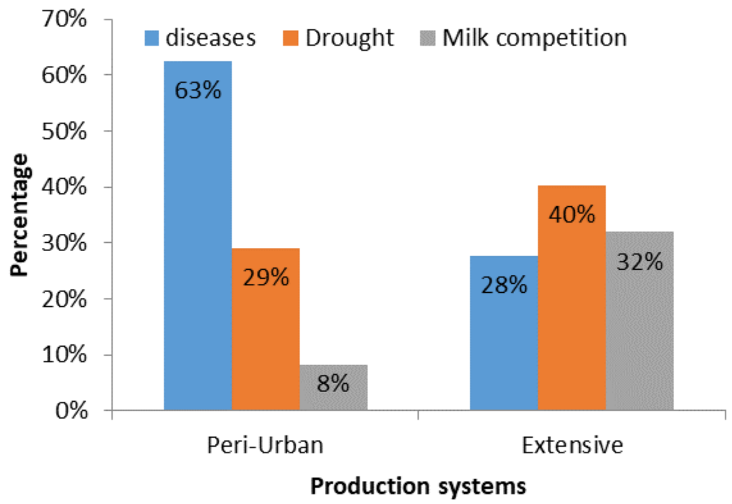


Figure 3. 7 Major factors responsible for retardation of camel calf growth by production system

In addition, there is a common belief in the Rendille community that when sexually active men milk the suckling dams their calf tend to express retarded growth; a condition they term as '*Saam'*. *Saam* is a condition that calves tend to be in constant poor health, have weeping eyes and retarded growth. For this reason, the Rendille community allows only young boys to milk suckling dams after they have cleaned their hands with water if available or camel urine to prevent "occurrences of *Saam"*. They further belief that soap and perfumes affect camel calves and lead to retarded growth and for the same reason women are not allowed to milk lactating dams. *Saam* is also a common belief among other indigenous camel keeping communities in Kenya like Somali and Gabra. Although there is no scientific prove of '*Saam* condition; the most probable explanation of this condition is poor hygiene of milkers leading to contamination of teats and by extension contaminating young calves. Therefore, it is advisable for milkers and individuals handling young calves to maintain high levels of hygiene.

The study further established that camel calves were introduced late to water for the first time and also had long watering intervals ranging between 1-14 days depending on availability of water (Figure 3.8). Calves were mostly introduced to water at between 3-6 months of age. This practice has led to retarded growth. Most animals need to drink at least once every other day for them to be healthy and productive. Because of this, water is the most important thing in all systems for raising animals. Animals use water as a way to transfer both physical and chemical energy, such as when they cool off by evaporation or when they change their metabolism (ILCA, 1983).

Yagil and Etzion (1980) say that young camels can live on their mother's milk alone when they are first born. However, as they grow and ruminate, the water requirements go up considering the dry feed intake and extreme temperatures in ASALs. Water intake promotes early and rapid rumen development (AVA, 2020).

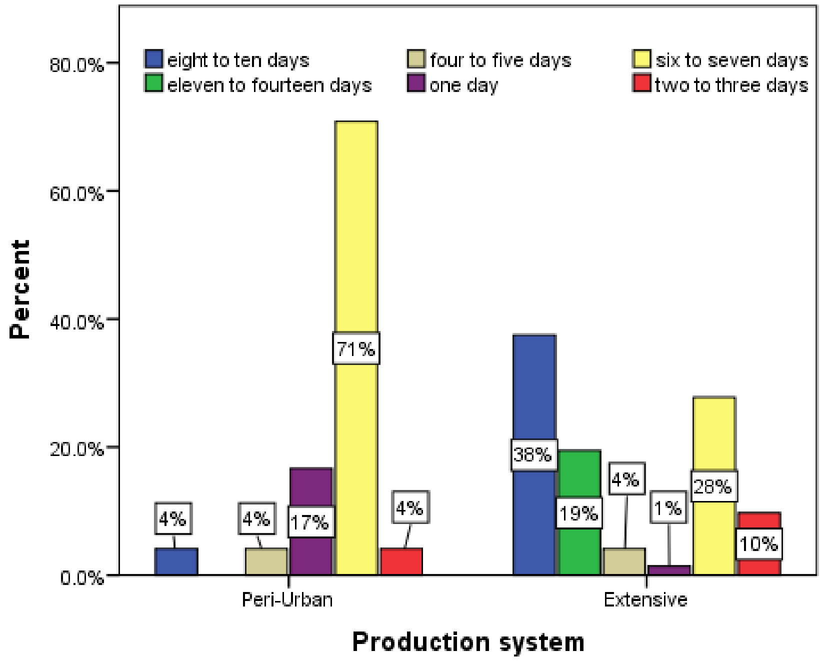


Figure 3. 8 Camel calves watering interval under different production systems

3.3.4 Starter Forages

Natural browses sourced from communally owned rangelands were the sole starter feeds available in pastoral and peri-urban camel production systems in Kenya. In the two production systems, pastoralists commonly depend on natural browses as starter feeds and also as supplements during dry/drought seasons. Calves were introduced to solid feeds at about one and a half month of age.

In general, animal factors, behavioral factors, sensory factors, physical environment, plant environment and availability of plant species were reported as a major factor for plant selectivity by ranging animals (Arnold & Dudzinski, 1978). Camel keepers, select the most palatable browse species available in their locality to feed the camel calves. The selection is based on their ingenious knowledge gained over time passed on from one generation to another. The palatable parts which are mainly leaves, twigs and fruits are cut and fed to the calves in confinement daily. The forages used as starter feeds are fewer compared to the available forages when calves are released for free range system (Table 3.2 and 3.3).

This study revealed that, pastoralists when selecting starter browses for their camel calves consider; availability of the browse throughout the year, palatability and nutritive value of a browse (Table 3.2). Ever green browses are commonly used and most preferred. In addition, leaf biomass, succulence and availability around homesteads are key factors to be considered (Table 3.2 and 3.3). Women and girls are charged with the responsibility of cutting and feeding the preferred forages for the young camel calves. *Grewia bicolor, Salvadora Persica* and *Cordia sinensis* were the most preferred starter forage feeds across study sites owing to leaf biomass, and their wide distribution in the rangelands of northern Kenya.

Plate 3. 2 Calves fed with harvested browses **Plate 3. 3** Camel calf separated at an early age

Table 3. 2 Commonly used/preferred starter forages for camel calves before releasing for free range grazing in pastoral and peri-urban camel production system

Names of the best starter forages for camel calves					Availability			Trend over the last 10 years' period
Botanical name	**Local name (Rendille /Samburu)**	**Site/location found**	**Parts Harvested For feeding**	**Reason for preference**	**Rainy**	**Dry**	**Drought**	
Acacia mellifera	Bilhil /Iiti	Karare/Kamboi	Twigs and leaves	Palatable	Available	Not available	Not available	Constant
Combretum molle	Ikho/Lemaoi	Karare/Kamboi	Twigs and leaves	Leafy, palatable	Available	Available	Available	Decreasing-used as timber
Lannea schweinfurthii	Iltudupia	Karare/Kamboi	Twigs and leaves	Leafy, palatable	Available	Available	Available	Constant
Grewia bicolor juss	dabach/Sitetii	Karare/Kamboi/ Korr/Kargi	Twigs and leaves	Ever green	Available	Available	Available	Increasing
Rhus natalensis krauss	Lmisigiyoi	Karare/Kamboi	Twigs and leaves	Ever green	Available	Available	Available	Constant
Euphorbia tirucalli	*Loile*	Karare/Kamboi	Twigs	Ever green	Available	Available	Available	Constant
Justicia exigua	Lemanera	Karare/Kamboi	Twigs and leaves	Ever green	Available	Available	Available	Constant

Salvadora Persica	Hayei/ *Sokotei*	Kargi/Korr/ Ngurunit	Twigs, leaves and seeds	Ever green	Available	Available	Available	Constant
Cordia sinensis	Gayer/ *iLgoita/salapani*	Kargi/Ngurunit/ Korr	Twigs, leaves and seeds	Leafy and promote calf growth	Available	Not available	Not available	Decreasing
Leptothrium senegalense	Ballah	All study sites	Leaves, stems and seeds	Palatable	Available	Not available	Not available	Diminishing
Cenchrus ciliaris	Lorokwe	All study sites	Leaves, stems and seeds	Palatable	Available	Not available	Not available	Diminishing
Aristida mutabilis	Ririma	All study sites	Leaves, stems and seeds	Palatable	Available	Not available	Not available	Diminishing

Calves have less experience selecting diverse browse species and are unable to browse on taller plants like adults (Chimsa et al., 2013). The number of forage species preferred by calves was less than the number of plants preferred by mature camels in both the dry (21 species) and wet (30 species) seasons (Dereje & Uden, 2005). The high number of plants reported for mature camels may be due to their experience and ability to browse diverse and taller plant species that calves may not be able to access (Chimsa et al., 2013). This study confirms previous findings that forages reported for camel calves are lower than those reported for mature camels.

Table 3. 3 Commonly available/preferred forages for camel calves after releasing for free range in pastoral and peri-urban camel production system

Name of the forage (Best ranked by sites)				Reason for preference	Availability			Trend over the last 10 years' period
Botanical name	**Local name (Rendille/Samburu)**	**Site/location found**	**Parts browsed**		**Rainy**	**Dry**	**Drought**	
Acacia tortilis	Dahar/Ltepes	All study sites	Leaves, twigs and pods	Pods and leaves highly nutritive	Available	Available	Available	Constant
Acacia nilotica	Lkiroriti	Karare, Kamboi, Ngurunit	Leaves and twigs	Pods and leaves highly nutritive	Available	Available	Not available	Constant
Sericocomopsis hildebrandtii	Injim/Hanjim	All study sites	Leaves and twigs	Ever green	Available	Available	Available	Constant
Barleria acanthoides	Sucha	All study sites	Leaves and twigs	Ever green, seeds palatable	Available	Available	Available	Constant
Duosperma eremopholia	Durkurnyato/yabah	All study sites	Leaves and stems	leafy	Available	Available	Available	Constant
Aspilia	Loyabasei	All study	Leaves	Palatable	Available	Available	Not available	Constant

mossambicensis		sites	and twigs					
Indigofera spinosa	Khoro/Lkitagesi	Kargi, Korr, ,Ngurunit	Leaves and stems	Palatable	Available	Available	Not available	Constant
Securinega virosa	Lkirebuk	Karare, Kamboi, Ngurunit	Leaves and twigs	Palatable	Available	Available	Not available	Constant
Acacia brevispica	Girigiri	Karare, Ngurunit, Kamboi	Leaves and twigs	Palatable	Available	Available	Not available	Constant
Xanthoxylum chalybeum	Losuiki	Karare, Ngurunit, Kamboi	Leaves and twigs	Palatable	Available	Available	Not available	Constant
Acacia brevispica	Lekirkir	Karare, kamboi	Leaves and twigs	Palatable	Available	Available	Not available	Declining
Cenchrus ciliaris	Lorokwe	All study sites	Leaves, stems and	Palatable	Available	Available	Not available	Declining
Aristida mutabilis	Ririma		seeds	Palatable	Available	Available	Available	Declining
Cadaba farinosa	Geikuku	Korr, Kargi	Leaves and twigs	Ever green	Available	Available	Available	Constant
Maerua oblongifolia	Geigeri	Karare, Ngurunit, kamboi	Leaves, twigs and	Ever green	Available	Available	Available	Constant

			pods					
Acacia nubica	Holia/ldebe	All study sites	Leaves and twigs	Palatable	Available	Not available	Not available	Constant
Merua crasifolia	Dumey/ldumey	Kargi, korr, Ngurunit	Leaves and twigs	Ever green	Available	Available	Available	Declining
Duosperma spp	Yabah	All study sites	Leaves and stems	Palatable	Available	Available	Not available	Constant
Commiphora flaviflora	Hagar	All study sites	Leaves and twigs	Palatable	Available	Not available	Not available	Constant
Tarenna graveolens	Lmasiei/ Masei	Karare, Ngurunit, Kamboi	Leaves and twigs	Palatable	Available	Not available	Not available	Constant

3.3.5 Commonly Used Substitute/Supplement to Milk Feeding

The pastoralists were aware that locally available feed resources such as *acacia tortilis* pods, *Merremia ampelophylia*, *Tinnospora caffra, Cordia sinensis* and grasses such as *Cenchrus ciliaris* among other forages, animal (animal blood and mutton soup) and commercial (maize porridge) ingredients could be used as a substitute to milk feeding (Table 3.4).

According to the pastoralists, none of the substitutes are comparable to milk but it can sustain the calf if given in right quantities. The most preferred substitutes and easily available were porridge from maize, acacia tortilis pods, *Tinnospora caffra* and animal and commercial fats such salads. Although few pastoralists in peri-urban production system claimed to be aware of commercial substitutes to milk feeding such as milk substitutes and calf pellets, they had never fed them to camel calves because they were not available. It was clear during FGDs in both peri-urban and extensive production systems, pastoralists were willing to buy locally formulated or commercial milk substitutes or pellets to use as substitutes to milk feeding if they were available in the local markets.

Table 3. 4 Common substitutes to milk used by pastoralist for feeding camel calves

Name of the substitute	Site/location found	Source of substitute	Quantity used / day/calf (kg/litres)	Calf performance 1. Very good 2. Good 3. Fair 4. Poor	Cost/ unit sale (kg/L)/KES
Acacia tortilis pods	All sites	Rangelands	2kg	1	10
Grasses	All sites	Rangelands	3kg (after watering, 6month of age)	3	10
Simalelei (tuber)- *Merremia ampelophylia*	All sites	Rangelands	2kg	1	-
losiachi *(Tinnospora caffra)*	Karare/ Ngurunit	Rangelands	1kg	1	10
Fat/salad/Kimbo	Shops	Shops	0.5kg	1	100
Fiscus benjamina	Kargi/Korr/ Ngurunit	Rangelands	Barks boiled and given solution of 2-3 litres. It has also medicinal value. Used for treatment of internal abscess and worms	3	-
Lgoita (*Cordia sinensis)*	Kargi/Korr/Ngurunit	Rangelands-use leaves and twigs	2kg	2	10
Porridge	Shops	Shops	3-4ltrs	1	40
Blood	Own herd	Camel blood	5 litre once every two weeks	2	Own camel herd
Soup (sheep head)	Own flock	Sheep	2 litres once a month	2	50

3.4 Conclusion

The pastoralists were aware that locally available feed resources such as *Acacia tortilis* pods, *Merremia ampelophylia, Tinnospora caffra, Cordia sinensis* and grasses such as *Cenchrus ciliaris* among other forages, animal fats, commercial cooking oil, animal (animal blood and mutton soup) and commercial (maize flour) ingredients could be used for calf feeding as substitute to camel milk feeding.

CHAPTER FOUR

PROXIMATE COMPOSITION OF SELECTED BROWSES AND COMMON MILK SUPPLEMENTS FOR CAMEL CALVES IN KENYA

Abstract

A study on nutritive value of selected browses fed to camel calves and commonly used local feed supplements as an alternative to milk feeding was conducted in the Southern rangelands of Marsabit County. Four focus group discussions (FGDs) comprising of 12 persons per study site: Karare, Kargi, Korr and Ngurunit wards were conducted in the main camel keeping areas among the Rendille camel keeping communities to identify common browses and commonly used supplements. A total of 10 browses, 4 grass species and 6 commonly used supplements were identified, sampled and analyzed. Selected browses and common supplements were analyzed for their proximate composition. In addition, commonly used supplements were analyzed for their amino acid profiles, Ca, P and tannin levels. From the results, it was concluded that CP, DM, fat, NDF, ADF, and ME composition were highly variable, with significant ($P<0.05$) differences among the browses and grasses. Browses like *Grewia bicolor* (24% CP) and *Justicia exigua* (20% CP) have a potential to provide the recommended daily protein requirements for camel calves (20-24% CP) as plant-based milk substitute. Browses which had energy above 15 MJ Kg^{-1} DM, *Justicia exigua* (19.3 MJ. Kg^{-1} DM), *Acacia melliffera* (18.1 MJ. Kg^{-1} DM) and *Salvadora persica* (18.4 MJ. Kg^{-1} DM) were recommended for camel calves plant-based milk substitute. All the four grass species evaluated (*Aristida mutabilis* (16.3 MJ. Kg^{-1} DM), *Cenchrus ciliaris* (17.1 MJ. Kg^{-1} DM), *Leptothrium senegalense* (15.3 MJ. Kg^{-1} DM) and *Sporobolus* species (15. 9 MJ. Kg^{-1} DM) contained the minimum recommended energy to meet daily requirement of camel calves (15-20 $MJKg^{-1}$ DM). The common protein supplements used by pastoral camel keepers like *Acacia tortilis* pods (15.42% CP), *Tinnospora caffra* (14.05% CP) and *Prosopis juliflora* pods (11.08% CP) contained lower CP than the recommended 20-24%. However, the common energy source supplements used like sheep fat (26.87 MJ. Kg^{-1} DM), camel fat (28.57 MJ. Kg^{-1} DM) and maize meal (26. 10 MJ. Kg^{-1} DM) had adequate energy to meet daily energy requirements as plant-based milk substitute. The commonly used forage supplements i.e., *Acacia tortilis* pods, *Prosopis juliflora* pods and *Tinnospora caffra* are low in limiting amino acids methionine, lysine and threonine for calf nutrition, thus their supplementation is recommended. Tannins concentrations of commonly used supplements were within the safe range that would not be harmful to the animals. The *Acacia tortilis* pods (Ca, 3.72% and P, 0.91%) and *Prosopis juliflora* pods (Ca 1.44% and P 0.75%) used as common supplements have sufficient Ca and P

to meet daily requirements of camel calves and thus can be recommended to supply the two important minerals for the growth of the calves. However, *Prosopis juliflora* pods should be used in meal form because it can easily colonize rangelands through fecal propagation of seeds. It is concluded that all the forage plant species used by the pastoralists to feed camel calves before releasing for open free-range grazing and common supplements could be used as ingredients for formulation of plant-based milk substitute.

Key words: Calf performance, nutritive value, plant-based milk substitute, starter browses

4.1 Introduction

Insufficient feed in Kenya's Arid and Semi-Arid Lands (ASALs), both in terms of quality and quantity, is the main obstacle to the production of livestock (Mnene, 2006). As a result of famine, disease, and missed trade opportunities, approximately $2 billion worth of livestock is lost each year, contributing to increased food insecurity in ASALs (USAID, 2021). Due to a severe lack of pasture to feed livestock numbers during the dry seasons, pastoral communities are at risk of losing their way of life (Opiyo et al., 2011). In Northern Kenya and other arid regions of Africa, camels are better adapted to the arid climate and deteriorating rangelands (Farah et al., 2004a). Camel physiology enables them to live off diets low in protein and high in fiber (Lechner-Doll et al., 1990). Due to their height, camels can access feed sources that are inaccessible to other livestock species (Field, 1979).

In the ASALs, camels (*Camelus dromedarius*) are an essential part of pastoral communities' culture and are used for transportation, food production, income generation, and as a mode of transportation (Guliye et al., 2007; Mahmoud, 2010). Notwithstanding the financial importance of the camel throughout the world's dry and semiarid rangelands, nothing has been done to boost their productivity and nutrition. Camel calves are the replacement stock without which the camel herd cannot increase and pastoralists would not have access to milk (Chimsa et al., 2013). Camel calf rearing under traditional pastoral production systems is hampered by a lack of forage due to deteriorated rangelands and competition for milk by pastoralists for family and commercial consumption. There have been reports of calf mortality rates as high as 62% between birth and weaning age of one year (Kaufmann, 1998; Njanja, 2007). The camel likes to graze on a wide range of fodder plants, including trees, bushes, and occasionally bitter, prickly, and salty plants that naturally occur in the desert and other semiarid environments (Field, 1995; Wilson, 1984).

To increase the survival of camel calves, pastoralists use natural forages (leaves and twigs) to feed camel calves before releasing for free-range browsing. Natural forage supplements (pods, fruits and tubers) and commercial feeds like maize meal have been used to supplement camel calves during dry/drought season (Noor, 2013). When selecting browses/supplements for their camel calves, pastoralists mainly consider availability throughout the year, palatability and nutritive value.

Therefore, this study identified and evaluated alternative feed sources used by pastoral camel keepers to feed calves which could be used as plant-based milk substitute that can support calf growth and solve constraints of competition for milk for households' consumption and trade.

4.2 Materials and Methods

4.2.1 Site Description

The study was carried out in the Rendille camel-keeping settlements in the southern rangelands of Marsabit County's Kargi, Korr, Ngurunit, and Karare wards. Marsabit County is one of the ASALs Counties in Kenya, with the exception of the high potential areas in and around the Marsabit and Kulal Mountains and the Hurri Hills. The average amount of rainfall is quite modest, and its intensity and duration are both highly unpredictable. The bimodal rainfall regime that the County experiences has two peaks, one in April and the other in November. With an annual range that can go anywhere from 120 to 700 millimeters, the precipitation is scant, sporadic, and inconsistent, particularly in the low-lying areas. Temperatures can range anywhere from 23 to 34 degrees Celsius, with the hottest time of year falling between January and April.

4.2.2 Data Collection Method

A baseline survey using Focus group discussions (FGDs) comprising of 12 persons per site was conducted in the main camel keeping areas among the Rendille communities in Southern rangelands of Marsabit County, including Karare, Kargi, Korr and Ngurunit. The participants were purposefully selected based on their knowledge in identifying range plants species utilized by camel calves using local names and their knowledge on camel calves feeding. The study used open ended questions to guide the discussion and recorded all responses on a notebook and audio recording.

4.2.3 Sampling

All browses and supplements mentioned were listed and sampled (leaves, twigs and fruits) since they were fewer and specific to different study sites. Leaves and tender twigs of about 1-6 cm were picked from mature branches from their base and middle of the branches. Mature fruits on the sampled forages were picked with leaves and twigs. For the case of *Acacia tortilis* pods and *Prosopis juliflora* pods; mature pods that had just dropped from the trees were sampled for analysis. At all sites three experienced elders were recruited to guide sampling of forages and supplements. The forage samples were clipped using secateurs and about 1 kg of each species was collected, stored in forage bags and labeled in readiness for analysis. The samples were then kept under room temperature in open forage bags without disturbance for a period 5 days to facilitate drying. The dry forages were later ground and subjected to laboratory analysis.

4.2.4 Laboratory Analysis: Proximate, Tannins and Minerals Assay of Samples

To determine the), crude protein (CP), dry matter (DM), ash, and ether extract (EE) of local feed resources used as a starter feed for camel calves before releasing them for free-range browsing and other common supplements used by pastoral camel keepers, proximate analysis was performed using the standard AOAC methods (2006). Kjeldahl Nitrogen was used to determine the CP (N x 6.25). According to Van Soest's technique, acid detergent fiber (ADF), neutral detergent fiber (NDF), and acid detergent lignin (ADL) were all examined (1994).

The profile of amino acids was determined using an amino acid analyser, High Performance Liquid Chromatography (HPLC), in accordance with AOAC protocol (2006). The procedures outlined by Makkar for 70% aqueous acetone phenolic extraction (2003). According to the Tiitto's Folin Ciocalteu methods given by Julkunen, the total extractable phenolics (TEPH) were assessed (1985). Condensed tannins (CT) were detected and quantified as leucocyanidin equivalents using the Porter et al. method (1985). The determination of minerals (Ca, K, P, Mg, Fe, Cu, Mn, and Zn) via atomic absorption spectrophotometry (AAS).

4.2.5 Statistical Analysis

The General Linear Model technique of Statistical Analysis System (SAS, 2002) version 9.0 was utilized to conduct an analysis of variance (ANOVA) on data gathered on the proximate, fiber, and tannin contents of a completely randomized design (CRD). Tukey's HSD (Tukey's Honestly Significant Difference Test), with a significance level of 5%, was employed to distinguish between significantly different means.

4.3 Results and Discussion

4.3.1 Nutritive Value of Browses

The chemical composition of the browses and grasses is presented in Table 4.1.

Table 4. 1 Mean chemical composition (% DM) of commonly used starter browses

Samples	DM	Ash	CP	NDF	ADF	ADL	Fat	ME (MJ.Kg^{-1} DM)
Browses								
Lannea schweinfurthii	90.8^{e}	6.9^{i}	17.4^{d}	47.2^{h}	36.2^{i}	20.3^{e}	11.2^{b}	14.1^{f}
Grewia bicolor	92.9^{d}	8.8^{g}	24.2^{a}	47.2^{h}	30.8^{j}	10.9^{g}	8.9^{ed}	14.7^{ef}
Rhus natalensis	92.8^{d}	7.1^{i}	16.1^{ed}	61.2^{e}	51.8^{e}	29.6^{b}	9.6^{cd}	12.1^{h}
Combretum molle	93.3^{cd}	6.8^{i}	17.3^{d}	39.8^{k}	30.6^{j}	7.2^{i}	8.4^{f}	13.4^{g}
Cordia sinensis	92.1^{d}	12.1^{f}	19.3^{c}	58.9^{f}	56.8^{c}	24.5^{c}	9.1^{de}	12.2^{h}
Acacia mellifera	94.0^{cb}	8.4^{h}	20.2^{b}	44.4^{j}	34.7^{i}	6.1^{i}	9.2^{e}	18.1^{b}
Justicia exigua	92.9^{d}	8.1^{h}	20.4^{b}	43.6^{j}	42.7^{h}	22.6^{d}	8.9^{e}	19.3^{a}
Salvadora Persica	92.1^{d}	30.9^{c}	15.1^{e}	31.3^{k}	23.9^{k}	6.9^{i}	10.2^{c}	19.4^{a}
Euphorbia tirucalli	95.2^{b}	8.2^{h}	10.8^{f}	50.3^{g}	45.9^{g}	12.8^{f}	12.5^{a}	14.9^{ed}
Fiscus benjamina (leaves)	93.4^{cd}	22.3^{e}	11.8^{f}	46.2^{j}	53.2^{e}	1.2^{j}	9.8^{cd}	7.8^{i}
Fiscus benjamina (barks)	95.9^{a}	8.3^{h}	4.9^{j}	62.5^{d}	68.8^{a}	46.7^{a}	8.9^{e}	2.7^{j}
Grasses								
Aristida mutabilis	96.2^{a}	43.1^{a}	7.8^{h}	79.8^{a}	63.2^{b}	7.3i	5.2^{i}	16.3^{d}
Cenchrus ciliaris	94.8^{b}	27.8^{d}	6.1^{h}	77.8^{b}	55.0^{d}	7.4i	5.9^{h}	17.1^{c}
Leptothrium senegalense	96.0^{a}	30.5^{c}	8.6^{g}	79.5^{a}	58.3^{c}	18.4^{e}	5.6^{h}	15.3^{ef}
Sporobolus spp	94.9^{b}	32.1^{b}	7.4^{h}	68.1^{c}	49.6^{f}	8.8^{h}	6.9^{g}	15.9^{d}
SEM	0.186	0.217	0.209	0.291	0.308	0.261	0.177	0.189

ADF= acid detergent fiber, NDF= neutral detergent fiber, ADL= acid detergent lignin, DM= dry matter, ME= Metabolizable energy, ^{abc} mean values within a column with different superscript differ significantly at $P<0.05$.

Crude Protein, DM, Ether extract, NDF, ADF, and ME composition were highly variable, with significant ($P<0.05$) differences among the commonly used browses. The CP content of browses ranged from 10.8 % in *Euphorbia tirucalli* to 24.2 % in *Grewia bicolor* leaves and fruits. The crude protein level of different browses varied greatly, but within each browse, a higher protein content is typically indicative of a higher grade. Indeed, as forages mature, their crude protein level decreases as their fiber concentration increases (Rouquette et al., 2020). The range of CP content in commonly used browses validates the accuracy of knowledge in choosing the proper forage species as a source of protein for their camel calves. Even during the dry season, when it tends to decline, the majority of fodder trees and shrubs had crude protein content in their fruit and leaves that was above 10%. (Abdalla et al., 2014).

Comparing and assessing the quality of feeds frequently involves looking at their energy contents. Regression equations are used to determine the energy content of feed as opposed to other nutrients. Given their similar digestive functions, TDN values for cattle are the best estimate currently available and should accurately reflect feed energy for camelids (Rouquette et al., 2020).The ME in browses ranged from 7.8 $MJKg^{-1}$ DM in *Fiscus benjamina* to 19.32 $MJKg^{-1}$ DM in *Justicia exigua.* Therefore, these natural browses could be good sources of energy and protein to be used as ingredients for starter feeds or milk substitute for the camel calves.

Usually, pastoralists harvest branches for the calves only to utilize the leaves, twigs and fruits. Such practices could be detrimental to the environment over time, especially around the sedentarized areas. Thus, there is need to capacity build pastoralists on sustainable harvesting and conservation of browser forages especially, around sedentarized areas. They should only harvest the palatable parts when leaves and twigs are mature i.e., 2 months after rains through hand picking other than cutting. The harvested parts could be dried and stored for dry season utilization.

Between 90.6% in *Lannea schweinfurthii* and 95.2% in *Euphorbia tirucalli*, browses' DM content ranged. The nutrients needed by the animal for upkeep, growth, pregnancy, and lactation are present in the DM portion of the feed. Knowing a feed ingredient's moisture content is crucial because moisture affects the feed's weight, quality, and shelf life but does not add to the nutritional value for the animal. Animals do need water, but it's best to give it to them directly from a water source rather than through feed ingredients (Oetzel et al., 1993). The amount of a particular feed necessary to give an animal a specific amount of nutrients can be calculated by looking at the DM content of the feed.

Nutrient deficiencies or excesses are caused by changes in the DM content of feed. The DM in the starter forages was high due to the fact that the plants were sampled during the dry season. Unlike the conventional methods of feeding animals on dry matter basis of feeds, pastoralists feed the camel calves mostly on fresh branches without determining its DM content. They also do not consider body weights of the calves as a basis of feeding and meeting the daily nutritional requirements. Therefore, there is need to capacity-build camel keepers to use DM at 3% of calf body weight as a basis of offering feed on daily basis.

Ash content of browses ranged from 6.8 in *Combretum molle* to 30.9 in *Salvadora persica* (Table 4.1). Ash is the overall mineral content of a diet or forage. A high ash concentration in forages or TMR can distort estimations of forage energy and dry matter consumption. High ash levels in forages may be a quiet foe in animal nutrition (Hofmann & Taysom, 2005). This difference in proximate composition in the beginning forages may be attributable to differences in the species composition, soil type, location, and climate, which is consistent with Chartsworth's findings (1992).

The portion of a forage or feed sample that is insoluble in neutral detergent and contains the main building blocks of the plant cell wall, namely hemicellulose, cellulose, and lignin, is known as neutral detergent fiber (NDF). NDF content rises as plants mature and their ability to synthesize cell walls increases. Dry matter intake and chewing activity both decline as a diet's NDF content rises. In a specific feed, NDF is a highly reliable indicator of feed quality and plant maturity. For legume fodder, an NDF level below 40% would be regarded as high quality, whilst above 50% would be regarded as bad quality. For grass fodder, NDF 50% is regarded as high quality, but NDF > 60% is regarded as bad quality (Rouqutte et al., 2020).

Acid detergent fiber (ADF) fraction of forage or feed sample solubility is another indicator of fiber. ADF is a subset of NDF. Cellulose, lignin, and other indigestible components of cell walls, as well as other incredibly resilient materials, such as acid detergent insoluble nitrogen (ADIN), make up acid detergent fiber. ADF is frequently used to forecast feed energy content due to its nature. Similar to NDF, ADF is a reliable indicator of feed quality; higher levels within a meal indicate poorer feed. A target would be to have less than 35% ADF in legume forages or quality grass forages (Rouquette et al., 2020). Acid detergent lignin (ADL) is usually a bigger proportion of the acid detergent fiber (ADF) of browse leaves than of other forages. The NDF content in the starter browses were all above 40% which is an indication of poor-quality forages except for *Salvadora persica* which was 31.3%. This was probably due to the fact that samples were taken during dry season and

Salvadora persica is an evergreen plant. Therefore, it is important to note that, when considering using the palatable parts of starter browses as ingredients of animals' feeds, timely harvesting is of paramount importance in order to attain high quality feeds.

The ADF contents in all starter browses were also above recommended 35% which is an indicator of poor quality except for *Grewia bicolor, Combretum molle* and *Salvadora persica* which were within the recommended range for good quality forages. All lipid (fat) soluble substances are eliminated through the chemical process of ether extraction by dissolving them in ether. With the exception of situations where diets with a high fat content are being compared, this technique is not particularly useful for assessing feed quality (Rouqutte et al., 2020). Fat is crucial in ruminant diet, can assist increase the nutritional quality of milk and meat. Lipid is also a vital component of balanced diets and is often added to boost energy density substantially without raising the acid load in the rumen (Rouquette et al., 2020) also without increasing the bulkiness of the ration. Compared to carbohydrates, fat has 2.25 times more energy.

Following the optimization of the diet's carbohydrate intake, fat is frequently added to meet the remaining energy requirements. The proliferation of the bacteria that break down fiber can be inhibited by high levels of rumen accessible lipids (over 5% of the feed DM), which lowers the digestibility and intake of fiber. Rumen inert fats can be added if more energy is required than what is provided by carbohydrates and rumen accessible fats. Total fat should not exceed 7% of the DM in the meal. Fats can improve reproductive abilities (Herrerra-Camacho et al., 2011). Fat (EE) content of commonly used starter browsers ranged from 8.4% in *Combretum molle* to 12.5% in *Euphorbia tirucalli* which is sufficient as feedstuff ingredients used to formulate locally formulated plant-based milk substitute.

4.3.2 Nutritive Value of Range Grasses

The nutritional density of the fodder is the primary factor that affects its quality for use in animal production. It is essential to have knowledge about the quality of the fodder in order to properly plan and utilise the pastures in order to achieve maximum performance from the animals (Mahmoud, 2010). The four rangelands' grasses reported to be used as a starter feed for camel calves across all study sites were *Aristida mutabilis, Cenchrus ciliaris, Leptothrium senegalense* and *Sporobolus spp.* Their dry matter ranged was 95.1 and 96.2% *sporobolus spp* and *Aristida mutabilis* respectively.

Previous studies had reported that indigenous grasses such as *Eragrostsis superba* and *Cenchrus ciliaris* had higher dry matter yields and are well adapted to cultivation under the local environment (Bulle et al., 2010). The productivity potential of *Chloris gayana* has also been suggested by Ontitism et al. (2000). Nevertheless, the dry matter yield from the other grass species had also potential to support livestock for considerable period of time. One hectare of Chloris gayana produces enough dry matter to sustain 15 Tropical Livestock Units for 90 days, assuming that an animal can consume dry matter equal to 3% of its body weight, *Eragrostis superba* for 47 days and *Cenchrus ciliaris* for 26 days (Bulle et al., 2010). Therefore, propagation of adaptable grasses in arid and semi-arid lands (ASALs) to be used in feeding calves with other local feed ingredients during dry season could reduce high calf mortality rates reported in ASALs of Kenya which mostly emanates from malnutrition. The pastoralists mostly use grasses during dry season when the leaves of browse forages are dry and are not readily available.

Cenchrus ciliaris had a CP content of 5.79 while Sporobolus species had a CP content of 7.73. Camel calves' (20–24%) daily protein needs cannot be satisfied by grass alone. This is due to the fact that ruminants' protein requirements also consider the ruminal microbial population's protein and/or nitrogen requirements (Huston et al., 1981). Although being categorized as pseudo-ruminants, camels can benefit from the same nutrition as cattle, according to earlier reports (Mukasa, 1981). The animal requirements in the food range from 7 to 20% CP depending on the species, sex, and physiological state, whereas the microbial requirements are satisfied at 6-8% CP (Milford & Haydock, 1965).

The energy in the grasses is adequate to maintain the calves and spur growth. The energy ranges from lowest in *Leptothrium senegalense* 15.25 MJ to highest in *Cenchrus ciliaris* 17.11 MJ. According to NRC (2001), camel calves require in their diet about 15-20MJ, CP, 20-24%, EE, 10%, Ca, 1.0% and P, 0.7%. Neutral detergent fiber, which directly affects animal performance, is the main indicator of overall forage quality and digestibility (Linn, 2004). High NDF reduces the voluntary DM intake of grazing animals (El Shaer, 1994). As NDF rises, the neutral detergent solubles, including starches, sugars, lipids, and CP, decrease. El Shaer (1994) defined the normal range of nutritious fodders as having an NDF between 35 and 40 percent.

The NDF content in the grasses used as starter feeds for camel calves ranged from 68.05% in *Sporobolus spp* to 79.84% in *Aristida mutabilis.* ADF in *sporobolus spp* was 49.63% while *Aristida mutabilis* had 63.25%. Starter grasses' NDF and ADF content levels are a sign of their poor quality and indigestibility. However, because camels can keep fibrous feed in the rumen for a longer period of time, camels have a greater capacity to use it, facilitating better digestion (Lechner-Doll et al., 1990). Due to their special adaption, camels are less affected by their diet's high fiber content. The ash content of grasses was higher than that of browses. According to Kuria (2005), shrubs had a mean NDF content of 51.012.6% compared to 60.414.3% for grasses, herbs, and climbers. The findings of this study corroborate his findings. Shrubs and dwarf shrubs had higher DM and CP content than grasses, but lower fibre and ash content. Due to these qualities, grazing camels prefer the shrubs and dwarf shrubs, which are more palatable (El Shaer, 1994).

4.3.3 Nutritive Value of Commonly Used Supplements

The chemical composition of commonly used supplements and substitutes are presented in Table 4.2. The DM content ranged from 90.3 % in maize meal to 99.83 % in Camel hump fat. The CP content ranged from 0.18 % in Camel hump fat to 15.42 % in *Acacia tortilis* pods. Maize meal had lower NDF compared to *Acacia tortilis, Prosopis juliflora* and *Tinnospora caffra.* Camel hump fat had higher fat (EE) content compared to the natural browses and maize meal.

Table 4. 2 Chemical compositions (%) of commonly used supplements and substitutes

Sample	**DM**	**Ash**	**CP**	**NDF**	**Ether extract**	**ME ($MJKg^{-1}$ DM)**
Acacia tortilis pods	93.82^{c}	21.20^{b}	15.42^{a}	61.74^{c}	6.75^{d}	5.18e
Prosopis juliflora pods	93.08^{c}	22.13^{a}	11.08^{c}	64.98^{a}	9.21^{c}	4.83^{e}
Tinnospora caffra tuber	94.73^{b}	20.09^{c}	14.05^{b}	63.89^{b}	6.63^{d}	6.78^{d}
Maize meal	90.13^{d}	0.32^{d}	7.11^{d}	17.68^{d}	13.14^{b}	26.10^{c}
Sheep tail fat	99.67^{a}	0.00	0.34^{e}	N/D	100.30^{a}	26.87^{b}
Camel hump fat	99.83^{a}	0.00	0.19^{e}	N/D	100.09^{a}	28.57^{a}
SEM	0.175	0.166	0.126	0.156	0.135	0.204

CP, crude protein; DM, dry matter; OM, organic matter; NDF, neutral detergent fiber; ME, Metabolizable energy; CT, condensed tannins; [a, b, c] means values in the same column with different superscripts differ signficantly at $P<0.05$

Sheep tail fat, camel hump fat and maize meal had higher ME compared to the natural browses. Healthy pods and seeds of *Acacia tortilis* are a potentially priceless protein concentrate for ruminants in ASALs of Kenya. Tannins in *A. tortilis* pods don't significantly affect the feed's digestibility, and grinding the seeds to remove the tough outer layer can increase the digestibility of the seeds (Garikai et al., 2014). Nagpal et al. (1997), reported a CP of 20.16%, ash 4.50%, DM of 90.90% in *Acacia tortilis* pod in Botswana. There are many factors that affect how nutritious range forages are, and the degree to which they are interconnected can differ significantly from one region to another. Animal class, plant species, climatic influences, edaphic conditions, stage of maturity, and range condition all have an impact on the nutritional value of range forages (Oelberg, 1956).

Prosopis juliflora is a shrub introduced in arid and semi-arid lands of Kenya as a way of combating desertification. However, it has colonized rangelands of Kenya in Riverines like River Tana, Perkerra and Ewuaso Nyiro (Personal observation). It is evergreen, fast growing and drought resistant tree/shrub reported to possess allelo chemical compounds having negative impacts on other vegetation which is growing in their vicinity. *Prosopis juliflora* have biological nitrogen fixation properties type of bacterium in its roots (Van Soest, 1994). Mohammed et al. (2019) in Saudi Arabia reported 15.2% crude protein, 2.61% ether extract, 18.58% crude fibre and 6.04% ash, with 5.44 MJ/kg in *Prosopis juliflora* pods. Despite its nutritional values, FAO classifies it as a noxious plant species and pastoralists of Northern Kenya have observed it as a threat to existence of any other rangelands forage. Therefore, if it is to be used as an animal feed, it must be ground to crush the seeds to limit its propagation and spread.

Tinnospora caffra grows in hilly and Mountainous areas in ASALs of Kenya where its tubers are used as dry/drought season supplements for livestock, especially cattle and small ruminants. *Tinnospora caffra* is a climbing shrub producing stems up to 5 metres long that twine around other plants for support. Golicha (2015) documented *Tinnospora caffra* among preferred and adaptable forage species for cattle in Marsabit County of Kenya. The nutritive value is: DM =97.57%, CP =3.62, NDF=76.62, Estimated MJ=2.30 MJ. Kg^{-1} DM, Na= 0.02% and Ca=0.16%. In this study higher CP =14.05% was realized but was comparable in DM and NDF. The differences in CP could probably be attributed to soil type, location and quality of the samples collected for laboratory analysis.

4.3.4 Mineral Composition and Tannins Levels in Commonly Used Supplements

4.3.4.1 Mineral Composition

There aren't many studies examining the mineral status of camels and the feedstuffs typically available to them. This knowledge is necessary to increase camel productivity through mineral supplementation (Kuria, 2005). The importance of mineral nutrition for camels is recognized by Rendille herders, who have created standards for identifying mineral deficiency. Insufficient rumen fill, decreased milk production and lack of frothiness, licking of urine and soil, restlessness, bone-biting, and building night enclosures out of woody materials are some additional signs of mineral deficiency (Kuria, 2005).

The exact mineral needs of camels are not fully understood. However, it has been demonstrated that the requirements differ by breed, location, age, gender, nutritional state, and health status (Abdalla et al., 2014). Mineral requirements of camels varied with pregnancy status, lactation stage, and parity (Nagpal et al., 1997). Nagpal et al. (1997) established that camels can tolerate extremely high levels of salt in their diets. The recommended daily intake of calcium is 120-140 gd^{-1}. The Calcium, Phosphorus and tannin content in the commonly used forage supplements are presented in Table 4.3.

Table 4. 3 Mineral composition and tannins of the 3 commonly plant supplements

Species	**Calcium (%)**	**Phosphorous (%)**	**Total tannins (mg/g)**	**Condensed tannins (mg/g)**
Acacia tortilis pods	3.72[a]	0.91[a]	50.10[a]	1.60[b]
Prosopis juliflora pods	1.44[b]	0.75[b]	25.77[b]	9.19[a]
Tinnospora caffra tuber	3.70[a]	0.52[c]	3.04[c]	1.60[b]
SEM	0.079	0.012	0.093	0.047

[abc] means [a, b, c] means values in the same column with different superscripts differ signficantly at $P<0.05$

For all the forage supplements, *Acacia tortilis* was high in calcium (3.72%) and phosphorous (0.91%) compared to *Prosopis juliflora* and *Tinnospora caffra.* The *Acacia tortilis* pods and *Prosopis Juliflora* pods have sufficient Ca and P to meet daily requirements of camel calves based on NRC (2001) recommendations (Ca,1.0% and P,0.7% daily in the diet for camel calves). The most important macro and micro elements of commonly used starter browses, grasses and maize meal which is commonly used as supplements in form of porridge are presented in Table 4.4.

Table 4. 4 Major and minor mineral composition of commonly used browses

Species	P %	K %	Ca %	Mg %	Fe mg/kg	Cu mg/kg	Mn mg/kg	Zn mg/kg
Lannea schweinfurthii	0.36[b]	1.16[g]	0.10[k]	0.22[f]	294.50[h]	3.33[k]	51.70[c]	3.33[k]
Grewia bicolor juss	0.28[c]	1.55[d]	0.39[h]	0.12[i]	225.50[n]	4.77[j]	39.60[g]	23.30[c]
Rhus natalensis krauss	0.32[c]	1.65[c]	0.94[g]	0.66[a]	269.50[j]	9.17[g]	18.30[l]	26.70[b]
Combretum molle	0.32[c]	1.32[e]	1.29[e]	0.07[k]	221.20[o]	10.20[f]	26.70[i]	13.30[e]
Cordia sinensis	0.32[c]	2.44[a]	1.62[d]	0.07[k]	268.70[k]	14.50[cb]	23.30[k]	28.30[a]
Acacia mellifera	0.31[c]	1.58[d]	1.65[d]	0.43[c]	233.50[l]	13.80[cd]	13.30[h]	6.67[i]
Justicia exigua	0.43[a]	2.14[b]	1.73[c]	0.11[i]	230.30[m]	12.80[e]	26.70[i]	6.67[i]
Aristida mutabilis	0.13[f]	0.66[j]	0.09[k]	0.06[lk]	565.80[a]	15.20[b]	43.30[f]	14.70[d]
Cenchrus ciliaris	0.21[ed]	1.19[f]	0.14[kj]	0.07[k]	326.30[f]	15.10[cd]	58.30[b]	11.70[f]
Leptothrium senegalense	0.18[ed]	0.93[i]	0.09[k]	0.31[d]	231.00[m]	10.30[f]	29.70[h]	1.67[l]
Sporobolus spp	0.23[d]	1.22[f]	0.21[j]	0.09[j]	450.30[d]	16.70[a]	164.70[a]	8.33[h]
Salvadora Persica	0.22[d]	2.11[b]	2.27[a]	0.19[g]	301.30[g]	8.33[g]	14.70[m]	9.70[g]
Euphorbia tirucalli	0.32[c]	1.35[e]	0.12[kj]	0.52[b]	470.50[c]	6.67[h]	49.70[d]	9.70[g]
Fiscus benjamina(leaves)	0.21[ed]	1.06[h]	0.32[i]	0.15[h]	556.70[b]	13.80[cd]	48.30[e]	13.30[e]
Fiscus benjamina (barks)	0.16[ed]	0.17[k]	2.13b	0.05[j]	225.50[n]	10.80[f]	11.70[o]	3.33[k]
Posho meal	0.22[ed]	0.12[k]	1.07[f]	0.25[e]	415.00[e]	5.70[i]	6.67[p]	8.33[h]
SEM	0.017	0.009	0.008	0.003	0.119	0.164	0.200	0.141

[a, b, c] means values within a column with different superscripts differ at $P<0.05$

There hasn't been much research on mineral nutrition and metabolism in camels (Pugh, 1996; Faye & Bengoumi, 1997), and findings from studies with cattle are frequently cited as examples (Wilson, 1989). For all the browses species, *Justicia exigua* and *Cordia sinensis* had higher calcium, potassium and phosphorous compared to the other browses. *Cenchrus ciliaris* was high in Manganese. According to NRC (2001) mineral requirements for growing cattle calves are: 0.58% Ca, 0.20% Mg, 0.26% P, 0.70% K, 0.10% Na and 0.15% S. The most crucial macronutrients for developing calves are calcium and phosphorus because they are essential for bone development, muscle function, and energy metabolism (Radwinska & Zarczynska, 2014). Phosphorous was adequate in all the browses, grasses and maize meal while Ca was deficient in *Lannea schweinfurthii, Grewia bicolor, Euphorbia tirucalli, Fiscus benjamina,* grasses and maize meal, thus the need for supplementation for Ca if they are used as ingredients in feed formulation. For the Micro elements the NRC, (2001), requirements of beef cattle, growing calves are given as 40 mg/kg Cu, 50 $mg^{-1}kg$ Iron, 40 mg/kg Mn and 30 $mg^{-1}kg$ of Zn. Iron was sufficient in all the browse forages, grasses and maize meal. Copper and Zn were deficient in all, Mn was deficient in most of the browses, grasses and maize meal. Thus Cu, Mn and Zn require supplementation.

4.3.4.2 Tannins

Tannins stimulate the production of indigestible protein complexes, according to Mergedus et al. (2017), however this differs by animal type. According to D'Mello (1995), condensed tannins have a negative impact on nitrogen digestibility and growth rates. Drying decreases assayable tannin (Tambalo et al., 2023). According to Furstenburg & Van Hoven (1994), among other researchers, African ruminants keep away from browse plants with condensed tannins greater than 60 g/kg DM. The contents of condensed tannins and total tannins, respectively, ranged from 1.60 to 9.19 gkg-1DM and 3.04 to 50.10 gkg-1DM, respectively (Figure 4.1). Condensed tannins, in particular, tend to reduce feed intake, feed digestibility, and nutrient utilization when present in high concentrations (Ondiek et al., 2010). Usually, tannin concentrations greater than 50 gkg^{-1} in diets may negatively affect feed intake which in the long run affects animal performance (Mergedus et al., 2018). Tannins concentrations (Figure 4.1) were within the safe range that would not be harmful to the animals.

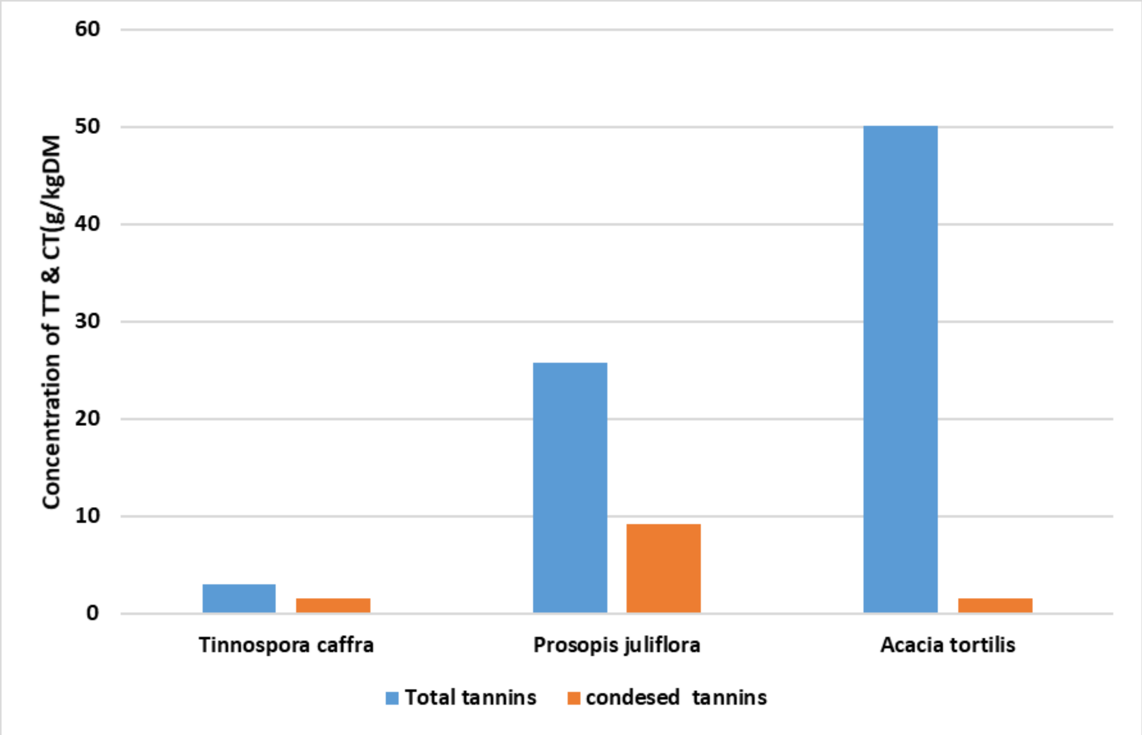


Figure 4. 1 Total tannins (TT) and condensed tannins (CT) contents of commonly used camel calf supplements

4.3.5 Amino Acid Profile of Commonly Used Forage Supplements

Amino acids are only found as building blocks of proteins, where the amino group is attached to the position of the carboxylic acid group (carboxyl group). Chemically, amino groups can bind in other places, but for animal nutrition, only amino acids matter (Pierre et al., 2014). Methionine and lysine are two amino acids that calves don't have enough of (Montano et al., 2016). Methionine and Lysine are the vital amino acids that are most often the first ones to run out in dairy production (NRC, 2001). The most essential amino acids for calves are threonine, methionine, and lysine which affect their health, growth, and ability to have babies (Li et al., 2019). Some amino acids, like lysine and methionine, helped plants grow better (Zinn & Shen, 1998). The amino acid profiles of the 3 commonly used plant supplements are presented in Tables 4.5.

Table 4. 5 Analyzed Amino acid profile of the 3 commonly used supplements

Total Amino acid Concentration (mg/g)			
Amino acid	***T. caffra***	***P. juliflora***	***A. tortilis***
Aspartic acid	3.81	9.73	2.46
Glutamic acid	3.68	14.57	6.26
Serine	2.16	5.48	4.90
Histidine	0.13	1.64	0.27
Glycine	3.42	12.42	3.55
Threonine	0.89	0.60	1.61
Arginine	0.73	0.97	0.44
Alanine	1.82	5.82	2.09
Tyrosine	35.96	62.50	7.34
Valine	0.87	0.45	1.71
Methionine	1.95	3.55	2.72
Phenyl alanine	0.67	1.54	1.95
Isoleucine	1.04	3.34	2.99
Leucine	1.08	3.90	17.91
Lysine	1.19	5.86	5.89

Essential amino acids including valine, threonine, phenylalanine, lysine, leucine, isoleusione, and histidine were present in the three commonly used supplements. The commonly used supplements contained significant amounts of glutamic acid, aspartic acid, glycine, and tyrosine. Lysine and Methionine amino acids were present in *Acacia tortilis* pods, *Prosopis juliflora* pods and *Tinnospora caffra* tubers although not in sufficient quantities and thus require supplementation. Feed formulations that fall short of the minimum requirements for metabolizable amino acids may result in lower weight gains and less efficient use of energy in growing calves. The protein's ability to provide enough essential amino acids for the growth of dairy calves depends on its amino acid composition and protein digestibility (NRC, 2001). Pierre et al. (2014) reported lysine (16 mg/g), methionine (4.7 mg/g), and threonine (10.9 mg/g) as limiting essential amino acids in calves weighing (60-220 kg) gaining 900 g per day. Therefore, methionine, lysine and threonine in analyzed commonly used supplements (Table 4.5) require supplementation to promote growth and development of camel calves.

4.4 Conclusion

The study established that all the forage plant species used by the pastoralists to feed camel calves before releasing for open free-range grazing and common supplements could be used as ingredients for formulation of plant-based milk substitute. For instance, *Grewia bicolor* (24% CP) and *Justicia exigua* (20 % CP) have a potential to provide recommended daily protein requirements for camel calves (20-24 % CP). Browses which have recommended energy above 15 $MJKg^{-1}$ DM to meet daily energy requirement of camel calves for formulation of plant-based milk substitute were *Justicia exigua* (19.3 $MJKg^{-1}$ DM), *Acacia melliffera* (18.1 $MJKg^{-1}$ DM) and *Salvadora persica* (18.4 $MJKg^{-1}$ DM). The *acacia tortilis* pods (Ca 3.72% and P 0.91%) and *Prosopis juliflora* pods (Ca 1.44% and P 0.75%) have sufficient Ca and P to meet daily requirements of camel calves and thus can be recommended to supply the two important minerals for the calves' growth.

CHAPTER FIVE

EFFECTS OF FEEDING COMMERCIAL AND PLANT-BASED MILK SUBSTITUTES ON PERFORMANCE OF CAMEL CALVES IN KENYA

Abstract

The growth of camel calves in pastoral production system is constrained by limited milk feeding. Their survival is important for camel herd growth and milk availability for the camel keepers. Seventy (70) days feeding trial was conducted to determine the nutritive value, dry matter intake, weight gain, feed conversion ratio (FCR), and apparent digestibility coefficients in 15 growing camel calves with a body weight of 102.3 ±1.3 Kg (mean ± SE). The calves were randomly assigned to a plant-based milk substitute (PBMS) and commercial milk substitute (CMS) diets in a randomized complete block design (RCBD) with five replications. The CP content (gkg^{-1}DM) was 181.2 in plant-based milk substitute (PBMS) and 203.1 in commercial milk substitute (CMS). The DM was 93.5 gkg^{-1}DM in CMS and 88.7 gkg^{-1}DM in PBMS. The OM content was 188 gkg^{-1}DM in CMR and 185.1 gkg^{-1}DM in PBMS. The ME contents was higher in CMS (17.4 $MJKg^{-1}$ DM) compared to PBMS (15.4 $MJKg^{-1}$ DM). The NDF and ADF contents of CMS, were lower compared to PBMS 128.0 gkg^{-1}DM and 85.1 gkg^{-1}DM, respectively, while in PBMS was higher 174.8 gkg^{-1}DM and 110.8 gkg^{-1}DM respectively. Forage observation was conducted for the unrestricted calves (Control and CMS) grazing in communal rangelands. The CP (%**)** content of selected preferred forages ranged from 12.61 in *Ximenia americana* and 24.2 in *Grewia bicolor* while ME of 3.69 $MJKg^{-1}$ DM in *Ximenia americana* and 20.46 $MJKg^{-1}$ DM to *Aspilia mossambicensis.* The NDF, ADF and ADL contents in preferred forages were higher in *Cordia sinensis* compared to other forage species. The study revealed that calves on CMS (761.4 kg) and PBMS (566.3 kg) had a higher ADG compared to the calves on pastoral management regime (453.7 kg). The FCR was higher in commercial milk substitute (14.5) compared to plant-based locally formulated milk substitute (13.9). Dry matter intake in PBMS was (2.41 kg/day) and CMS (2.0 kg/day). It is concluded that camel calves on commercial and locally formulated plant-based milk substitute had a higher average daily gain (ADG) compared to control. In addition, feed conversion ratio (FCR) was higher in commercial milk substitute compared to locally formulated plant-based milk substitute.

Key words: ASALs, camel calf, milk substitutes, pastoral production system, performance

5.1 Introduction

The camel (*Camelus dromedarius*) offers pastoral communities with dependable revenue, transportation, and social benefits like prestige and sometimes participation in cultural rites (Guliye et al., 2007). Camel production in the world is gaining prominence due to its climate resilience and lower emission of greenhouse gases (GHG) (Guerouali & Laabouri, 2018). Camel production statistics show that Kenya had 4,721,900 heads of camel (KNBS, 2019), a growth from 2,864,732 in 2012 (FAO, 2021). Kenyan camel farming is becoming increasingly profitable, with meat camels selling for between US$700 and US$800 depending on size (Kuria et al., 2012). The camels supply urban population in northern Kenya and Nairobi with milk throughout the year unlike the cattle which yield little milk during the dry season. For reasons of taste, nutritional value, health, and cultural beliefs such as quenching thirst even when traveling for great distances, camel milk is preferable to milk from other livestock species. Due to these well established and perceived benefits, there is a high demand for camel milk, but the production cannot meet the demand (Noor, 2013). Due to high market prices (US$ 1.2-2.0/litre), there is a tendency to harvest camel milk for sale at the expense of calf growth (Personal observation, 2021).

Without camel calves, a herd cannot expand, and pastoralists would not have access to camel milk. Camel calves are the cornerstone of a camel herd (Kuria et al., 2011). Early-life nutrition for calves at the recommended amount will result in rapid development, early maturation, and the best carcass output (Kertz et al., 2017). Rearing of camel calves in traditional pastoral production system is faced with several constraints such as high pre-weaning calf mortality that emanates from inadequate milk for suckling to calf because of high competition from households for food and income, inadequate forages during dry seasons and diseases among other factors (Ahmed, 2018).

Milk substitutes have been used in cattle calves for survival, faster growth rate and early reproductive maturity (Li, 2023). Although plants that may be used to formulate milk substitute can be found in camel keeping areas, little is known about their effectiveness as substitutes to feeding camel milk in improving camel calf nutrition. This study evaluated the performance of camel calves fed on locally formulated plant-based milk substitute and commercial cow milk substitute.

5.2 Materials and Methods

5.2.1 Site Description

The study was conducted in Karare ward in Marsabit County among the Rendille camel keeping community. Karare is in the southern part of Mt. Marsabit where previously cattle keeping predominated area but currently with climate change, camel production is taking over. Marsabit County is located between longitude 36^o 3'East and 38^o 59' East and latitude 01^o 15' North and 04^o 27' North (Google map, 2021). The County experiences a bimodal rainfall regime with two peaks, in April and November (Marsabit meteorological station, June 2021). The rainfall is low, erratic and unreliable, especially in the low-lying areas, with an annual range of 120-700 mm. The temperatures vary from 23 to 34^{o}C, with the period between January and April being very hot (Martin et al., 1981). Karare ward is in agro-ecological zone IV with deep clay soils and the study area has a diversity of natural forages for camels.

5.2.2 Feed Preparation

The most used forages by camel keepers to feed their camel calves before releasing for free-range grazing and other feed supplements used during dry/drought seasons were identified and used as ingredients to formulate plant-based milk substitute. During the rainy season, leaves of *Grewia bicolor* and *Lannea schweinfurthii* were manually stripped from the trees. *Acacia tortilis* pods and *Balanites aegyptiaca* fruits were also gathered from the collective grazing rangelands in Marsabit County. After harvesting, the leaves, fruits, and pods were spread out on a polythene sheet and allowed to air dry for seven days in the shade to prevent scorching and nutrient loss (Plate 5. 1)

Plate 5. 1 Drying of forage leaves under shade

The ingredients used to prepare the experimental diets were ground to pass through a 4 mm sieve. Whole maize meal, premix and molasses were purchased from reputable suppliers. Plant based milk substitute was formulated and mixed according to NRC, 2001 for formulation of camel calf milk substitute (15.0-20.0 $MJKg^{-}1$ DM, 20-24% CP). All ingredients used in formulation of plant-based milk substitute is what camel keepers use as starter browses before releasing camel calves for free-range browsing or supplements for feeding camel calves in Northern Kenya during dry/drought season. Commercial milk substitute (Afya bora milk substitute) was purchased from Unga Feed Company limited.

5.2.3 Experimental Animals, Feeding Regimes and Management

The experimental procedures were conducted according to the Egerton University Animal Welfare Law, the regulation (EUREC/APP/177/2022) on the protection of animals used for research purposes (Appendix I). Fifteen (15) growing camel calves of about 3 months of age, of Somali breed and their crosses with Rendille and Turkana camels weighing approximately 102.3±1.3 Kg (mean±SE) were randomly assigned to plant-based milk substitute (PBMS**)** and commercial milk substitute (CMS) diets in a completely randomized block design where blocking was done by breed. The calves on PBMS were confined (Plate 5.2) throughout the experimental period and offered PBMS feed at 3% of body weight on daily basis. Calves on CMS were not confined but were fed 1 litre of commercial milk substitute (Plate 5.3) in the morning and 1litre in the evening as a replacement for pastoral camel milk feeding regime estimated to be fed to camel calf by pastoralists daily. One kilogram dry matter of commercial milk substitute was mixed with 6 litres of water to prepare 6 litres of commercial milk substitute as per the manufacturers' recommendation. The daily intake and rejection of PBMS and CMS were recorded on daily basis.

Five unconfined camel calves on pastoral camel milk feeding regime were used as control (browsed during the day). In the control group, calves were allowed to stimulate the dam for milk let down, then milk was extracted from three quarters and one left for the calf to suckle. After about 30 minutes suckling, the calves were separated in the evening until the following day and the same was repeated in the morning and calves grazed the whole day on their own. The camel calves on PBMS were assigned to individual pens (Plate 5.2) with each treatment having 5 replicates. The experimental period was 70 days, consisting of a 14-day adaptation and 56 days' data collection period, respectively. Before the start of the feeding trials, camel calves were weighed, treated against internal and external parasites using ivomectin sub-cutaneous injection. The five confined calves on PBMS were given free access to clean drinking water daily while those on CMS and pastoral milk feeding regime were on watering interval of five days which was according to pastoralists' management regime. Weighing was done weekly, on Tuesdays from 0700 hr to 0830 hr throughout the experimental period. The treatment diets were:

PBMS- Plant based milk substitute

CMS- Commercial milk substitute

CONTROL- Pastoral milk feeding regime

Plate 5. 2 Calves feeding on PBMS Plate **5. 3** Calf feeding on CMS

5.2.4 Grazing Observation and Sampling Methods for Preferred Forages for Camel Calves

Calves that were on pastoral management regime (control) and those on commercial milk substitute were allowed to graze around the homestead. The calves on commercial milk substitute were only provided an equivalent of camel milk what pastoralists "claimed" to feed them on daily basis i.e., which is 2 litre of CMS per day (1 litre in the morning and 1 litre in the evening).

The study used focused group discussions comprising of 12 experienced camel keepers to identify important browses in their environment that camel calves utilized after releasing for free-range browsing. This was followed by field browsing observation of 15 minutes per calf where complete bites made by calf on various forages and parts eaten were recorded. To identify the many forage species that calves browse, the study team was joined by two knowledgeable elders. The moment the calf raised its head to chew, and swallow signified the end of a bite. A total of 25 calves were observed. Five calves per herd were randomly observed from a group of grazing camel calves for a period of 5 days. The grazing observation was done early in the morning between 08:00-10:00 hr, when the calves were actively browsing. The frequencies of browsed forages were done based on number of bites and the top 11 plant species preferred by camel calves were sampled for proximate analysis.

Plate 5. 4 Observing an individual calf browsing

Plate 5. 5 Group of calves browsing

5.2.5 Data Collection

Performance was assessed using weekly weight calculations and daily feed consumption records. Up to the conclusion of the experiment, camel calves were weighed every week after an overnight fast. The initial weights of all the experimental calves were taken at the start of the experiment. This was followed by two weeks' adaptation period to experimental diets (PBMS and CMS). The data was collected for 8 weeks. The rate of weight gain over a week was estimated as the average daily gain (ADG). Every day, feed offered, and refusals were recorded, and the difference between the two was used to determine feed dry matter intake (FDMI). Feed intake was divided with weight increase to get each calf's FCR.

ADG = Weight gain/Period of 1 week.

FCR = Feed Intake/ weight gain

5.2.6 Laboratory Analysis: Proximate and Minerals Assay of Samples

Proximate analysis of preferred browses was analyzed to determine their dry matter (DM), ether extract (EE), crude protein (CP), and ash according to the standard methods of AOAC (2006). The CP was calculated as Kjeldahl Nitrogen (Nx6.25). Acid detergent fibre (ADF) Neutral detergent fiber (NDF) and acid detergent lignin (ADL) were analyzed according to the procedure described by Van Soest et al. (1994). Minerals (macro and micro elements) were determined using atomic absorption spectrophotometry (AAS).

5.2.7 Statistical Analysis

The statistical analysis system (SAS, 2002) version 9.0's General Linear Model approach was used to do an analysis of variance (ANOVA) on the data collected on proximate analysis, feed intake, apparent digestibility, FCR, and average daily gain (ADG). Using Tukey's HSD (Tukey's Honestly Significant Difference Test) at a significance level of 5%, significant means were separated. The linear Model for RCBD used was;

$$Yijk = \mu + \tau i + \beta j + \tau\beta ij + \varepsilon ijk\ i$$

where:

Yijk = observation k in treatment i and block j

μ = the overall mean

τi = the effect of treatment (T1...T3) i

βj = the effect of block (Breed) j

τβij = the interaction effect of treatment i and block j.

εijk = random error

5.3 Results and Discussion

5.3.1 Chemical Composition

The experimental diets included in the feeding trial were developed to meet the nutritional needs of developing camel calves (NRC, 2001) where ME, 15-20 $MJkg^{-1}$ DM, CP, 20 -24%, 10% EE, Ca 1% and P 0.7%). The CP, ME, Ash, EE, DM, OM, NDF and ADF composition were significantly ($P<0.05$) different between the two experimental diets (Table 5.1). The CP content (kg^{-1}DM) was 0.1812 in plant-based milk substitute (PBMS) and 0.2031 in commercial milk substitute (CMS). The ME contents was higher in CMS (17.4 $MJKg^{-1}$ DM) compared to PBMS (15.4 $MJKg^{-1}$ DM). The DM was 93.5 % in CMS and 88.7 % in PBMS. The OM content was 188 gkg^{-1}DM in CMS and 185.6 gkg^{-1}DM in PBMS. The NDF and ADF contents of CMS (128.5 and 85.1 gkg^{-1}DM), were lower compared to PBMS (174.8 gkg^{-1}DM and 110.8 gkg^{-1}DM). The EE contents were higher in CMS (20.1 gkg^{-1}DM) compared to PBMS (15.5 gkg^{-1}DM).

Results of the nutrient composition of experimental diets are presented in Table 5.1.

Table 5. 1 Chemical composition ($gkg^{-1}DM$) and Metabolizable energy ($MJKg^{-1}$ DM) of experimental diets

Parameters	PBMS	CMS	SEM
CP	181.20^{b}	203.10^{a}	0.166
ME	15.40^{b}	17.40^{a}	0.112
Ash (%)	7.30^{b}	9.70^{a}	0.134
EE	15.50^{b}	20.10^{a}	0.183
DM (%)	88.70^{b}	93.50^{a}	0.266
OM	185.10^{b}	188.00^{a}	0.214
NDF	174.80^{a}	128.50^{b}	0.195
ADF	110.80^{a}	85.10^{b}	0.183

CP=crude protein, EE= Ether extract, ME= Metabolisable energy, DM=dry matter, OM=organic matter, ADF= Acid detergent fibre, NDF=Neutral detergent fibre.$^{a,\,b}$ means in a row with different superscripts are significantly different at $P<0.05$

Kehoe et al. (2007) recommended 22% CP and 15.6 % fat in dairy calves' milk substitute while Silper et al. (2014) reported 94.6% DM; 20.7% CP and 17.0 % Fat. The results of this study revealed that PBMS was lower in CP (18%) while that of CMS was similar to what other authors reported. The shortfall of 2% CP in PBMS may have resulted from quality of local feed ingredients used to constitute the PBMS; thus, need to set upper limit of CP (24%) requirement in future formulations to avoid such deficit while also ensuring use of high-quality local feed ingredients. The energy content of the two experimental diets was within the recommended range by NRC (2001). The CP (181.2 $gkg^{-1}DM$) and energy (15.4 $MJKg^{-1}$ DM) contents of plant-based milk substitute using locally available feed ingredients indicates there is a potential of utilizing locally available feed ingredients for constituting plant-based milk substitute for camel calves in ASALs of Kenya where feeds are the major constraints in camel calf rearing.

In pastoral camel production systems, where milk is mostly consumed at home and sold to generate cash, competition for milk is also high. A cost-effective milk substitute can increase both the performance of growing calves and farm profitability (Kehoe et al., 2007). This confirms that deprivation of milk to the calves is a reality in pastoral camel production systems thus need for camel calf supplementation to address nutrition deficit. Plant based milk substitute is usually less expensive compared to milk-based commercial milk substitutes thus affordable for camel keepers.

Results of the major and minor mineral elements profile of experimental diets are presented in Table 5.2.

Table 5. 2 Major (%) and trace (mg/kg) elements composistion in plant-based and commercial milk substitute

Mineral elements	PBMS	CMS	SEM
Major elements			
Phosphorus	0.12^{b}	0.65^{a}	0.00745
Potassium	1.58^{a}	0.99^{b}	0.00577
Calcium	0.78^{b}	1.58^{a}	0.00745
Magnesium	0.32^{a}	0.11^{b}	0.00746
Trace elements			
Iron	547^{a}	105^{b}	0.57735
Copper	1.67^{b}	2.67^{a}	0.00471
Manganese	164^{a}	65.3^{b}	0.40893
Zinc	49.0^{b}	75.3^{a}	0.14402

PBMS- Plant based milk substitute, CMS- Commercial milk substitute.

^{a,b} means in a column with different superscripts are different at $P<0.05$

Minerals make up a very small fraction of the daily diets of calves and are required as a very minor portion of dietary components. Nonetheless, they play a crucial role in several metabolic processes, including bone growth, immunological response, muscular contractions, and nervous system activity (Weyh et al., 2022). Calves' growth can be compromised if they have a deficiency of minerals. Although camels are classified as pseudo ruminants, it has been previously reported that they are fairly similar to cattle in terms of nutrition (Mukasa-Mugerwa, 1981). According to Sharma et al. (2020), diets of young calves should have a crude protein of 20-28%, fat (10-22%), crude fiber (1-2 %), calcium (1%), phosphorus (0.7%), magnesium (0.07%) and iron (100 mg/kg). In the commercial milk substitute, Ca

(1.58), P (0.99), Fe (105) and Mg (0.11) were all within the acceptable range reported by other authors.

In the case of plant-based milk substitute, P (0.99), Fe (547) and Mg (0.32) were also within the recommended range apart from Ca which was less by 0.03% and thus require supplementation to meet daily calf requirements. According to NRC (2000), growing cattle require potassium 0.60%, zinc 75-100 mg/kg, Copper 10 mg/kg and Manganese 20 mg/kg. Potassium and manganese levels in both diets were within the recommended levels. Zinc in the commercial milk substitute was within the recommended range but lower for plant-based milk substitute, hence required supplementation. Copper levels in the two diets were lower than the recommended levels, thus required supplementation.

5.3.2 Digestibility of PBMS and CMS

The two-stage Tilley and Terry (1963) laboratory technique (incubation with rumen fluid followed by acid-pepsin digestion) was used to determine the *in vitro* organic matter digestibility of dried forages. It involved, first incubation with rumen liquor and then with acid pepsin solution to simulate digestion in the rumen and abomasum respectively. Using herbage samples of known *in-vitro* digestibility (Y), the regression equation: Y = 0.99X - 1.01 (SE=±171.803), the *in vitro* digestibilities of CMS and PBMS were calculated, where X = *in vitro* digestibility, y=82.85x.

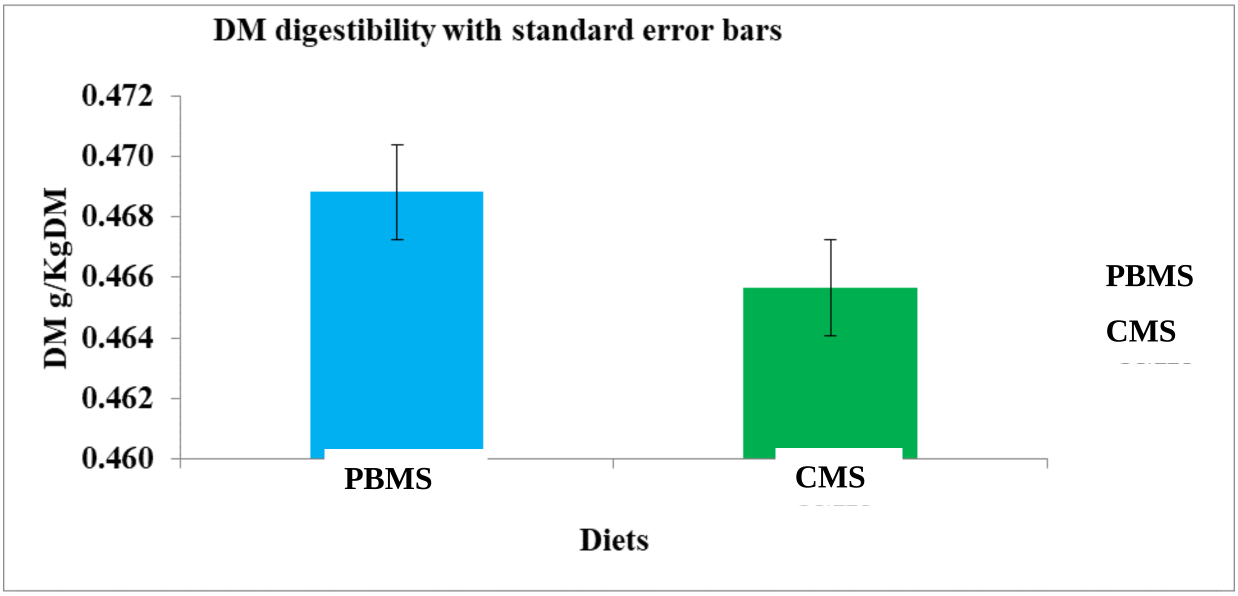


Figure 5. 1 DM digestibility with standard error bars for PBMSand CMS

The *in-vitro* digestibility characteristics of the experimental diets did not vary widely among the CMS and PBMS samples. The total DM digestibility (g/Kg) in Figure 5.2 show PBMS (46.9 %) was higher compared to CMS (46.6 %) during the trial. The availability of high fermentable carbohydrates necessary for microbial growth and the accessibility of feed to microbial enzymes may be the cause of the greater rate of digestibility in PBMS (Getachew et al., 2000).

5.3.3 Nutritive Value for Most Preferred Forages

The nutritive values of the top 11 most preferred forages: *Acacia brevispica, Aspilia mossambicensis, Harrisonia abyssinica, Erucastrum arabicum, Duosperma eremophilum, Securinega virosa, Cordia sinensis, Ximenia americana, Rhus natalensis, Lannea schweinfurthii and Grewia bicolor* from northern rangelands were assessed for their potential as protein, energy, and mineral sources for grazing camel calves (Table 5.3 and 5.4). The ultimate determinant of the nutritional value of fodder for cattle is its effect on animal performance. Consequently, the quality of fodder is evaluated based on milk production, weight growth, reproductive efficiency, and other animal responses (Madison, 2016). For camel pastoralists and agro-pastoralists, native tree and shrub species are important sources of feed (Derero & Kitaw, 2018). The three most important components for the growth and development of calves are water, energy, and protein. Although necessary, vitamins, minerals, and fiber also play a supporting role in health (Thomas, 2016).

The CP (%**)** content of the preferred forages ranged from 12.61 gkg^{-1}DM in *Ximenia americana* and 24.2 gkg^{-}1DM to *Grewia bicolor*. The comparatively high CP content of the eleven selected forages showed the likely contribution of rangelands forages as protein sources. They are therefore important feed resources for utilization for camel calves' nutrition in the arid and semi-arid lands (ASALs). Kemboi et al. (2021a) evaluated the nutritive value of local browses from drylands of Kenya and reported similar result on crude protein (172.3 gkg^{-1}DM) especially in *Acacia brevispica.* The ME content ranged from 3.69 $MJKg^{-1}$ DM in *Ximenia americana* and 20.46 $MJKg^{-1}$ DM in *Aspilia mossambicensis. Aspilia mossambicensis, Harrisonia abyssinica, Erucastrum arabicum* had ME of (15.0-20.0 $MJKg^{-}$1 DM) that is adequate to meet daily requirement of calves (NRC, 2001).

Table 5. 3 Proximate compositions of preferred forages in rangelands for camel calves

Sample	**DM%**	**Ash%**	**CP%**	**NDF%**	**ADF%**	**ADL%**	**EE (gkg-1 DM)**	**ME (MJKg-1 DM)**
Acacia brevispica	90.79[e]	6.03[i]	17.30[e]	47.53[d]	30.77[c]	10.00[g]	13.16[d]	4.87[i]
Aspilia mossambicensis	89.48[h]	19.36[a]	16.04[g]	30.99[i]	24.47[d]	15.56[d]	18.81[a]	20.46[a]
Harrisonia abyssinica	91.19[c]	7.20[f]	16.84[f]	33.84[h]	30.81[c]	14.97[e]	13.18[d]	17.03[b]
Erucastrum arabicum	90.65[e]	14.01[b]	14.77[i]	43.37[f]	35.90[b]	11.45[f]	15.87[b]	16.91[b]
Duosperma eremophilum	89.66[g]	4.52[j]	21.62[b]	36.44[g]	20.44[e]	10.01[g]	15.63[b]	13.33[f]
Securnega virosa	90.36[f]	10.32[d]	17.58[c]	33.69[h]	30.50[c]	8.24[h]	12.87[e]	13.70[e]
Cordia sinensis	91.92[b]	12.93[c]	15.57[h]	52.56[b]	55.24[a]	48.43[a]	11.70[e]	12.88[g]
Ximenia Americana	90.93[d]	8.66[e]	12.61[j]	56.77[a]	32.32[c]	22.54[b]	13.96[c]	3.69[j]
Rhus natalensis	90.28[f]	6.47[h]	12.36[k]	49.91[c]	36.33[b]	13.83[d]	13.42[d]	9.03[h]
Lannea schweinfurthii	90.8[e]	6.9[g]	17.4[d]	47.2[e]	36.2[b]	20.3[c]	11.2[f]	14.1[d]
Grewia bicolor	92.9[a]	8.76[e]	24.2[a]	47.2[e]	30.8[c]	10.9[g]	8.9[g]	14.7[c]
SEM	0.0267	0.0267	0.0176	0.0317	0.0374	0.0234	0.0271	0.0284

ADF= Acid detergent fibre, NDF=Neutral detergent fibre, CP=Crude protein, DM=Dry matter, EE= Ether extract, OM=Organic matter, ME= Metabolisable energy, SEM=Standard error of mean, [a, b, c, d, e, f, g, h, i] mean values within a column with different superscripts differ at $P<0.05$

Without additional fat, typical ruminant diets typically contain only a little amount of fat, or approximately 2.5% of dry matter. To reach a total ration fat concentration of 6% of dry matter, more fats may be supplied. Fats in ruminant diets can cause unfavorable metabolic changes in the animal as well as the rumen microbial population. Reduced fiber digestion, dyspepsia, unhealthy rumen conditions, and a decrease in milk fat concentration are some of these impacts (Thomas, 2016). In calf nutrition, 10-22% of fat is recommended for inclusion in calf diets (Sharma, 2020). The fat contents in preferred forages for the camel calves ranged from 8.9 to 18.81 gkg^{-1}DM. Apart from *Grewia bicolor,* all other forage species had fat content adequate to meet daily requirement of camel calves.

Dry matter is the substance that remains after water has been removed, while moisture content indicates how much water is in the feed item. The DM portion of feeds contains the nutrients the animal needs for maintenance, growth, pregnancy, and lactation. The DM contents of the forages ranged 89.48 to 92.9%. A calf consumes 1.6% to 1.8% of her body weight on daily basis **(**Thomas, 2016).

The ADF is frequently used to predict feed energy content. ADF is a reliable indication of feed quality, similar to NDF; higher levels within a meal imply lower quality feed. NDF content below 40% and above 50% would be regarded as good and poor, respectively, for legume forages. NDF 50% for grass forages would be regarded as high quality, and > 60% as lesser value (Rouquette et al., 2020). The NDF, ADF and ADL contents were higher in *Cordia sinensis* compared to other forage species which is an indicator of poor feed quality and most of other forages were within the recommended range of good quality forages. Particularly for Cordia sinensis, NDF and ADF values were comparable to those published by Deng et al. (2017). The ash content in the forages ranged from 6.03% - 19.36%. Ash is the total mineral content of a forage or diet. High ash content of feeds may dilute the amount of nutrients available to the animal.

5.3.4 Mineral Composition of Most Preferred Forages

Mineral composition of the most preferred forages in rangelands for camel calves are presented in Table 5.4. All the forages were deficient in P (0.7%), but adequate in K (0.6%). *Acacia brevispica, Aspilia mossambicensis, Rhus natalensis* and *Lannea schweinfurthii* had low levels of Ca (1%), *Ximenia Americana* had Fe (100 mg/kg) within the recommended range. Only *Harrisonia abyssinica* had the recommended levels of Cu (10 mg/kg). *Harrisonia abyssinica* and *Securinega virosa* had Mn content (20 mg/kg**)** within the recommended levels and all forages were deficient in Zn. These results agree with the results of Sagala (2020) and Ondiek et al. (2010) on the mineral content especially of *Acacia brevispica.* Results of this study are also similar to the findings reported by Deng et al. (2017) and Kemboi et al. (2021b) especially on macro elements in *Cordia sinensis* and *A. brevispica.*

Table 5. 4 Mineral composition of most preferred forages in rangelands for camel calves in peri-urban camel production system in Karare area in Marsabit County

Sample	**P**	**K**	**Ca**	**Mg**	**Fe**	**Cu**	**Mn**	**Zn**
	(%)				**($Mg^{-1}kg$)**			
Acacia brevispica	0.29^{e}	0.66^{k}	0.36^{h}	0.08^{h}	23.5^{i}	1.33^{f}	1.17^{j}	5.00^{k}
Aspilia mossambicensis	0.34^{c}	2.11^{b}	0.89^{g}	0.14^{g}	3.83^{j}	8.17^{b}	13.2^{c}	6.83^{i}
Harrisonia abyssinica	0.29^{e}	1.75^{g}	1.73^{c}	0.30^{c}	83.8^{c}	11.2^{a}	21.8^{b}	14.2^{c}
Erucastrum arabicum	0.34^{c}	2.17^{a}	1.51^{d}	0.34^{b}	41.5^{g}	1.17^{g}	2.00^{g}	18.5^{b}
Duosperma eremophilum	0.37^{b}	2.04^{c}	2.40^{a}	0.67^{a}	56.3^{e}	0.83^{h}	3.50^{f}	10.0^{h}
Securnega virosa	0.26^{g}	1.78^{f}	1.91^{b}	0.28^{d}	98.0^{b}	1.17^{g}	56.8^{a}	5.17^{j}
Cordia sinensis	0.39^{a}	1.98^{e}	1.29^{e}	0.14^{g}	53.7^{f}	2.00^{c}	11.7^{d}	20.0^{a}
Ximenia americana	0.29^{f}	2.01^{d}	1.49^{d}	0.31^{c}	105.5^{a}	1.83^{d}	1.50^{i}	13.3^{d}
Rhus natalensis	0.32^{d}	1.42^{h}	0.33^{i}	0.16^{f}	31.2^{h}	1.50^{e}	0.83^{k}	11.3^{f}
Lannea schweinfurthii	0.32^{d}	0.93^{i}	0.94^{f}	0.14^{g}	77.5^{d}	0.83^{h}	1.67^{h}	10.3^{g}
Grewia bicolor	0.23^{f}	0.89^{j}	1.28^{e}	0.25^{e}	83.8^{c}	1.17^{g}	4.50^{e}	13.0^{e}
SEM	0.0031	0.0032	0.0101	0.0032	0.1391	0.0169	0.0272	0.0289

SEM=Standard error of mean, $^{a, b,c,d,e, f,g,h,i}$ mean values within a column with different superscripts differ at $P<0.05$

5.3.5 *In-vitro* DM Digestibility of the Preferred Forage Species

Among the nine forage species, there were significant differences in the preferred forage species' *in-vitro* DM digestibility characteristics. The total DM digestibility (g/Kg) presented in Figure 5.3 show variations in the digestibility potential, with *Acacia brevispica* (839 g/kg DM) being the highest and *Duosperma eremophilum* (283 g/kg DM) being the lowest. *Duosperma eremophilum* ranked the lowest in *in-vitro* digestibility potential; this could be due to the high level of tannins and smell which affect nutrient utilization by the microbes (Kemboi et al., 2017). The variation in gas production among the indigenous browse species might be due to the quantity of substrate fermented (Osuga et al., 2006). The *in vitro* DM digestibility (g/Kg) shows that the majority of chosen forage species may contain potentially degradable nutrients, which emphasizes the significance of these forages as sources of nutrition for camel production.

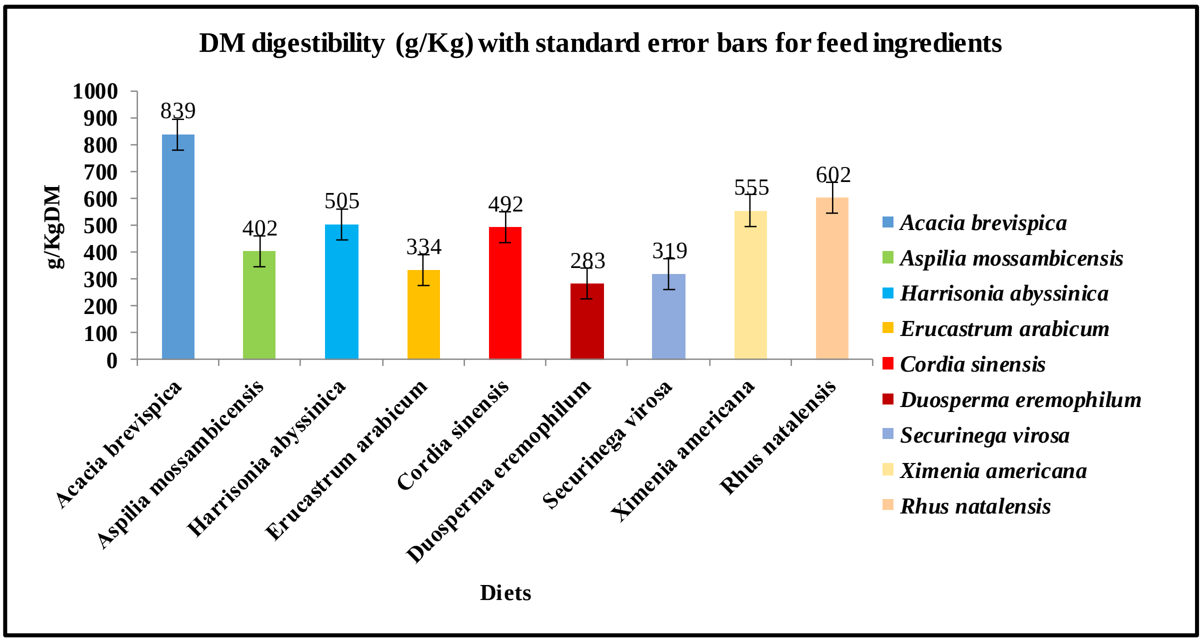


Figure 5. 2 Tilley and Terry DM digestibility with standard error bars for most preferred forage

5.3.6 Feed Intake, Average Daily Weight Gains, Feed Conversion Ratio and Apparent Nutrient Digestibility

Average daily weight gains, feed intake, and apparent nutrient digestibility of camel calves fed on commercial and plant-based locally milk substitute and a control are presented in Table 5.5.

Table 5. 5 Dry matter feed intake (kg/day), average daily gains (kg) and apparent nutrient digestibility (g/kg DM**)** of camel calves fed on commercial and plant-based locally milk substitute and a control

Parameters	**CONTROL**	**PBMS**	**CMS**	**SEM**
DM Intake	ND	2.41^{a}	2.0^{a}	0.0243
ADG	0.4537^{c}	0.5663^{b}	0.7614^{a}	0.3095
Initial weight(kg)	111.31^{a}	100.28^{a}	95.44^{b}	
				1.044
Final weight(kg)				
	136.66^{b}	132.88^{b}	139.38^{a}	1.042
FCR				
	ND	13.9^{b}	14.5^{a}	0.155
Digestibility coefficients				
CP	117.8^{a}	95.1^{c}	107.9^{b}	0.195
DM	921.1^{b}	932.7^{a}	893.9^{c}	0.440
ADF	98.7^{a}	96.4^{b}	92.3^{c}	0.701
NDF	178.7^{a}	153.4^{b}	141.3^{c}	0.142

NDF=Neutral detergent fibre, ADF= Acid detergent fibre, CP=crude protein, DM=dry matter, ADG=average daily gains, FCR=feed conversion ratio, SEM=Standard error of mean,
a, b, c, d, mean values within a column with different superscripts differ at $p<0.05$

Calves on commercial and plant-based locally formulated milk substitute had a higher ADG compared to control (Table 5.5 and Figure 5.3) perhaps as a result of the increased dry matter intake attributed to the growing camel calves getting sufficient nutrients for increase in body weight. The two diets resulted in higher weight gains when compared with pastoral management regime (Table 5.5). This was consistent with the findings of Jaeger et al. (2020), who found that newborn dairy calves fed a milk substitute with a 20% crude protein concentration gained an average of 0.77 and 0.78 kg/d per day. Results on camel calf performance showed that nutritional interventions had a substantial ($P>0.05$) impact on how well the study's growing camel calves performed in terms of growth. There were no significant interactions between block (breed) and the three experimental diets on DM intake and ADG ($P>0.05$). All the calves had positive weight gains. Apparent digestibility coefficient of the nutrients ($g/kg^{-1}DM$**)** increased significantly ($P< 0.05$) in Control and PBMS compared to calves on CMS which could be because of less milk suckling among the controls and high dry matter intake among calves on plant-based milk substitute. Calves on control seemed to browse more aggressively than the calf on CMS due to the limited milk suckling. In addition, calves on CMS seem to have met their daily requirements thus browsed less during the day. Dry matter DM) intake (kg/day) in calves fed on PBMS compared to those fed on CMS was not statically different. Estimates of nutrient availability in feedstuffs are provided by apparent digestibility coefficient, which is used to choose ingredients that improve nutritional value (Fagbenro, 1999).

The changes in chemical composition of foods, which are influenced by their processing or place of origin, may help to explain differences in apparent digestibility coefficients of substances (Köprücü & zdemir, 2005). Feed conversion ratio (FCR), which is the proportion of feed intake to live-weight growth, is the most often used indicator of feed efficiency (Lamb & Maddock, 2009). FCR was higher in commercial milk substitute compared to plant-based locally formulated in milk substitute. Lower FCR value in PBMS indicates higher efficiency compared to CMS. It is particularly desirable for perfect camel production to grow camels that convert quickly (have a reduced FCR).

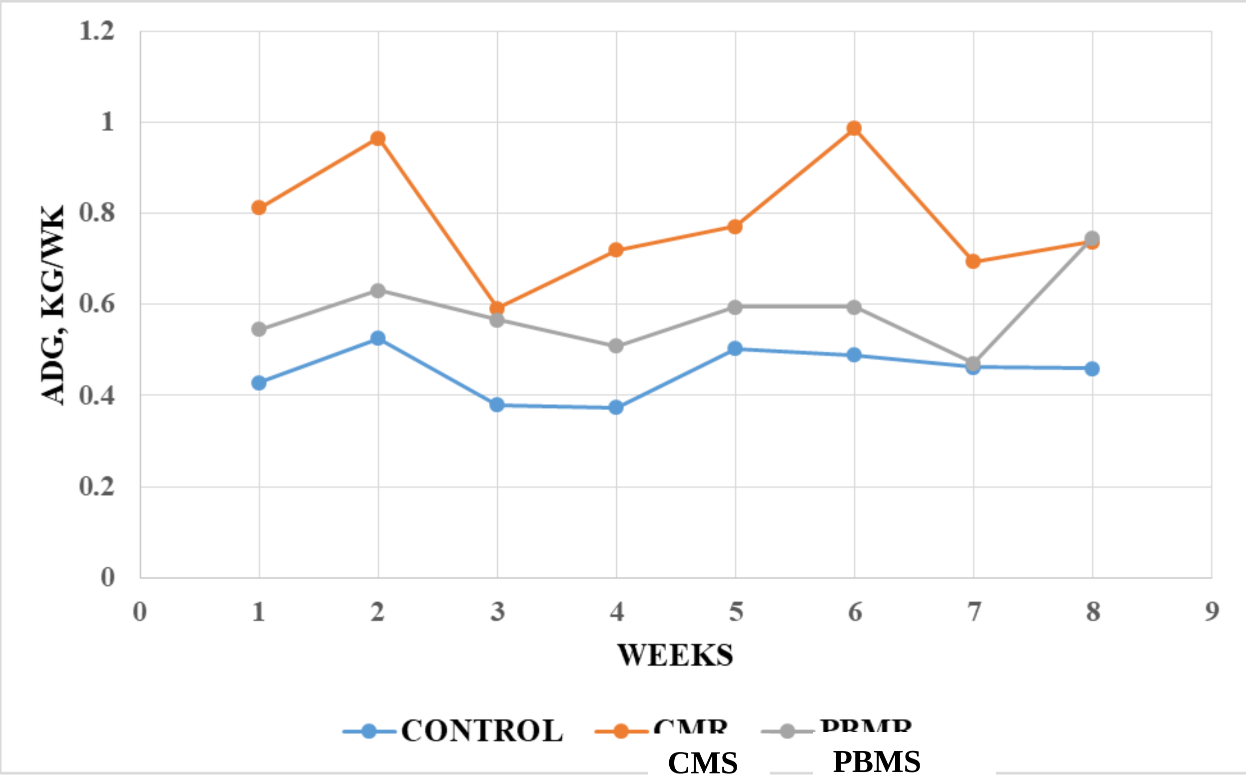


Figure 5. 3 Effects of experimental diets on weekly average daily gains of growing camel calves

5.4 Conclusion

The study established that dry matter intake (kg/day) in calves fed on PBMS compared to those fed on CMS were not statistically different. The study further establisehd that camels on commercial and locally formulated plant based milk substitute had a higher average daily gain (ADG) compared to control. Also, as compared to locally developed plant-based milk substitute, commercial milk substitute had a greater feed conversion ratio (FCR).

CHAPTER SIX

ECONOMIC ANALYSIS OF FEEDING LOCALLY FORMULATED AND COMMERCIAL MILK SUBSTITUTE TO CAMEL CALVES IN THE ARID AND SEMI-ARID LANDS OF KENYA

Abstract

Camel herd expansion has enormous potential, but calf mortality is still a problem for Kenya's pastoral camel keepers. This is a result of, among other things, competition among calves for milk, domestic consumption, and trade. The nutrition and household income of camel calves could be improved by switching to commercial milk substitute (CMS) and locally made Plant Based Milk Substitute (PBMS) instead of camel milk feeding. Ten camel calves were randomly assigned to 70 days of each of two different diets, PBMS and CMS, with five calves in each diet. A 5 calves control group receiving pastoral milk feedings was also observed. While calves on PBMS were confined for the duration of the experiment, calves on CMS were not, but were instead given 2 litres of CMS per day, 1 liter each in the morning and evening. Every week, the calves were all weighed. To determine whether employing PBMS and CMS as an alternative to camel milk is financially feasible, this study used a Cost Benefit Analysis (CBA). To demonstrate the advantages of PBMS over CMS, costs such as milk substitute, labor, and veterinary medications were recorded and extrapolated for 10 years. Afterwards, it was determined whether each feeding regime was financially viable using the financial analytical tool known as Net Present Values (NPV). The findings demonstrated that utilizing PBMS to feed calves is more cost-effective than using CMS or a pastoral feeding regimen. The study suggests pastoral camel keepers promote PBMS to increase household income and the nutritional condition of suckling camel calves.

Key words: benefit cost ratio, camel calves, cost-benefit analysis, milk substitute, net present value

6.1 Introduction

Camels play a significant role in food and nutrition security because their milk and meat are rich in important nutrients for human health (Elhadi & Wasonga, 2015; Guliye et al., 2007; Hussen & Schuberth, 2021). Compared to other ruminants, camel milk is richer in minerals such as potassium, sodium, iron, copper, magnesium, zinc, vitamin C and important fatty acids, proteins and enzymes, making it an important healthy option (Abrhaley & Leta, 2018). Many pastoralists in the arid and semi-arid regions (ASALs) rely heavily on the production of camels for their livelihoods (Faraz et al., 2019b; Noor et al., 2013). The global demand for camel meat and milk is slowly but steadily rising owing to increased awareness on their nutritional and medicinal values (Abrhaley & Leta, 2018; Badawy et al., 2018; Faraz et al., 2019a; Mohammadabadi, 2021). The similarity of camel milk to human milk also increases its potential for use in infant nutrition (Berhe et al., 2017; Desouky & Salama, 2021). In the last decade, production of camel meat has increased by 40% while that of milk has been at 5% (FAO, 2021). Camel production statistics estimates show that Kenya had 4,721,900 heads of camel (KNBS, 2019), a growth from 2,864,732 in 2012 (FAO, 2021). Kenya comes in fourth in terms of camel population, after Chad (8,276,416), Somalia (7,243, 792) and Sudan (4,895,000) (FAO, 2021).

Feeding camel calf with milk substitute is a critical technology in improving productivity of the camel herds through supporting the lives of the vulnerable calves (Kertz et al., 2017). By unraveling the costs and benefits that accrue to this technology, a farmer can invest in the technology with the full knowledge of what to expect. Cost-benefit analysis presents a simple way of analyzing a technology. It shows financial and economic viability of an investment thereby enabling one to choose between options (Gittinger, 1982; Karimi et al., 2022). Economic analysis has been applied by various scholars in different fields. To compare feeding regimes, Kaygisiz et al. (2007) compared piglets fed with sunflower seed meal (SFM) diet or soybean meal (SBM) diets, while the control groups were fed food wastes. Using NPV and sensitivity analysis, Pillars et al. (2009) calculated the costs and gains of implementing disease control measures on contaminated dairy farms. To clearly show the viability of adopting such a technology whose full impacts may take a longer time to be realized, NPV tool is used to discount future values of the investments (Gittinger, 1982).

Research into the costs and benefits of using substitutes formulated from locally available forages and other feeds ingredients is limited. The main objective of this study was to fill this gap in knowledge and provide information on costs and benefits of alternative feeding regimes for camel calves in ASALs of Kenya. This involved use of milk substitutes formulated using locally available feed ingredients compared to commercial cow calf milk substitutes and conventional pastoral milk feeding regime and management practices for suckling camel calves.

6.2 Materials and Methods

6.2.1 Study Area

This study was conducted in Marsabit County, Karare ward situated between latitude 02^{o} 45^{o} North and 04^{o} 27^{o} North and longitude 37^{o} 57^{o} East and 39^{o} 21^{o} East. The County is classed as an Arid and Semi-Arid Land because it is located in four major biological zones: sub-humid, semi-arid (mostly woodlands), arid (primarily bushlands), and highly arid (scrublands) (ASAL). Rainfall is bimodal, with long rains occurring between April and May and short rains occurring between November and December. These rainfalls often produce 200 mm to 1000 mm of precipitation. The main economic activity is livestock keeping and cross border trade. In ASALs of Kenya, livestock contributes over 90 percent of employment and household incomes (Nyariki & Amwata, 2019). Karare ward was purposively selected due to presence of enough camel calves for the feeding trials in one herd and being in a peri-urban camel production system, where camel milk is sold in Marsabit town on daily basis. Peri-urban production was considered because of limited camel herd mobility which allowed for smooth running of the field experiments.

6.2.2 Data Collection

This study combined qualitative and quantitative data. First, key informant interviews were conducted to gain familiarity with the pastoral systems in the area of interest. The household survey was conducted in Karare ward, which has an estimated 886 households (KNBS, 2019). To obtain the sample, the formula for finite populations was adopted (Kothari, 2004).

$$n = \frac{z^2.p.q.N}{e^2(N-1)+z^2.p.q}$$

Where, n is the size of the sample and N is the size of the population, e is the acceptable error assumed to be 5 percent, z is the standard variate at a 95 percent confidence level, p is the sample proportion which is assumed to be 95 percent and $q = 1 - p$

$$67\ households = \frac{1.96^2.(0.95)(0.05)884}{0.05^2(884-1) + 1.96^2(0.95)(0.05)}$$

An additional 13 households were added to the required sample to cater for any gaps during the interviews adding up to 80 household units.

Subsequently, a cross-sectional survey was conducted on the pastoral households to collect primary data using semi- structured and pre-tested questionnaires. These questionnaires captured cost structures and socio-economic characteristics of camel keepers in the study areas. Focus group discussions (FGDs) comprising of 12 persons per group were also conducted in the study site to gain a deeper understanding of camel production and calf mortality. Local feed resources used for calf supplementation by pastoralists during the dry and wet seasons were identified. Preferred forages used for supplementation for calves while in pen confinement were also identified and ranked.

The top 10 plant species were then sampled for laboratory analysis. Proximate composition of the samples was done to determine dry matter, crude protein and minerals. The best plants in terms of nutrients, such as protein, energy and minerals were used as ingredients of plant-based milk substitute. The following ingredients were used to constitute plant-based milk substitute; *Acacia tortillis* pods, *balanites aegyptiaca* fruits, *Grewia bicolor leaves, Lannea schweinfurthii* leaves, maize meal, premix (minerals and vitamins), and molasses. Fifteen growing camel calves, 3 months old, of Somali breed and their crosses with Rendille and Turkana camels weighing approximately 102.3 Kg ±1.3 (mean±SE) from Marsabit County were randomly assigned to plant-based milk substitute (PBMS**)** and commercial milk substitute (CMS) from Unga feeds limited (Afya bora milk substitute) diets in a completely randomized block design. Five unconfined camel calves on pastoral camel milk feeding regime were used as control.

6.2.3 Estimation of Cost and Benefit

Cost benefit analysis aims at providing a consistent way of evaluating alternatives for the purpose of decision making (Pillars *et al*., 2009). The cost of each component used in the formulation of milk substitutes was estimated and quantified using local currency. The cost of CMR was valued at local retail market price while the cost of camel milk was valued at farm gate price. The value of a camel calf was estimated at the market value. Further economic analysis was also done using NPV, BCR and Sensitivity Analysis. NPV was estimated using the formula:

$$NPV = \frac{C_t}{(1+r)^t}$$

where *NPV* is the Net Present Value, C_t is the net cashflow at time *t, r* is the discounting rate which varies depending on the market environment and *t* is the time of cash flow (Gittinger, 1982; Khan, 1993). The BCR is calculated by finding the ratio between discounted total benefits and discounted total costs. A positive NPV indicates that it is worth investing in the technology and vice-versa. Further to this, different scenarios were modeled to represent different feeding regimes and situations that inform a farmer on risks that they may expect in the investment (Kashangaki & Erickson, 2018). For camel milk substitutes, data on costs and benefits derived from three alternatives which included i) the pastoral system ii) use of commercial substitute and iii) a locally formulated milk substitute were collected. These would provide clear and plausible alternatives that farmers can adopt in improving the nutrition of camel calves. Labor costs for this study included the cost of collecting locally available materials used in formulating PBMS, feeding and taking care of the calves.

This study focused on three feeding regimes; firstly, PBMS was formulated using locally available materials collected from the local environment, with some additional bought ingredients. These included *Acacia tortilis* pods, *Balanites aegyptiaca* fruits, *Grewia bicolor* leaves, *Lannea schweinfurthii* leaves, maize meal, premix, and molasses. *Acacia tortilis* pods have been shown to have a positive effect on lactating camels by increasing available milk and calf weight (Sagala et al., 2021). Secondly, CMS is an already formulated commercial substitute, readily available in the local agro-vet shops. Two kilograms of the CMS diluted in 12 litres of water is enough to feed 5 camel calves per day. The average cost per kilogram of CMS is KES 87.00. Lastly, the pastoral system, which was the control for this study, did not incur substitute costs because the calf generally suckled an estimated two litres from the dam daily till it is weaned.

The commencement of feeding with CMS will be done after 7 days of colostrum feeding or later till the calf is weaned (6 months). Estimation for the period the calf is fed on substitute is 183 days. During this period the camel calf is fed on PBMS or CMS, and the benefit received is the amount of milk saved by the household.

6.3 Results and Discussion

6.3.1 Cost of Camel Milk Substitutes

One of the most important aspects of cost-effectiveness in feeding animals is affordability of ingredients used in formulating the feeds. This is largely because feeds account for a substantial proportion of total costs in livestock management. In Africa, dairy feed costs could contribute to 50-70% of total milk production costs (Alqaisi *et al*., 2011). In Kenya, camels are grazed in communal lands, meaning that herding costs are higher and may contribute to over 60% of camel production costs (Kuria *et al*., 2016). Milk substitutes are important to the well-being of the camel calves and to the sustainability of the herd in households where camel milk is used for home consumption and trade. The ingredient composition and cost of substitutes are presented in (Table 6.1).

Table 6. 1 Composition and Cost of Local Milk Substitute (PBMS)

Ingredients	Quantity (Kg)	Unit price	Total cost (KES)
Acacia tortilis pods	224	5.90	1,328.00
Maize meal	140	28.00	3,920.00
Premix	10	250.00	2,500.00
Molasses	120	15.00	1,800.00
Grewia bicolor	434	5.90	2,574.00
Lannea schweinfurthii	420	5.90	2,491.00
Balanites fruits	140	5.90	830.00
Total	**1,488**	**10.37**	**15443.00**

From birth to three weeks, pre-ruminant calves are often fed liquid nutrition in the form of whole milk or milk substitutes produced from milk byproducts. At a later age, a large amount of milk proteins can be substituted with other protein sources of plant origin in milk substitute formulations. After three weeks, rumen fermentation commences, and then higher digestibility prepared solid meals can be administered as an alternative to whole milk (Kertz et al., 1984). Ingredients in milk substitutes can come from a variety of sources, usually plants or milk. The later formulas are less expensive, but milk proteins are substantially easier for newborn calves to digest.

In the pastoral systems, where this study is based, the communities tap onto free resources available in the environment. These resources include communal lands, pastures, water and in this case the natural occurring ingredients for the PBMS. These resources are not easy to cost due to the nomadic nature of pastoral management systems. Table 6.2 depicts a case scenario for costing PBMS assuming no labour costs are incurred to collect the ingredients.

Table 6. 2 Composition of milk substitute assuming zero labour costs

Ingredients	Quantity (Kg)	Unit price	Total cost (KES)
Acacia tortilis pods	224	0	0
Maize meal	140	28	3,920
Premix	10	250	2,500
Molasses	120	15	1,800
Grewia bicolor	434	0	0
Lannea schweinfurthii	420	0	0
Balanites fruits	140	0	0
Total	**1,488**	**5.5**	**8,220**

The table above shows that the cost of PBMS without labour costs is almost halved. This assumption is based on the practice that herders collect these ingredients as they manage the camels on a daily basis. This cost is covered in the monthly labor cost for the herders.

6.3.2 Labour Costs

For CMS, labor costs constituted feeding and taking care of the calves. For this study, KES 200 per day was incurred for 70 days for the 10 calves under CMS and PBMS. This figure was then extrapolated for 183 days, the number of days before the calves are weaned. For every year that calving is experienced, it is assumed that the same additional labour cost will be incurred for calves under CMS and PBMS. For the pastoral system, lesser labor costs were incurred because the calves were left at the family villages/*manyattas* and were fed by those left at home till the calves are strong enough to browse in communal rangelands. In this study however, daily cost of labour under pastoral regime was estimated at average cost of KES 178 per day, obtained from survey of pastoral farmers. This is the extra labour costs assumed to be incurred each year when calving takes place.

6.3.3 Veterinary Costs

These were estimated from the cost of administration of drugs during the study and from estimates from data collected for this work on general camel management practices. Veterinary costs were incurred across all feeding regimes. However, without the use of a milk substitute, it was noted that there were additional costs of treatment incurred for the calves.

6.3.4 Water Costs

Water is an important cost component for livestock production in the ASALs. While camel water requirements may not be as high as the other livestock, the immobility of young calves meant that water had to be provided at an accessible point. Water cost did not vary across the three regimes. Majority of the households incurred monthly water charges for all the animals kept in the homestead. For the purpose of the study, KES 2,500.00 was used for both the camel calves under PBMS and CMS, for the 70 days. This figure was then extrapolated to illustrate the costs for 183 days. Under the pastoral regime, an average of KES 2,643.00 was incurred per month as cost of water. Considering that this figure was incurred for an average of 28 camels in a herd, for this analysis, it was assumed that this figure varied with the size of the camel herd. From this, an estimated cost of water per camel in the pastoral regime was estimated.

6.3.5 Milk Saved

The results of the study indicated that on average a calf is fed on 2 litres of camel milk per day. When the camel calf is fed on milk substitutes, then the camel milk saved is available for either human consumption or the market. Due to the usage of milk substitute, the farmer was able to sell the milk that was otherwise utilized by calf and make an additional profit. When the calf is left to suckle, as is the case under pastoral regime, then it was assumed that no milk was saved. The average cost of a litre of camel milk was estimated at KES 120.00 per litre in Marsabit town. The benefit of milk saved was assumed to be only during the years when there was calving.

6.3.6 Total Value of Calves in Herd

Based on literature (Reimus et al., 2020), a mortality rate of 24 percent was used to calculate the value of herd for CMS and PBMS feeding regimes. A 35 percent mortality rate for pastoral systems was used to derive surviving herds. Market prices for camel calves through the years were used to derive the value of calves as they matured. A higher mortality rate reduces the number of surviving camel calves and vice versa. Apart from mortality rates, herd size also varies depending on the calving interval and calving rates and the number of female calves born. For this study, a calving rate of 80 percent calving interval of 2.5 years and 50 percent chance of a calf being born female was assumed based on baseline survey estimates conducted at the beginning of the study.

The results of the predicted herd growth for the three feeding regimes are shown in Figure 6.1. Although there was increased growth of the herd under the three feeding regimes in the long run, it is under PBMS and CMS that the camel herd grows at a faster rate. The effects of milk substitutes on calf mortality and herd growth therefore accrue in the long term.

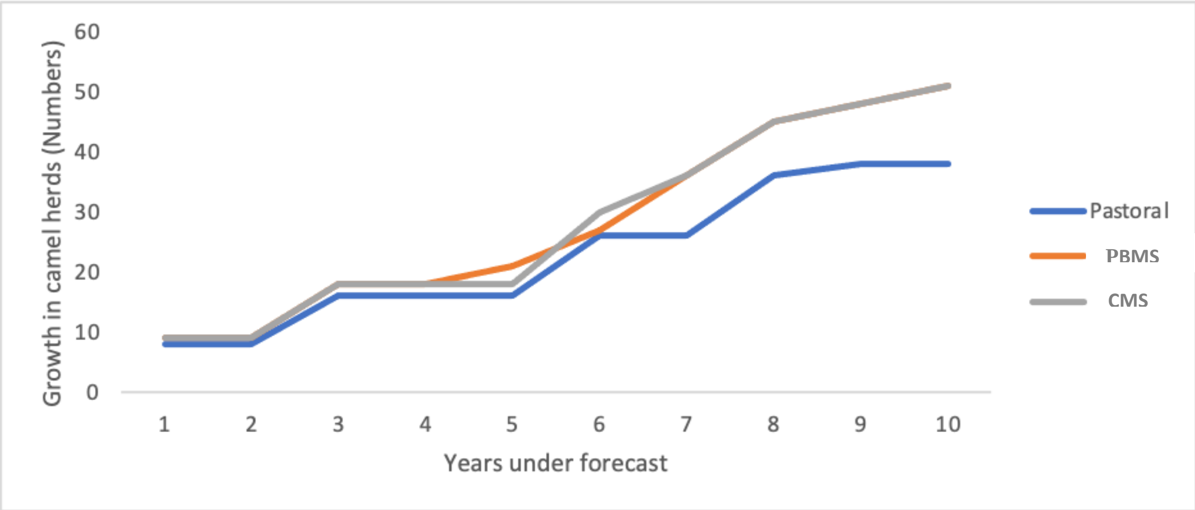


Figure 6. 1 Projected growth of camel herds in the three regimes

The findings are shown in Table 6.3 below, which details the socioeconomic characteristics of the sampled pastoral households. The average age of the home head was 50 years old, and 75% of households had male heads.Most of the household heads had no formal education (86 percent). The main economic activity was livestock rearing even though some sampled households had other income generating activities. A majority also did not use milk substitutes in feeding their calves (89 percent) while 90 percent indicated to have experienced diseases among camel calves in the year before the survey. Indeed, the data further showed that among the pastoral systems, mortality among calves was a high; 61 percent of the farmers indicated to have lost a calf in the previous year.

Table 6. 3 Socio-economic characteristics of sampled pastoralist

Variable	**Observations**	**Mean**	**Std. Dev.**
Age of household head (years)	80	50.075	14.90032
	Variable	**Frequency**	**Percentage**
Gender of Household head	Female	20	25
	Male	60	75
Household head’s education level	None	69	86.25
	Primary	4	5
	Secondary	3	3.75

	Tertiary	4	5
Main economic activity	Livestock only	57	71.25
	Livestock and Business	11	13.75
	Livestock and salaried	12	15
Use of milk substitute on calves	No	64	80
	Yes	16	20
Calf affected by diseases in 2020	None	8	10
	Yes	72	90
Calf died in 2020	None	31	38.75
	yes	49	61.25

6.3.7 Livestock Ownership

Mean number of different types of livestock owned by the respondents is shown in Table 6.4. The results reveal that the sampled pastoral households had diversified livestock enterprises. Besides camels, the pastoralists also kept sheep, goats, cattle, and chicken. Indeed, this is a key characteristic of the pastoral communities that enables them cope with various risks. The households had an average of 28 camels, 24 heads of cattle, 40 goats, 31 sheep and at least 3 chickens.

Table 6. 4 Mean number of different livestock owned in the study area.

Variable	**Observation (N)**	**Mean**
Sheep	80	31.3
Goats	80	40.5
Chickens	80	3.3
Cattle	80	24.4
Camel	80	28.2

Camel herd characteristics (Table 6.5) show that on average, the sampled households had 2 intact camel bulls, 3 castrated, 5 camel calves, 4 dry camels and 6 lactating camels. The average age for a calf to reach reproductive maturity was estimated at 5 years with an average calving interval of 2 years. This is consistent with Bakheit et al. (2016) and Gherissi et al. (2020) who reported that camels had a calving interval of 18-24 months and an age at first calving of 48 - 54 months. The results further indicate a difference in the value of a female and male calf. A female calf of one year was valued (KES 37,630.00) while a male calf at the same age was estimated at (KES 22,000.00).

Table 6. 5 Camel herd composition in the study area.

Variable	**Observation**	**Mean**
Camel bulls	80	2.28
Camel calves	80	5.93
Dry camels	80	4.47
Lactating camels	80	6.03
Castrated bulls	80	3.55
Age to reproductive capacity	80	4.96
Average calving period	80	2.10
Price of male camel calf	80	23,386.67
Price of female camel calf	80	37,630.14

6.3.8 Cost Structures for the Pastoral Systems

Cost structures presented on Table 6.6 below indicate that camel calves in the pastoral regime depend on camel milk from birth to weaning age. The nutritional requirements of the calves are significantly impacted when dams go over long distances while leaving the calves within the homesteads because pastoral camel farmers move from one spot to another in search of pasture and water.

Table 6. 6 Cost structures in the pastoral systems

Variable	**Observation (N)**	**Mean**
Monthly wages	80	5,444.26
Treatment cost	80	2,717.72
Daily milk produced per camel (Litres)	80	3.43
Home camel milk consumption (Litres)	80	2.84
Milk available for sale (Litres)	80	3.98
Monthly water cost (KES)	80	2,643.53

From the costs obtained in pastoral regimes however, it is difficult to separately estimate the costs attributed to young calves alone since they are incurred for the whole herd. The average daily cost of labor is estimated at KES 178.00, while monthly wage is KES 5,444.00. The monthly cost of treatment of common diseases and acaricide was KES 2,700.00.

6.3.9 Economic Comparison of Commercial and Plant Based Milk Substitute

Cost benefit results (Table 6.7) were obtained from 5 camel calves fed on PBMS, 5 on CMS and 5 in the normal pastoral system which depended on suckling camel milk.

Table 6. 7 Economic comparisons of feeding camel calves on PBMS versus CMS and pastoral regimes

	PBMS	CMS	Pastoral
Costs	KES	KES	KES
Cost of local substitute	19,215	79,605	-
Water	12,200	12,200	12,200
Labor costs	32,574	32,574	18,000
Veterinary cost			3,400
Total cost	**66,615**	**T 127,005**	**33,600**
Benefits			
Milk saved	219,600	219,600	-
Veterinary cost saved	1,850	1,850	
Number of calves	5	5	5
Number of surviving calves with substitute *(*24% with substitute, 35% without*)*	4	4	3
Value of calf	35,000	35,000	35,000
Total value of calves in the herd	133,000	133,000	113,750
Total benefits	**354,450**	**354,450**	**113,750**
B-C	287,835	227,445	80,150
BCR	5	3	3

The cost of feeding and maintaining the 5 calves under each regime per day was captured and a total cost for 6 months was then estimated using costing techniques. The daily cost of labor and water did not vary during the entire experiment period. Subsequently, under the PBMS regime, the cost of collecting plant-based materials is assumed not to vary during the 6 months' period. Also, the price of CMS did not vary, since the market value remained constant during the study period. Veterinary costs were captured when they were incurred during the experimental period and the same was estimated for a 6-month period. Analysis therefore was based on costing theory by calculating costs, average costs and total costs. These costs then incorporated in the CBA to estimate the overall BCR for each regime. For this study, the main benefits were obtained from milk saved when substitutes were used in place of camel milk and the value of the calf.

The higher benefits against expenses revealed by the study's findings suggested that using the PBMS over the CMS was more cost-effective (Table 6.7). PBMS was compounded from locally available plant materials hence the main cost incurred was the cost of labor for collection. The CBA analysis shows that the benefits from using PBMS is greater than the other two regimes. The difference emanates from the cost of buying the CMS which was higher compared to the cost of formulating PBMS. Under CMS and PBMS, the benefits included reduced mortality which was captured by the value of the calves saved. The reduced mortality rate in calves fed on the CMS and PBMS was attributed to the improved immunity that resulted from using milk substitutes. Feeding the calves on milk substitutes increased the availability of camel milk for sale and (or) consumption in the household. The results indicated that there was a higher benefit- cost ratio for PBMS (5), verses CMS (3) and pastoral system (3). From this analysis, for every shilling invested in the PBMS technology, 5 shillings was generated compared to 3 shillings in both pastoral and commercial regimes. The positive BCRs for the three regimes showed that they are all profitable and are operating above the break-even points. However, the PBMS represented a better regime compared to the other two. This generally showed that while the pastoral system was a low input regime, more can be gained from tapping and utilizing the freely occurring local resources.

6.3.10 Projected Benefits of Use of Milk Substitutes Over 10 Year Period

Given a camels' herd calving rate of 80%, Table 6.8 shows a projected benefit cost scenario of the three regimes over a 10-year period. This estimation was based on the assumption that a calf once born uses milk substitutes for the 183 days (6 months), after that it is allowed to move with the herd. When compared to CMS, PBMS was cheaper, thus farmers will have a higher chance of consistently feeding the calf as recommended. This can improve the calf's immunity and reduces mortality (Ihuthia, 2010). With a calving interval of 2 years (Bakheit et al., 2016), this study estimated that at year 3 the dams will have additional calves. Additionally, a calf is expected to reach maturity by the age of 5 years (Gherissi et al., 2020). With an estimated 80 percent calving rate as obtained from the baseline survey, the camel herd will increase. Even though majority of previous studies had valued increase in weight as a benefit (Sagala et al., 2021), this study used the value of calf herd and milk saved as the benefits. The nature of camel pastoral production is unique since pastoral camel keepers hardly slaughter their camel calves for meat. Females are incorporated into the breeding herd while the males may be slaughtered at maturity or selected as breeding bulls/stock.

Table 6. 8 Comparison of benefits (KES) of feeding regimes over 10 year of projection period

Economic variables	**PBMS**	**CMS**	**Pastoral**
	Y10	Y10	Y10
Total value of calf herd	3160348	3,160,348	2,286,627
Benefits *less* costs	3,209,497	3,161,185	2,188,913
NPV	1,033,372	1,017,817	704,771
Discounted benefits	1,074,112	1,074,112	736,233
Discounted Costs	40,740	56,295	31,461
Size of camel herd	51	51	38

NPV estimates for 15 dams are projected in Table 6.8. The results showed that keeping camels is profitable to the pastoral camel keepers as shown by the positive NPV across the three feeding regimes. However, the differences lie in the higher benefit derived from milk saved and life of calves saved when milk substitutes are used. The PBMS saved the farmer more because of its availability at cheaper prices compared to the CMS. The cost of CMS and PBMS is incurred every two-year interval based on the assumption of a two-year calving interval and that all 15 dams calve down in year one. The cost will also be incurred in the fifth year when the calves mature and start breeding. Comparisons of the regimes implied that promoting PBMS among pastoral farmers can have benefits in improving the income of camel farmers. The most important cost in PBMS feeding regime is the cost of labor incurred in collecting the ingredients and feeding the calves.

Compared to the other regimes, the pastoral system is a low-cost regime reflecting the socio-economic situation of the pastoral communities in the ASALs. Most of the costs were derived from water resource and veterinary costs for the camels. For this system, there was no extra milk saved, and therefore no gain for lack of adoption of this technology. Basically, most of the cost and benefit values for the local camel milk substitute and the commercial substitute were not different except on the cost of the milk substitute. The commercial substitute was more expensive (KES 43.50 per Kg) than the one formulated with local ingredients (KES 21.00 per Kg), giving the PBMS a financial advantage. Extra labour costs emanating from care given to the young calves are incurred seasonally during the calving periods. Similarity for CMS and PBMS is in the mortality rate which was assumed to be lower that of the pastoral system. This an important aspect in the sustenance of the camel herds and their profitability.

6.3.11 Benefit:Cost Ratio Comparisons

Benefit Cost Ratio (BCR) is an important indicator showing the ratio of costs to benefits; a ratio of more than one implies more benefits attributed to the technology and subsequently those that accrue to a farmer when they adopt the same (Sassone & Schaffer, 1978). The graph below (Figure 6.2) compares the three regimes.

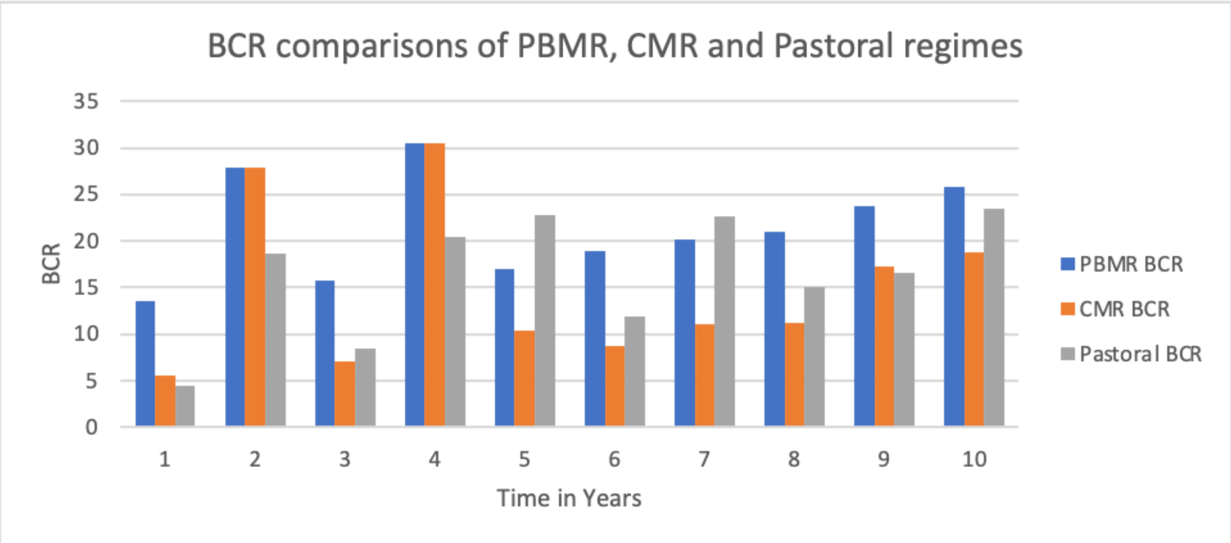


Figure 6. 2 Benefit cost ratio for the 3-calf feeding regimes

The BCR for PBMS shows a robust trend throughout the 10-year period under estimation; it is higher than CMS and pastoral regimes. In year five and seven however, BCR for PBMS is lower than the pastoral but still higher than CMS. This is because in year five and seven, the calves born at the start of year1 and year 3 have matured and have increased the number of lactating females. Thus, the costs for milk substitutes are higher when compared to the pastoral regimes. In the long run more benefits are realized from the PBMS regime.

6.3.12 Net Present Value Analysis

The Net Present Value (NPV) analysis is a tool used in financial analysis to determine whether adopting a technology is viable. The NPVs of the three regimes under analysis gave an indication of returns to the camel substitute technology if adopted. In light of increasing demand for milk and meat globally (Tadesse et al., 2012), the NPV is a tool that may help chose productivity enhancing technologies like the milk substitutes. In decision making using NPV, the best option to select is the one with the highest NPV values. Comparison of the three regimes with a discounting rate of 12 percent showed that all the three regimes were positive, meaning that they were all profitable in the long run.

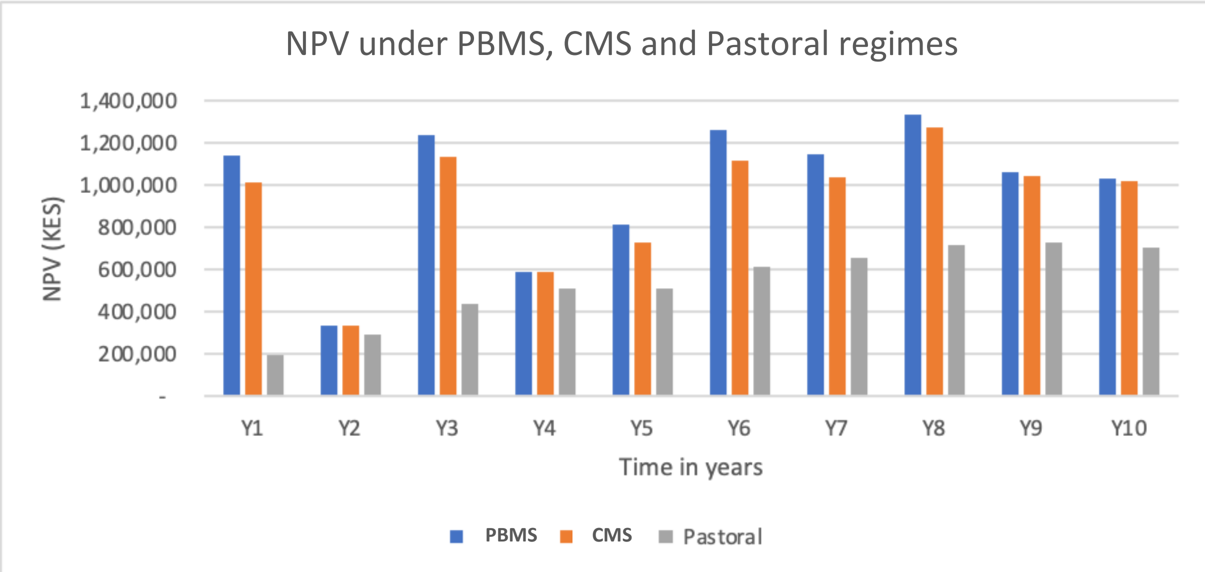


Figure 6. 3 Chart showing forecasted NPV values for PBMS, CMS and Pastoral regimes

However, the PBMS yielded the highest return; therefore, it was more lucrative than the other two. The benefits that accrued to PBMS were greater over the years, therefore availed more benefits to the farmer in the long run.

6.3.13 Net Present Values Under Varying Mortality Rates

Estimations for this study assumed a mortality rate of 24 percent for calves fed on the substitutes and 35 percent for calves on pastoral systems (Wong et al., 2022). Other factors such as drought, diseases and management practices can also influence calf mortality (Ihuthia, 2010; Kamber et al., 2001). NPV scenarios were therefore developed to show the situation of camel farming should there be a decrease or an increase in mortality rates, assuming a constant discounting rate of 12 percent. Mortality rate was varied at 0, 20, 50 and

100 percent to show best and worst scenarios. When mortality rates were lower, the estimated future benefits were higher under PBMS as compared to the CMS. Although annual costs are important in estimating yearly benefits, the actual benefits are realized in year 4 to 5 when the calves have reached maturity age and start calving or can be sold for meat.

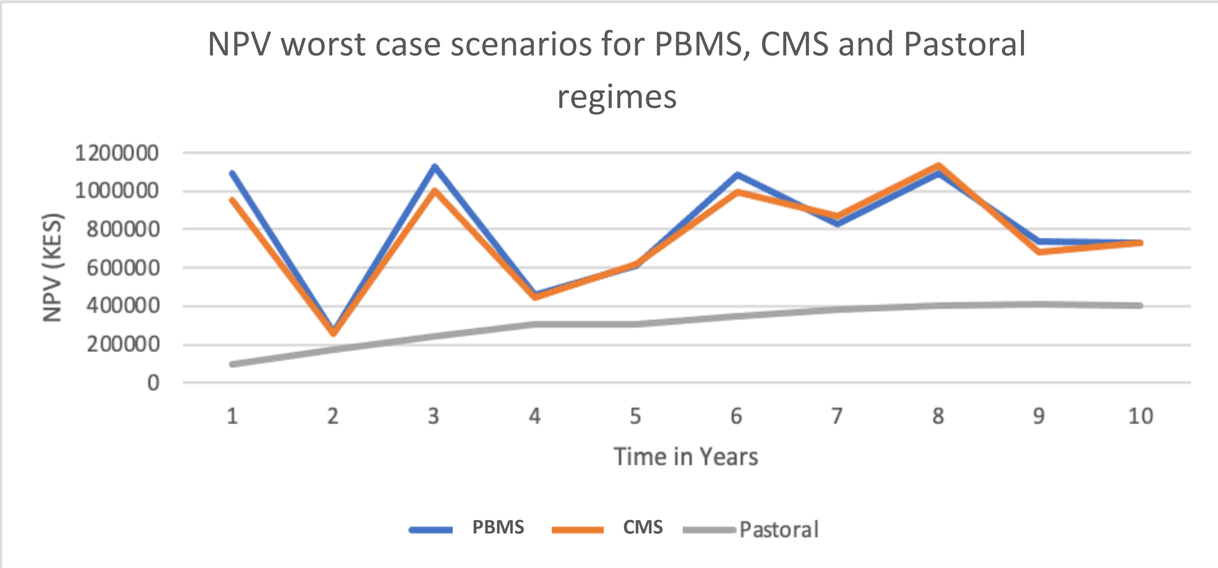


Figure 6. 4 Worst case scenarios under varied mortality rates

Assuming a worse- case scenario (Figure 6.4) where mortality rate increased from 24-41 percent for PBMS and CMS and 35-60 percent for pastoral regimes, CMS and PBMS would still be profitable. This finding implied that in extreme situations such as severe droughts, using a milk substitute would be more profitable than not using one. Under extreme weather conditions, pastoralists have to travel even longer distances in search of water and pastures (Chinasho et al., 2017; Ndiritu, 2021). This implied that any supplementation for the calves is paramount to their survival.

6.3.14 Incremental Value Analysis

The chart (Figure 6.5), shows benefits derived from increase in camel herds estimates over a 10-year period.

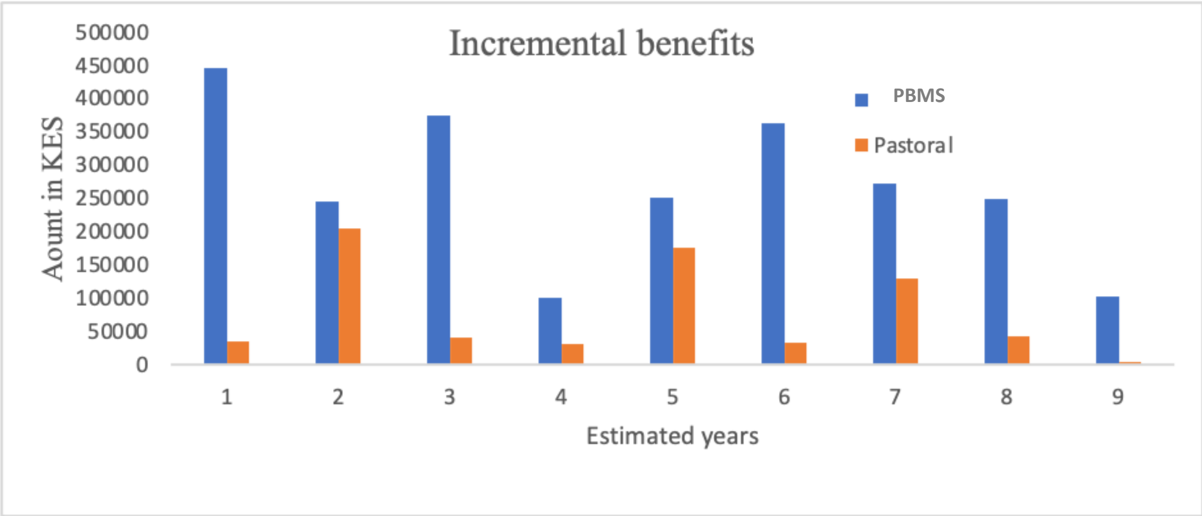


Figure 6. 5 Chart comparing incremental benefits between pastoral and PBMS

Incremental benefits were obtained by estimating the change in value of the camels in the current year less the previous years' value. The value of the camel/ calf was obtained from market value given by the pastoral camel keepers. Once a calf is born, its market value increases steadily till maturity. The value of mature dams increases two-fold since the calves born also give additional value. Incremental benefit also captures the value of milk obtained from milk saved with the use of PBMS. The costs captured were assumed to be incurred every year, indicative of the cash that pastoral camel keepers need to have to meet expenses. The figure 6.5 shows the incremental benefits from PBMS and Pastoral feeding regimes where milk substitutes were not used.

Even though the majority of pastoral farmers kept other animals which can be easily sold and slaughtered for cash purposes, this study assumed benefits and costs that accrued only to the camel enterprise. Under PBMS, the additional benefits less variable costs obtained are more, compared to the pastoral regimes. This implies that the sales from camel milk are enough to meet expected expenditure for the calves. By the tenth year, the benefits from pastoral regimes will hardly be enough to sustain expenses from the increasing herds. This finding shows that in pastoral systems camel farmers may not be making tangible losses, but may not be liquid enough to sustain the camel production business.

6.3.15 Sensitivity Analysis

Three important variables were considered in this analysis: an increase in prices of feeds, camel milk market prices, and discount rates. An increase in price of the substitute formulating ingredients is an important variable that may motivate or deter adoption of the milk substitutes. While such a technology may improve productivity of the herd, increased prices mean higher cost of acquiring the technology, which may in turn discourage its adoption. This is because profitability is an important driver in enhancing productivity (OECD, 2015), and cost effectiveness of any technology is paramount in enhancing its adoption and use. In this study, prices of the PBMS were increased by 10%. The resulting NPV showed a slight reduction of 0.14 depicting that the local formulation may not be sensitive to prices.

Due to the increased demand of the camel milk, an increase by 10% in market prices of camel milk may be an important driver in increasing the welfare of the farmers. This is an important strategy that can improve productivity through market pull dynamics (USAID, 2020). Good market prices can attract more investments into the enterprises through the increased welfare gains emanating from participating in such markets. A sustained price would also mean that market push-pull dynamics can enhance not just the participation in the markets but adoption of productivity enhancing technologies such as the milk substitutes, better milk handling practices such as cooling systems as well as better camel herd management practices. These practices in the long run bring about sustained herds and increased welfare of camel keepers. In this study, a 10% increase in prices of camel milk prices would improve the NPV by 3.43% in the PBMS regime. This is important for resource poor camel keepers who rely on the camels for cash flows to sustain their livelihoods.

The other important factor that this study considered is the discount factor. This enables camel keepers to understand the worth of the camel herds in present value terms. A camel enterprise is a long-term investment and operates under numerous risks. This factor enables the camel keeper to discern whether the opportunity cost of investing his money in a milk substitute is a worthy risk or not. The substitute is anticipated to improve the herd through reduced calf mortality and morbidity, and ultimately increased productivity. By investing their money in substitutes, they forgo the opportunity to use or earn money in another enterprise such as in sheep and goats or cattle, which represents other important livelihoods for the community. A discount factor of 12% is the average lending rate of commercial banks in Kenya (Central Bank, 2021), and shows the cost of obtaining credit, which is an important driver in acquisition of technologies.

Increasing a discount rate means that credit becomes expensive and therefore accessibility to the farmers becomes limited. In this study, the discount factor was increased by 10%. In both the pastoral regimes and the PBMS regime, there was a significant change in NPV values. There was a 6.0% decrease in PBMS regime, and 6.6% decrease in the pastoral regimes. This means that the pastoral systems may thrive better if macroeconomic policies that support credit access were enabled for the pastoral camel keepers. It also points to the importance of enabling institutions that provide credit to pastoralists to function optimally. Sound macroeconomic policies are important in enabling pastoral enterprises and generally the growth of all sectors of the economy.

Table 6. 9 Variation of different parameters on NPV

Sensitivity Scenarios	Net NPV	% Change
PBMS12% discount rate (Base)	9,946,394	-
PBMSwith 10% feed price increase	9,931,483	-0.14
PBMSwith 10% increase in milk price	10,287,219	3.43
PBMSwith 10% increase in discount rate	9,350,783	-6.0
Pastoral with 10% discount increase	4,991,112	-6.6
Pastoral with 12 % discount (Base)	5,341,483	-

6.4 Conclusion

The CBA showed that PBMS has more benefit to the pastoral farmers in the short and long run when compared to the CMS. BCR analysis showed that PBMS is cheaper than CMR. NPV analysis showed that there are more benefits that accrue to the farmers by investing in PBMS technology compared to CMS.

CHAPTER SEVEN

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

7.1 General Discussion

The survival of rural pastoral communities, particularly those located in arid and semi-arid regions (ASALs), depends heavily on the presence of camels as a species of livestock (Aujla et al., 2013; Noor et al., 2013). The production of camels, which results in the supply of both milk and meat, helps to ensure the food and nutritional safety of households (Ahmad et al., 2010). In addition to this, they are utilised in the process of dowry exchange and the conveyance of bottled water and other household goods from one grazing region to another (Guliye et al., 2007). Calves are the replacement stock for the herd, which is essential for the growth of the herd; nevertheless, without calves, the camel caretakers would not have access to milk (Kuria et al., 2011). Bringing up camel calves using conventional methods of pastoral production has a number of problems, which results in high death rates (Chimsa et al., 2013).

The pastoral system had a mortality rate of 35.2%, whereas the peri-urban system had a mortality rate of 4.3%. In both pastoral and peri-urban camel production systems in Kenya, the most common causes of death among camel calves are disease, drought, predation, and parasitism. These four factors account for approximately 80% of all camel calf deaths. In Kenya's ASALs, malnutrition is a widespread problem, and it's usually caused by a combination of insufficient milk suckling and drought. For instance, during dry periods, when there is scarcity of water and feed for calves and lactating dams, less milk is available for the calves. Mortality rate of calves, about 40%, mostly occurs in the early stage of life, mainly in the first 1-3 months (Mock et al., 2020). Common causes of death at this stage of life (1-3 months) have been reported to be diarrhoea, deprivation of colostrum and hereditary disorders like navel bleeding (Cho & Yoon, 2014) which agree with this study. The mortality rates are high in extensive camel production system and more interventions are required in terms of camel calves' nutrition, health and general husbandry management. If the mortality is reduced to acceptable levels, it implies that camel herds will increase and more milk, meat and income will be generated from camel production systems in Kenya which by extension contribute to Kenyan GDP growth.

Diseases, drought and competition for milk between the calf and households for trade and human consumption were major factors responsible for camel calves retarded growth.

Retarded growth of calves leads to delayed reproductive maturity, reduce production potential and delay supply of quality replacement stock. Pastoralists did not have any substitute to milk feeding for camel calves but supplemented calves during dry/drought period. To pastoralists survival of the calf to bridge the drought period was more important than to meet nutritional daily requirements for the calf. It is imperative to build capacity of camel keepers to feed the camels calves adequately for the calves to attain faster growth rate, attain early reproductive maturity and attain its full production potential.

This study established that proximate composition (CP, DM, fat, NDF, ADF, and ME) of locally available feed resources were highly variable, with significant ($P<0.05$) differences among the browses and grasses. In the northern Kenya rangelands, browses are readily available compared to grasses and browses have higher protein and fats contents compared to the grasses. If the recommendation of this study of harvesting the mature leaves and twigs could be adapted against current practice of cutting branches, the browses could be utilized sustainably for camel calves' production in ASALs without much negative impacts to the environment. In ASALs of Kenya, land degradation is a reality with increased human and livestock population thus need for environmental conservation and prudent use of available livestock feed resources in the rangelands. Harvesting of leaves, twigs, pods and fruits could be done during rainy season and when pods are in season and stored for use during dry season.

Grewia bicolor and *Justicia exigua* had a crude protein (CP) of 24 and 20% respectively indicating potential to provide recommended daily protein requirements for a camel calf (20-24% CP) as plant-based milk substitute in the ASALs. *Justicia exigua, Acacia melliffera* and *Salvadora persica* had a metabolisable energy of 19.3, 18.1 MJ Kg^{-1} DM and 18.4 $MJKg^{-1}$ DM respectively. This was above 15 $MJKg^{-1}$ DM the recommended energy requirements to meet daily energy requirement of camel calves for plant-based milk substitute (NRC, 2001). *Aristida mutabilis* (16.3 $MJKg^{-1}$ DM), *Cenchrus ciliaris* (17.1 MJKg-1 DM), *Leptothrium senegalense* (15.3 MJ. Kg^{-1} DM) and *Sporobolus species* (15.9 MJ Kg^{-1} DM) were within the recommended energy levels to meet daily requirement of a camel calves (15-20 $MJKg^{-1}$ DM). The browses and grasses which have required CP content and ME for formulation of PBMS should be protected, conserved and propagated for sustained camel calves' nutrition in ASALs of Kenya. Crude protein of the common supplements used by pastoral camel keepers like *Acacia tortilis* pods (15.42% CP), *Tinnospora caffra* (14.05% CP) and *Prosopis juliflora* (11.08% CP) was lower than the recommended 20-24% crude protein to meet daily growth requirement of a camel calves. The results of the analysis imply that individual supplement could not meet daily nutritional requirements of camel calves and thus camel keepers should be capacity built on formulation of PBMS and right choice of feed supplements.

The commonly used forage supplements i.e., *Acacia tortilis pods, Prosopis juliflora* and *Tinnospora caffra* were low in limiting amino acids such as methionine, lysine and threonine for calf nutrition, thus need for supplementation. In pastoral camel keeping areas, the limiting amino acids which could be used to fortify available browses and other supplements are not available in the local markets thus need for capacity building of livestock feeds suppliers to stock such ingredients. The total tannins and condensed tannins contents in common supplements ranged from 3.04 to 50.10 gkg^{-1}DM and 1.60 to 9.19 gkg^{-1}DM, respectively. High concentrations of condensed tannins tend to lower feed digestibility and nutrient utilization (Kemboi et al., 2017; Ondiek et al., 2013). Tannins concentrations of commonly used supplements were within the safe range that would not be harmful to the animals. Tannin concentrations greater than 50 g kg^{-1} in diets lower feed intake and nutrient utilization which negatively affects animal performance (Mergeduš et al., 2018). *Acacia tortilis* pods mineral content (Ca 3.72% and P 0.91%) and *Prosopis juliflora* pods (Ca 1.44% and P 0.75%) used as common supplements had sufficient Ca and P to meet daily requirements of camel calves and thus can be recommended to supply the two important minerals for the growth of the calves.

On the effects of feeding commercial (CMS) and plant-based milk substitute (PBMS), crude protein content (gkg^{-1}DM) was 181.2 in PBMS and 203.1 in CMS. The DM was 93.5 % in CMS and 88.7 % in PBMS. The ME contents was higher in CMS (17.4 $MJKg^{-1}$ DM) compared to PBMS (15.4 $MJKg^{-1}$ DM). The results of the analysis of locally formulated PBMS indicates the potential of locally available feed resources to be used as plant-based milk substitute. However, the ingredients used for PBMS should be based on local availability, high quality and camel preference to ensure availability of the nutrients in the recommended quantities.

The *in-vitro* digestibility characteristics of the experimental diets did not vary widely among the CMS and PBMS herbage samples. The total DM digestibility (%) in PBMS (46.9%) being higher compared to CMS (46.6%) during the trial. Camel on commercial and plant-based locally formulated milk substitute had a higher ADG compared to control perhaps as a result of the increased dry matter intake attributed to the growing camel calves getting sufficient nutrients for increase in body weight. This was similar to the results reported by Jaeger et al. (2020) on average daily gain (0.77 and 0.78 kg/d) of newborn dairy calves fed on milk substitute with 20% crude protein concentrations. The results of the trials imply that both commercial milk substitute (CMS) and locally formulated plant-based milk substitute (PBMS) could be used as replacement to camel milk feeding in Arid and semi-arid lands of Kenya to enhance calf performance and avail camel milk for income and home consumption for pastoral households. In addition, PBMS also has potential to be commercialized after fortification with low-cost feeds ingredients in areas it had nutritional deficiencies such as CP, minerals and limiting amino acids. FCR was higher in commercial milk substitute compared to plant-based locally formulated milk substitute. Lower FCR value in PBMS indicate higher efficiency compared to CMS.

The CBA showed that PBMS has more benefit to the pastoral farmers in the short and long run when compared to the CMS. BCR analysis showed that PBMSis cheaper than CMS. Additionally, NPV analysis showed that there are more benefits that accrue to the farmers by investing in PBMS technology compared to CMS. The benefits of PBMS emanate from the use of cheaply available resources that can be harnessed by pastoral farmers. Promotion and investment in PBMS technology is therefore critical for its adoption and productivity enhancement in the camel herds. Adoption of this technology has the potential to stimulate environmental conservation the plant species used in this technology.

7.2 General Conclusions

The following conclusions can be drawn from this study;

i. The pastoralists have a substitute to milk feeding although they use them as supplements rather than substitutes.
ii. All the forages used by pastoralists before release of calves for free range grazing and supplements could be used as ingridients in formulation of locally formulated plant-based milk substitute. For instance, *Grewia bicolor and Justicia exigua* is adequate in protein, *Justicia exigua* and *Acacia melliffera* are suffcient in energy, whereas *acacia tortilis* and *Prosopis juliflora* pods can effecticvely cater for Ca and P minerals which are key in calf growth and development.
iii. The PBMS intake was comparable to CMS. All the three feeding regimes had positive ADG but calves on CMS and PBMS performed better than calves on pastoral milk feeding regime (control). Lower FCR value in PBMS indicates higher efficiency of utilization compared to CMS.
iv. PBMS is more beneficial and economical to use in the long run as compared to CMS and pastoral feeding regimes.

7.3 Recommendations

i. Pastoralists are aware of existing feed resources that could be used to formulate PBMS although they are not using them to formulate PBMS. Therefore, they should be capacity-built on formulation and utilisation of PBMS. In Peri-urban production system, camel farmers are aware of availability of commercial milk subsitutes but are not using them due to unavailability in their markets. Therefore, animal feed stockists should be encouraged to avail them to camel keepers in peri-urban production system.
ii. Pastoral camel keepers should be capacity-built on sustainable utilization of local feed resources for formulation of PBMS.
iii. Entrepreneurs should be enticed to invest in supply of low-cost feed grinders and mixers to camel keepers to enable them grind and mix the local feed resoruces.
iv. The study suggests that pastoral camel keepers and common interest groups (CIGS) promote PBMS to improve the nutritional health of nursing camel calves and to commercialize it.

7.4 Further Research

From the results of this study, further research is recommended to:

i. Evaluate available technologies for enhancement of degradation of fibre in PBMS.
ii. Evaluate effects of adoption of PBMS on environmental conservation.
iii. Evaluate available cost-effective CP, minerals and essential amino acids sources for fortification of PBMS.
iv. It is necessary to test PBMS in dry season and more arid pastoral areas because the experiment was conducted in high potential rangelands during the rainy season.

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APPENDICES

Appendix A: Questionnaires for objective one and two

Open-ended questionnaire for Objective One and Two

KENYA AGRICULTURAL AND LIVESTOCK RESEARCH ORGANISATION

BEEF RESEARCH INSTITUTE

P.O. Box 3840 Nakuru

Open ended Questionnaire

Open ended questionnaires for focus group discussions

1.What are the major factors causing camel calf mortalities?

Rank 1. Malnutrition 2. Diseases 3. Cannibalism 4. Others (rank)

2. Mortality for camel calves are common at what age:**1**: 1-3 months **2**. 3-6 months **3.** 6-12 months **4**. Over 1 year

2.What are the major factors responsible for retarding growth in camel calves before weaning?

3.What type of forage do you use for feeding camel calves before opening for free range browsing?

Name of the forage (Best five)		Reason for preferred forage	Where they are found			Trend over the last 10 years' period
Botanical name	Local name		Rainy	Dry	Drought	

4.What are the main camel calves preferred forages, reasons for preference, grazing area found and trends in terms of availability in last 10 years?

Name of the forage (Best five)		Reason for preferred forage	Grazing area			Trend over the last 10 years' period
Botanical name	Local name		Rainy	Dry	Drought	

Name of the substitute	Source of substitute	Quantity used /day/calf (kg/litres	Calf performance 1. Very good 2. Good 3. Fair 4. poor	Cost/ unit sale(kg/L)

5.Are there traditional sources of feeds used as a substitute to milk feeding that you know and you

have ever used? 1. Yes [____] 2. No [____]

6. If yes, state the type of substitute and quantity used on daily basis per calf and cost incurred.

7. How would you rate the quality of traditional substitute to milk you are currently using for your calves? a). very good b) good c.) fair d). poor

8. Are you aware of other milk substitute for calves currently available in the market/ your locality 1. Yes 2. no

9. If yes, which ones

10. If new substitute to milk are introduced in the market can you buy?

11. If yes, what type of substitute?

12. what are major constraints affecting camel calve rearing?

13. what are major constraints affecting camel production?

Thank you

***Kalath Kulaba*-Rendille**

***Ashe Oleng*-Ariaals.**

Survey questionnaire for Objective One and Two

KENYA AGRICULTURAL AND LIVESTOCK RESEARCH ORGANISATION

BEEF RESEARCH INSTITUTE

P.O. Box 3840 Nakuru

Questionnaire

Appendix 1: **SURVEY QUESTIONNAIRE FOR BENCHMARKING OF CAMEL CALF NUTRITION AND HEALTH IN EXTENSIVE, PERI-URBAN AND CAMEL RANCHES IN KENYA.**

PART A : GENERAL INFORMATION OF STUDY SITE

1. Questionnaire code. [________] **2. Questionnaire No.** [______]

3. Name of Enumerator [____]

4. Date of interview [___ /____/____] **5. Site** [________________] 6. **County** [_________________]

7. Sub-County [_________________] **8. Ward** [_____________] **9. Location** [_______________]

10. Manyatta [_________________] 13**. Fora Name** [________________]

14. Name of the respondent___________________________

DATA REVIEWED BY [________________________________]; **DATE** [__________]

SCHEDULE 1: RESPONDENT SOCIAL AND DEMOGRAPHIC INFORMATION

1.1. Respondent to give details of his/her social and demographic background in the table below

Relationship to HH Head	Gender	Age (count)	Education	Income category*	Occupation	Responsibility in community	Marital status	Ethnicity	Religion
[_____]	[___]	[_____] yrs	[_____]	[_____]	[______]	[________]	[___]	[______]	[___]

*Income in the last six months from the day of interview

Codes

Relationship to household head

1= self 2= wife 3= daughter 4= employee
5= husband 6= son 7= relative 8=other (specify)

Gender

1=male 2= Female

Education Level

1= Pre-primary 2= Primary 3= Secondary 4= None 5= Other (specify)____

Income category per month (in KES)

1=)100-1,000 2=)1,000-2,000 3=)2,000-5,000 4=)5,000-10,000 5= above (10,000

Occupation /Economic activity

1= livestock alone 2= livestock and business 3. firewood/charcoal
4=Salaried employment 5= crop and livestock 6= Others specify

Responsibility in the community

1=Village elder 2=Village committee (specify)
3= Chief 4=MCA 5= Youth leader
6= Women leader 7= Others specify

Marital status

1 = Married 2 = Single 3 = Divorced 4 = = Widow / widower 5.Others (specify)

Ethnicity

1=Borana 2=Somali 3=Rendille 4=Samburu 5=Turkana 6=Burji 7=Gabra 8=Sakuye 9=Others specify__

Religion

1 = Christian 2 = Muslim 3 = Traditional 4 = Other (specify)

1.2. Give details of household members (including HH head) living permanently on the compound (use codes above)

ID	Relationship to HH Head	Gender	Age (count)	Education	Occupation	Marital status
1						
2						
3						
4						
5						

6						
7						

SCHEDULE 2: GENERAL HERD INFORMATION

	2.0. No. of camels owned									
2.1. No. of years involved in camel Husbandry	Mature females	mature breeding males	mature castrates	Weaners females	weaner males	female calves	male calves	Breeds kept	Age heifer reaches reproductive maturity	Age male reaches reproductive maturity

2.2. Main purpose for keeping camels (rank best three)		2.3. Did you achieve all the purposes [1=YES; 2=NO]	2.4. If not, what were the constraints
1			
2			
3			

SCHEDULE 3. CAMEL BREEDING MANAGEMENT

3.1. How many bulls do you use for breeding? No. [__________]
If more than one, why?

____

____

____

3.2. What were the sources of your breeding bulls for the past 25 years [_______?] [1= within my herd only; 2= within my herd and neighbouring herds; 3= within my community but far regions; 4=outside community herds? 5=others specify]

3.3. Do you retire camel breeding bulls? [1= Yes 2= No]

3.4. If yes, at what age do you retire them? _____________ Years

3.5. If not, why?

____

____

3.6. Do you refrain breeding bulls to mate its mother? [1= Yes; 2= No]

3.7. If yes, how and why?

____

____

____

3.8. Do you refrain a breeding bull to mate its daughters and sisters? [1= Yes; 2= No]

3.9. If yes, how and why?

____

____

____

3.10. Do you retire/cull breeding females? [1= Yes; 2= No]

3.11. If yes, at what age and reasons for culling; age________ years.

Give Reasons ____

____

3.12. When you want to upgrade your camel herd for desired traits, which approach do you prefer? [_______]

[1=Use of female animal to attain the desired traits 2=Use of males to attain desired traits 3=Use both]

3.13. do you ever see young camel calves with deformed legs which recover later in live? Yes, [_____] No [_____]

3.14. Did you ever observe abnormalities in the camel calves in your herd like deformed jaws, umbilical cord bleeding, blindness or deafness which was not caused by accident and which do not recover? Yes, [_____] No [_____]

3.15. if yes, which one? 1. Umbilical cord bleeding [_____] 2. Deformed jaw [_____] 3. blindness [_____]

4. deafness [_____] 5. Under knee 6. Others (specify) [_____]

3.16. Please give the following information in your herd for the past four year

	Sea	Age of breeding bull	No. of dam ready for service	No. Served	Heat repeat	No. Conceived	calve born alive	No. of calves died	Cause of deaths	Management type	Number weaned	Abortion	Still birth	Calf deformity
2016	LR													
	SR													
2017	LR													
	SR													
2018	LR													
	SR													
2019	LR													

	SR													

Management type 1=Fora 2=Manyatta 3=Peri urban 4. Ranch LR=Long Rain; SR=Short Rains

3.17. what is calving interval of your herd______________

<u>SCHEDULE 4</u>: Calf management at birth

1. Have your camels had some problems during giving births for the past 5 years? YES [____] NO [____]
2. If yes, how many in numbers in the past 5 years?
3. If yes, what are the problems 1. dystocia 2. wrong orientation of foetus at birth 3.others(specify)

3. were calves successfully delivered? YES [____] NO [____]

4. Have you had camel dams rejecting the calf? YES [____] NO [____]

5. At what parity does the camel reject the calf 1. First calving [____] 2. Second calving [_]3. Third calving [____] 4. Others (specify).

6. If yes, what have you done to make the dam accept the calf 1. Forced mothering [____] 2. Hand rearing the calf [____]3. Inflict pain [____] 5. Others

7. What special care do camel calves require at birth 1. Ensure calve breathing [____] 2. disinfection of calf navel [____] 3. Tie umbilicus with sterilized string [____]4. Others specify

8.After how long does the calf start suckling the colostrum from the mother? 1. thirty minutes [____] 2. One hour [____] 3. three hours [____] 4. Four to six hours [____] 5. Six to twelve hours [____] 6. After 12 hours

9. Frequency of suckling colostrum 1. Once a day 2. Twice a day 3. Three times a day 4. Four times a day 5. More than five times

10. State whether the calf is given assistance to get the first colostrum 1. Always [____] 2. Rarely [____] 3. Not at all [____]

11. When calf is suckling colostrum, is there limitation on the amount 1. Yes [____] 2. No. [____]

12. If yes, how is this done? 1. Allow suckling one quarter [____2. Allow suckling two quarter [____]2. Allow suckling three quarter [___]3. Allow suckling all four quarter [____] 5. Milk four quarter but not exhaustively [____] 6. Others

13. If yes, why do you restrict colostrum feeding?

14.Any consideration of level of parity when restricting colostrum? Yes [____] No [____]

15. if yes, which level of parity 1. First calver [____] 2. Second calver [____] 3. Third calver [____] 4. Fourth calver [____] 5. All [____] 6. others [____]

16. Any reason for specific level of parity?

17. Please state other special calf management practices you give to camel calf at birth that was not mentioned so far?

SCHEDULE 5: Milk feeding

1. How many days after calving is camel milk acceptable for human consumption? 1. Immediately [____] 2.one day [____] 3. 2 days [____]4. Three days [____] 5. Four to six days [____] 6. One week [____] 7. Two weeks and above [____]
2. Do you separate calve from the dam after birth?1. Yes [____] 2. No [____]
3. If yes, at what age 1. First week [____] 2. Second week [____]3. Third week [____] 4. Fourth week [____] 5. Others (Specify)
4. When you start milking what proportion of milk is fed to the calf? 1. Allow suckling one quarter [____] 2. Allow suckling two quarter 3. Allow suckling three quarter [___]4. Allow suckling all four quarters [____] 5. Milk all quarters and allow calf to suckle
5. How many times do calves suckle during the day? 1. Once a day [____] 2. Twice a day [____] 3. Three times a day 4. Four times a day [____]
6. How many times do calves suckle during the night? 1. Once [____] 2. Twice [____] 3. Three times 4. Throughout the night [____] 5. Others (specify0
7. How much milk was the calf allowed to suckle in different growth stages?

Age in months	1-2	2-3	4-5	>6
No of teats				

8. What is the average daily milk yield of your camel in the: 1 first month of lactation [____] 2. Second month [____] 3. third month [____] 4. Fourth month [____] 5. Fifth month [____] 6. Sixth month [____]
9. Can you estimate on average amount of milk that you feed to the calf on daily basis in litres? 1. The first week [____] 2. Second week [____] 3. Third week [____] 4. Fourth week [____] 5. Second month [____] 6. Third month [____] 7. Fourth month [____] 8. Fifth month [____] 8. Sixth Month [____].
10. Do you sell camel milk 1. Yes [____] 2. No [____]
11. If yes, what proportion do your sell from a daily yield of one female camel with a suckling calve? 1. A quarter of the yield 2. Half of the yield 3. Three quarter of the yield 4.all the daily yield.

12. How much of the daily yield of the same dam do you use for home consumption? 1. A quarter of the yield 2. Half of the yield 3. Three quarter of the yield 4.all the daily yield.
13. Are male calves allowed to suckle the same amount of milk with female calve on daily basis 1. Yes [____] 2. No [____]
14. If NO, please explain the difference in terms of milk fed:1. Half of what you feed to female calve 2. Quarter of what you feed to female calve 3. Three quarter of what you feed to female calve 4. Others (specify)
15. Why are you feeding less milk to male calve ?1. Less valued compared to female calve [____] 2. Cultural reasons [____] 3. others (specify)
16. How do you raise an orphan calf? 1. Foster mother [____] 2. Hand feeding [____] 3. Others (specify) [____]
17. If hand feed what type of feed do you use 1. Whole milk [____] 2. Porridge [____] 3. Animal fat and porridge [____] 4. Others [____]
18. Do you think human, and calf milk competition is a problem? 1. Yes [____] 2. No [____]
19. If yes, how best can it be addressed?

20. . What is your perception on the rate of growth of calves with age? [1= high, 2= moderate, 3= low,] (*Tick in each category)*

Age in months	<1	1-3	4-6	7-9	10-12
_Physical assessment					

21. Name major factors responsible for retarding growth in calves before weaning? (Rank in order of importance)

____

____

____

____ -.*(Rank: 1- most important, 2- important, 3- less important, 4- least important)*

22. What are the common causes of calf mortality related to nutrition? 1. Deprivation of colostrum 2. Deprivation of milk 3. Lack forage 4. All of the above 5. Others________________-
23. For the last 5 years how many calves did you lose for the following reasons

Years	Number of calves died	Due to limited colostrum feeding (numbers)	Due to limited milk feeding (numbers)	Limited forage/ drought (numbers)	Unknown cause (numbers)	Disease (specify) (numbers)

2020						
2019						
2018						
2017						
2016						

<u>SCHEDULE 6</u>: Forage, water and salt supplementation

1. At what age do you introduce forage to your camel calf after birth? 1. First month [____] 2. Second month [____] 3. third month [____] 4. Fourth month [____]
2. What type of forage do you use for feeding camel calves before opening for free range browsing?

Name of the forage (Best five)		Reason for preferred forage 1= highly nutritive 2= mineral(s)/required salt(s) content 3= palatable/digestible 4= other (specify)	Where they are found			Trend over the last 10 years' period 1= Constant 2= increasing 3 = decreasing
Botanical name	Local name		Rainy	Dry	Drought	

3. At what age do you open camel calves for free range browsing after birth ?1. First month [____] 2. Second month [____] 3. third month [____] 4. Fourth month [____]
4. What are the main camel calves preferred forages, reasons for preference, grazing area found and trends in terms of availability in last 10 years?

Name of the forage (Best five)		Reason for preferred forage 1= highly nutritive 2= mineral(s)/required salt(s) content 3= palatable/digestible 4= other (specify)	Grazing area			Trend over the last 10 years' period 1= Constant 2= increasing 3 = decreasing
Botanical name	Local name		Rainy	Dry	Drought	

5.Are there traditional sources of feeds used as a substitute to milk feeding that you know and you

have ever used? 1. Yes [____] 2. No [____]

6. If yes, state the type of substitute and quantity used on daily basis per calf and cost incurred.

Name of the substitute	Source of substitute	Quantity used /day/calf (kg/litres	Calf performance 5. Very good 6. Good 7. Fair 8. poor	Cost/ unit sale(kg/L)

7. How would you rate the quality of traditional supplements you are currently using for your calves? _____

[1= very good; 2= good; 3= Fair; 4= Poor]

8. Are you aware of other feed supplements for calves currently available in the market/ your locality [1=Yes; 2= No]

9. If yes, which ones [1=Natural stands 2=Natural salt. 3=Commercial feeds 4=commercial minerals 5=others (specify)

10. Do you give salt supplement to your camel calves? 1. Yes [____] 2. No [____]

11. I f yes, what type of salt 1. Natural licks [____] 2. Commercial salt [____] 3. Table salt [____].

12. How frequent do you give? 1. Throughout [____] 2. Weekly [____] 3. After two weeks [____] 4. Once a month [____] 5. After two months [____] 6. After six months [____] 7. Others (specify) [____]

13. At what age do you introduce water to your calves after birth? 1. First week 2. Second week 3. Third week 4. Fourth week 5. Second month 6. Third month 7. Fourth month 8. Others (specify)

14. What is their watering interval 1. One day [____] 2. Two to three days [____] 3. Four to five days' days [____] 4. Six to seven days [____] 5. Eight to ten days [____] 6. Eleven to fourteen days [____]

15. what is the source of water for your calves 1. Shallow well [____] 2. Bore hole [____] 3. Seasonal rivers [____] 4. Water pan [____] 5. Dam [____] 6. Others (specify) [____]

16.What distances do calves cover during foraging and watering in different seasons (Km)

Watering distance [__________] foraging distance [__________] **(wet season)**

Watering distances [__________] foraging distance [___________] **(Dry season)**

17. What are the Major constraints to camel calf feeding in your area?

18.Name the peak months of feed shortage in the normal year.

19. Name the peak months of feed abundance in the normal year.

<u>SCHEDULE 7</u>: Calf health management

1. Rank important calves' diseases/agents in your area in order of importance?

Diseases /agents	Calf

1.0		
1.2		
1.3		
1.4		
1.5		
1.6		
1.7		
1.8		
1.9		
1.10		

2. Do you associate some agent of diseases/diseases with specific grazing area(s)? [1= Yes 2= No] (Tick one)

3. If yes, name the agent of diseases/diseases and associated area(s)

Agent of diseases/diseases	grazing area(s)

4. Are there some unknown agent of diseases/diseases of camel calves in your area? [1= Yes 2= No] (Tick one)

5. If yes, describe the clinical signs and stage it affect calf in months?

Description of diseases /agents	**Stage it affect Calve in months**

6. Which are your sources of drugs? (Tick √)

1=Own collection of Traditional herbs 2=Traditional medicine men 3=Buy from community local open markets 4=Buy from community local shops (Agrovets) 5=Buy from Paravets/CBAHWs 6= Buy from CBOs/NGOs 7=Veterinary department 8= others

7. Where do get your veterinary services?1= Paravets/CBAHWs 2= CBOs/NGOs 3=Veterinary department 4. Traditional medicine men 5= others

8. Do you believe some camel calves diseases are due to taboos and/or bad omen? [1= Yes 2= No] (Tick one)

9. If yes, which are these?

	Diseases	Associated taboo/myth	Stage it affect calves in months
1			
2			
3			
4			

10 Do you know of any diseases associated with poor feeding of camel calves? [1= Yes 2= No] (Tick)

	If yes , which are these diseases	And how do you treat them
1		
2		
3		
4		
5		
6		

11. Do you know of any diseases passed from camel dam or bull/sire to camel calves? Yes_______/ No_______

	If Yes, name them?	And how do you prevent them
1		
2		
3		
4		
5		

6		

12. For the last 10 years how many calves in your herd were born alive, died and sold?

The past ten years	No. of calve born alive	sex		No. Died	No. Alive	No. Sold	Cause of death
		Male	female				
2011							
2012							
2013							
2014							
2015							
2016							
2017							
2018							
2019							
2020							

*NB-Record any disease and /deaths observed during the interview day

No	Diseases	Death	comments
1			
2			
3			

13. what are key constraints to calve rearing______________________________

14. what are key constraint to camel production____
____
____
____
____
____
____
____
____
_____

Thank you

Kalath Kulaba-Rendille

Ashe Oleng-Ariaals.

Results Summary

Appendix B: SAS output for objective one

Dependent Variable: Crude protein (CP)

The GLM Procedure

Dependent Variable: CP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	366.0948000	36.6094800	39224.4	<.0001
Error	21	0.0196000	0.0009333		
Corrected Total	31	366.1144000			

R-Square	Coeff Var	Root MSE	CP Mean
0.999946	0.180585	0.030551	16.91750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
species	10	366.0948000	36.6094800	39224.4	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	10	366.0948000	36.6094800	39224.4	<.0001

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Standard LSMEAN

species	CP LSMEAN	Error	Pr > |t|	Number
Acaciabr	17.2500000	0.0216025	<.0001	1
Aspiliam	16.0333333	0.0176383	<.0001	2
Cordiasi	15.5666667	0.0176383	<.0001	3
Duosperm	21.6166667	0.0176383	<.0001	4
Erucastr	14.7666667	0.0176383	<.0001	5
Grewiabi	24.1666667	0.0176383	<.0001	6
Harrison	16.8300000	0.0176383	<.0001	7
Lanneasc	17.4333333	0.0176383	<.0001	8
Rhusnata	12.3566667	0.0176383	<.0001	9
Securine	17.5766667	0.0176383	<.0001	10
Ximeniaa	12.6066667	0.0176383	<.0001	11

Least Squares Means for effect species
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: CP

i/j	1	2	3	4	5	6
1		<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001		<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001		<.0001	<.0001	<.0001
4	<.0001	<.0001	<.0001		<.0001	<.0001
5	<.0001	<.0001	<.0001	<.0001		<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001	
7	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
8	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
9	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
10	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
11	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Least Squares Means for effect species
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: CP

i/j	7	8	9	10	11
1	<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001	<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001	<.0001	<.0001	<.0001

4	<.0001	<.0001	<.0001	<.0001	<.0001
5	<.0001	<.0001	<.0001	<.0001	<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001
7		<.0001	<.0001	<.0001	<.0001
8	<.0001		<.0001	0.0004	<.0001

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Least Squares Means for effect species
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: CP

i/j	7	8	9	10	11
9	<.0001	<.0001		<.0001	<.0001
10	<.0001	0.0004	<.0001		<.0001
11	<.0001	<.0001	<.0001	<.0001	

The GLM Procedure

t Tests (LSD) for CP

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	21
Error Mean Square	0.000933
Critical Value of t	2.07961
Least Significant Difference	0.053
Harmonic Mean of Cell Sizes	2.869565

NOTE: Cell sizes are not equal.

Means with the same letter are not significantly different.

t Grouping	Mean	N	species
A	24.16667	3	Grewiabi
B	21.61667	3	Duosperm
C	17.57667	3	Securine
D	17.43333	3	Lanneasc
E	17.25000	2	Acaciabr
F	16.83000	3	Harrison
G	16.03333	3	Aspiliam
H	15.56667	3	Cordiasi
I	14.76667	3	Erucastr
J	12.60667	3	Ximeniaa
K	12.35667	3	Rhusnata

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The GLM Procedure

Ryan-Einot-Gabriel-Welsch Multiple Range Test for CP

NOTE: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	21
Error Mean Square	0.000933
Harmonic Mean of Cell Sizes	2.869565

NOTE: Cell sizes are not equal.

Number of Means	2	3	4	5	6

Critical Range	0.0730637	0.0794505	0.0829265	0.0852425	0.0869455

Number of Means	7	8	9	10	11
Critical Range	0.0882707	0.0893413	0.0902297	0.0902297	0.0916278

Means with the same letter are not significantly different.

REGWQ Grouping	Mean	N	species
A	24.16667	3	Grewiabi
B	21.61667	3	Duosperm
C	17.57667	3	Securine
D	17.43333	3	Lanneasc
E	17.25000	2	Acaciabr
F	16.83000	3	Harrison
G	16.03333	3	Aspiliam
H	15.56667	3	Cordiasi
I	14.76667	3	Erucastr
J	12.60667	3	Ximeniaa
K	12.35667	3	Rhusnata

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The GLM Procedure

Tukey's Studentized Range (HSD) Test for CP

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II
error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	21
Error Mean Square	0.000933
Critical Value of Studentized Range	5.08062
Minimum Significant Difference	0.0916
Harmonic Mean of Cell Sizes	2.869565

NOTE: Cell sizes are not equal.

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	species
A	24.16667	3	Grewiabi
B	21.61667	3	Duosperm
C	17.57667	3	Securine
D	17.43333	3	Lanneasc
E	17.25000	2	Acaciabr
F	16.83000	3	Harrison
G	16.03333	3	Aspiliam
H	15.56667	3	Cordiasi
I	14.76667	3	Erucastr
J	12.60667	3	Ximeniaa
K	12.35667	3	Rhusnata

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The GLM Procedure

Bonferroni (Dunn) t Tests for CP

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type

II

error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	21
Error Mean Square	0.000933
Critical Value of t	3.85927
Minimum Significant Difference	0.0984
Harmonic Mean of Cell Sizes	2.869565

NOTE: Cell sizes are not equal.

Means with the same letter are not significantly different.

Bon Grouping	Mean	N	species
A	24.16667	3	Grewiabi
B	21.61667	3	Duosperm
C	17.57667	3	Securine
D	17.43333	3	Lanneasc
E	17.25000	2	Acaciabr
F	16.83000	3	Harrison
G	16.03333	3	Aspiliam
H	15.56667	3	Cordiasi
I	14.76667	3	Erucastr
J	12.60667	3	Ximeniaa
K	12.35667	3	Rhusnata

Dependent Variable: Metabolisable energy

The GLM Procedure

Dependent Variable: ME

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	777.7378909	77.7737891	31961.8	<.0001
Error	22	0.0535333	0.0024333		
Corrected Total	32	777.7914242			

R-Square	Coeff Var	Root MSE	ME Mean
0.999931	0.386030	0.049329	12.77848

Source	DF	Type I SS	Mean Square	F Value	Pr > F
species	10	777.7378909	77.7737891	31961.8	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	10	777.7378909	77.7737891	31961.8	<.0001

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

species	ME LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
Acaciabr	4.8366667	0.0284800	<.0001	1
Aspiliam	20.4266667	0.0284800	<.0001	2
Cordiasi	12.8466667	0.0284800	<.0001	3
Duosperm	13.2966667	0.0284800	<.0001	4
Erucastr	16.9133333	0.0284800	<.0001	5
Grewiabi	14.6666667	0.0284800	<.0001	6
Harrison	17.0266667	0.0284800	<.0001	7
Lanneasc	14.1333333	0.0284800	<.0001	8

Rhusnata	9.0266667	0.0284800	<.0001	9
Securine	13.6666667	0.0284800	<.0001	10
Ximeniaa	3.7233333	0.0284800	<.0001	11

Least Squares Means for effect species
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: ME

i/j	1	2	3	4	5	6
1		<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001		<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001		<.0001	<.0001	<.0001
4	<.0001	<.0001	<.0001		<.0001	<.0001
5	<.0001	<.0001	<.0001	<.0001		<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001	
7	<.0001	<.0001	<.0001	<.0001	0.2159	<.0001
8	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
9	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
10	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
11	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Least Squares Means for effect species
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: ME

i/j	7	8	9	10	11
1	<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001	<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001	<.0001	<.0001	<.0001
4	<.0001	<.0001	<.0001	<.0001	<.0001
5	0.2159	<.0001	<.0001	<.0001	<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001
7		<.0001	<.0001	<.0001	<.0001
8	<.0001		<.0001	<.0001	<.0001

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The GLM Procedure
Least Squares Means

Adjustment for Multiple Comparisons: Tukey

Least Squares Means for effect species
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: ME

i/j	7	8	9	10	11
9	<.0001	<.0001		<.0001	<.0001
10	<.0001	<.0001	<.0001		<.0001
11	<.0001	<.0001	<.0001	<.0001	

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The GLM Procedure

t Tests (LSD) for ME

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	22
Error Mean Square	0.002433
Critical Value of t	2.07387
Least Significant Difference	0.0835

Means with the same letter are not significantly different.

t Grouping	Mean	N	species
A	20.42667	3	Aspiliam
B	17.02667	3	Harrison
C	16.91333	3	Erucastr
D	14.66667	3	Grewiabi
E	14.13333	3	Lanneasc

F	13.66667	3	Securine
G	13.29667	3	Duosperm
H	12.84667	3	Cordiasi
I	9.02667	3	Rhusnata
J	4.83667	3	Acaciabr
K	3.72333	3	Ximeniaa

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The GLM Procedure

Ryan-Einot-Gabriel-Welsch Multiple Range Test for ME

NOTE: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	22
Error Mean Square	0.002433

Number of Means	2	3	4	5	6
Critical Range	0.1148475	0.1248511	0.1302971	0.1339291	0.1366031

Number of Means	7	8	9	10	11
Critical Range	0.1386868	0.1403725	0.1417731	0.1417731	0.1439822

Means with the same letter are not significantly different.

REGWQ Grouping	Mean	N	species
A	20.42667	3	Aspiliam
B	17.02667	3	Harrison
B			
B	16.91333	3	Erucastr

C	14.66667	3	Grewiabi
D	14.13333	3	Lanneasc
E	13.66667	3	Securine
F	13.29667	3	Duosperm
G	12.84667	3	Cordiasi
H	9.02667	3	Rhusnata
I	4.83667	3	Acaciabr
J	3.72333	3	Ximeniaa

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The GLM Procedure

Tukey's Studentized Range (HSD) Test for ME

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II
error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	22
Error Mean Square	0.002433
Critical Value of Studentized Range	5.05555
Minimum Significant Difference	0.144

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	species
A	20.42667	3	Aspiliam
B	17.02667	3	Harrison
B			

B	16.91333	3	Erucastr
C	14.66667	3	Grewiabi
D	14.13333	3	Lanneasc
E	13.66667	3	Securine
F	13.29667	3	Duosperm
G	12.84667	3	Cordiasi
H	9.02667	3	Rhusnata
I	4.83667	3	Acaciabr
J	3.72333	3	Ximeniaa

The GLM Procedure

Bonferroni (Dunn) t Tests for ME

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II
error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	22
Error Mean Square	0.002433
Critical Value of t	3.83139
Minimum Significant Difference	0.1543

Means with the same letter are not significantly different.

Bon Grouping	Mean	N	species
A	20.42667	3	Aspiliam
B	17.02667	3	Harrison

B			
B	16.91333	3	Erucastr
C	14.66667	3	Grewiabi
D	14.13333	3	Lanneasc
E	13.66667	3	Securine
F	13.29667	3	Duosperm
G	12.84667	3	Cordiasi
H	9.02667	3	Rhusnata
I	4.83667	3	Acaciabr
J	3.72333	3	Ximeniaa

Appendix C: SAS output for objective two

Dependent Variable: Crude protein (CP).

The GLM Procedure

Dependent Variable: CP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	366.0948000	36.6094800	39224.4	<.0001
Error	21	0.0196000	0.0009333		
Corrected Total	31	366.1144000			

R-Square   Coeff Var   Root MSE   CP Mean

0.999946	0.180585	0.030551	16.91750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
species	10	366.0948000	36.6094800	39224.4	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	10	366.0948000	36.6094800	39224.4	<.0001

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

species	CP LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
Acaciabr	17.2500000	0.0216025	<.0001	1
Aspiliam	16.0333333	0.0176383	<.0001	2
Cordiasi	15.5666667	0.0176383	<.0001	3
Duosperm	21.6166667	0.0176383	<.0001	4
Erucastr	14.7666667	0.0176383	<.0001	5
Grewiabi	24.1666667	0.0176383	<.0001	6
Harrison	16.8300000	0.0176383	<.0001	7
Lanneasc	17.4333333	0.0176383	<.0001	8
Rhusnata	12.3566667	0.0176383	<.0001	9
Securine	17.5766667	0.0176383	<.0001	10
Ximeniaa	12.6066667	0.0176383	<.0001	11

Least Squares Means for effect species
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: CP

i/j	1	2	3	4	5	6
1		<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001		<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001		<.0001	<.0001	<.0001
4	<.0001	<.0001	<.0001		<.0001	<.0001
5	<.0001	<.0001	<.0001	<.0001		<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001	
7	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
8	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
9	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
10	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
11	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Least Squares Means for effect species
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: CP

i/j	7	8	9	10	11
1	<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001	<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001	<.0001	<.0001	<.0001
4	<.0001	<.0001	<.0001	<.0001	<.0001
5	<.0001	<.0001	<.0001	<.0001	<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001
7		<.0001	<.0001	<.0001	<.0001
8	<.0001		<.0001	0.0004	<.0001

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Least Squares Means for effect species
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: CP

i/j	7	8	9	10	11
9	<.0001	<.0001		<.0001	<.0001
10	<.0001	0.0004	<.0001		<.0001
11	<.0001	<.0001	<.0001	<.0001	

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The GLM Procedure

t Tests (LSD) for CP

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	21
Error Mean Square	0.000933
Critical Value of t	2.07961
Least Significant Difference	0.053
Harmonic Mean of Cell Sizes	2.869565

NOTE: Cell sizes are not equal.

Means with the same letter are not significantly different.

t Grouping	Mean	N	species
A	24.16667	3	Grewiabi
B	21.61667	3	Duosperm
C	17.57667	3	Securine
D	17.43333	3	Lanneasc
E	17.25000	2	Acaciabr
F	16.83000	3	Harrison
G	16.03333	3	Aspiliam
H	15.56667	3	Cordiasi
I	14.76667	3	Erucastr
J	12.60667	3	Ximeniaa
K	12.35667	3	Rhusnata

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The GLM Procedure

Ryan-Einot-Gabriel-Welsch Multiple Range Test for CP

NOTE: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	21
Error Mean Square	0.000933
Harmonic Mean of Cell Sizes	2.869565

NOTE: Cell sizes are not equal.

Number of Means	2	3	4	5	6
Critical Range	0.0730637	0.0794505	0.0829265	0.0852425	0.0869455

Number of Means	7	8	9	10	11
Critical Range	0.0882707	0.0893413	0.0902297	0.0902297	0.0916278

Means with the same letter are not significantly different.

REGWQ Grouping	Mean	N	species
A	24.16667	3	Grewiabi
B	21.61667	3	Duosperm
C	17.57667	3	Securine
D	17.43333	3	Lanneasc
E	17.25000	2	Acaciabr
F	16.83000	3	Harrison
G	16.03333	3	Aspiliam
H	15.56667	3	Cordiasi
I	14.76667	3	Erucastr
J	12.60667	3	Ximeniaa
K	12.35667	3	Rhusnata

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The GLM Procedure

Tukey's Studentized Range (HSD) Test for CP

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	21
Error Mean Square	0.000933
Critical Value of Studentized Range	5.08062
Minimum Significant Difference	0.0916
Harmonic Mean of Cell Sizes	2.869565

NOTE: Cell sizes are not equal.

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	species
A	24.16667	3	Grewiabi
B	21.61667	3	Duosperm

C	17.57667	3	Securine
D	17.43333	3	Lanneasc
E	17.25000	2	Acaciabr
F	16.83000	3	Harrison
G	16.03333	3	Aspiliam
H	15.56667	3	Cordiasi
I	14.76667	3	Erucastr
J	12.60667	3	Ximeniaa
K	12.35667	3	Rhusnata

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The GLM Procedure

Bonferroni (Dunn) t Tests for CP

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	21
Error Mean Square	0.000933
Critical Value of t	3.85927
Minimum Significant Difference	0.0984
Harmonic Mean of Cell Sizes	2.869565

NOTE: Cell sizes are not equal.

Means with the same letter are not significantly different.

Bon Grouping	Mean	N	species
A	24.16667	3	Grewiabi
B	21.61667	3	Duosperm
C	17.57667	3	Securine
D	17.43333	3	Lanneasc
E	17.25000	2	Acaciabr

F	16.83000	3	Harrison
G	16.03333	3	Aspiliam
H	15.56667	3	Cordiasi
I	14.76667	3	Erucastr
J	12.60667	3	Ximeniaa
K	12.35667	3	Rhusnata

Dependent Variable: Metabolisable energy

The GLM Procedure

Dependent Variable: ME

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	777.7378909	77.7737891	31961.8	<.0001
Error	22	0.0535333	0.0024333		
Corrected Total	32	777.7914242			

R-Square	Coeff Var	Root MSE	ME Mean
0.999931	0.386030	0.049329	12.77848

Source	DF	Type I SS	Mean Square	F Value	Pr > F
species	10	777.7378909	77.7737891	31961.8	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	10	777.7378909	77.7737891	31961.8	<.0001

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

species	ME LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
Acaciabr	4.8366667	0.0284800	<.0001	1
Aspiliam	20.4266667	0.0284800	<.0001	2

Cordiasi	12.8466667	0.0284800	<.0001	3
Duosperm	13.2966667	0.0284800	<.0001	4
Erucastr	16.9133333	0.0284800	<.0001	5
Grewiabi	14.6666667	0.0284800	<.0001	6
Harrison	17.0266667	0.0284800	<.0001	7
Lanneasc	14.1333333	0.0284800	<.0001	8
Rhusnata	9.0266667	0.0284800	<.0001	9
Securine	13.6666667	0.0284800	<.0001	10
Ximeniaa	3.7233333	0.0284800	<.0001	11

Least Squares Means for effect species
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: ME

i/j	1	2	3	4	5	6
1		<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001		<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001		<.0001	<.0001	<.0001
4	<.0001	<.0001	<.0001		<.0001	<.0001
5	<.0001	<.0001	<.0001	<.0001		<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001	
7	<.0001	<.0001	<.0001	<.0001	0.2159	<.0001
8	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
9	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
10	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
11	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Least Squares Means for effect species
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: ME

i/j	7	8	9	10	11
1	<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001	<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001	<.0001	<.0001	<.0001
4	<.0001	<.0001	<.0001	<.0001	<.0001
5	0.2159	<.0001	<.0001	<.0001	<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001
7		<.0001	<.0001	<.0001	<.0001
8	<.0001		<.0001	<.0001	<.0001

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Least Squares Means for effect species

Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: ME

i/j	7	8	9	10	11
9	<.0001	<.0001		<.0001	<.0001
10	<.0001	<.0001	<.0001		<.0001
11	<.0001	<.0001	<.0001	<.0001	

The GLM Procedure

t Tests (LSD) for ME

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	22
Error Mean Square	0.002433
Critical Value of t	2.07387
Least Significant Difference	0.0835

Means with the same letter are not significantly different.

t Grouping	Mean	N	species
A	20.42667	3	Aspiliam
B	17.02667	3	Harrison
C	16.91333	3	Erucastr
D	14.66667	3	Grewiabi
E	14.13333	3	Lanneasc
F	13.66667	3	Securine
G	13.29667	3	Duosperm
H	12.84667	3	Cordiasi
I	9.02667	3	Rhusnata
J	4.83667	3	Acaciabr
K	3.72333	3	Ximeniaa

The GLM Procedure

Ryan-Einot-Gabriel-Welsch Multiple Range Test for ME

NOTE: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	22
Error Mean Square	0.002433

Number of Means	2	3	4	5	6
Critical Range	0.1148475	0.1248511	0.1302971	0.1339291	0.1366031

Number of Means	7	8	9	10	11
Critical Range	0.1386868	0.1403725	0.1417731	0.1417731	0.1439822

Means with the same letter are not significantly different.

REGWQ Grouping	Mean	N	species
A	20.42667	3	Aspiliam
B	17.02667	3	Harrison
B			
B	16.91333	3	Erucastr
C	14.66667	3	Grewiabi
D	14.13333	3	Lanneasc
E	13.66667	3	Securine
F	13.29667	3	Duosperm
G	12.84667	3	Cordiasi
H	9.02667	3	Rhusnata
I	4.83667	3	Acaciabr
J	3.72333	3	Ximeniaa

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The GLM Procedure

Tukey's Studentized Range (HSD) Test for ME

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	22
Error Mean Square	0.002433
Critical Value of Studentized Range	5.05555
Minimum Significant Difference	0.144

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	species
A	20.42667	3	Aspiliam
B	17.02667	3	Harrison
B			
B	16.91333	3	Erucastr
C	14.66667	3	Grewiabi
D	14.13333	3	Lanneasc
E	13.66667	3	Securine
F	13.29667	3	Duosperm
G	12.84667	3	Cordiasi
H	9.02667	3	Rhusnata
I	4.83667	3	Acaciabr
J	3.72333	3	Ximeniaa

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The GLM Procedure

Bonferroni (Dunn) t Tests for ME

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	22
Error Mean Square	0.002433
Critical Value of t	3.83139

Minimum Significant Difference 0.1543

Means with the same letter are not significantly different.

Bon Grouping	Mean	N	species
A	20.42667	3	Aspiliam
B	17.02667	3	Harrison
B			
B	16.91333	3	Erucastr
C	14.66667	3	Grewiabi
D	14.13333	3	Lanneasc
E	13.66667	3	Securine
F	13.29667	3	Duosperm
G	12.84667	3	Cordiasi
H	9.02667	3	Rhusnata
I	4.83667	3	Acaciabr
J	3.72333	3	Ximenia

Appendix D: SAS output for objective three

Dependent variable: Intake

The GLM Procedure

Dependent Variable: intake

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	48.42942857	5.38104762	129.52	<.0001
Error	690	28.66771429	0.04154741		
Corrected Total	699	77.09714286			

R-Square Coeff Var Root MSE intake Mean

0.628161	9.241080	0.203832	2.205714

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Trt	9	48.42942857	5.38104762	129.52	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	9	48.42942857	5.38104762	129.52	<.0001

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Trt	intake LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
MR1	2.00000000	0.02436256	<.0001	1
MR2	2.00000000	0.02436256	<.0001	2
MR3	2.00000000	0.02436256	<.0001	3
MR4	2.00000000	0.02436256	<.0001	4
MR5	2.00000000	0.02436256	<.0001	5
TMR1	2.35142857	0.02436256	<.0001	6
TMR2	2.20857143	0.02436256	<.0001	7
TMR3	2.64285714	0.02436256	<.0001	8
TMR4	2.71857143	0.02436256	<.0001	9
TMR5	2.13571429	0.02436256	<.0001	10

Least Squares Means for effect Trt
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: intake

i/j	1	2	3	4	5	6	7	8	9	10
1		1.0000	1.0000	1.0000	1.0000	<.0001	<.0001	<.0001	<.0001	0.0036
2	1.0000		1.0000	1.0000	1.0000	<.0001	<.0001	<.0001	<.0001	0.0036
3	1.0000	1.0000		1.0000	1.0000	<.0001	<.0001	<.0001	<.0001	0.0036
4	1.0000	1.0000	1.0000		1.0000	<.0001	<.0001	<.0001	<.0001	0.0036

5	1.0000	1.0000	1.0000	1.0000		<.0001	<.0001	<.0001	<.0001	0.0036
6	<.0001	<.0001	<.0001	<.0001	<.0001		0.0016	<.0001	<.0001	<.0001
7	<.0001	<.0001	<.0001	<.0001	<.0001	0.0016		<.0001	<.0001	0.5177
8	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		0.4594	<.0001
9	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.4594		<.0001
10	0.0036	0.0036	0.0036	0.0036	0.0036	<.0001	0.5177	<.0001	<.0001	

Dependent Variable: ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	2.47011051	0.41168509	10.31	<.0001
Error	113	4.51341949	0.03994177		
Corrected Total	119	6.98353000			

R-Square	Coeff Var	Root MSE	ADG Mean
0.453705	32.95208	0.199854	0.606500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BREED	1	0.01584375	0.01584375	0.40	0.5301
IWGT	1	0.25437493	0.25437493	6.37	0.0130
TREATMENT	2	2.19252789	1.09626395	27.45	<.0001
BREED*TREATMENT	2	0.00736394	0.00368197	0.09	0.9120

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BREED	1	0.12629083	0.12629083	3.16	0.0781
IWGT	1	0.01954509	0.01954509	0.49	0.4857
TREATMENT	2	2.16232251	1.08116126	27.07	<.0001
BREED*TREATMENT	2	0.00736394	0.00368197	0.09	0.9120

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The GLM Procedure

Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

TREATMENT	ADG LSMEAN	Standard Error	LSMEAN Pr > |t|	Number
CTR	0.42390381	0.03968212	<.0001	1
MR	0.80437154	0.03521551	<.0001	2
TMR	0.55661471	0.04051409	<.0001	3

Least Squares Means for Effect TREATMENT
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: ADG

i/j	1	2	3
1		-7.0381	-2.31563
		<.0001	0.0577
2	7.038103		4.834139
	<.0001		<.0001
3	2.315629	-4.83414	
	0.0577	<.0001	

The GLM Procedure
Least Squares Means

BREED	TREATMENT	ADG LSMEAN	Standard Error	Pr > |t|
C	CTR	0.39619713	0.07332201	<.0001
C	MR	0.75303732	0.04254755	<.0001
C	TMR	0.50952675	0.07272076	<.0001
S	CTR	0.45161048	0.04457619	<.0001
S	MR	0.85570576	0.05252358	<.0001
S	TMR	0.60370267	0.03533924	<.0001

Appendix E: Excel output for objective four

PBMR

Cost- benefit of using locally formulated Milk replacer(15 females)											
Costs	**Yr1**	**y2**	**y3**	**y4**	**y5**	**Y6**	**Y7**	**Y8**	**Y9**	**Y10**	
Cost of replacers	46116		46116		15372	46116	30744	46116	15372	15372	
Water	13371.43	10028.57	23400	20057.14	24514.29	36771.43	42342.86	53485.71	50142.86	50142.86	
Labor	32574		32574		32574	32574	32574	32574	32574	32574	
Veterinary costs	7584.667	5688.5	13273.17	11377	13905.22	20857.83	24018.11	30338.67	28442.5	28442.5	
Total cost	99646.1	15717.07	115363.2	31434.14	86365.51	136319.3	129679	162514.4	126531.4	126531.4	
Benefits											
Milk saved	527040		527040		175680	527040	351360	527040	175680	175680	
Number of calves in the herd (1st calving). 80% calving rates.	12										
Surviving calves(Mortality rate(.24)	9.12	9.12	9.12	9.12	9.12	9.12	9.12	9.12	9.12	9.12	
Market value of 1 calf/	355	479	519	569	650	650	650	650	650	650	

mature camel	**00**	**50**	**50**	**50**	**00**	**00**	**00**	**00**	**00**	**00**
Total value of calves in the herd	**323760**	**437304**	**473784**	**519384**	**592800**	**592800**	**592800**	**592800**	**592800**	**592800**
		113544	**36480**	**45600**	**73416**	**0**	**0**	**0**	**0**	**0**
2nd calving			**12**							
Number of calves			**9.12**	**9.12**	**9.12**	**9.12**	**9.12**	**9.12**	**9.12**	**9.12**
Market value of one calf			**35500**	**47950**	**51950**	**56950**	**65000**	**65000**	**65000**	**65000**
			323760	**437304**	**473784**	**519384**	**592800**	**592800**	**592800**	**592800**
3rd calving										
number of calves (Y6)						**12**				
Mortality rate(.24)						**9.12**	**9.12**	**9.12**	**9.12**	**9.12**
value of calves						**35500**	**47950**	**51950**	**56950**	**65000**
value of calves						**323760**	**437304**	**473784**	**519384**	**592800**
4th Calving								**9.12**	**9.12**	**9.12**
								35500	**47950**	**51950**
								323760	**437304**	**473784**
					4.56					
					3.6					

					48						
Calves born in Y1, 1st calving					**2.77248**	**2.77248**	**2.77248**	**2.77248**	**2.77248**	**2.77248**	
					35500	**47950**	**51950**	**56950**	**65000**	**65000**	
					98423.04	**132940.4**	**144030.3**	**157892.7**	**180211.2**	**180211.2**	
Calves born in Y1, 2nd calving							**2.77248**	**2.77248**	**2.77248**	**2.77248**	
							35500	**47950**	**51950**	**51950**	
							98423.04	**132940.4**	**144030.3**	**144030.3**	
Calves born in Y3, 1st calving							**2.77248**	**2.77248**	**2.77248**	**2.77248**	
							35500	**47950**	**51950**	**56950**	
							98423.04	**132940.4**	**144030.3**	**157892.7**	
Calves born in Y3, 2nd calving									**3**	**3**	
									35500	**47950**	

									106500	143850	
Calves born in Y1, 3rd calving										3	
										35500	
										106500	
Total value of calf herd	**850800**	**437304**	**1324584**	**956688**	**1340687**	**2095924**	**2315140**	**2933958**	**2892740**	**3160348**	
Total benefits	**1377840**	**437304**	**1851624**	**956688**	**1516367**	**2622964**	**2666500**	**3460998**	**3068420**	**3336028**	
B-C	**1278194**	**421586.9**	**1736261**	**925253.9**	**1430002**	**2486645**	**2536821**	**3298483**	**2941889**	**3209497**	
discount factor	**1.12**	**1.2544**	**1.404928**	**1.573519**	**1.762342**	**1.973823**	**2.210681**	**2.475963**	**2.773079**	**3.105848**	
NPV	**1141245**	**336086.5**	**1235836**	**588015.6**	**811421.3**	**1259812**	**1147529**	**1332202**	**1060874**	**1033372**	**9946394**
Discounted benefits	**1230214**	**348616.1**	**1317949**	**607992.5**	**860427.4**	**1328875**	**1206189**	**1397839**	**1106503**	**1074112**	
Discounted Costs	**88969.73**	**12529.55**	**82113.22**	**19976.97**	**49006.11**	**69063.58**	**58660.18**	**65636.83**	**45628.48**	**40739.71**	

BCR	**13.82734**	**27.8235**	**16.05039**	**30.43468**	**17.55755**	**19.24133**	**20.56232**	**21.29656**	**24.25027**	**26.36523**	
NB.											
I assumed a herd of 15 females that calve at the same time. Camels are seasonal breeders.											
calving rates are 2 in 5 years-in the 3rd year it calves again											
Mortality with replacers .24											
mortality without replacers .35											

Pastoral system

Cost- benefit with pastoral system(15 females)											
Costs	**Yr 1**	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**	**Y7**	**Y8**	**Y9**	**Y10**	
Cost of replacers	-		-								
Water	13371	8914	22286	17829	17829	34543	28971	41229	42343	42343	
Labor	32,5		32,57			32,57					

	74		4			4		32,574	32,574		
Veterinary costs	17,486	11,657	29,143	23,314	23,314	45,171	37,886	53,914	55,371	55,371	
Total cost	**63,431**	**20,571**	**84,003**	**41,143**	**41,143**	**112,288**	**66,857**	**127,717**	**130,288**	**97,714**	
Benefits											
Milk saved	-		-								
Vet cost saved	-		-								
Number of calves in the herd (1st calving). 80% calving rates.	12										

Surviving calves (Mortality rate(.35)	8	8	8	8	8	8.0	8	8	8	8	
Market value of 1 calf/ mature camel	35,500	47,950	51,950	56,950	65,000	65,000.0	65000	65000	65000	65000	
Total value of calves in the herd	276,900	383,600	415,600	455,600	520,000	520,000	520,000	520,000	520,000	520,000	
2nd calving			12								
Number of			8	8	8	8.0	8	8	8	8	

calves											
Market value of one calf			35,500	47,950	51,950	56,950.0	65000	65000	65000	65000	
			276,900	383,600	415,600	455,600	520,000	520,000	520,000	520,000	
3rd calving											
number of calves (Y6)						12					
Mortality rate(.35)						8	8	8	8	8	
value of calves						35,500	47,950	51,950	56,950	65,000	
value of calves						276,900	374,010	405,210	444,210	507,000	

4th Calving								8	8	8	
								35,500	47,950	51,950	
								276,900	374,010	405,210	
Mature calves (1st calving						4					
						3					
Calves born in Y1, 1st calving						2	2	2	2	2	
						35,500	47,950	51,950	56,950	65,000	

						71,994	97,243	105,355	115,495	131,820	
Calves born in Y1, 2nd calving									2	2	
									35,500	47,950	
									71,994	97,243	
Calves born in Y3, 1st calving								2	2	2	
								35,500	47,950	51,950	
								71,994	97,243	105,355	
Total											

value of calf herd	**276,900**	**383,600**	**692,500**	**839,200**	**935,600**	**1,324,494**	**1,511,253**	**1,899,459**	**2,142,951**	**2,286,627**	
Total benefits	276,900	383,600	692,500	839,200	935,600	1,324,494	1,511,253	1,899,459	2,142,951	2,286,627	
B-C	213,469	363,029	608,497	798,057	894,457	1,212,206	1,444,395	1,771,742	2,012,663	2,188,913	
Discount factor	1.1200	1.25440	1.4049280	1.57352	1.762342	1.973823	2.210681407	2.475963176	2.773078757	3.105848208	
NPV	**190,597**	**289,404**	**433,116**	**507,180**	**507,539**	**614,141**	**653,371**	**715,577**	**725,786**	**704,771**	**5,341,483**
Discounted benefits	247,232	305,804	492,908	533,327	530,885	671,030	683,614	767,159	772,770	736,233	
Discounted costs	56,635	16,399	59,791	26,147	23,346	56,889	30,243	51,583	46,983	31,461	
BCR	**4**	**19**	**8**	**20**	**23**	**12**	**23**	**15**	**16**	**23**	

Appendix F: Abstract of published paper on objective one

Researchjournali's Journal of Agriculture

Vol. 8 | No. 9 September | 2021 *1*

Evaluation of Existing Indigenous Knowledge and Practices On Camel Milk Substitutes in Rearing Camel Calves Under Extensive and Peri-Urban Production Systems in Kenya

Tura Isako, Kingo'ri A.M., Ondiek J.O & Onjoro P. A.

Egerton University, Department of Animal Science, P.O. Box 536-20115 Egerton, Kenya

ABSTRACT

Mortality rates, the causes, calf retardation and evaluation of existing indigenous knowledge and practices on milk substitutes in rearing camel calves were evaluated in extensive and peri-urban camel production systems in Kenya. The study used key informant questionnaires (KI) and focus group discussions (FGDs) methods to collect the data. Simple systematic random sampling survey method was used to collect key informants' data. FGDs comprising of 12 camel keepers were purposefully selected and conducted per study site based on their knowledge in camel husbandry. The key informant data was entered and analyzed using Statistical Package for Social Sciences (SPSS, 2019). Data collected using focus group discussions (FGDs) from different sites were analyzed using constant comparison analysis method. The study established that mortality rates were 35.2 and 4.3% in pastoral and peri-urban system, respectively. Diseases, droughts, predations and parasites were the four major causes of camel calf mortality. In peri-urban system, diseases accounts for up to 49%, parasites 16% predators 2% and drought 33% of the mortality while in extensive system drought accounts for 53%, predation 15%, parasites 17% and diseases 15% of the mortality. The study further established that diseases, drought and competition for milk between the calf and households for trade and human consumption were major factors responsible for camel calves retarded growth. In peri-urban system, diseases accounts for 63%, drought 29% and competition for milk 8% while in extensive system drought accounts for 40%, diseases 28% and competition for milk 32%. This study established that Pastoralists did not have any substitute to milk feeding for camel calves., However, when the dam dries early due to pregnancy, sudden death of dams and during dry/drought period they supplement the calves with locally available feed resources such as camel blood animal fat, *acacia tortilis* pods, *Merremia ampelophylia, Tinnospora caffra, Cordia sinensis* and grasses such as *Cenchrus ciliaris* among others forages. The study concluded that feed was major factor affecting performance and survival of camel calves. Therefore, there is need to improve camel calves feeding system in both pastoral and peri-urban production systems for enhanced performance.

Key words: substitute to milk, camel calves, mortality rates, retarded growth, pastoral production systems

Appendix G: Abstract of published paper on objective two

International Journal of Veterinary Sciences and Animal Husbandry 2021; 6(5): 31-39

International Journal of Veterinary Sciences and Animal Husbandry

ISSN: 2456-2912
VET 2021; 6(5): 31-39

www.veterinarypaper.com Received: 16-07-2021
Accepted: 18-08-2021

I Tura
Egerton University, Department of Animal Science, P.O Box, Egerton, Kenya

JO Ondiek
Egerton University, Department of Animal Science, P.O Box, Egerton, Kenya

AM Kingo'ri
Egerton University, Department of Animal Science, P.O Box, Egerton, Kenya

PA Onjoro
Egerton University, Department of Animal Science, P.O Box, Egerton, Kenya

Corresponding Author: I Tura
Egerton University, Department of Animal Science, P.O Box, Egerton, Kenya

Proximate composition of selected browses and common milk supplements for camel calves in Kenya

I Tura, JO Ondiek, AM Kingo'ri and PA Onjoro

Abstract
A study on nutritive values of selected browses fed to camel calves and commonly used local feed supplements to milk feeding was conducted in the southern rangelands of Marsabit County. Selected browses and common supplements were analyzed for their proximate composition. In addition, commonly used supplements were analyzed for their amino acid profiles, Ca, P and tannin levels. The samples were analyzed for their potential to formulate plant-based milk replacer or starter feeds for camel calves. The study used focused group discussions (FGDs) to identify available browses and commonly used supplements. Four focus group discussions (FGDs) comprising of 12 persons per study site: Karare, Kargi, Korr and Ngurunit wards were conducted in the main camel keeping areas among the Rendille camel keeping community. A total of 10 browses, 4 grass species and 6 commonly used supplements were analyzed. This study established that CP, DM, fat, NDF, ADF, and ME composition were highly variable, with significant ($P<0.05$) differences among the browses and grasses. Browses like *Grewia bicolor* (24% CP) *and Justicia exigua* (20% CP) have a potential to provide recommended daily protein requirements for a camel calves (20-24% CP) as starter feeds and plant-based milk replacer. Browses which have recommended energy above 15 MJ. Kg-1 DM to meet daily energy requirement of camel calves for starter feeds and plant-based milk replacer are *Justicia exigua* (19.3 MJ. Kg-1 DM), *Acacia melliffera* (18.1 MJ. Kg-1 DM) and *Salvadora persica* (18.4 MJ. Kg-1 DM). All the four grass species evaluated (*Aristida mutabilis* (16.3 MJ. Kg-1 DM), *Cenchrus ciliaris* (17.1 MJ. Kg-1 DM), *Leptothrium senegalense* (15.3 MJ. Kg-1 DM) and *Sporobolus species* (15. 9 MJ. Kg-1 DM) have recommended energy to meet daily requirement of a camel calves (15-20MJ.Kg-1 DM). The common supplements used by pastoral camel keepers like *Acacia tortilis* pods (15.42% CP), *Tinnospora caffra* (14.05% CP) and *Prosopis juliflora* (11.08% CP) as protein sources have lower than the recommended 20-24% CP. However, the energy sources used as common supplements like sheep fat (26.87 MJ. Kg-1 DM), camel fat (28.57 MJ. Kg-1 DM) and maize meal (26. 10 MJ. Kg-1 DM) have adequate energy to meet daily energy requirements as starter feeds and plant-based milk replacer. The commonly used forage supplements i.e., *Acacia tortilis* pods, *Prosopis juliflora* and *Tinnospora caffra* are low in limiting amino acids methionine, lysine and threonine for calf nutrition, thus recommended for supplementation. Tannins concentrations of commonly used supplements were within the safe range that would not be harmful to the animals. The *Acacia tortilis* pods (Ca 3.72% and P 0.91%) and Prosopis juliflora pods (Ca 1.44% and P 0.75%) used as

NACOSTI and Ethical approval

Appendix H: NACOSTI approval

REPUBLIC OF KENYA

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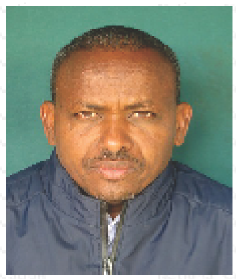

This is to Certify that Mr.. Tura Isako of Egerton University, has been licensed to conduct research in Marsabit on the topic: Feeding Camel Calves with Locally Available Plant-Based Milk Replacer for Enhanced Performance in Kenya for the period ending : 15/October/2020.

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553541

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Appendix I: Ethical approval

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TEL: (051) 2217808
FAX: 051-2217942

P. O. BOX 536
EGERTON

EGERTON UNIVERS… H ETHICS COMMITTEE

EU/RE/DVC/009
Approval No. EUREC/APP/177/2022 **18th May, 2022**

Tura Isako
Egerton University
Animal Science Department
P.O.Box 3480-20100
Nakuru
Email: turaisako@yahoo.com

Dear Tura,

RE: ETHICAL APPROVAL: FEEDING CAMEL CALVES WITH LOCALLY AVAILABLE PLANT-BASE MILK REPLACER FOR ENHANCED PERFORMANCE IN KENYA

This is to inform you that ***Egerton University Research Ethics Committee*** has reviewed and approved your above research proposal. Your application approval number is ***EUREC/APP/177/2022***. The approval period is ***18th May, 2022 – 19th May, 2023.***

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. You are required to adhere Institutional Experimental Animals use and Care policy.
iii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***Egerton University Research Ethics Committee***.
iv. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***Egerton University Research Ethics Committee*** within 72 hours of notification
v. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***Egerton University Research Ethics Committee*** within 72 hours
vi. Clearance for Material Transfer of biological specimens must be obtained from relevant institutions.
vii. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.

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