CAMEL HERD GROWTH AND MILK COMMERCIALIZATION IN ISIOLO AND MARSABIT COUNTIES, KENYA

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF (DOCTOR OF PHILOSOPHY IN ANIMAL SCIENCES) IN THE SCHOOL OF AGRICULTURE AND ENVIRONMENTAL SCIENCES OF KENYATTA UNIVERSITY

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DECLARATION

I **Florence Karimi Thiakunu,** declare that this thesis is my original work and has not been presented for a degree in any other University or any other award.

Signature:  Date: 27th November, 2025

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We confirm that the work reported in this thesis was carried out by the candidate under our supervision

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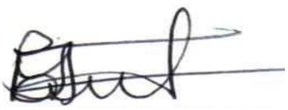
   Signature:  Date: 27th November, 2025

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DEDICATION

This work is dedicated to my beloved mother, the late Jerusha Rwamba, whose guidance initiated my academic path and continued to inspire me throughout this study.

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ABBREVIATIONS AND ACRONYMS

ADF	Acid Detergent Fiber
AOAC	Association of Official Agricultural Chemists
ASAL	Arid and Semi-Arid Lands
CBOs	Community-Based Organizations
CDRs	Community Disease Reporters
CF	Crude Fiber
CL	Corpus Luteum
CMT	California Mastitis Test
CP	Crude Protein
DM	Dry Matter
DMI	Dry Matter Intake
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GOK	Government of Kenya
KALRO	Kenya Agriculture and Livestock Research Organization
KNBS	Kenya National Bureau of Statistics
ME	Metabolizable Energy
NACOSTI	National Commission for Science, Technology, and Innovation
NDF	Neutral Detergent Fiber
NFE	Nitrogen Free Extract
NGO	Non-Governmental Organization
ROI	Return On Investment
Std C.	Standardized Coefficient
Std E.	Standard Error
Unstd C.	Unstandardized Coefficient

DEFINITION OF OPERATIONAL TERMS

Calving interval	The period between the birth of one calf and another from the same cow
Commercialization	Process of transforming milk production from subsistence to market-oriented activities, where key elements are technology investment, institutional support and integration into markets.
Feed supplementation	Providing additional nutrients to camels beyond what they obtain from regular browsing.
Gross mortality	Deaths in a population n in a specified time period
Herd adjustments	Deliberate change of the age and sex percentages in the herd
Herd composition	The age and sex proportions in a herd
Human capital	Skills, knowledge, experience, and attributes that contribute to personal earning potential
Market Participation	Involvement of individuals in buying and selling goods in a market.
Microbial diseases	Any disease caused by microorganisms such as bacteria, fungi, viruses, or parasites
Morbidity	Presence of a disease in a population
Input market	Business acquisition of resources for production
Output market	Sale of finished goods to the consumers
Performance	Milk production in litres in both the wet and dry seasons and the calving interval
Tail cocking	The distinct upward arching of the tail in camels, which pastoralists believe is an indication of pregnancy

ABSTRACT

Rising animal product demand offers pastoralists a chance to boost economic growth through camel rearing. Causes of calf mortality, the effect of improving diet during mating and commercialization factors are inadequate. A study was carried out in Isiolo and Marsabit counties to investigate factors influencing herd growth and the commercialization of camel milk. The study aimed to evaluate the impact of herd structure and concentrate supplementation on performance and milk quality. Additionally, it examined factors affecting calf morbidity and survival rates, decisions, and the extent of pastoralists' market participation. The findings will be useful to pastoralists, animal health workers and stakeholders in camel milk value chain. Data were collected through questionnaires from 379 camel-rearing households. The information gathered included the number of camels by age and sex categories, calf diseases, and market participation. A diet containing 11.76% crude protein and 2,897 Kcal/kg metabolizable energy was supplemented for 9 weeks during mating season to 10 camels, while 10 others served as the control. Post-supplementation parameters included milk yields, serum glucose, proteins, minerals, and mating dates. Weekly milk samples were analyzed in triplicate using the Kjeldahl method for protein content and Gerber method for fat content. Pregnancy confirmation was through progesterone analysis using micro particle immunoassay. Commercialization was assessed using a questionnaire to determine the decision and the extent of milk sales, feed and mineral purchases, and hiring labour. Paired mean comparisons were done to identify differences in production, serum biochemical levels, milk protein, and fat levels with 95% confidence. Means and frequencies for herd structure, calf diseases, and market participation were performed at a 0.05 significance level. Linear regression analyses were conducted to ascertain the influence of herd structure on performance and herd management on calf morbidity and mortality. Further linear regression was done to determine how demographic, physical resources and human capital affect market participation at a 0.05 level of significance. In Isiolo, there were more adult female camels (above 12%) compared to Marsabit (below 10%). The tail cocking method used by pastoralists for pregnancy diagnosis was ineffective. A higher percentage of 6–8-year-old females increased production by 18% (wet season) and 25.9% (dry season) Gross calf mortality was 44.11%, primarily due to predation (11.43%), followed by tick paralysis (10.51%) and microbial diseases. Less deworming, early milk sales, and shorter suckling raised the incidence of pneumonia cases ($p<0.05$). All supplemented camels were mated within the first two weeks and had a higher conception rate (40%) compared to unsupplemented camels (10%). Mean daily milk production was 25.26±0.42 liters for the supplemented group and 22.79±0.41 liters for the unsupplemented group-($p<0.001$). Mean biochemical profiles, milk protein, and fat were significantly higher after supplementation ($p<0.05$). Market participation was influenced by the proportion of milk sold during the dry season and access to extension services. The study concluded that strategic herd proportions adjustments combined with supplemented feeding can improve camel fertility, hence the herd growth. Predation, tick paralysis, and microbial diseases were the main causes of calf mortality. Extension services increased milk sales by 38.9%. This study recommends that pastoralists adjust herd compositions and the implementation of predator-related loss compensation policy. Feed supplementation at around the time of mating and establishment of extension services institutions would enhance the commercialization of camel milk.

CHAPTER ONE: INTRODUCTION

1.1 Background information

Agriculture remains the cornerstone of human survival, primarily through its role in ensuring food security. Since the 1970s, developing nations have experienced a significant transformation known as the "livestock revolution", driven by rising demand for animal products (Latino et al., 2020). This shift is closely tied to urbanization and the growing income levels among middle-class populations, which have altered dietary preferences toward animal products. Therefore, developing countries can seize the opportunity to enhance food security and promote economic growth. This is particularly important in the ASALs, where livestock rearing is the only viable method of utilizing scarce natural resources and has long remained underdeveloped.

A key pathway to achieving these goals is through transitioning from subsistence farming to market-oriented production systems. It fosters stronger engagement with both input and output markets (Jaleta et al., 2009). It enables farmers to invest in technology, access institutional support, and integrate into broader economic engagement. Commercialization not only boosts productivity but also facilitates the distribution of agricultural products to wider markets, enhancing income and livelihoods. However, climate change poses a significant threat to pastoralist communities, especially in ASALs.

Prolonged droughts lead to mass livestock deaths, reduced reproductive capacity, and delayed herd recovery (Githu et al., 2022). In response, pastoralists adopt adaptive strategies such as migrating to new areas and shifting livestock species (Habte et al., 2022). Many are replacing cattle with more resilient animals like goats and camels, which are browsers and better suited to harsh environments (Kagunyu and Wanjohi, 2014; Shuiep et al., 2012; Yosef et al., 2013). Camel production has gained prominence globally, particularly in ASALs, due to their resilience to extreme conditions. The global camel population has grown from 19 million in 2013 (FAO, 2013) to nearly 39 million by 2020(Faye, 2020), with the majority being one-humped dromedaries.

In Pakistan, camel feeding practices include selecting high-protein plant parts, supplementing with straw, and leguminous leaves. Concentrates are made from flour and molasses and provided to milking camels. They further receive ample water to enhance milk yield. Sesame oil is used to improve body condition in undernourished camels (Abbas et al., 2016).

In sub-Saharan Africa, livestock contributes 18% to agricultural GDP, significantly lower than the 45–50% experienced in developed countries (Erdaw, 2023). Breeding practices in Somalia and Ethiopia emphasize selecting males based on pedigree and phenotypic characteristics. These include body size, hardiness, and testicle dimensions (Marshall et al., 2016).

Kenya has experienced a notable increase in camel numbers, rising from 0.8 million in 1999 to 4.6 million by 2019 (KNBS, 2009; KNBS, 2019). However, the commercialization of milk and meat products has not been achieved. Due to the remoteness of the area, pastoralists do not have access to extension and animal health services. Therefore, they utilize their indigenous knowledge for livestock management (Nkuba et al., 2021).

Isiolo and Marsabit in Kenya are traditional camel-rearing regions, with 12% and 29% of households keeping camels, respectively. Arid and very arid form most extensive parts of both counties, receiving rainfall of less than 300mm per annum (Jaetzold et al., 2008). In Isiolo, camel milk trade is a major source of income and employment (Mwaura et al., 2015). In Marsabit, milk is sold in open-air markets without formal cooperatives, limiting the potential for organized trade and economic scaling (Isako & Kimindu, 2019).

Camel reproduction is managed through natural mating during a short breeding season. With a gestation period of 360 to 420 days, calving intervals are long(Bene et al., 2021). Pregnancy confirmation is essential for determining reproductive potential and guiding destocking decisions. Culling unproductive animals reduces grazing pressure and enhances overall herd productivity (Hurst et al., 2012). Adjusting herd composition to favor females can significantly improve milk production (FAO, 2011).

Pregnancy testing methods include observation, clinical manipulation, and hormonal analysis. Many camel-rearing communities rely on indigenous techniques like tail cocking, which has shown 95% accuracy (Purohit, 2010). Tail cocking is a reaction of coiling the tail upwards when the male camel or a human being approach. Pastoralists are very confident that it is an indication of pregnancy. Indeed, in Algeria, they do pregnancy testing using the tail cocking method through a male parade 21 days after mating when they expect the non-pregnant camels to be on oestrus (Gherissi et al., 2020). Scientific methods such as progesterone hormone analysis offer even greater reliability (Kamoun and Jemmali, 2014).

Calves, especially heifers, are vital for maintaining genetic potential and herd productivity (Palczynski et al., 2022). High calf mortality rates in Kenyan ASALs (35% to 50%) pose a serious challenge (Muluneh et al., 2022; Ihuthia, 2010). Mortality is influenced by genetic factors and immune status.

Colostrum feeding is critical for building immunity in young animals. Hygiene during suckling, the quantity of colostrum, and the duration of suckling all affect disease prevalence and survival rates. Climate change exacerbates calf morbidity and mortality through both direct and indirect effects (Lacetera, 2019). Direct impacts include poor nutrition and water scarcity, which weaken immunity. Indirect effects involve the growth of disease-causing organisms and vectors, such as ticks and mosquitoes, due to erratic weather patterns and conditions (Omazic et al., 2019).

Camels primarily feed by browsing trees and bushes, selecting high-quality legumes. However, frequent droughts have diminished feed resources, threatening camel nutrition and productivity (Godde et al., 2020). Intensifying camel production without adjusting husbandry practices can lead to nutritional deficiencies and hinder commercialization efforts (Noor et al., 2013; Mirkena et al., 2018). Addressing these challenges is essential for sustaining camel milk production and improving livelihoods in ASALs.

In the Kenyan ASAL regions, animal disease monitoring is carried out through a network of stakeholders, notably animal health workers and Community Disease Reporters (CDRs). They are chosen by the communities based on their literacy levels, reliability, and experience with livestock (Ikiror et al., 2020), under the supervision of veterinary authorities. With the help of mobile smartphones, they transmit real-time symptom reports for documentation, eliminating the need for long-distance travel. The collected information is then analyzed by trained animal health professionals for diagnosis and response (Sentamu et al., 2024).

Engaging in agricultural marketing is a powerful tool for enhancing commercialization. It allows farmers to reach broader markets, connect with suppliers and service providers, and secure better incomes. These earnings enable investment in improved inputs, technology, and infrastructure (Wangu et al., 2021). Farmers benefit from forming alliances for collective bargaining, which enhances their negotiating power and helps achieve economies of scale.

Market-oriented agriculture involves the strategic allocation of resources toward the production and sale of agricultural products (Zhai et al., 2023). Participation in output markets positively impacts various stakeholders, including farmers, transporters, processors, and retailers. It generates income, which goes a long way in the improvement of food security and economic empowerment (Ingutia & Sumelius, 2022). Furthermore, it reduces vulnerability, which comes with the reliance on subsistence farming, particularly in ASALs. It also contributes to better social services such as education, healthcare, and housing. It is an effective strategy for alleviating rural poverty and improving nutrition, as farmers can purchase diverse and nutritious foods with their earnings (Ogutu et al., 2020). Input market engagement boosts productivity and cost-efficiency by aligning production with consumers' demand (Hemming et al., 2018).

1.2 Statement of research problem

There is an emerging camel milk production system around major towns in response to rising urban demand. Isiolo has recorded a higher adoption of Somali camel breeds compared to Marsabit (Kuria et al., 2016). However, there is limited information on whether this practice involves deliberate management of age and sex ratios to enhance productivity. Pastoralists often confirm pregnancy through tail cocking, but its accuracy in relation to progesterone levels has not been scientifically verified.

In Kenya, camel population growth has remained slow over the past two decades compared to other dairy species. This is attributed to a short breeding season, long gestation period, and high calf mortality rates ranging between 35–50% (Muluneh et al., 2022), factors that hinder commercialization (Mirzaei, 2012). Studies by KALRO reveal that pastoralists lack adequate knowledge to address causes of high calf mortality (Kuria et al., 2011).

Camel milk yield declines sharply by 38% in pregnant and 14% in non-pregnant animals by the ninth week of lactation, and milk ceases completely during the first trimester of gestation (Nagy et al., 2015). Improved health and management practices significantly enhance milk output (Bakheit et al., 2017), yet no studies have assessed the effect of feed supplementation on milk and reproduction.

Pastoralists have a wealth of experience in camel management. This is coupled with the increasing milk demand that boosts household incomes in areas like Isiolo (Akweya et al., 2012; Elhadi et al., 2015). Despite that, the role of physical assets and human capital in influencing market participation across ASAL regions remains poorly understood.

1.3 Research questions

i. How are camel herds structured and their effect on performance, and what criteria for selecting and culling female camels? Is the tail cocking method of confirming pregnancy effective?
ii. How do the camel calf management practices affect the incidence of life-threatening challenges?
iii. Does camel feed supplementation influence production and reproduction?
iv. How do the demographic characteristics, physical assets, and human capital affect market participation?

1.4 Research Objectives

1.4.1 General Objective

The general objective was to evaluate camel herd growth and milk commercialization in Isiolo and Marsabit Counties, Kenya.

1.4.2 Specific Objectives

The specific objectives were to:

i. Analyse camel herd size, composition, and its effect on herd performance.
ii. Determine the constraints to camel calf survival and associated risk factors.
iii. Determine the effects of camel feed supplementation on milk yield and reproduction.
iv. Assess how the demographic characteristics, physical assets and human capital affect camel milk input and output in market participation.

1.5 Hypotheses

To guide the study, the following hypotheses were set and later tested:

HO_1: Camel herd size and composition do not affect milk production.

HO_2: Camel calf management and parasite control do not affect the likelihood of calf diseases.

HO_3: There is no difference in milk production and conception rate between supplemented and unsupplemented camels.

HO_4: Demographic characteristics, physical assets, and human capital do not affect market participation.

1.6 Justification

The study aimed to address key constraints affecting camel herd growth and milk commercialization. Gaining insight into how herd composition impacts productivity helps farmers determine the ideal age and sex structure needed for herd expansion and sustainable production. Assessing the effectiveness of the tail cocking method is essential to establish whether it is suitable for routine application or if alternative techniques should be explored through additional research.

Identifying prevalent diseases, life-threatening conditions, and their risk factors is vital for creating effective control measures and informing policy decisions. This knowledge enables farmers to adopt preventive practices and guides veterinary services in prioritizing interventions. Furthermore, exploring the effects of concentrate supplementation during mating enhances understanding of reproductive management and overall herd performance. Examining factors influencing market participation assists stakeholders in identifying the necessary skills, assets, and infrastructure for investment. Ultimately, the study's findings support the development of appropriate policies and strategies that foster socioeconomic development and promote a resilient camel production and marketing system.

1.7 Theoretical framework

Resource allocation theory in animal production states that animals' genetic potential can only be realized in an environment in which essential feed resources are adequately supplied (Rauw & Glazier, 2009). Sometimes resources may be supplied to animals that do not have the genetic potential for production or may not be physiologically capable of production. Darwin's theory of natural selection proposed that living organisms evolve and adapt to the environment, and it is only those with special characteristics that can survive and reproduce (Ruse, 1975).

Domestication of animals is the process of adopting animals for human use. Animals are bred to promote certain traits, which add value to the purpose for which they are domesticated(Ahmad et al., 2020). Proper management of young mammals starts with colostrum feeding, followed by continued suckling and gradual introduction to nutritious feeds. This creates immunity against diseases in the life of young animals. The calf-rearing environment has to be clean so that it does not encourage the growth of harmful pathogens that may cause diseases such as diarrhoea and pneumonia (Brown et al., 2023).

Herd immunity is further enhanced through vaccination against common infectious diseases (Laupèze & Doherty, 2023). Calf management interferes with the natural selection process that would control the herd's growth. Enhancing disease control interferes with natural selection by reducing the selective pressures that diseases impose on populations. It brings significant benefits that improve lifespan and stability. Careful management and balanced strategies can help mitigate the negative impacts on natural selection while maximizing the positive outcomes for both human and animal populations.

In mammals, the hormone prolactin controls milk production after parturition (Utiger, 2023). The quality and quantity are then dependent on the feed availability.

Although milk production is dependent on many dietary nutrients, the energy and protein content in the feeds are critical for maintenance, production, and reproduction. Other components, such as minerals and vitamins, facilitate protein and energy metabolism, and they also have a bearing on production. The ruminant diet contains fibre, which is a measure of the structural component of plant cells which resulting in a greater amount of fermentable energy. Fiber digestibility is an indicator of forage quality, which increases the dry matter intake and hence enhances production and performance. Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) are commonly used in feed analysis. Fibers that are high in NDF and ADF take up more space and produce less energy, in addition to reducing the dry matter intake (Wu, 2018).

Soon after parturition, milk production increases exponentially, attaining its peak at 3 months. Afterwards, it gradually reduces until drying off (Österman & Bertilsson, 2003). To realize the peak, animals mobilize fat, hence compromising their body weight and body score. In a study by Raziq et al. (2010), the highest milk yield for camels was attained at the third to fifth parties (Mustafa et al., 2015). Other researchers, however, found the daily yields not to be related to parities but to the stage in the lactation cycle. This is again dependent on the season and the availability of feed.

All functions in an animal’s body require resource allocation. Association between the magnitudes of more than one variable, such as production and reproduction, may have a negative association because resources are always limited, and sometimes both variables may not be achieved simultaneously. There is a trade-off that is not always a result of resource allocation but also because of environmental, morphological, and physiological constraints (Rauw & Glazier, 2009).

In cattle, milk production drops significantly in the third trimester of gestation, suggesting high nutritional demand for the growing foetus. Camels in traditional extensive systems have been found to undergo a sudden drop in milk at around day 35 of gestation, and then they dry off by day 90, hence compromising production for reproduction (Nagy et al., 2015).

Knowledge of input and output market participation and factors influencing them is important to advise on the incentives that can be recommended for economic growth. Market participation is based on some theories, such as agricultural development theory, which holds that market participation causes and occurs as a result of economic development. The household decision to sell the output and to use inputs is based on utility maximization theory (Barrett, 2007).

Agricultural marketing is characterized by making choices to purchase modern farm production inputs, farm implements, and other on-farm investments. Trading centres provide the demand for agricultural products because there are people with the purchasing power to consume the farm products. That is the place where the needed inputs and services are found. Prices of the products and inputs are determined by the market forces and factors accompanying transaction costs. High transaction costs discourage livestock farmers from participating in markets. Another theory holds that market participation is based on asset endowment. Households with production and transportation assets participate more in the market than those without (Barrett, 2008).

Farmers with assets participate better than households that do not have assets. Farmers utilize inputs, and at times, there is the substitution of non-traded inputs based on profit maximization theory. The induced demand theory argument holds that commercialization increases farmers' income, therefore growing markets for the domestic industry. Therefore, improved income increases demand for modern inputs, farm implements, and other on-farm investments. Thus, the idea of maximizing profits comes first in the decision to participate in the market.

1.8 Conceptual Framework

Figure 1.8.1 shows the conceptual framework adopted from Rogers (2016), which is based on the theoretical knowledge of the topic researched and the literature review. Increasing the presence of females of reproductive age within a camel herd offers the potential for enhancing economies of scale in resource mobilization. This demographic shift leads to improved efficiency in resource utilization, resulting in heightened productivity per camel per day. Furthermore, enhancements in reproductive factors such as age at first calving, calving intervals, and milking periods contribute to this improved productivity. The age and sex of camels that are productive are also in the reproductive state if only the environment, including feeds, is okay.

The susceptibility of camel calves to diseases is influenced by various factors, especially those impacting their immunity. These include the timing of initiating milk sales from the dam, the promptness of colostrum administration to the calf, and the quantity of milk consumed. Apart from reducing camel productivity, elevated levels of subclinical mastitis heighten the risk of calf diarrhoea. Bacteria in milk cultures within the gastrointestinal tract precipitate the condition and can also cause death.

Supplementing feed augments the animal's ability to meet its dietary needs for maintenance, production, and reproduction. The feed supplements, being rich in nutritional components such as proteins, fats, and minerals, play a crucial role in this regard. Concurrently, improvements in serum biochemical elements serve as the foundational constituents for reproductive hormones and enzymes utilized in feed metabolism.

The acquisition of human capital through extension services and participation in marketing groups enhances production efficiency, resulting in surplus yields for sale. Diversification into off-farm income sources bolsters disposable income, empowering farmers to invest in necessary inputs for their camels. Moreover, the presence of a robust marketing infrastructure and proximity to trading centres diminishes transaction costs associated with marketing activities, thereby facilitating greater market participation.

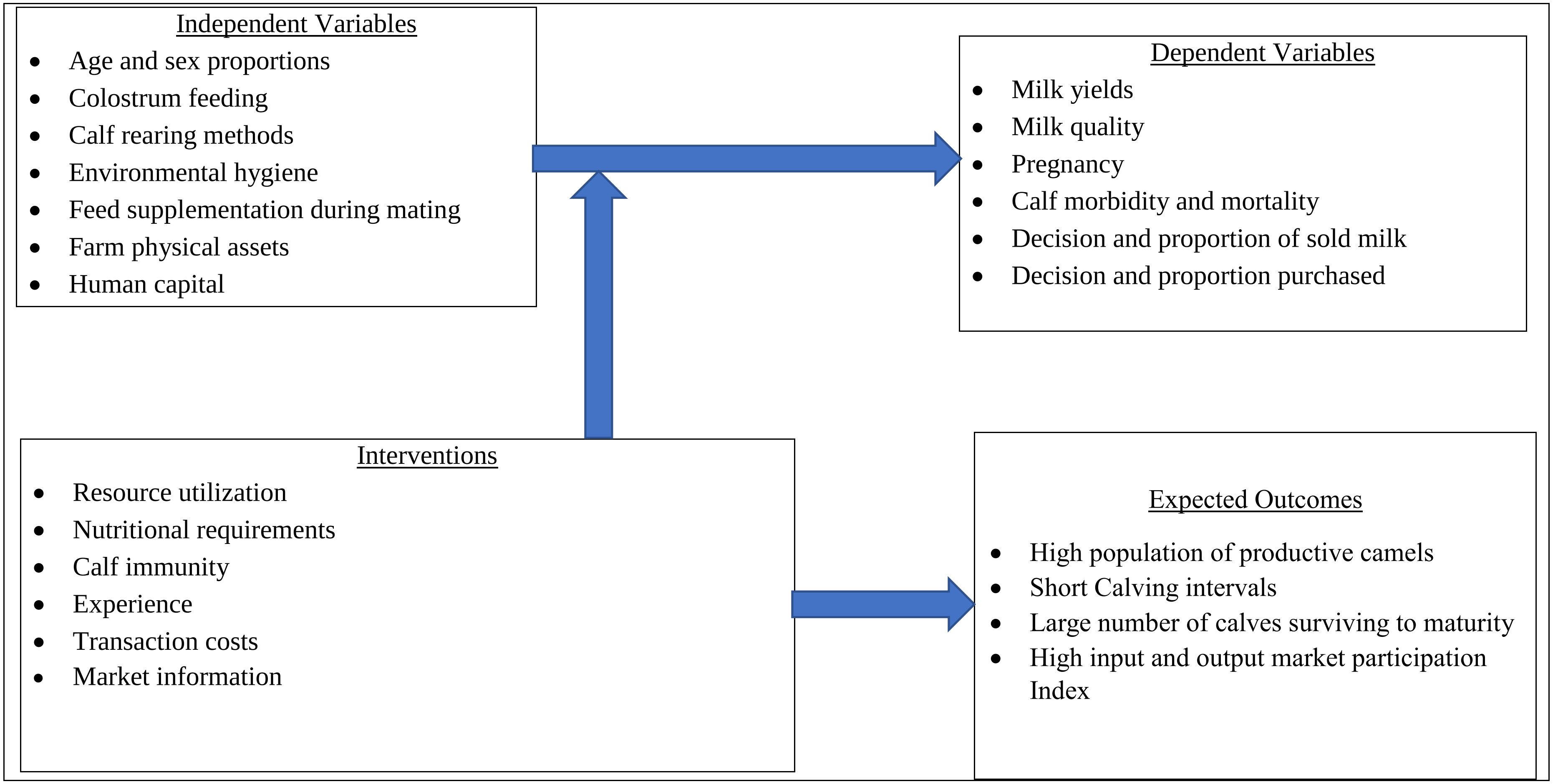

Figure 1.8.1: Conceptual Framework

Source: Adopted from Rogers, 2016

1.9 Scope of the study

The study covers Isiolo and Marsabit Counties of Northern Kenya for the period between January and September 2022. The experimental design's rationale for choosing the wet months was to effectively monitor supplementation and production during the wet mating season. Determination of calf morbidity and survival rate relied on data from one year before the survey. The value of the inputs was quantified using the months of the year when farmers buy fodder and other inputs, because it was difficult to quantify the inputs consumed. Camel herd performance referred to milk production and calving interval. The study focused only on milk sales as output market participation and no other camel products. Information on common calf diseases relied on the knowledge of the clinical symptoms reported by community disease reporters. They were later interpreted by qualified animal health workers.

1.10 Limitations of the Study

The study to assess the effect of feed supplementation was conducted in the wet season because it coincides with the mating season. Laisamis Sub-County of Marsabit County was purposively selected due to insecurity in other sub-counties. The year 2022 was a year of general elections, and there were incidents of ethnic rivalries within Marsabit County. Consequently, a dusk-to-dawn curfew had been imposed throughout the whole County. The insecurity was more in other sub-counties, with some NGOs and other development partners having relocated from Marsabit County headquarters to Laisamis town. The Sub-County is almost the same area as Isiolo County and therefore was representative.

CHAPTER TWO: LITERATURE REVIEW

2.1 General Overview

Growth in the human population has increased demand for natural resources, which forces them to do agricultural-related activities with high environmental impact. As a result, there is an accumulation of greenhouse gases such as carbon dioxide and methane. These cause global warming with devastating effects (Lashof & Ahuja, 1990). Droughts have been occurring more frequently than before. Further, heatwaves, fumes, intense rainy storms, and floods have been noticed in the recent past (You & Wang, 2021). Therefore, mitigation effects should aim at conserving biodiversity and arrangements to capture methane from waste management.

Pastoralism is the practice of livestock herding as the primary source of economic activity in a society. It is characterized by the movement of herds in search of pastures and water (Awinia, 2020). Livestock herd size is connected to commercialization because larger herds generate products beyond what is needed for home consumption and other purposes. This motivates households to sell the excess in the market. (Belay et al., 2021).

The ASAL communities practice pastoralism because it is the only suitable method of utilizing scarce natural resources (Ndathi et al., 2013). In the past, production has been mainly for subsistence and controlled by natural forces. This is without the conscious control of the herd structure, calf management, and feed conservation. Most pastoralists do not participate in output and input markets (Lumbungu et al., 2015).

Climate change has affected food security such that the vulnerable communities rely so much on humanitarian food aid. Food production relies on the availability on the farm as well as the distribution. Economic and physical accessibility of food is also important. Food production also requires that it is well utilized in terms of nutrients and taking care of public health aspects. For food production to be consistent, farmers need to have sustainable agriculture systems (Calloway et al., 2023).

Desertification, because of climate change, has impacted pastoralists negatively all over the world. With droughts and floods alternating frequently, pastoralists' animals die in such high numbers during drought. Therefore, they do not have critical stock to continue with production afterwards (Lesorogol, 2004). This has been exacerbated by encroachment and conversion of land to other uses, which has affected the migratory routes and hence undermined pastoralism. Therefore, pastoralists are forced by circumstances to change their way of earning a living to avoid being trapped in the web of poverty.

Arid and Semi-Arid Lands form part of fragile ecosystems in the world. They are prone to overgrazing, degradation of the environment, and a lack of surface water to sustain vegetation. This situation is made worse by the effects of climate change. There is a lack of biodiversity in special plants and animals, which weakens the ecosystem. The increased temperatures and precipitation make the area more vulnerable. When the basic amenities for human beings are not met, they resort to destroying the environment further by doing activities such as cutting down trees for fuel (Mude et al., 2007). Extreme weather also causes flooding, hence the breeding of mosquitoes and incidence of Rift Valley fever and other vector-borne diseases such as trypanosomiasis (Fouque & Reeder, 2019).

Water reduction results in a low biomass for the animals that become undernourished. Therefore, there is stress, dehydration, and weight loss. Pastoralists move from place to place in search of pastures and water as a way of coping with feed and water scarcity. Because of that, there are always ethnic conflicts in competition for meagre resources in the grazing areas and watering points (Dubow et al., 2022; Huho, 2012).

The mitigating strategies applied by the pastoralists include abandoning pastoralism and seeking wage employment. They do water conservation, rotational grazing, leaving some areas for the dry season, feed diversification, and supplementation to maintain animals. Community-based resource management and sharing is a popular coping strategy that includes grazing land and watering points (Kemal et al., 2022). Pastoralists rely on indigenous early warning signs and take necessary precautions. The most common strategy that they are doing now is changing to climate-resistant crops and animals (Mekuyie et al., 2018). Further, in animals, they are also changing the breeds and species (Silvestri et al., 2012; Yosef et al., 2013). This is how camel production has been gaining increasing importance and is indeed replacing cattle (Kagunyu & Wanjohi, 2014; Faye, 2014). Indeed, it has been established that in the ASALs, the pastoralists prefer browsers (camels and goats), which can feed on the scanty leguminous shrubs (Rahimi et al., 2022).

Camels were among the early animals to be domesticated in the deserts due to their potential and ability to carry baggage on sandy soils. They belong to the family Camelidae of the order Artiodactyla, which means even-toed and padded feet. The order has the genus Camelus with 3 species, Vicugna and Guanaco with 2 species each. The three Camelus are *C. dromedaries* (one-humped) and the two-humped species *C. bactrian* (domesticated) and *C. feris* (wild). Vicugna has 2 species *V. vicugna* and *V. alpaca,* while the Llama genus has *L. llamas* and *L. guanaco* (Fowler, 2008). Due to their anatomical characteristic of padded feet, they patiently walk for long distances on the sandy soils carrying baggage, a feature which made them be referred to as the *"Ships of the desert".* Their use has changed, and now the camel is the animal to be relied on as the animal of choice for food security and economic development in the fragile ecosystems (Faraz, 2020).

Studies have shown that by increasing camels by 10% and goats by 14% and reducing cattle by 24% the overall milk production can increase by 5.7%. Further, water and feed demand are lowered by 15.3% and 11.2% respectively. Also, dairy emissions are reduced by 7.9% hence making it more environmentally friendly than cow-rearing (Rahimi et al., 2022).

Changing to camels, however, has been challenged and might not result in resilient livelihoods; therefore, support is needed for the camel owners. According to Watson et al. (2016)Camel rearing may indeed be very risky. This is due to their feeding behaviour, where they move from one tree to the other and can destroy the already fragile environment. They are also known to trump the watering points, hence destroying the flora and fauna (Edwards et al., 2010). Therefore, there is a need for research and appropriate support from the government and development partners to rely on camels for food security and economic development.

The two-humped camels are found in the cold deserts of Iran, Afghanistan, and Pakistan. One-humped camels are mainly found in the hot arid deserts of the Middle East, India, and Africa. In Turkey and Kazakhstan, pastoralists are cross-breeding the *C. bactrian* and *C. dromedaries.* This is intended to get a productive animal that can survive in the harsh climatic conditions of Central Asia (Dioli, 2020).

The global camel population has doubled in the last few years of this century. This is, however, with varied regional differences (Schwartz, 2013). The world camel population is mostly one-humped camel *Camelus dromedarius*. The East African region (Djibouti, Ethiopia, Eritrea, Kenya, Somalia, and Sudan) has the highest growth, with the population more than tripling in the last 20 years. Somalia has the highest population in the region, followed by Ethiopia and Kenya (FAO, 2013; Faye, 2014). In Kenya, there has been a camel population increase of more than 300% from 1999 to 2019, according to KNBS (2019). The increase has been attributed partly to differences in the production systems, the changing use of camels as well and the changing market opportunities for their products (Schwartz, 2013).

In Pakistan, camel productivity is affected by poor healthcare and breeding services that do not conserve genetics. Further, poor grazing methods that do not take care of the fragile ecosystems and the extinction of the most palatable shrubs hurt the future of camel rearing (Ali et al., 2009).

Three camel production systems in Kenya are not mutually exclusive (Muli et al., 2009). They include a traditional extensive production system where camel population can be small-scale with 1-20 camels or large-scale with as many as 500 camels. The level of husbandry practices is quite low, and camels are kept for many purposes, such as a form of assets and social status. The other method is the emerging peri-urban camel production system, where camels are reared around trading centres because milk prices are competitive. In this method, camel owners have some degree of improvement in husbandry practices, and they sell a substantial amount of their output. This system has been reported in areas such as the Somali regional state, Ethiopia (Hussein et al., 2011), and Isiolo, Kenya (Noor et al., 2013). There is some level of commercialization in that they sell a larger proportion of their outputs than in the extensive production system. Finally, the ranching system has been practiced in the Laikipia Plateau (Muli et al., 2009).

Isiolo and Marsabit Counties are among those with the highest percentage of households rearing camels in Kenya, at 12% and 29% respectively (KNBS, 2019). Isiolo County has 148,859 camels distributed among 6771 households in three Sub-Counties, namely Garbatulla, Isiolo, and Merti. The average number of camels is 28. Marsabit has 215,234 camels distributed among 22,093 households in four Sub-Counties four Subcounties namely, Moyale, North Horr, Saku, and Laisamis. with the average camel population of 28 (KNBS, 2019). Among the Isiolo sub-counties, Garbatulla has the highest number of households rearing camels (2989) camel population (82,312), and the average camel population (28). In Marsabit, Laisamis Subcounty has the highest number of households keeping camels (8433) while Moyale has the highest camel population (82,225) and average herd size (12) (KNBS, 2019).

Despite the low percentage of households keeping camels in Isiolo compared to Marsabit, camel milk marketing is organized. They send milk to Nairobi's Eastleigh area daily (Nori, 2023). This is just like the way cows' milk is delivered to milk processing plants in central Kenya, where the dairy industry is well developed. Recently, there has been value addition in camel milk by making *susa* (fermented camel milk), yogurt, and powdered milk to increase shelf life. Further, they have several trading cooperative societies that sell milk to urban canters (Nori, 2023). As a result, the camel milk trade has become the most important source of household income in areas neighbouring Isiolo town, having a monthly turnover of 88,167 US$ (Mwaura et al., 2015). In Marsabit, camel milk producers and traders sell milk in open-air markets and have no organized cooperative societies (Isako & Kimindu, 2019).

2.2 Camel Herd Structure and Production

Herd structure is the way a herd is constituted in terms of the herd size, age, breed, and sex of a specific species. The herd composition depends on the reason for which animals are kept. A more organised method of camel rearing has been noted. In the United Arab Emirates where conscious efforts are made to increase the productive females in their camel-rearing systems. However, milk production is an average of 2 litres per day, high calf mortality, and a calving interval of more than 3 years (Kutty & Yousuf, 2017).

In Saudi Arabia, there have been changes in herd size and an increase in camel populations. There is a tendency for most camel owners to settle around towns, and they come along with their camels (Babiker, 2014). In this emerging model, the camel herd is made of only female mature camels that are being milked. They collaborate with their relatives in the rural areas, such that the camels that are dry are taken away to the rural areas for breeding and are transported near towns once they are in production. The pastoralists who keep camels away from towns tend to keep large numbers of animals.

There are differences in the camel herd composition in different parts of the Arid and Semi-Arid lands of Ethiopia, depending on how far they are from major trading centres (Hussein et al., 2011). The rural herd composition is made up of dry camels, young stock, and bulls that have been selected for breeding. Further, the male camels that are not used for breeding are slaughtered or sold in other areas. This has led to the population of female camels in the herd being more than 75% in all camel-rearing areas of Ethiopia (Tadesse et al., 2014). In Libya, the situation is different because, according to Idris et al. (2017), the herd composition is that there is a greater proportion of young animals than old ones. This is an indication that camels are reared for livelihood despite the increase in demand for camel milk in urban centres.

A comparison of herd composition by Noor et al. (2012) in the rural pastoralists and peri-urban areas in Isiolo established that the proportion of breeding females was more in peri-urban systems compared to the rural pastoral system. The converse was true for the breeding males, whose proportion was found to be significantly higher in the rural pastoralist system. Other categories of camels in the herd composition, such as the proportion of males and female calves, immature males and females, remained significantly the same. This indicates that the peri-urban system was keener in meeting its objective of milk production, while the other system may have had a different objective. The camel milk trade in Isiolo town is the most important source of employment and household income. Indeed, milk traders in Isiolo town earn an average monthly income of Kshs 11.1 million and 10 million in the wet and dry seasons, respectively (Mwaura et al., 2015).

With the demand for milk and other animal products, there is a need for genetic modification to enhance traits that add value to camel rearing. These include the potential for milk production, longevity, and adaptability to the marginal areas where total rainfall is deficient and water is scarce. Phenotypic classification of camel traits was done once as the first step towards developing an animal to work with in meat and milk production in Saudi Arabia (Abdallah & Faye, 2012; Doili, 2016). This, however, did not consider the production traits but was a good step towards profiling traits for selection. In Pakistan, several camel breeds are known to be the best producers of milk, such as the Merecha breed, though their production traits have not been profiled (Faraz et al., 2013).

Camels serve not only as a primary source of milk but also offer meat, wool, hides, labor, and recreational value. They act as a financial safety net for families, who sell them to cover household expenses. Camel meat, known for being lean, is gaining popularity as a sustainable protein option. In various regions, women are increasingly participating in the production and sale of camel milk and meat, contributing to their economic independence (Amsidder et al., 2024). In isolated areas, camels are vital for transportation where motorized transport services are not easily accessible. Tourism activities such as camel rides and safaris provide additional income for the local population (Bolormaa et al., 2025).

2.3 Breeding practices

Camels have a large genetic potential that can be utilized through multi-trait genetic improvement. There is an opportunity to do this in camels, but it has not been successful (Abri & Faye, 2019). They can be genetically bred for production, health, and environmental tolerance traits. Genetic improvement of production traits in other animal species, which has revolutionized livestock industries in the world, has not been done in camels. There is high adoption of the Somali breed of camel in peri-urban areas of Isiolo due to their capacity for high milk and meat production, because they produce more milk and are heavier compared to other Kenyan breeds (Kuria et al., 2016).

There is very little extent of camel selection in the arid parts of Ethiopia. Here, the herders utilize their indigenous knowledge to select a breeding bull based on the history of their ancestors, who are perceived to sire female calves. In addition, the breeding females are selected on the criteria that they have high growth rates and well-developed milk veins, which is an indication of milk production potential (Mirkena et al., 2018). However, in other places in Ethiopia, camel herders emphasize more on selecting breeding males and not the females. The bull is selected based on adaptability, and those that are resistant to common diseases and tolerant to feed and water scarcities are preferred (Tadesse et al., 2014).

A study towards having a written camel rational breed standard was carried out based on available literature and empirical observations of camels in Saudi Arabia. Camels were then classified into four different types based on their phenotypic characteristics (Abdalla & Faye, 2012). A proposed standard for dairy camel judging was later developed through discussions with the camel-keeping nomads in the Middle East and the Horn of Africa (Doili, 2016). Important phenotypic observable characteristics and performance traits for milk production were considered.

Pastoralists have never been satisfied with the female population. Therefore, they do not have a wide selection of females for breeding. However, they cull female animals that have failed to reproduce. These are camels that take too long to conceive after calving, have habitual abortions, or stillbirths (Kuria et al., 2012).

Building a camel herd is important for the improvement of genetic progress and increasing numerical productivity. In the traditional extensive system, male and female camels mature at 4 years, hence the first calving for females is at 6-7 years (Ali et al., 2018). The main parameters contributing to building a camel herd are calf survival and female fertility. One single most important indicator of reproductive efficiency is the calving interval, which depends on the post-partum conception rate. Camels are seasonal breeders, and the breeding season depends on feed availability since available nutrients in animals are directed toward meeting other needs before reproduction. Therefore, with a good feeding regime, the calving interval can be reduced significantly.

Building camel populations in traditional extensive systems is difficult because they take too long to mature and have about 2-3 months breeding season. Furthermore, the gestation period is 365 to 410 days; hence, a calving interval is usually more than 2 years. Camel calf mortality has been reported by Ihuthia (2010) to be as high as 50% which is a major drawback to building herd population. Furthermore, this affects milk production as well because camels require the presence of a calf for milk let-down.

The most common adult camel diseases include mange, camel pox, contagious ecthyma, trypanosomiasis, and mastitis (Agab, 2006). Mastitis can be clinical or subclinical form. In the clinical, the animal manifests in watery, bloody, or abnormally thick milk, swelling, pain to touch, and failure to produce milk. Subclinical mastitis does not show any signs, though it is more common than clinical mastitis and can only be tested using a laboratory test, such as the determination of somatic cell count, California Mastitis Test, and determination of pH through mastitis indicator papers. All these methods are more than 80% accurate in determining subclinical mastitis in camel milk (Kathiriya & Shah, 2009). It always comes before the clinical form, lasting for a longer period, but it affects milk quality and quantity (Jilo & Mata, 2017). It allows bacterial multiplication, infecting the animal later and becoming clinical. The calf can suckle the milk, hence ingesting the pathogens which may cause diarrhoea.

2.4 Camel feeding

Production for the market exerts pressure on the feed resource base, and the available browse is not sufficient; hence, supplementation with concentrates is critical. In established dairy farms, feed expense is the highest variable input cost affecting the output and profits (Diro et al., 2019). To minimize cost, concentrates are made from materials sourced from within the vicinity where farms are situated. Most feed resources for the camel are through browsing trees and bushes. They select feeds of good quality from mostly leguminous shrubs (Faraz et al., 2022). The water that camels consume is mostly from succulent plants and wells. Intensification of camels puts pressure on the feed resource base, which may predispose them to nutritional deficiencies. Consequently, this may depress productivity and impede the intended commercialization. Seasonality has been reported to depress the further commercialization of camel production (Noor et al., 2013; Mirkena et al., 2018).

Therefore, pastoralists who plan for the dry season and either store feeds or supplement their animals are likely to remain productive and participate in the market.

In their study, Hussein et al. (2008), established that in the ASALs, the average milk yield per cow per day is 3.26 and 1.63 litres in wet and dry months, respectively, while yields in camels are 7.12 and 3.85 litres in wet and dry seasons, respectively. Camels increase their milk production significantly with an improved management system where there is feed supplementation, good healthcare, and sufficient water (Bakheit-et al., 2017).

Building a camel herd requires a reduction in the calving interval without compromising milk production. Nagy et al. (2015) found that milk production under a traditional extensive system reduces significantly during the first month of pregnancy and dries up completely in the first trimester of gestation. This study is supported by the nomadic pastoralists, who indicate that camels stop lactating soon after conception. Indeed, pastoralists indicate that this is one sign that confirms pregnancy, and this is a major hindrance in the efforts to increase production. Information on whether the same holds in other systems where there is improvement in husbandry practices and feed supplementation is scanty.

2.5 Reproduction management

The herd growth parameters include the age at first calving and the calving interval, which are determined by the nutritional status. The other parameters considered according to Jaji et al. (2017) include the reproductive parameters such as the oestrus in camels, which are also influenced by the season and therefore by nutrition. Abortions are widespread, and they also affect the herd growth parameters.

Building camel populations in traditional extensive systems is difficult because they take too long to mature, have a short breeding season, and a long calving interval. The calving interval can be reduced significantly if camels are mated three months post-partum (Ali et. al, 2018). Reproductive efficiency is determined by parameters such as age at sexual maturity, time taken to have post-partum oestrus, conception rate, and delivery of a healthy calf at term. The calving interval is one parameter for measuring reproduction efficiency. In camels, like other domestic animals calving interval depends on how long a female takes to be on oestrus after calving, the rate of conception after mating, and whether the pregnancy proceeds to term or not.

The reproduction efficiency is affected by the level of supplementation and the type of herbage that the camels feed on (Mostafa et al., 2016). In a pastoralist's natural environment, the calving interval is two to three years, mainly due to the seasonality in breeding, late post-partum oestrus, and long gestation period (Merkt et al., 1990). It has been established by Nagy et al. (2015), that there is a 38% reduction in milk production in the 9th week of pregnancy compared to a 14% decrease in the same period for non-pregnant camels. Further, there is a turning point on day 35 of camel conception where milk drops suddenly. It has not been established whether the same would be the case in high-level feed supplements.

In animal production, it is a good practice to determine the pregnancy status soon after mating or insemination to plan for the next parturition and milk production (Stevenson & Ahmadzadeh, 2011). Further, it is a desirable thing to identify animals that could be having a reproduction problem so that they are attended to medically, and if not possible, are culled. Therefore, pregnancy diagnosis is a tool for balancing the herd structure and keeping animals that are productive and doing away with those that do not add any value to the herd.

Pregnancy diagnosis encompasses various invasive and non-invasive techniques and methods (Merkt, 1990). One of the most straightforward but often unreliable methods involves waiting until parturition, or the act of giving birth, occurs. While this approach can provide a definitive answer, it is not always dependable due to the variability in gestation periods among different species and individual animals.

Another physical method relies on the concept of non-return to oestrus, which is based on the idea that an animal's reproductive cycle does not repeat after conception (Purohit, 2010). However, this method can be rendered ineffective if an animal experiences other pathological conditions that prevent them from returning to oestrus, making it an uncertain means of pregnancy diagnosis.

Additionally, the "cocking the tail" method is another method that relies on physical observation of the camel after mating. This method involves visual inspection of the animal's tail position (Khanvilkar et al., 2009). It holds significance in camel-keeping communities worldwide (Gherissi et al., 2020), where it is quite popular and trusted. However, just like in other animal species, its reliability can vary.

Observing physical signs such as a distended abdomen and abdominal ballottement can also be used to diagnose pregnancy. These methods involve visually and tactfully examining the animal's abdomen for signs of pregnancy-related changes (Stevenson & Ahmadzadeh, 2011). While they can provide valuable information, their accuracy can be influenced by factors such as the skill of the examiner and the species of the animal being examined.

Rectal palpation is another technique used for pregnancy diagnosis, particularly in cattle. This method relies on a qualified worker manually palpating the uterus and other reproductive organs of the animal through the rectum (Purohit, 2010). It has been applied successfully in cattle for an extended period, though it has its limitations. For some animals, inserting a hand or arm into the rectum may not be practical, and it also requires proper restraint of the animal within a farm structure, which may not always be feasible.

Rectal palpation, although recommended for use in camels, may pose practical challenges due to the height of the camels and their tendency to move around. Whether the camel is in a standing or sitting position, conducting rectal palpation can be cumbersome, and even when performed, it may not yield accurate results (Tripathi et al., 2022). Animal health workers often express confidence in their diagnoses only after the first trimester of pregnancy, which further limits the applicability of this method.

Hormonal assays are another reliable method for pregnancy diagnosis. This method involves assessing the levels of specific hormones that increase in concentration during pregnancy. The presence of these hormones, particularly progesterone, serves as an indicator of pregnancy (Deguchi et al., 2004; Zaher et al., 2017).

In non-pregnant camels, progesterone levels range from 0 to 2.73 mmol/L, and after a successful mating, they increase to 7.42 mmol/L within two days, and they remain elevated throughout the pregnancy. Any camel displaying a serum progesterone level exceeding 3.5 mmol/L is considered to be pregnant (Mostafa et al., 2016; Kamoun & Jemmali, 2014). However, this technique typically requires laboratory analysis and may not be readily available in field settings.

Ultrasonography is a valuable diagnostic tool, particularly in large domestic animals. It allows for the visualization of reproductive structures using high-frequency sound waves to create real-time pictures. This method relies on the detection of a corpus luteum (CL) that is larger than the CL found in a non-pregnant state. Additionally, it enables the observation of the developing foetus and can provide dimensions that aid in estimating the age of the foetus (Skidmore, 2000). While ultrasonography is highly effective, it often requires sophisticated equipment and trained personnel, making it less accessible in rural areas.

Biochemical changes in the urine can also be indicative of pregnancy. These are the barium chloride and cuboni methods, which indirectly assess the chemical changes using barium chloride and concentrated sulphuric acid, respectively. The barium chloride test is done by mixing urine with BaCl and observing the precipitation that occurs when an animal is not pregnant. It was found to be effective in pregnancy confirmation sows (Lalrintluanga & Dutta, 2009).

Cuboni's method utilizes the change in colour after mixing urine with concentrated sulphuric acid. It is effective in determining pregnancy in donkeys and Alpacas (Kubátová et al., 2016) and also in Bactrian camels (Fedorova et al., 2015). However, these methods have their limitations and have not been proven to have definitive pregnancy diagnoses in dromedary camels.

2.6 Calf rearing

The proper care and management of young animals, be they camels or cattle, is paramount for their future productivity and survival. Extensive research has emphasized the critical role of nutrition and various practices in ensuring the well-being of these young animals and preventing diseases. Research has conclusively shown that providing young animals with a well-balanced diet is an indispensable practice to facilitate their early maturation and reproductive readiness (Lopez & Heinrichs, 2022). For instance, calves that receive a diet tailored to their needs mature earlier and are better prepared for production and reproduction. This underscores the pivotal role of diet in shaping the future productivity of these animals.

Additionally, the initial stages of life for young animals are critical for their long-term health. Right after birth, it is essential to feed them colostrum, as it allows them to acquire crucial antibodies from their mother, significantly enhancing their immunity. The significance of nutrition goes beyond mere growth; it is an indispensable factor in strengthening immunity and preventing diseases. Therefore, ensuring optimal nutrition is essential to minimize these risks and enhance the survival chances of these vulnerable animals. As these young animals continue to grow, their diet should evolve in parallel. A gradual weaning process onto a high-protein diet is essential to promote rapid growth. The proper diet is crucial for their development and future utility, be it for milk production, work, or reproduction.

Colostrum serves as a foundational pillar for their health and prospects. Nonetheless, while milk is a valuable source of nutrition, it can also introduce disease-causing pathogens and lead to diarrhoea in young animals (Kapoor et al., 2023). Therefore, maintaining a clean and hygienic environment and regularly disinfecting the navel cord are indispensable practices in calf management. These hygiene practices contribute significantly to the overall health and well-being of young animals. This is particularly important because pneumonia and diarrhoea are two major causes of calf mortality, particularly in pastoral areas where mortality rates can be as high as 50% (Ihuthia, 2010). Further, milk feeding should continue until the young animal reaches a point where they can feed independently. This careful transition from milk to a more solid diet is another fundamental aspect of young animal management.

Predation poses a substantial threat to young animals, particularly in regions like Samburu County, where it accounts for 50% of camel calf mortality (Onono et al., 2010). Calves are exceptionally susceptible to predation due to their frailty, making them easy targets for predators. To address this issue, protective measures and strategies are crucial to safeguard the young animals' lives.

Disease management is another critical facet of young animal care. In semi-intensive livestock systems, improvements in calf and maternal health are evident when compared to traditional systems (Azhar & El-Shimaa, 2016). Understanding the specific pathogens responsible for diseases, such as *E. coli*, *Staphylococcus aureus*, and Staphylococcus species in camel calves (Al-Ruwaili et al., 2012), is vital for designing effective prevention and treatment protocols. In Southern Ethiopia, the prevalence of subclinical mastitis is a significant concern, indicating that a substantial 69.9% of sampled udder quarters in this region exhibited subclinical mastitis. Notably, Streptococcus species were isolated in 26.1% of cases, while Staphylococcus species were identified in 22.9% of cases (Geresu et al., 2021).

The growth rate of camel calves is highest in the first seven months, particularly when they have access to maternal milk. A study conducted by Tadesse et al. (2014) in parts of Ethiopia revealed that some camel herders delay feeding colostrum until three days after birth and wean the calves suddenly onto pasture shared with adult animals. Providing mother's milk is crucial because it has been established that when dams do not produce adequate milk during the breeding season, calves experience negative weight gain (Erickson & Kalscheur, 2020). Hence, the timeliness and quality of nutrition are central to calf management.

In assessing the current state of young animal care, studies have shed light on disparities in practices across different regions. For example, a baseline survey by Kuria et al. (2016a) found that only 50% and 61% of farmers allow newborn calves to receive sufficient colostrum in Marsabit and Isiolo counties, Kenya, respectively. This highlights the need for standardized practices and awareness campaigns to improve young animal management.

The health and mortality rates of young animals are also influenced by specific factors. For instance, Abb-Schwedler et al. (2014) observed that the incidence of diarrhoea was four times higher in cattle calves fed milk from dams with subclinical mastitis, leading to recurrent diarrhoea in those calves. However, it is essential to acknowledge that these studies were conducted in dairy cattle and not camels, indicating the need for targeted research in different livestock sectors.

A study by Tora et al. (2021) found that calf morbidity was highest for calf diarrhoea, at 10.17%, followed by pneumonia at 6.55%, and septicaemia at 5.22%. The highest mortality was attributed to calf septicaemias (3.4%), followed by diarrhoea (2.42%), with pneumonia having the lowest mortality rate at 0.59%. These statistics underscore the imperative nature of proper care and management practices.

Furthermore, specific practices, such as the timing of colostrum feeding and weaning, have a direct impact on calf mortality rates. Calves that received colostrum later than six hours after birth were 3.69 times more likely to die than those fed colostrum earlier than 6 hours. Likewise, calves weaned before four months of age were 4.42 times more likely to die. These findings reinforce the importance of precise and timely management practices.

In the Somali region of Nigeria, camel husbandry practices indicate that colostrum feeding for calves is inadequate, with only a small percentage (9.8%) allowing unlimited colostrum feeding soon after birth. This reduction in milk-sucking frequency has a detrimental impact on calf immunity and increases the likelihood of disease and death. Diseases such as diarrhoea, Orf, and plant poisoning are common in calves under six months of age. After six months, trypanosomiasis becomes a prominent issue as the calves begin to mix with other potentially infected animals (Rirash et al., 2017).

2.7 Milk production

In mammals, the peak and the persistence in milk production after calving depend so much on environmental factors, especially nutrition. The period before the peak is the best for testing the effect of the environmental factors. If feeding and other environmental factors are good, the peak is high and production is persistent, which translates to a high volume of production in that lactation (Gross, 2023).

In Saudi Arabia, the supplementation of camels with a Total Mixed Ration(TMR) improved the amount and the quality of milk and the health of the calves. There was increase in the serums levels of macro and micro nutrients that are required in minute quantities to increase the efficiency of the body's metabolic processes (Abdelrahman et al., 2022).

A more sedentary model of camel production is taking root, especially in the peri-urban areas in Sudan. This arrangement is made especially for milk production, which is sold to the town residents. Indeed, camel milk fetches three times the price of cow's milk in some peri-urban areas of Sudan. Lactating camels are confined in a fenced area and fed on agricultural crop residues together with concentrates. The main source of earnings from this arrangement is the milk sales and the sale of the male calves (Shuiep et al., 2012). However, milk sales are often hindered by the high incidence of camel mastitis. There are also high incidences of milk spoilage before it reaches the consumer, an indication that camels suffer a high incidence of subclinical mastitis.

Approaches for determining the level of subclinical mastitis fall into the categories of direct and indirect methods. Each offers distinct advantages and insights into the presence and severity of subclinical mastitis (Adkins & Middleton, 2018).

Direct methods involve direct measurement of relevant factors, such as somatic cell count and direct bacterial count. Somatic cell count provides a quantitative assessment of the number of somatic cells in milk, with a higher count indicating the presence of inflammation in the mammary gland (Sharma et al., 2011). Likewise, direct bacterial count directly identifies and quantifies the bacteria present in the milk, which can serve as a clear indicator of infection.

Indirect methods, on the other hand, rely on more subtle indicators to detect subclinical mastitis. One widely used indirect method is the California Mastitis Indicator Test (CMT). This test leverages the viscosity of milk after mixing it with a CMT indicator reagent to determine somatic cell count. During an infection, the body responds by sending somatic cells to combat inflammation, causing an increase in milk viscosity when mixed with the CMT reagent, which is an indicator of subclinical mastitis (Deng et al., 2020). There is a high relationship between the somatic cell count and the bacterial count (Lopes Júnior et al., 2012).

Another indirect approach is the measurement of milk pH. In cases of mammary gland inflammation, the permeability of blood capillaries increases, allowing blood constituents to enter the milk and elevate the pH level. This method relies on indicator papers that undergo a colour-change, shifting from orange to blue when there is inflammation as a result of subclinical mastitis (Plummer & Plummer, 2011).

Recent research has provided valuable insights into the accuracy and reliability of these methods. The pH test demonstrates an impressive accuracy rate of 90.45% when compared to the CMT, with an accuracy of 81.82% when using cultural examination as the standard (Kathiriya & Shah, 2009). Furthermore, the pH test exhibits a positive predictor value of 84.2% and a negative predictor value of 99.5% (Ndirangu et al., 2019). These findings underscore the efficacy of both CMT and pH-based tests for accurately detecting subclinical mastitis in various livestock, including cattle and camels. The pH-based method was found to be effective in determining camel mastitis (Jilo, 2017).

2.8 Agricultural commercialization

Participation in agricultural markets reflects the commercialization of agricultural activities, especially in rural areas. The output market refers to the sale of agricultural products, such as milk and animals, while the input market refers to the purchasing of products from the market that are used in the production process. Both input and output market participation are crucial for sustained production and economic development. In the output market participation farmers sell their outputs, generate income, and can interact with consumers of their products and other players in the value chain.

Smallholder commercialization represents a significant shift in the agricultural landscape. This is where farms transition from subsistence-oriented production to actively engaging with the market for both input procurement and output sales. This transformation entails a deliberate shift towards not only producing for personal consumption but also for-profit maximization by selling agricultural products (Abate et al., 2023). It also involves a more intensive and efficient use of resources to enhance productivity.

Commercialization of camel meat and milk is improving in peri-urban areas of Isiolo County, though this is constrained by a poor road network and a lack of knowledge on clean milk production. Milk is transported and sold to Isiolo town and Nairobi when it is still raw (Nori, 2023). The level of input use, which is a parameter of market participation, differs with the region and is higher in Isiolo than in Marsabit (Kuria et al., 2016b). The inputs commonly used by camel farmers are dewormers, acaricides, minerals, water, and herding labour. It was established by Noor et al. (2013) that the provision of transportation and cooling infrastructure as well as knowledge of clean milk production, can improve milk market participation.

In camel production, smallholder commercialization can be achieved by harnessing available technologies such as artificial insemination to improve the genetic potential. It also requires resource mobilization to generate surplus production beyond what is required for household consumption (Jaleta et al., 2009). The surplus can then be directed towards the market for sale, thereby contributing to the income of the farming household (Rapsomanikis, 2015). In Saudi Arabia, the camel rearing systems are changing, but with different systems having diverse objectives of keeping camels (Abdallah & Faye, 2012).

The challenges in the Arid and Semi-Arid Lands (ASALs) are distinctive. In these regions, animals are often raised for non-commercial purposes and are subjected to suboptimal animal husbandry practices (Lumbungu et al., 2015). These practices are hindered by a range of constraints, including limited access to critical resources and services (Rapsomanikis, 2015). Within arid and semi-arid lands, camel milk market access is typically quite limited, resulting in predominantly subsistence-oriented production. Many communities that rear camels primarily produce milk for feeding their calves and for household consumption. This is partly due to the cultural significance of camel milk, often regarded as a valuable offering as a "*gift for visitors*". Indeed, it is taboo to sell camel milk in Ethiopian pastoralist communities. They believe once milk is sold, the camels will stop producing and eventually die

(Gebremichael et al., 2019). As a result, the integration of camel milk into the broader market chain has been a gradual process in these communities, impacting their overall economic contributions.

2.9 Output market participation

Factors that influence output market participation are classified as demographic, human capital, and physical resource endowments. Assets such as transportation and storage resources, and owning a transportation infrastructure such as a vehicle or a motorbike, positively affect market participation. Refrigeration equipment is also a marketing infrastructure because it facilitates keeping milk for a long time (Olwande & Mathenge, 2012; Ordofa et al., 2021). Further distance to the market and market information can facilitate participation. The output prices and registration with a farmer group help in market information for output and input markets.

In Pakistan, camels are highly valued as animals that improve the household's diet. However, there is a lack of market investment and veterinary care, and extension services(Faraz et al., 2021). A study using a logit model in Ethiopia established that the decision to sell cows' milk through cooperatives was related to the level of education and family size (Bekele, 2021). Other factors include off-farm income, total livestock-owned perception of the cooperative, and the distance to the selling outlet.

In Zimbabwe, output market participation in general agricultural products was only 19%. The decision was positively affected by age, size of household, education level household head, agricultural income, access to irrigation, drought power, and distance. It also depends on the sex of the household head, where women head households participate less than men head households. It is positively influenced by the availability of extension services and the draught power. It was negatively influenced by the education levels of the members of the household, experience, and dependency, as well as the off-farm employment (Dube, 2020).

The decision to sell chickpeas in Ethiopia is influenced by the age of the household head, family size, and the price. However, the amount to sell is positively influenced by the quantity of chickpeas produced, the frequency of the extension services offered to the farmers, and ownership of transport infrastructure (Worku et al., 2022).

In eastern Ethiopia, 99% of the camel farmers participate in the camel milk market for the surplus. Camel milk market participation for the surplus marketed volumes was positively affected by the distance and number of camels and was responsive to market information. This was positively correlated to the price, showing that the law of supply and demand does not affect the sales volumes (Bedilu et al., 2017). The same was found in the Somali region state (Mahamud & Mahamud, 2022). This only considered the volumes of milk sold without first considering the percentage that participated in the market.

In Western Ethiopia, 72.27% participate in the sale of Teff. Both the decision to sell teff and the intensity depend on land size, volume produced, sex, education level, additional off-farm income, and the accessibility of market information (Kifle et al., 2022). In smallholder dairy value chains in Zimbabwe, the decision to sell milk is positively affected by the number of cows, household size, level of education, and access to information, including extension services. In the volumes, they are associated with land size and negatively associated with the distance to the marketplace. Both decision and intensity are associated with the number of cows and the age, as well as the agro-ecological zones (Chamboko et al., 2017).

It is important to recognize that in many regions worldwide, milk trade is in the informal sector in its raw form, which raises concerns about quality and safety control (Gebremichael et al., 2019). Moreover, there remains a significant challenge in gaining access to urban markets where the demand for milk is typically higher. In Saudi Arabia, four different production systems do not differ significantly in the number of camels and the level of production. However, only the intensive system, which makes up only 5% of camel farmers, does market integration. This system is made up of only one farmer, and the farm belongs to a research institute who have formal milk market integration. The milk is well packaged, and farms have signed agreements to supply other members in the supply chain, despite poor product diversification. All others have poor market integration, and milk is packaged in traditional methods and is sold without any formal agreement by the marketing chain actors (Faye et al., 2014).

In Ethiopia, milk marketing chain actors are organized into marketing groups which are formal and are formed under legal procedures. Some, however, are informally formed with only family members to minimize the transportation cost. In both forms of organization, milk is sold in an unprocessed form. There is poor development of the marketing infrastructure and other support activities. There are private processors constructed with the help of development partners, but they operate at below capacity (Tegegne et al., 2013). Milk is sold locally and in raw form to as far as the Republic of Somaliland and Djibouti (Wolkaro et al., 2017; Mebrahtu et al., 2017). This means that there is good potential for milk to become a foreign income earner if camel management practices and the creation of a marketing chain are given policy attention.

2.10 Input market participation

Intensification, within the context of smallholder farming, denotes the process by which farmers manage to increase the output per unit of input they invest. This is achieved through the adoption of improved technologies and practices (Jones-Garcia & Krishna, 2021). It leads to more efficient use of resources and a higher yield of agricultural products

In the input market participation farmers acquire the inputs needed for the production process. In animals, these include feed supplements, minerals, acaricides, dewormers, and water. Sometimes the family members cannot fully provide the services that are needed and therefore household head hires workers and other attendants from other sources. This provides wage employment to the rural poor communities.

Factors that influence input market participation include information, infrastructure, and the available technologies for marketing (Chamboko et al., 2017). In addition to those factors, input use is influenced by credit accessibility, government subsidies, and the availability of suppliers (Olwande & Mathenge, 2012).

For the pastoralists of Tana River County of Kenya, livestock market participation is mainly for those selling rather than buying. It was established that 70% participate in the market. The decision to participate depends on the availability of extension workers, market information, and farmer group registration. The extent of market participation depends on the price, distance to the marketplaces, level of education, and herd size (Lutta et al., 2021).

2.11 Research gaps

In the United Arab Emirates, deliberate measures have been undertaken to increase the proportion of productive female camels. Despite these efforts, the camel's average milk yield remains at approximately 2 litres per day, with a high calf mortality rate of 27% and a calving interval exceeding three years (Kutty & Yousuf, 2017). Research by Nagy et al. (2015) in Dubai, UAE, revealed a significant decline in milk production by the 35th day after conception, particularly within extensive production systems. However, it remains uncertain whether this decline persists under intensive feeding conditions with high levels of supplementation.

In Saudi Arabia, studies have explored optimal herd composition for production (Babiker, 2014) and examined the effects of supplementing camels with total mixed rations on milk yield and calf health (Abdelrahman et al., 2022). Findings indicate that camel rearing practices vary across systems and production objectives

(Abdallah & Faye, 2012). In Pakistan, camel herders often feed leguminous plants and concentrates, yet poor market integration and limited veterinary support continue to constrain productivity (Faraz et al., 2021).

Extensive studies on camel production, health, and marketing have also been conducted in Ethiopia's Somali Regional State (Mahamud & Mahamud, 2022). A gradual transition toward improved management practices is evident in peri-urban camel production systems in Ethiopia and northern Kenya (Tadesse, 2014; Mirkena et al., 2018). Similarly, in Egypt, Abdel and Roushdy (2016) compared traditional and semi-intensive systems to assess calf growth rates and disease prevalence, revealing notable differences between the two systems.

Noor (2013) demonstrated that maize germ-based concentrate significantly outperformed acacia pod-based feed in enhancing camel productivity, underscoring the critical role of diet in influencing milk yield and weight gain. These studies however did not explore the variations in reproductive performance among female camels under different feeding regimes. This is an important consideration for understanding the interconnections between camel production and reproduction.

According to Olwande and Mathenge (2011), several factors influence farmers' participation in agricultural commercialization, including proximity to consumers and prevailing market prices. In Isiolo, Kenya, only 12% of total camel milk production is marketed, indicating minimal smallholder involvement in the milk trade (Muli et al., 2009). There remains a scarcity of comprehensive data on the determinants of camel milk market participation, and it is still unclear whether profits from camel products drive increased investment in production inputs.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Camel Herd Structure and Performance

Focus Group Discussions (FGDs) and a cross-sectional study were conducted from July to August 2022 in each County. Data on the herd size and composition (the number of age and sex categories) were collected from 379 households through structured questionnaires. The pregnancy test was performed on seventeen camels four months after the mating season by tail cocking and the progesterone assay method. Analysis was done using descriptive, correlation, and linear regression statistics at a 0.05 significance level.

3.1.1 Study Area

The study was carried out in Isiolo and Marsabit Counties (Figure 3.1.1), which are among the traditional camel-keeping Counties in Kenya. In Isiolo County, there are areas referred to as milk clusters found in the Isiolo and Garbatulla sub-counties (Mwaura et al., 2015). Therefore, the study was specifically carried out in those 2 for Isiolo County. In Marsabit County, the study was conducted in the Laisamis Sub-County, selected because of the high number of camels and the high number of households keeping camels. The proportion of households keeping camels is 12% and 29% for Isiolo and Marsabit, respectively. Isiolo County is right at the middle of Kenya covering an area of 25,336 km^2. About 65% of Isiolo County is very arid, 30% arid, and 5% semi-arid (Jaetzold et al., 2008). According to the Kenya National Bureau of Statistics (KNBS, 2019), Isiolo County has 148,859 camels distributed among 6771 households in three Sub-Counties.

Marsabit County is the largest in Kenya, covering an area of 70,961 km^2 at the end of Northern Kenya. The rainfall system is bimodal (April-May and November-December), ranging between 200mm and 1000 mm per annum (p.a). The arid and very arid areas form the most extensive part of Marsabit, located below 700m above sea level, with rainfall below 300 mm per annum. Marsabit has 215,234 camels distributed among 22,093 households in four Sub-Counties (KNBS, 2019). In most of Marsabit, camel rearing is the way of life due to the low rainfall. They experience extreme weather conditions; hence, camels and goats (browsers) are the most preferred animals.

Pregnancy testing using the indigenous method was done at Ngaremara, where there is a Camel Research Centre; camels were gathered for an overnight stay after a day's browse. Checking for tail cocking was done in the morning before they went out to browse.

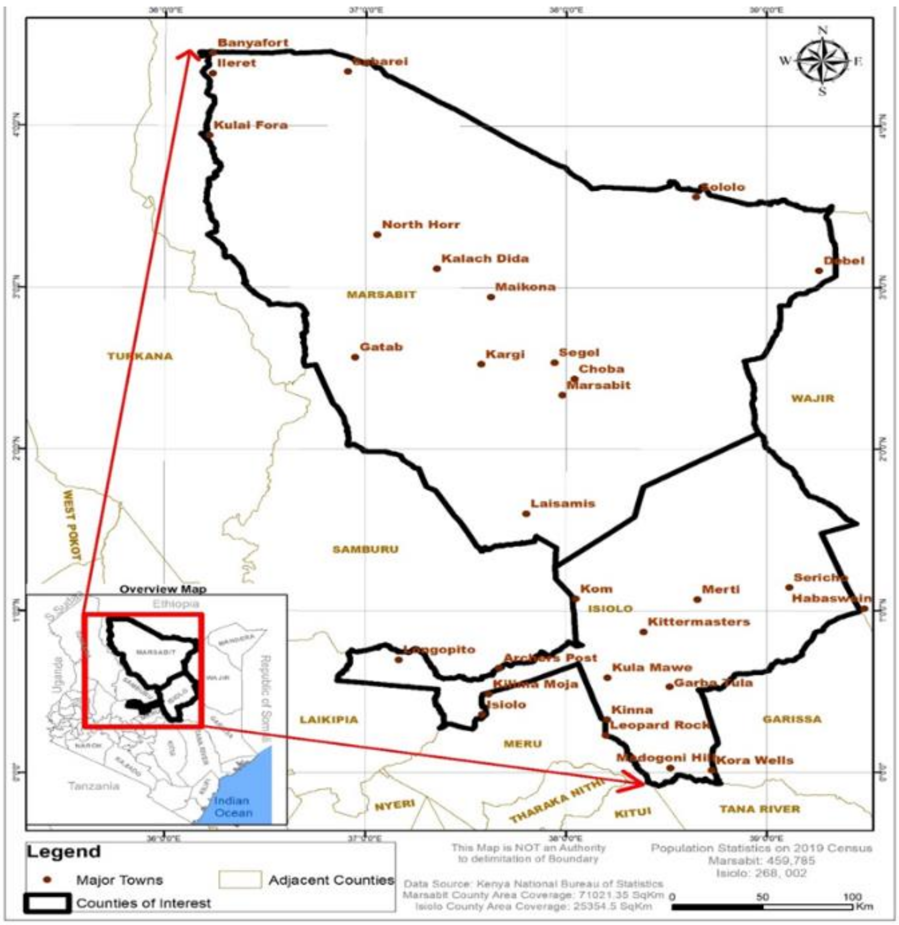

Figure 3.1.1 Map of Kenya showing the location of Isiolo and Marsabit Counties. (KNBS, 2019)

3.1.2 Research Design

The research design was cross-sectional, relying on the recall for one year before the study. Data was collected through two focus group discussions (FGDs), which were composed of 14 people, including community disease reporters (CDRs), staff from the Ministry of Livestock, and pastoralists. From the FGDs, the insights of herd dynamics, common camel calf diseases, and market participation were highlighted. Household surveys were done through questionnaires, which were uploaded to the Kobocollect toolbox. Through the questionnaire, the herd structure and performance, common camel calf diseases, and predisposing factors were determined. Further, the pastoralists' demographics, assets as well as market participation were discussed.

3.1.3 Sample Size Determination

The sample population was all the camel-keeping households in Isiolo and Marsabit Counties. The sample size was determined in two stages using formulae 3.1.1,3.1.2, 3.1.3, and 3.1.4 provided by Pfeiffer (2010). The first stage was to get the sample size for an infinite population and then adjust for a finite population. This was done by first setting the level of statistical significance at 0.05 and the standard normal deviation at 1.96.

The formula used was;

$$n=Z^2pq/L^2 \qquad 3.1.1$$

Where,

n = Desired sample size for infinite population.

Z = normal deviation at the required confidence level.

p=proportion of the population estimated to have the attributes being measured.

q = 1-p and L = set statistical significance.

In this case, there is insufficient knowledge of the population with the attribute, so a value of 0.5 is recommended, hence the sample size was.

$$1.96^2 X 0.5^2 \div 0.05^2 = 384 \qquad 3.1.2$$

The second stage was to get a sample for a target population of 28,864 households; the sample size was adjusted using the formula.

$$n'=1\div(1/n+1/N) \qquad 3.1.3$$

(Pfeiffer, 2010)

Where:

n'=adjusted sample size for the finite population.

n=sample size, infinite population.

N=population size, hence the sample size was

n'=1÷ (1/384+1/28, 864) =379 3.1.4

3.1.4 Sampling Plan

A two-stage sampling method was applied because the study involves a wide geographical area. In Isiolo, there were areas referred to as camel milk clusters, which are concentrated in Isiolo and Garba Tulla Sub-Counties. Therefore, in the first stage for Isiolo County, Garba Tulla, and Isiolo Central Sub-Counties were purposively sampled due to their potential for milk production (Mwaura al., 2015). In Marsabit County, the first stage purposively sampled Laisamis Sub-County based on the high camel population and a high number of households keeping camels (KNBS, 2019). The other sub-counties were left out due to security reasons at that time.

In the second stage, a convenient sample was drawn from camel-keeping households who were willing to participate until the sample size for every Sub-County was attained. Samples were drawn from the three Sub-Counties proportional to the number of households keeping camels. Likewise, respondents drawn from the locations were proportional to the number of households keeping camels. They were 137 drawn from Kulamawe, Gotu, and Kinna locations in Isiolo County. From Marsabit County, 242 respondents were drawn from Laisamis, Lontolio, Koya, and Merile locations.

3.1.5 Data Collection

Two Focus Group Discussions (FGDs) were held in Isiolo and Laisamis (Plate 1). The aim was to get insights into the camel herd dynamics and to familiarize with the camel rearing community. In Isiolo, the group members were 12 (10 men and 2 women), comprised of 5 Community Disease Reporters (CDRs), 4 technical staff from the Livestock department, and 3 facilitators. In Marsabit, the group was bigger than in Isiolo because the study was covering a larger area with 4 locations. Hence, FGD comprised 18 (14 men and 4 women) with 10 CDRs, 4 technical staff, one social worker, staff from the Ministry of Livestock, pastoralists and 3 facilitators. The information sought was regarding the management of camels and cultural significance, as indicated in Appendix 4.

The data collection tool was a questionnaire administered by CDRs in specific local languages. The languages included Somali, Turkana, and Boran, mainly from Isiolo, Rendille, and Samburu from Laisamis. Questionnaires were administered using a web-based and smart mobile app known as Kobo Toolbox (Lakshminarasimhappa, 2021) as described by (Poloju et al., 2021). The Kobo toolbox was uploaded to CDRs' smartphones (Plate 2).

Camel herd size, age, and sex composition, and their effects on productive and reproductive performance, were determined through respondents' recall for one year before the study. The herd size and camel herd structure were determined based on age categories of male or female (Table 3.1.1).

Table 3.1.1: Herd composition categories

Age	Category	Purpose
Males below 2 years	Male calves	Reared for selling or breeding
Females below 2 years	Female calves	Reared as replacement heifers
Males 2-4 years	Steers	Reared for selling or breeding
Females 2-4 years	Heifers	Not yet mated but have the potential depending on the attainment of critical weight.
Males 4-6 years	Young bulls	Can be slaughtered for meat if they are not intended for breeding in areas where milk production is the objective of rearing camels.
Females 4-6 years	Bulling heifers	The females in this category could be in the first lactation.

Males 6-8 years	Young adult bulls	Reared for selling or breeding
Females 6-8 years	Pregnant heifers	Second or third lactation
Males more than 8 years breeding	Productive males	Used for mating
Females more than 8 years old breeding	Productive females	Active and milk production could be affected by pregnancy status.
Males more than 8 years not breeding	Old males	Very old males which are of no purpose in the herd
Females more than 8 years not breeding	Old females	Could be still producing milk depending on the feed and water availability.

The performance was measured on milk production per herd per day in both wet and dry seasons. Reproductive performance was determined by age at first calving, calving interval, and duration of milking. A comparison of the tail cocking and progesterone assay was done on 17 camels belonging to Ewaso Ng'iro North Development Authority in Isiolo County. Blood was drawn from the jugular vein (Dioli, 2022). It was then put in a plain vacutainer with a clot activator. The camels were observed for cocking the tail to confirm pregnancy (Plate 4).

Camel herders made a sudden approach from the rear of the female camel and observed the tail cocking. This was done every morning before the camels went out to browse. Tail cocking was traditionally confirmatory that the camel was pregnant. It is a characteristic posture that a camel attains when a male animal or a human being approaches. The animal stands with the head held high, and the tail is curled upwards (Purohit et al., 2020). The Progesterone levels can be measured in the body fluids such as saliva, milk, urine, and blood plasma (Kamel & Azza, 2021). The best scientific method for pregnancy diagnosis is the progesterone assay in the serum (Faraz et al., 2022).

3.1.6 Laboratory blood analysis for pregnancy

Sampled blood from seventeen camels was analyzed at the Lancet laboratories in Nairobi, Kenya. The method converts the substrate to a reaction product that can emit light with a wider dynamic range of luminous intensity. The intensity has a linear relationship with the concentration of progesterone in nmol/L. Pregnancy was confirmed based on the progesterone levels, and more than 3.5 nmol/L is considered pregnant (Faye & Bengoumi, 2018; Mostafa et al., 2016; Kamoun & Jemmali, 2014).

3.1.7 Description of Variables

The variables used to determine the effects of herd structure on productive and reproductive performance are shown in Table 3.1.2.

Table 3.1.2: Variables for milk production influencing factors.

Variable Description	**Variable Type**	**Measurement variables**
DEPENDENT VARIABLES		
Milk production in litres per camel per day in the wet season	Ordinal	1= None;2=Below 10; 3=10-19;4=20-29;5=30 and above
Milk production in Litres per camel per day in the dry season	Ordinal	1= None;2=Below 10; 3=10-19;4=20-29;5=30 and above
Age at first calving in years	Ordinal	1=Below 5; 2=5-9;3=10-15;4=Beyond 15
Calving interval in months	Ordinal	1=below 18; 2=18-24;3=25-29;4=30 and above
Lactation period in months	Ordinal	1=below 24; 2=25-29;3=30-36;4=beyond 36

INDEPENDENT VARIABLES		
Herd size	Scale	Number
No milking camels	Scale	Number
Percentage of milking camels	Scale	Percentage
Male calves below 2 years	Scale	Number
Female calves below 2 years	Scale	Number
Male 2-4 years	Scale	Number
Female 2-4 years	Scale	Number
Male 4-6 years	Scale	Number
Female 4-6 years	Scale	Number
Male 6-8 years	Scale	Number
Female 6-8 years	Scale	Number
Males above 8 years of breeding	Scale	Number
Females above 8 years and breeding	Scale	Number
Males above 8 years and not breeding	Scale	Number
Females above 8 years and not breeding	Scale	Number

3.1.8 Data Management and Statistical Analysis

Data were recorded directly in the Kobo toolbox as the CDRs gathered information from the pastoralists. Immediately, the information was reflected in the researcher's portal of the Kobo toolbox. The information was then uploaded to the Excel worksheet and later transferred to SPSS version 25 for statistical analysis.

Descriptive statistics were used to determine age and sex percentages as well as reproductive performance. Mean was applied for age and sex percentages. Frequencies were used to assess milk production and reproductive performance for every location. Inferential statistics established the effects of age and sex percentages on performance and the correlation between the indigenous and scientific methods of pregnancy testing. Regression analysis was used to show the effects of each age and sex percentage on milk production in the wet and dry seasons.

Medians were used as measures of central tendency for milk production in wet and dry seasons (Rangaswamy, 2006). It is a suitable alternative to facilitate a regression analysis (Subedi, 2016). The dependent variable was tested for normality by comparing it with the expected normal distribution curve. After they were found not to show normal distribution, they were transformed with Log_{10} and tested again. Collinearity diagnosis was carried out, and variables that could not be tolerated were left out of the model. Results were given in narrations, tabulations, figures and tables, and a linear regression model.

A cross-tabulation was done to check the correlation between cocking the tail method of pregnancy diagnosis and the scientific method of progesterone assay. Pearson correlation coefficient was determined with a null hypothesis that the population correlation coefficient =0.

3.2 Determination of Common Camel Calf Diseases, morbidities, survival rate, and associated factors

The methodology used is the same as for the determination of camel herd structure and performance described in Sections 3.1.1, 3.1.2, 3.1.3, 3.1.4, and 3.1.5. Camel calf disease and life-threatening incidents were determined through respondents' recall with the assistance of CDRs. Factors predisposing camel calves to diseases and life-threatening situations were measured based on the frequency of controlling internal and external parasites, the method of feeding colostrum, the suckling period, and the proportion of milk suckled.

The level of subclinical mastitis was determined by randomly selecting one lactating camel in the herd which represented 0.5% of the lactating camels in the population (Daniel, 2012).

The method that was done on the camel side relies on an indicator paper. The mastitis indicator paper detects the milk pH level, which becomes elevated in cases of mammary gland inflammation. It comes because of increased blood capillaries, the permeability allowing blood constituents to enter the milk ducts. The indicator papers undergo a colour change, shifting from orange to blue when there is inflammation as a result of the subclinical mastitis (Plummer & Plummer, 2011). The level of subclinical mastitis was based on the number of the udder quarters affected, as shown in Plate 3.

3.2.1 Description of variables

Descriptions of variables used to determine calf morbidity, survival, and the associated factors are shown in Table 3.2.1.

Table 3.2.1: Variables for testing calf morbidity and mortality predisposing factors

Variable Description	Variable type	Measurement variables
DEPENDENT VARIABLES		
Disease morbidity	Scale	Actual number
Disease mortality	Scale	Actual number
INDEPENDENT VARIABLES		
External parasite control interval	Ordinal	1=Weekly;2=2 weekly;3= beyond two weeks;4=none
Deworming interval	Ordinal	1=less than 3 months;2= 3 to 6 months;3=7 months to 1 year;4=yearly;5=more than 1 year; 5=none

Time taken to introduce the calf to colostrum after birth	Ordinal	1= Immediately; 2= After one day;3; After 2 days;4= After 3 days;4=None
How soon milk from a specific camel is sold	Ordinal	1=more than 4 months;2=3 to 4 months;3= 1 to 2 months;4=less than one month
Proportion of milk suckled	Ordinal	1=2 quarters;2=one quarter;3=not quantified;4=none
Period of suckling the calf	Ordinal	1=19-24 months;2=13-18 months;3=7-12 months ;4=0-6 months
Level of sub-clinical mastitis	Ordinal	1=none;2=one quarter;3=two quarters;4=three quarters;5=all quarters
Hygiene at milking	Ordinal	1=Wash hands and udder;2=wash udder;3=wash hands;4=wash udder only;5=none

3.2.2 Data Management and Statistical Analysis

Data was obtained and stored as described in Section 3.1.8. Frequencies and percentages were used to quantify the incidence of common camel calf diseases at the household level. Frequencies for predisposing factors in each location were also assessed. Inferential statistics analyzed the impact of these factors on disease morbidity and mortality.

The mean was calculated to determine mortality and morbidity rates for each disease. Means were used to determine morbidities and gross mortalities in the locations of the two counties. The common disease risk assessment was done by the probability impact method (Dumbravă & Iacob, 2013). Linear regression analysis for morbidity and mortality. The null hypotheses for the coefficient were rejected at a 0.05 level of significance.

The dependent variable was tested for normality by comparing it with the expected normal distribution curve. After they were found not to show normal distribution, they were transformed with Log_{10} and tested again. A multiple linear regression model for calf survival and disease morbidity, respectively, was estimated by Ordinary Least Squares. The morbidity and mortality percentage is denoted by *Yi* in the model equation 3.2.1.

$$Yi=\beta 0+\beta 1xi1+\beta 2xi2+...+\beta pxip+\epsilon \quad \ldots\ldots 3.2.1$$

Where;

Yi=Dependent variable

β*0*=Y intercept (Constant term)

βp=Slope coefficient for each independent variable

xi=Independent variable

ϵ=The model's error term

(Kutner, 2005)

3.3 Effects of Camel Feed Supplementation on Milk Yield and Reproduction Performance during Mating Season.

Twenty camels were used for the experimental design after deworming at the beginning of the study. Formulated feeds were gradually introduced to ten camels by adding 1 kg daily. They were enticed with green acacia pods for 2 weeks until all supplemented camels were able to feed 3.5 kg in the evening after browsing. Milking was done in the mornings after allowing the calves to stimulate the teats for 2 minutes for the milk letdown reflex. Production of milk in litres was recorded daily, and total production per camel was tabulated weekly. Milk samples were collected every week and analyzed for protein and fat levels.

3.3.1 On Station Trial

The study was carried out at Ewaso Ng'iro North Development Authority (ENNDA) Research Centre in Ngaremara ward, Isiolo County, Latitude 0^{o}21'20.29" N and Longitude 37^{o}34'59.90" E. This station had adequate facilities for controlled on-station trials. A proximate analysis of the feed ingredients and ration was performed at the University of Nairobi and Chuka University animal nutrition laboratories.
Twenty camels that were in early lactation and in their 3rd -6th parities were selected. They were dewormed before the start of the feeding trial. Supplementation was done in one group, and the other group acted as the control.

Feed ration preparation was done basing the formulation on the dairy cattle standard. Milking was only done in the morning, and milk production was monitored in litres. Pooled milk samples from supplemented and unsupplemented camels were collected separately for fat and protein analysis. Mean milk protein and fat levels were compared every week. Mating was monitored for the time of mating and repeat breeders. For biochemical nutritional elements analysis, 10 ml of blood was drawn from the jugular vein towards the end of the experiment for serum mean comparisons. Progesterone assay and tail cocking comparison were done on the 5th week.

Serum analysis for the protein, glucose, and minerals was conducted at Kericho National Veterinary Investigation Laboratories. Progesterone hormone analysis was conducted at the Lancet Laboratories, Nairobi. Protein and fat content in the milk were analyzed at Meru University of Science and Technology's food science laboratories.

3.3.2 Feed Ration Preparation

The feed was formulated to meet the nutrient requirements of dairy cattle (National Research Council, 2021). A feed supplement containing 16.8% CP and 8.44 MJ/Kg of digestible energy was formulated using ingredients shown in Table 3.3.1. The feeding ingredients were balanced using Excel software. The ingredients were sourced from local market feed dealers in Meru and Isiolo Counties. Rhodes grass was shredded and packed in gunny bags separately, while the dry grain ingredients were crushed using a hammer mill and later mixed evenly together with salt and limestone. Molasses and urea mixture were constituted daily for every individual camel to avoid the chances of urea toxicity (Faye et al., 2018). A total of 2,500 kgs was constituted in bulk since ten camels consumed 35 kgs of the ration per (3.5 kg per camel) per day for 70 days.

Table 3.3.1: Ingredients and calculated chemical composition of camel supplement feed

Ingredients	Amount (Kgs)	Ratio (%)	DM (%)	CP (%)	DE (MJ/Kg)
Maize germ	20.00	15.33	13.79	2.45	1.84
Maize grain	11.00	8.43	7.57	0.84	1.20
Wheat bran	8.00	6.13	5.52	0.86	0.62
CSC	7.00	5.36	4.89	1.61	0.46
Sunflower cake	20.00	15.33	13.79	3.83	1.46
Acacia pods	10.00	7.66	6.90	1.53	0.73
Rhodes Grass	40.00	30.65	26.05	2.45	2.15
Molasses	10.00	7.66	6.13	0.00	NA
Urea	1.50	1.15	1.03	3.22	NA
DCP	1.00	0.77	0.75	0.00	0.00
Limestone	1.50	1.15	1.13	0.00	0.00
Salt	0.50	0.38	0.33	0.00	0.00
Total	**130.50**	**100.00**	**87.88**	**16.80**	**8.44**

Key/ Legend: C- Calcium; CP- Crude Protein; DM- Dry Matter; DCP- Di-Calcium Phosphate; CSC- Cotton Seed Cake; P- Phosphorus

3.3.3 Feeding experiment

The experiment was conducted in January, February, and March 2022 using twenty camels in their 2-6 parities and less than three months after calving. The after-only with control experimental design was used as described by Kothari (2004). The design was preferred because it was challenging to have pre-treatment measurements. The camels were therefore divided into two groups, the test group and the control group. One group was supplemented with 3.5 kg of formulated ration per camel after the day's browse, and the other group was the control. All camels browsed for six hours in January and February, and hours were adjusted to eight in March after the onset of the dry season.

Constituting 3.5 kgs per camel was done by mixing 2 kg of grain mixture with 1 kg of Rhodes grass in every feeding trough. Then 3 kg of molasses and 300g of urea were mixed with 20 litres of water. Supplement for one camel was made by adding two liters of molasses urea mixture to every feeding trough with ground grain and Rhodes grass, and mixing thoroughly (Plate 5). Camels were allowed to graze along with their calves during the day and were only separated in different enclosures at night.

3.3.4 Proximate feed analysis

Proximate analysis for the feed ingredients and ration was done using a method by AOAC (1995). The crude protein content was determined by the Kjeldahl method of digestion, distillation, and titration until the nitrogen content in the feed sample was determined. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using the method described by Van Soest et al. (1991).

3.3.5 Serum Progesterone Analysis

Pregnancy diagnosis was done by progesterone assay 5 months after the mating season. A blood sample was drawn from the jugular vein into a 10 ml Vacutainer with a clot activator. Blood was centrifuged using a TGL-16M micro high-speed benchtop refrigerated centrifuge. This was done at 2,000 revolutions per minute for 10 minutes to separate the serum from the other blood components. The serum was withdrawn with a syringe and transferred to a clean test tube. The pure yellow clear serum was analyzed for progesterone levels through electro-chemiluminescent microparticle immunoassay, as described by Deguchi et al. (2004) and Zaher et al. (2017) using Abbott Alinity I Analyzer. This method converts the substrate to a reaction product that can emit light with a wider dynamic range of luminous intensity. The intensity has a linear relationship with the concentration of the measured substrate in mmol/L. The progesterone levels range from 0- 2.73 mmol/L in non-pregnant state. These levels increase to more than 7.42 mmol/L two days after a successful mating (Faye & Bengoumi, 2018). It is maintained and increased throughout the pregnancy, dropping at the time of parturition.

Any camel serum progesterone level more than 3.5 mmol/L was considered pregnant (Faye & Bengoumi, 2018; Mostafa et al., 2016; Kamoun & Jemmali, 2014). Pregnancy testing aimed to classify camels into four groups depending on pregnancy and supplementation statuses. These were pregnant and supplemented, pregnant and unsupplemented, not pregnant and supplemented, and not pregnant and unsupplemented.

3.3.6 Monitoring Milk Production

Complete milking was done only in the morning after allowing the calf to suckle a bit to stimulate the teats for milk let down. The calves were then allowed to browse along with their mothers and suckle during the day. Milking was not done in the evenings, and the calves were separated in a different enclosure until morning. Milk production per camel was recorded in litres for nine weeks. The production for the day was arrived at by multiplying the morning milking production by two because the most common frequency of milking camels is twice a day. Milk samples were collected every week and pooled separately for the supplemented and unsupplemented camels. The sampled milk was hence transported the same day to the food science laboratories of Meru University of Science and Technology. The samples were preserved at 4 °C and later analyzed for fat and protein composition using Gerber and Kjeldahl methods, respectively.

3.3.7 Milk Protein Analysis

Protein content in milk was analyzed every week in triplicate using the Kjeldahl method, which tests for the levels of nitrogen as described by Elkot et al. (2021). In this method, a nitrogen atom in the milk sample is converted to ammonia which is distilled from an alkaline medium and absorbed in boric acid. Ammonia is then determined by titration with mineral acid. This is with the assumption that the level of nitrogen in milk protein is 15.67%. Therefore, the percentage of protein is determined using equation 3.3.1.

$$\text{Percentage Protein} = (\text{Nitrogen} \times (1 \div 15.67)) \times 100 \qquad 3.3.1$$

(Di Marzo et al., 2021).

3.3.8 Milk fat analysis

Milk was pooled from different camels for supplemented and unsupplemented camels. The percentage of milk fat was determined every week in triplicate using the Gerber method by weight method as described by Hadef et al. (2018) and Elkot et al. (2021). This is by mixing sulphuric acid with milk in a butyrometer, then adding aso-amyl alcohol before thoroughly mixing and centrifugation to separate fat, which is now straw yellow. The fat column is then brought to the graduation mark. The difference between the upper and lower scale readings corresponds to the lowest fat meniscus and surface of separation of fat and acid, and is the percentage of fat content in the milk.

3.3.9 Serum Biochemical Analysis

A blood sample was drawn from the jugular vein into a 10 ml Vacutainer with a clot activator. Blood was centrifuged using a TGL-16M micro high-speed benchtop refrigerated centrifuge. This was done at 2,000 revolutions per minute for 10 minutes to separate the serum from the other blood components. The serum was withdrawn with a syringe and transferred to a clean test tube. The pure yellow, clear serum was analyzed for the biochemical nutritional elements. These were glucose levels, total protein, calcium, phosphorus, and magnesium levels using spectrophotometry as described by Renjini & Dileep (2017). This is a method used to measure the concentration of solutes in a solution by checking the amount of light absorbed. Light absorbed then passes through a digital display meter that can record the weight of solute per a specific volume of the solution in mg/dL or mmol/litre. It was done using a Beckman Spectrophotometer.

3.3.10 Description of Variables

The variables used to describe the effects of feed supplementation on milk production, reproduction, milk protein and fat percentages, and serum biochemical profiles after supplementation are shown in Table 3.3.2.

Table 3.3.2:Variables describing effects of feed supplementation on performance and serum biochemical profiles.

Variable Description	Variable type	Measurement variables
DEPENDENT VARIABLES		
Daily milk production	Scale	Number
Weekly milk production	Scale	Number
Milk protein levels	Scale	Number
Milk fat levels	Scale	Number
Serum biochemical levels	Scale	Number
Mating	Categorical	0=not mated; 1= mated
Repeat mating	Categorical	0=no repeat; 1= repeat
Pregnancy status	Categorical	1=pregnant; 0=not pregnant
INDEPENDENT VARIABLES		
Supplementation	Categorical	0=not supplemented; 1=supplemented
Pregnancy/supplementation status	Nominal	Supplemented and pregnant Supplemented and not pregnant Unsupplemented and pregnant Unsupplemented and not pregnant

3.3.11 Statistical analysis

Statistical analysis was done using SPSS Version 20. The study aimed to evaluate the impact of supplementation on daily milk production and serum composition in two groups of camels. The analysis included comparisons of mean values for various parameters such as serum glucose, protein, albumen, calcium, phosphorus, and magnesium. These comparisons were conducted once between supplemented and unsupplemented camels. Additionally, fat and protein percentages were assessed every week in triplicate, and the means for each pair were compared.

The research involved a comprehensive examination of weekly milk production differences among four categories of camels based on pregnancy status and supplementation. Paired sample tests were employed to determine the statistical significance of these differences. Mean comparisons were used to evaluate the impact of supplementation on daily milk production and serum composition. The differences were for serum glucose, protein, albumen, calcium, phosphorus, and magnesium were measured once. Additionally, fat and protein percentages were assessed every week in triplicate, and the means for each pair were compared. The results were expressed as Mean ± SE, and mean differences were considered significant at a confidence level of P=0.05.

3.3.12 Benefit Cost Analysis

The economic benefit of supplementing camels for milk was calculated by first determining the incremental cost. This is the cost of the feed, which was supplemented. The value of the increment in milk was calculated by multiplying the difference by the price of milk of Ksh 200 (1.67 US$ equivalent) per litre to get the increment income. Then the benefit-to-cost ratio was calculated using formula 3.3.2.

Benefit Cost Ratio = value of extra milk added after supplementation ÷ cost of supplementation. 3.3.2

If the ratio is more than 1, then the investment is profitable, and if less than 1, then the fed supplementation is making a loss.

3.4 Factors affecting camel Farmers' market participation.

The methodology used is the same as for the determination of camel herd structure and performance described in Sections 3.1.1, 3.1.2, 3.1.3, 3.1.4, and 3.1.5. Binary regression determined how demographic, physical resources, and human capital affect the decision of market participation at a 0.05 level of significance. Multiple linear regression determined how the same factors affect the extent of market participation.

3.4.1 Determinants of Pastoralists' Participation in Input and Output Markets

According to Von Braun & Kennedy (1994), household market participation can be expressed in terms of output market and input market. The output market participation index is the proportion of the milk sold to the milk produced. Likewise, the input market participation index is the proportion of the value of purchased inputs to the total value of inputs. The inputs considered were months of purchasing feeds and minerals, and hired workers. The information sought was the distance to the trading centers, availability of marketing information, infrastructure, and extension services.

3.4.2 Sample selection

Bias correction due to non-market participation was determined by using the Heckman 2-stage econometric model (Rezaee et al., 2022). This model is widely utilized in other studies (Worku et al., 2022). Each nonresponse is considered at the selection level. This was by first determining the decision to participate. Therefore, the first stage determined the decision to sell milk, purchase feeds and minerals, and hire labour. The dependent variables used were categorical, while the independent variables comprised a mix of categorical, ordinal, and scale variables (Table 3.4.1). Data on farmers' characteristics, production, and level of market participation were obtained through an interview schedule with a prepared checklist administered to CDRs using the local language.

Table 3.4.1: Variables to determine factors affecting decisions for input and output market participation.

Variable Description	**Variable type**	**Measurement variables**
DEPENDENT VARIABLES		
Participation in milk sales	Categorical	1=Participated; 0=Never participated
Participation in feed purchase	Categorical	1=Participated; 0=Never participated
Participation in mineral purchase	Categorical	1=Participated; 0=Never participated
Participation in hiring labor	Categorical	1=Participated; 0=Never participated
INDEPENDENT VARIABLES		
County	Categorical	1=Isiolo; 0=Marsabit
Sex	Categorical	1=Male; 0=Female
Length of practice	Ordinal	Number
Another source of livelihood	Categorical	1=No; 0=Yes
Extension service	Categorical	1=No; 0=Yes
Total camels	Scale	
No milking camels	Scale	Number
Percentage milking	Scale	Number
Milk produced per camel in the wet season	Ordinal	Number
Milk produced per camel in the dry season	Scale	Number
Distance to consumer	Scale	Number

In the second stage, the extent of participation was determined for only those who decided to participate by getting market participation indices. Output market participation indices were the percentage of milk sold in the wet and dry seasons.

Then, the input participation indices were the number of months in the year that they purchased feed and minerals. The dependent variable was a scale while the independent variables were mixed categorical, ordinal, and scale (Table 3.4.2).

Table 3.4.2: Variables to determine factors affecting the extent of input and output market participation.

Variable Description	Variable type	Measurement variables
DEPENDENT VARIABLES		
Percentage of milk sold in the wet season	Scale	Actual percentage of milk sold
Percentage of milk sold in the dry season	Scale	Actual percentage of milk sold
Months of purchasing feeds	Ordinal	1=None; 2=Less than 4 months;3=4-6 months;4=7-9 months;4=More than 9 months
Months of mineral purchase	Ordinal	1=None; 2=Less than 4 months;3=4-6 months;4=7-9 months;4=More than 9 months
No hired workers	Ordinal	1=None; 2=1-2;3=3-4;4=More than 4
INDEPENDENT VARIABLES		
County	Categorical	0=Isiolo; 1=Marsabit
Sex	Categorical	1=Male; 0=Female
Length of practice in years	Ordinal	1=Below 10; 2=11-20;21-30;4=Above 30
Another source of livelihood	Categorical	0=No; 1=Yes
Extension service	Categorical	0=No; 1=Yes
Total camels	Scale	Number
No milking camels	Scale	Number

Percentage milking	Scale	
Milk produced per camel in the wet season	Ordinal	1=below 10; 2=10-19;3=20-29;4=above 29
Milk produced per camel in the dry season	Scale	Number
Distance to consumer	Scale	Number
Member of a registered group	Categorical	0=No; 1=Yes
Type of agreement	Ordinal	1=verbal; 2=signed contractual
Marketing Infrastructure owned	Ordinal	1=None; 2=Refrigerator;3=Motorbike;4= Refrigerator & Motorbike
Knowledge of milk prices before	Categorical	0=No; 1=Yes
Distance to the consumer	Scale	Number

3.4.3 Data Analysis

The findings from the focus group discussions of the two groups were analysed by meticulously capturing all verbal interactions and identifying recurring themes. Data from questionnaires were obtained and stored as described in Section 3.1.8. Descriptive statistics and the Heckman 2-stage Econometric Model Equation estimated using the Probit model for market participation. The equation for the level of participation estimated using the Tobit Model gets coefficients for every variable of regression at a 95% level of confidence.

Data for the determination of input and output market participation were analyzed through descriptive statistics, followed by the Heckman 2-stage model to approximate two equations with two dependent variables. The first model determined the factors that influence the choice of participating or not participating in the output and input markets. The first stage was analyzed by probit regression analysis model, showing the probability of participating in milk sale or purchase of feeds, minerals, and hiring labor in equation 3.4.1 (Alsoruji et al., 2018).

$$Y= B_o+B_1(X_1) +B_2(Z_2)+B_3(Z_3) + \ldots\ldots +B_i(Z_i). \qquad 3.4.1$$

where market participation is denoted by 1 and non-participation by 0, Y=Probability of market participation

B_o=Y intercept or probability of participating when all independent variables are zero.

B_1, $B_2 \ldots B_i$=Change in log odds for a unit increase in the probability of market participation

Z_1 Z_2 $Z_3 \ldots$ Z_i =Independent variables

The second stage determined factors influencing the extent of participation in terms of the proportion of milk sold to milk produced and the proportion of months of purchasing inputs to the months of the year. A regression model was used for analysis with formula 3.4.2.

$$Y=A+B_1(Z_1) +B_2 (Z_2) +B_3 (Z_3) + \ldots +B_i (Z_i) + e. \qquad 3.4.2$$

Where (Y) is the dependent variable, while (A) is a constant, $Z_1Z_2Z_3 \ldots$ Zi is the independent variable, and B_1, B_2, $B_3 \ldots B_i$ are partial regression coefficients.

The selection equations are as follows: Probability of participating in the market is denoted by (P). Therefore, equation 3.4.3 is for the probability of market participation.

$$P= A+B_1 \text{ (County) } +B_2 \text{ (Sex) } +B_3 \text{ (Length of practice) } + B_4 \text{ (other source of livelihood) } +B_5 \text{ (extension services) } +B6 \text{ (proportion milking) } +B_7 \text{ (Distance to consumer) } +B_8 \text{ (percentage of milk sold) } +B_9. \qquad 3.4.3$$

The statistical method for the second stage was estimated by Ordinary Least Squares (Equation 3.4.4). The proportion of milk sold reflects the output market participation index and months of purchasing inputs, showing the input market participation index. They are both denoted by Y as follows:

$Y = A + B_1$ (County) +B2 (Sex) $+B_3$ (Length of practice) + B_4 (another source of livelihood) $+B_5$ (extension services) B_6 (proportion miking) $+B_7$ (Distance to consumer) $+B_8$ (percentage of milk sold) + B_9 (member of registered group) $+B_{10}$ (type of agreement) $+B_{11}$ (Market infrastructure owned) + B_{12} (Knowledge of the price before) + e. 3.4.4

3.4.4 Data Collection and Analysis Summary

Table 3.4.3: Data collection and analysis summary

Objective	Study Design	Variables	Sampling Units	How data was Obtained	Method of analysis
1. Analysis of camel herd composition and milk productivity	Descriptive	<u>Independent</u> The proportion of female calves less than 2 years old The proportion of male calves less than 2 years old The proportion of female calves 2-4 years old The proportion of male calves 2-4 years old Proportion of female camels 4-6 years The proportion of male camels 4-6 years		Scheduled interview Observation	Frequency counts, percentages, and means. Linear regression analysis for milk production. The null hypotheses for the coefficient were rejected at a 0.05 level of significance. Pearson's correlation coefficient. The null hypothesis for *r* was rejected at a 0.05 level of significance.

		The proportion of female camels 6-8 years old The proportion of male camels 6-8 years old Proportion of breeding female camels >8 years old Proportion of breeding male camels >8 years old Proportion of female camels >8 years not breeding Proportion of male camels > 8 years old not breeding Dependent Average milk production Calving interval Proportion of calf survival beyond 2 years			
2. Determine the camel calf disease morbidities,	Cross-sectional.	Independent Age	Households	Scheduled interview	Descriptive statistics for every common camel calf disease

survival rate, and the associated factors.		Level of education How soon colostrum was fed after birth in hours. How soon milk from a particular camel is sold Calf suckling period Methods of disease control Level of subclinical mastitis Hygiene at milking Methods of disease control <u>Dependent</u> No sick calves and the recurrence of a particular disease in 12 months No dead calves of a particular disease in 12 months.		Physical Observation	incidence and the predisposing factors. Means and frequencies for the occurrence of diseases. Means and the frequencies of the predisposing factors. Morbidities and Mortalities of common camel calf diseases were determined. Means were used to determine the morbidities and gross mortalities in the locations of the two counties. Linear regression analysis for morbidity and mortality. The null hypotheses for the coefficient were rejected at a 0.05 level of significance.

3. Determine the effects of camel feed supplementation on milk yield in early pregnancy.	Experimental	<u>Independent</u> Age of females Age of male Method of production Conception Level of supplementation Calf presence Age of camel Pregnancy <u>Dependent</u> Conception Milk production	Experimental Animals	Questionnaire, laboratory examination, and Observation	Weekly reproductive parameters monitored. Paired mean comparisons. Means expressed as Mean ± SE at P=0.05 confidence level.
4. Assess factors affecting camel milk input and Output market participation.	Cross-Sectional	<u>Independent</u> County Sex of camel owner Herd size Another source of livelihood	Households	Interview schedule	Descriptive statistics and Heckman 2 stage Econometric Model. Equation estimated using the Probit model for market participation.

		Percentage of milking camels Percentage of milk sold Distance to the trading center Availability of extension services. Registration in the milk marketing group Marketing infrastructure owned Prior price information <u>Dependent</u> Output market participation index. Input market participation index.			The equation for the level of participation estimated using Tobit Modell gets coefficients for every variable of regression at a 95% level of confidence.

3.5 Scientific and Ethical Reviews

The research proposal was reviewed by the Animal Science Department of Kenyatta University (KU) in the School of Agriculture and Environmental Sciences. Approval for research was sought and granted by the KU Graduate School (Appendix 1). Ethical Review was carried out by the KU- Ethical Review Committee and approved (Appendix 2). Permission from NACOSTI was granted, and the permit was issued (Appendix 3). Informed signed Consent forms were made available before the interview and explained to the interviewee in a language they understood (Appendix 5). A signed consent was sought from Ewaso Ng'iro North Development Authority (Appendix 6). Participation was voluntary, and the participants' identities were protected. For the experiment, two camel attendants were given some monthly incentives for the three-month period of the study. The study camels were treated humanely, observing the animal welfare freedoms. These included basic freedoms from hunger, thirst, discomfort, pain, injury, and disease, and freedom to express normal behaviour (Webster, 2001). Camels were dewormed and provided with external parasite control during the period of the experiment. The investigator bore the cost of treatment of the camels that fell sick during the process of the experiment. In Marsabit County, every pastoralist interviewed was rewarded with one litre of the camel dewormer 10% Albendazole.

CHAPTER FOUR: RESULTS

4.1 Camel herd size and composition, and its effect on herd performance

4.1.1 General Information

More than 70% of camel owners were male and had another source of livelihood. The percentage of pastoralists having another source of livelihood was highest in Kinna, followed by Kulamawe and Lontolio, and lowest in Merille and Gotu locations. The people who were available for interviews in both Counties were the owners or herders. The percentage of hired employees was low in both counties. (Table 4.1.1).

Table 4.1.1: Number and percentage of the households' general information per location

Counties	Isiolo								Marsabit											
Locations	Kulamawe n=62		Gotu n=30		Kinna n=45		Total n=137		Laisamis n=64		Lontolio n=60		Koya n=60		Merille n=58		Total n=242		Overall n=379	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Sex of the owner																				
Male	54	87	24	81	40	89	118	86	46	71	37	61	49	82	44	76	177	73	295	77
Female	8	13	6	19	5	11	19	14	18	29	24	39	11	18	14	24	66	27	85	22
Relationship with the owner of the camel																				

Self	3	5	1	3	1	2	5	4	45	70	20	34	45	75			110	46	115	30
Spouse	7	11	2	7	4	9	13	9	12	20	15	24	14	23	23	39	64	26	77	20
Child	2	3	4	13	1	2	7	5	4	6	2	3	1	2	24	42	31	13	38	10
Herder	50	81	7	23	39	87	96	70	2	3	23	37	0	0	8	14	33	13	131	34
Hired	0	0	16	55	0	0	16	12	1	2	1	2	0	0	3	5	5	2	22	6
Having other source of income																				
Yes	57	92	17	58	43	96	117	86	64	100	49	81	43	72	34	59	190	79	307	81
No	5	8	13	42	2	4	20	14	0	0	12	19	17	28	24	41	53	21	72	19

The general camel herd management and performance were as shown in Table 4.1.2. Most Isiolo pastoralists kept the Somali type of camels, while the majority of Marsabit pastoralists kept the Rendille type. In both Counties, the most used method in the feed scarcity coping mechanism was migrating to other areas, and 9% of Marsabit purchased feeds. More pastoralists were seeking advice on how to manage camels in Isiolo than in Marsabit. In Isiolo, they were seeking advice from Ministry staff, and in Marsabit from the neighbours.

Table 4.1.2: Number and percentage of households with general camel management characteristics.

	Isiolo(N=137)		Marsabit (N=242)		Total(N=379)	
	No	%	No	%	No	%
Type of camel						
Somali	132	86	0	0	132	*35*
Rendille	5	14	189	77	194	50
Turkana	0	0	1	0.4	1	0.3
Cross Breeds	0	0	52	21.4	52	14.3
Feed Scarcity coping mechanism						
None	50	36	19	8	69	18
Migrate	66	49	198	82	264	70
Combination	19	14	2	0.8	21	5
Buy feeds	2	1	23	9	25	6
Information on whether they seek extension services						
Yes	94	69	130	54	224	59
No	43	31	110	46	153	41
Personnel offering extension services						
GK	7	5	2	0.8	9	2
Private	0	0	2	0.8	2	0.5
CDR	0	0	5	2	5	1
Neighbors	0	0	30	12	30	8
Combination	130	95	203	84	333	88

Note. GK: Government of Kenya, CDR: Community Disease Reporter

4.1.2 Camel herd structure

The percentage of milking camels was higher in Isiolo than in Marsabit. The average number of milking camels was more than 8 in all locations of the two counties, with Gotu having 23 and only 9 in Merille, despite the large herd size. In Isiolo County, the Gotu location has the highest average herd size of 85, followed by Kulamawe and Kinna with 46 and 40 camels, respectively. The average herd sizes for Isiolo were 52, ranging from 16 to 204. The percentage of milking camels was highest in Kinna, followed by Kulamawe and Gotu (Table 4.1.3).

Table 4.1.3 : Herd Structure and composition in locations of Isiolo County

County	Isiolo							
Locations	Kulamawe		Gotu		Kinna		Total	
Herd Structure	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Herd size	46	17-93	85	40-204	40	16-69	52	16-204
No milking camels	15	8-25	23	8-35	16	8-25	17	8-35
Percentage of milking camels	30	14-74	22	12-50	32	15-61	29	12-74
Male calves below 2 years	4	0-8	9	3-17	4	0-8	5	0-17
Female calves below 2 years	6	2-12	6	1-13	6	2-12	6	0-13
Male 2-4 years	3	0-9	7	0-14	2	0-10	4	0-14
Female 2-4 years	5	1-10	6	1-16	4	2-9	5	0-16
Male 4-6 years	3	0-10	4	0-15	2	0-6	3	0-15
Female 4-6 years	5	0-11	14	3-36	4	0-10	7	0-36
Male 6-8 years	2	0-8	1	0-21	2	0-5	2	0-21
Female 6-8 years	5	0-10	17	0-49	5	0-10	8	0-49
Males above 8 years of breeding	1	0-2	1	1	1	0-5	1	0-5

Female above 8 years and breeding	7	0-15	21	0-73	5	0-15	9	0-73
Male above 8 years and not breeding	1	0-8	0	0	1	0-7	1	0-8
Females above 8 years and not breeding	6	0-12	0	0-2	5	0-15	4	0-15

In Marsabit County, Merile location had the highest herd size, and the lowest was Lontolio. The mean herd size was 45, ranging from 3 -171 camels. The percentage of milking camels in Marsabit County was highest in Lontolio and lowest in Marille. The number of camel age and sex categories was almost the same, but showed a notable increase in the number of female adult camels. The mean number of males more than 8 years old and breeding ranged from 1-3 across all the locations in the County (Table 4.1.4).

Table 4.1.4: Herd structure and composition in the locations of Marsabit County

County	Marsabit									
Locations	Laisamis		Lontolio		Gotu		Merille		Total	
Herd Structure	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Herd size	32	3-75	23	4-58	51	9-130	74	12-171	45	3-171
No milking camels	11	8-16	10	8-25	12	8-25	9	8-35	10	8-35
Percentage of milking camels	16	0-47	28	0-91	16	0-38	13	4-33	18	0-91
Male calves below 2 years	3	0-6	4	0-20	5	0-14	6	1-16	4	0-20

Female calves below 2 years	3	0-7	3	0-8	4	0-8	7	1-22	4	0-22
Male 2-4 years	2	0-6	2	0-6	4	0-13	6	1-25	3	0-25
Female 2-4 years	3	0-7	2	0-5	4	0-9	6	1-16	4	0-16
Male 4-6 years	2	0-9	1	0-6	3	0-18	6	1-15	3	0-18
Female 4-6 years	2	0-8	2	0-6	4	0-19	7	1-25	4	0-25
Male 6-8 years	3	0-8	1	0-12	4	0-21	5	1-13	3	0-21
Female 6-8 years	3	0-9	4	0-20	6	1-19	7	1-45	5	0-45
Males above 8 years of breeding	1	0-4	1	0-8	5	0-29	5	1-20	3	0-29
Female above 8 years and breeding	3	0-10	3	0-12	5	0-20	7	1-16	4	0-20
Male above 8 years and not breeding	3	0-8	1	0-5	3	0-21	6	1-26	3	0-26
Females above 8 years and not breeding	6	0-21	1	0.6	4	0-19	6	1-19	4	0-21

4.1.3 Herd age and sex percentages

The overall ratio of males to females was 1:1.8, with a difference in the ratio for Isiolo (1:2.8) and Marsabit (1:1.7). The percentages of the herd composition in Isiolo and Marsabit Counties are shown in Table 4.1.5. Isiolo County had higher percentages of all female camels from four years old than Marsabit. However, this excluded those beyond 8 years and not breeding. On the contrary, Marsabit County had the highest percentage of males more than 4 years old, including those that were not used for breeding. In Isiolo County, the percentage of female camels above 4 years was higher in the Gotu location than in other locations. Marsabit pastoralists showed significant uniformity in age and sex percentage distribution. However, Laisamis location had a significantly higher percentage of females more than 8 years and not breeding (19.99%). Further Lontolio location pastoralists had a significantly higher number of calves less than two years in both sexes and females 6-8 years at 99% confidence levels.

Table 4.1.5: Herd age and sex percentages in Isiolo and Marsabit, and specific locations

	Counties		Isiolo Locations			Marsabit Locations			
Age and Sex	Isiolo	Mar sabit	Kula mawe	Gotu	Kinn a	Lais amis	Lonto lio	Koy a	Meri lle
Male<2 years	9.38	10.7	8.39	10.78	9.79	8.72	16.30	10.4	7.48
Female<2 years	12.14	9.35	13.28	7.02	14.0	8.21	11.21	9.05	8.99
Male 2-4 years	6.93	7.17	7.11	9.73	5.46	7.11	6.46	7.40	7.75
Female 2-4 years	10.29	8.08	11.36	6.73	11.2	7.43	7.90	8.05	9.03
Male 4-6 years	5.52	6.37	6.51	4.99	4.51	6.97	4.69	0.00	7.48
Female 4-6 years	12.16	8.36	11.00	16.74	10.7	7.19	7.18	9.84	9.37

Male 6-8 years	3.44	6.09	3.80	1.71	4.11	6.88	4.53	6.10	6.83
Female 6-8 years	13.12	11.9	11.18	18.25	12.3	7.98	18.08	12.0	9.62
Male>8 years B	0.21	0.56	0.20	0.14	0.29	0.22	0.56	0.77	0.71
Female > 8 years B	15.31	9.63	12.97	23.49	13.0	9.10	10.05	10.2	9.25
Male >8 years NB	0.95	6.51	1.34	0.00	1.05	8.27	3.88	5.42	8.44
Female >8 years NB	8.63	10.3	11.05	0.18	11	19.9	4.12	7.87	8.34

Abbreviations: M<2, males less than 2 years; F<2, females less than 2 years; M 2-4, male 2 to four years; F 2-4, female two to four years, M 4-6, male four to six years; F 4-6, female four to six years; M 6-8, male six to eight years; F 6-8, female six to eight years; M>8B, male more than eight years and breeding; F>8B, female more than eight years and breeding; M>8NB, male more than eight years and not breeding; F>8NB, female more than eight years and not breeding.

4.1.4 Camel Milk Production and Reproductive Performance

The performance in all the locations in Isiolo and Marsabit counties was as shown in Table 4.1.6. In Isiolo, only 2% of the households produced less than 10 litres per herd per day in the wet season, while in Marsabit, 53% produced less than 10 liters per herd per day. In the dry season, 69% of Isiolo pastoralists produced more than 10 liters per day, while 65% in Marsabit produce less than 10 litres and 19% produce no milk. Age at first calving was the same for the two Counties with many of the households having 10-15 years of the age at first calving. The calving interval was slightly shorter in Marsabit, with 12% having a calving interval below 18 months, than in Isiolo, with only 1% having a calving interval below 18 months. Likewise, the lactation period was shorter in Marsabit, with 70% below 24 months, than in

Isiolo, where 49% was between 24 and 29 months. Age at first calving was 10-15 years for 86% and 72% in Isiolo and Marsabit Counties, respectively.

Table 4.1.6: Camel herd, milk production, and reproductive performance

	Isiolo								Marsabit											
Location	Kulamawe n=62		Gotu n=30		Kinna n=45		Total n=137		Laisamis n=64		Lontolio n=60		Koya n=60		Merille n=58		Total n=242		Overall n=379	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Milk production in litres per herd per day during the wet season																				
Below 10					3	7	3	2	28	44	53	89	8	13	39	68	128	53	131	35
10-19	24	38	1	3	20	44	45	32	36	56	6	10	20	33	18	31	80	33	125	33
20-29	36	59	6	19	21	48	63	46			1	2	25	43			26	11	89	24
Above 29	2	3	23	77	1	2	26	19					7	12	1	2	8	3	34	9
Milk production in litres per herd per day during the dry season																				
None					1	2	1	0.7	9	14	34	57	2	3	1	2	46	19	47	12
Below 10	21	33	1	3	20	44	42	30	53	83	26	43	25	41	53	92	157	65	199	52
10-19	36	59	10	32	22	50	68	50	2	3			28	48	4	7	34	14	102	27
20-29	5	8	19	65	2	4	26	19					5	8			5	2	31	8
Age at first calving																				
5-9	12	19			7	15	19	14	3	5	17	28	23	38	26	44	69	28	88	23
10-15	50	81	30	100	38	85	118	86	61	96	43	72	37	62	32	56	173	72	291	77

Calving Interval																				
Below 18	2	3					2	1			16	26	3	5	10	19	29	12	31	8
18-24	34	56	11	36	22	51	67	49	32	50	32	54	36	61	22	38	122	51	189	50
24-29	26	41	19	65	23	49	68	48	32	50	12	20	21	34	23	39	88	36	156	41
Above 29															3	5	3	1	3	0.8
Lactation Period																				
Below 24	21	33	1	3	16	35	38	27	61	96	38	64	38	64	31	54	168	70	206	55
24-29	36	59	29	97	27	61	92	68	3	5	20	33	9	15	25	42	57	23	149	39
30-36	4	6			1	2	5	4			2	3	4	7	1	2	7	3	12	3
Above 36	1	2			1	2	2	1					9	15	1	2	10	4	12	3

4.1.5 Effect of herd size on performance

The effects of herd size on performance are shown in Table 4.1.7. In the regression model for the effect of herd size on milk production, the coefficients for the herd size were all negative and significant for Marsabit county (p=0.000). In Marsabit County, increasing the herd size by one unit reduced production per camel per day by 38.5% and 49.1% (p=0.000) in the wet and dry seasons, respectively. In Isiolo county, the herd size had a negative effect on milk production per camel per day, but not significant in both wet and dry seasons (p=0.945) and (p=0.217) respectively. The calving interval was positively and significantly affected by the herd size in Isiolo County, but not in Marsabit County. In Isiolo County, the larger the herd the longer the calving interval. Increasing herd size by one unit in Isiolo increased the calving interval by 22.9% (p=0.006). However, herd size did not have a significant effect on calving interval in Marsabit County(p=0.359).

Table 4.1.7: Effect of herd size on milk production and calving interval

Model		Unstandardized Coefficients	Standardized Coefficients	t	Sig.
		Milk production			
Wet season	(Constant)	2.80		16.577	.000
	Total no of camels		-.325	-6.683	.000
Dry county	(Constant)	1.99		10.310	.000
	Total no of camels		-.358	-6.986	.000
Isiolo wet	(Constant)	1.09		1.594	.113
	Total no of camels		-.006	-.069	.945
Isiolo Dry	(Constant)	1.86		13.214	.000
	Total no of camels		-.105	-1.239	.217
Marsabit Wet	(Constant)	3.39		13.720	.000
	Total no of camels		-.385	-6.445	.000
Marsabit Dry	(Constant)	2.90		11.166	.000
	Total no of camels		-.491	-7.803	.000
		Calving interval			
All	(Constant)	22.036		59.755	.000
	Total no of camels		.125	2.468	.014
Isiolo	(Constant)	22.346		42.923	.000
	Total no of camels		.229	2.766	.006
Marsab	(Constant)	21.988		45.534	.000

Total no of camels	.059	.919	.359

4.1.6 Effect of herd proportions on performance

Regression results for the effect of age and sex percentages on performance are shown in Table 4.1.8. The milk production model in the wet and dry seasons was the same. In the regression model, the coefficients for the proportion of above 8 years and not breeding were positive and significant in both wet and dry seasons (p=0.000). The proportion of females 6-8 years positively and significantly influenced milk production in wet (p=0.023) and dry (p=0.002) seasons. The variable females above 8 years and breeding were rejected due to multicollinearity intolerance. The model, however, could explain 12% in both wet and dry seasons.

The constant had to be converted to the actual litres' production by calculating the antilogarithm. The constants, therefore, for wet and dry seasons were 1.68 and -1.69, respectively. Models for the wet season and dry seasons are shown in equations 4.1.1 and 4.1.2, respectively. Increasing the proportion of female camels 6-8 years by one unit increases milk production per camel per day by 0.18 and 0.26 litres in wet and dry seasons, respectively. Likewise, increasing the proportion of female camels that are more than 8 years old and not breeding by one unit increases milk production per camel per day by 0.26 and 0.44 litres in the wet and dry seasons, respectively.

$$P=1.68+0.18\,(PF\ 6\text{-}8)+0.324\,(PF>8NB) \qquad 4.1.1$$

$$P=-1.69+0.259\,(PF\ 6\text{-}8)+0.444\,(PF>8NB) \qquad 4.1.2$$

Where,

P is the average production per camel per day.

PF6-8 is the proportion of females 6-8 years old,

PF>8NB proportion of females more than 8 years old and not breeding.

Table 4.1.8: Effect of herd proportions on milk production in the wet and dry season

	Wet season			Dry season		
Adjusted R Squared	0.116			0.117		
Constant	0.225			-0.227		
	Standardized Coefficients Beta	T	Sig.	Standardized Coefficients Beta	T	Sig.
Male calves below 2 years	-.047	-.775	.439	.047	.757	.450
Female calves below 2 years	-.047	-.792	.429	.041	.650	.516
Male 2-4 years	-.051	-.935	.350	.080	1.411	.159
Female 2-4 years	-.048	-.851	.395	-.071	-1.19	.235
Male 4-6 years	-.077	-1.350	.178	-.025	-.421	.674
Female 4-6 years	.079	1.261	.208	.064	.965	.335
Male 6-8 years	-.009	-.154	.878	.064	1.051	.294
Female 6-8 years	.180	2.286	.023	.259	3.170	.002
Males above 8 years of breeding	.008	.131	.896	.074	1.186	.236
Male above 8 years and not breeding	-.056	-.906	.365	.016	.241	.810
Females above 8 years and not breeding.	.324	4.431	.000	.444	5.735	.000

4.1.7 Traditional and Scientific Pregnancy Confirmation

From Table 4.1.9, five of the camels tested had over 3.5 nmol/L, with levels ranging from 11.9 to 26, hence positive for pregnancy. By the traditional method of tail cocking, 13 were reported pregnant. Camel numbers 1801, 1805, 1808, and 1815 were confirmed pregnant through progesterone assay and were also confirmed pregnant by the traditional method. Three other camels, 1804, 1809, and 1820, were confirmed not pregnant by both scientific and traditional methods. One camel, 1818, was confirmed not pregnant by the traditional method but pregnant through the scientific method (false negative). However, there were nine camels confirmed pregnant by the traditional method and found not pregnant through the scientific method (false positive). However, Camel no 1818, although pregnant by progesterone levels, was reported as not pregnant by the traditional method (false negative).

Table 4.1.9: Progesterone levels and the cocking the tail comparisons

Camel no.	Progesterone levels nmol/L	Science	Traditional
1801	26	+	+
1803	0.6	-	+
1805	15.2	+	+
1807	<0.6	-	+
1808	12.3	+	+
1813	0.9	-	+
1815	16.9	+	+
1817	1	-	+
1819	0.8	-	+
1820	0.6	-	-
1802	0.8	-	+
1804	0.6	-	-
1806	0.8	-	+
1809	1.1	-	-
1812	1.2	-	+
1816	0.9	-	+
1818	11.9	+	-

Key: Symbols: +, Pregnant; -, Not pregnant

The cross-tabulations and the correlation coefficients of traditional and scientific methods of pregnancy diagnosis are shown in Table 4.1.10. The correlation coefficient was 0.054, which is very weak though positive and is not significant (p =0.083).

4.1.10: Correlations of scientific and traditional methods of testing pregnancy

P.D. Method		Scientific	Traditional
Science	Pearson Correlation	1	.054
	Sig. (2-tailed)		.838
	N	17	17
Traditional	Pearson Correlation	.054	1
	Sig. (2-tailed)	.838	
	N	17	17

4.2 Camel calf common diseases, morbidities, survival rate, and associated factors

4.2.1 Prevalence of the Common Camel Calf Diseases and the Life-threatening Incidents

Camel calf diseases were reported with varying incidence in the locations of the two counties. The household incidence of common bacterial and viral diseases in the locations is shown in Table 4.2.1. The highest incidence of calf diarrhoea was notable in all locations in Marsabit, especially Lontolio and Merille. It was low in the Isiolo locations, and the lowest was in the Gotu location. Households in both counties recorded pneumonia incidence of more than 65% apart from Gotu and Laisamis, with 50% each.

Contagious ecthyma (Orf) was very common in the two counties, with the incidence in the two counties being more than 75% with Marsbit having 82.2% and Isiolo having 76.4%. The highest was Kulamawe, Kinna, Koya, and Lontolio with 95.2, 93.5, 93.4, and 91.8, respectively. Pox was also very high, but higher in Marsabit than in Isiolo. Eye infection was moderate, but the incidence was higher in Marsabit. Eye infection was highest in Koya and Merille and lowest in Gotu and Laisamis, having an incidence of 12.9% and 12.1%, respectively.

Table 4.2.1: Household incidence of common bacterial and viral diseases in the locations

County	**Isiolo**								**Marsabit**											
Location	Kulamawe n=62		Gotu n=30		Kinna n=45		Total n=137		Laisamis n=64		Lontolio n=60		Koya n=60		Merille n=58		Total n=242		Overall n=379	
	No.	%	No.	%	No	%	No	%	No	%	No	%	No	%	No	%	No.	%	No.	%
Diarrhoea																				
Yes	31	50	6	19.	23	50.8	60	43.6	26	40.9	49	82	39	65.6	45	78	159	66	219	57.9
No	31	50	24	80.6	22	49.2	77	56.4	38	59.1	11	18	21	34.4	13	22	83	34	160	42.1
Pneumonia																				
Yes	53	85.7	15	50	38	84.8	106	77.9	32	50	51	86.9	56	91.8	40	69.5	179	74.1	285	75.5
No	9	14.3	15	50	7	15.2	31	22.1	32	50	8	13.1	5	8.2	18	30.5	63	25.9	94	24.5
Calf Diphtheria																				
Yes	35	57.1	1	3.2	23	52.2	59	43.6	20	31.8	34	57.4	39	65.6	35	61	128	53.4	187	49.9
No	27	42.9	29	96.8	22	47.8	78	56.4	44	68.2	26	42.6	21	34.4	23	39	114	46.6	192	50.1
Eye infection																				

Yes	35	57.1	4	13	23	51	62	45	8	12.1	35	59	46	77	43	74.6	132	55	194	51.2
No	27	42.9	26	87	22	49	75	55	56	87.9	25	41	14	23	15	25.4	110	45	185	48.8
Orf																				
Yes	59	95	4	13	42	93.5	105	76.4	42	66.7	55	91.8	56	93.4	45	78	198	82	303	80.1
No	3	4.8	26	87	3	6.5	32	23.6	22	33.3	5	8.2	4	6.6	13	22	44	18	76	19.9
Pox																				
Yes	30	47.6	8	25.8	35	78	73	52.9	19	28.8	49	82	47	78.7	45	78	160	66	233	61.2
No	32	52.4	22	74.2	10	22	64	47.1	45	71.2	11	18	13	21.3	13	22	82	34	146	38.8

The incidence of helminthiasis was recorded to be more than 50% in Marsabit locations and less than 50% in Isiolo locations, apart from Kulamawe, which had an incidence of 60.3%. Predation was higher in Isiolo, especially in Kina and Kulamawe locations, than in Marsabit, which recorded the highest in Merille. Tick paralysis was the same in the 2 counties where more than 60% of the households' reported incidences, apart from Gotu, which had a low incidence of 25.8%. The incidence of calves getting sick because of consuming excess milk was low in both counties, but Marsabit recorded more cases than Isiolo. Calf diphtheria was the same in both counties, but lowest in Gotu (Table 4.2.2)

Table 4.2.2: Household incidence of parasitic and other life-threatening incidences in the locations

County	Isiolo								Marsabit											
Location	Kulamawe n=62		Gotu n=30		Kinna n=45		Total n=137		Laisamis n=64		Lontolio n=60		Koya n=60		Merille n=58		Total n=242		Overall n=379	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Worms																				
Yes	37	60.3	14	45.2	17	37	68	49.3	36	56.1	39	65.6	43	72.1	45	78	163	67.6	231	61
No	25	39.7	16	54.8	28	63	69	50.7	28	43.9	21	34.4	17	27.9	13	22	79	32.4	148	39
Predation																				
Yes	50	81	17	58.1	40	89.1	107	78.6	25	39.4	30	50	36	60.7	43	74.6	134	55.9	241	64.1
No	12	19	13	41.9	5	10.9	30	21.4	39	60.6	30	50	24	39.3	15	25.4	108	44.1	138	35.9
Tick paralysis																				
Yes	50	81	8	25.8	43	95.7	101	73.6	39	60.6	51	85.2	47	78.7	42	72.9	179	74.1	280	73.9
No	12	19	22	74.2	2	4.3	36	26.4	25	39.4	9	14.8	13	21.3	16	27.1	63	25.9	99	26.1
Excess milk																				

Yes	9	14.3	4	12.9	8	17.4	21	15	5	7.6	27	44.3	31	52.5	25	42.4	88	36	109	28.4
No	53	85.7	26	87	37	82.6	116	85	59	92.4	33	55.7	29	47.5	33	57.6	154	64	270	71.6

4.2.2 Camel calf disease morbidities and mortalities

Morbidity of diarrhoea was highest in the Marsabit locations, with Lontolio and Koya having 33.94% and 30.64% respectively. This was the percentage of those affected to those who survived. In Isiolo County, the morbidity was highest in Kinna and lowest in Gotu. Pneumonia followed the same trend as diarrhoea, with the highest in Lontolio and Koya and the lowest in Gotu and Laisamis. The same was observed in other diseases, such as orf and pox. Predation morbidity was highest in Kinna, Gotu, and Kulamawe, all in Isiolo County, and in Koya in Marsabit. Tick paralysis, effects of excess milk consumption, and calf diphtheria also showed an increase in morbidity in Lontolio and Koya than all the other locations except Kinna, which had high morbidity on tick paralysis (Table 4.2.3).

Common diseases' gross mortalities are shown in Table 4.2.4. The gross mortality, indicating the proportion of those dead to those that were born during the calving season, was 44.11%. The greatest contributors to the mortality were predation and tick paralysis. This was followed by microbial diseases such as pneumonia, diarrhea, calf diphtheria, worms, pox, and contagious ecthyma. Consumption of excess milk and eye infections contributed the lowest in gross mortality of 5% and 4.12% respectively. The worm mortality was higher in the Marsabit locations (Laisamis, Lontolio, and Merile) and lowest in Isiolo locations, which are Kulamawe, Gotu, and Kinna, with 1.68%, 0.00%, and 0.99% respectively. The highest calf mortality due to worms in Marsabit was recorded in Laisamis, Merile, and Lontolio, and the lowest was in Gotu.

Table 4.2.3: Common calf disease and life-threatening incidences morbidities

Disease/condition	Kulamawe n=62	Gotu n=30	Kinna n=45	Laisamis n=27	Lontolio n=28	Koya n=42	Merille n=23	Total n=257
Diarrhoea	14.32±2.33	4.55±1.84	17.12±3.24	16.84±4.26	33.94±5.01	30.64±4.51	19.68±6.09	19.15±1.50
Pneumonia	26.37±2.62	13.18±3.60	28.92±3.45	12.19±4.84	47.83±4.84	37.27±3.60	14.70±4.88	26.82±1.56
Orf	24.54±1.66	2.61±1.31	32.23±3.26	28.92±6.09	38.07±5.01	39.80±3.64	14.70±4.88	26.80±1.49
Pox	11.27±1.72	5.69±1.97	22.72±2.84	9.65±4.81	31.44±4.97	31.01±3.75	17.42±5.49	18.39±1.39
Eye Infection	15.34±2.34	1.49±0.77	13.30±2.22	3.09±3.09	17.31±3.97	28.70±3.75	16.51±5.30	14.53±1.26
Worm	16.97±2.28	8.97±2.35	10.19±2.32	40.41±5.89	23.72±5.43	29.62±4.30	18.32±5.96	20.15±1.53
Predation	27.31±2.94	28.55±5.42	38.71±3.89	9.97±4.76	12.46±3.13	22.89±3.93	14.70±4.88	24.23±1.62
Tick Paralysis	26.48±2.81	7.72±3.07	37.60±3.56	18.66±4.90	33.86±5.17	31.72±4.00	18.78±5.48	26.36±1.58
Excess Milk	3.47±1.10	3.30±1.91	3.30±1.15	0.00±0.00	19.52±5.08	24.56±4.33	10.38±4.98	8.83±1.19
Calf Diphtheria	14.81±2.07	0.58±0.58	15.42±3.16	11.15±4.25	23.74±5.54	25.60±3.91	15.77±5.21	15.63±1.38

Values are expressed as mean ± SE

Table 4.2.4: Gross percentage mortality per disease/condition and location

Disease/condition	Kulamawe n=62	Gotu n=30	Kinna n=45	Laisamis n=52	Lontolio n=46	Koya n=57	Merille n=54	Total n=346
Diarhoea	2.52±0.89	0.00±0.00	4.37±1.26	7.80±2.31	8.71±2.36	9.81±2.55	12.23±3.12	6.99±0.85
Pneumonia	6.99±1.31	2.09±1.21	8.86±1.79	5.23±2.19	10.42±2.87	8.04±2.34	13.49±3.44	8.27±0.91
Orf	3.64±1.09	0.00±0.00	1.92±0.98	10.42±2.63	9.44±2.47	3.06±1.30	12.51±3.16	6.35±0.81
Pox	3.40±1.01	0.00±0.00	4.98±1.58	5.38±2.24	9.31±2.75	9.47±2.86	10.27±2.97	6.55±0.88
Worm	1.68±0.85	0.00±0.00	0.99±0.59	14.10±2.96	10.59±2.88	2.76±1.31	12.63±3.46	6.67±0.90
Predation	13.13±1.51	9.25±2.24	14.54±1.99	5.92±2.60	13.55±3.02	5.05±1.65	16.98±3.09	11.43±0.93
Excess Milk	0.00±0.00	0.58±0.57	0.00±0.00	2.15±1.38	7.53±2.63	10.09±2.96	11.29±3.12	5.00±0.84
Diphtheria	3.14±1.04	0.00±0.00	4.58±1.61	8.74±2.69	6.46±2.41	9.11±2.58	11.57±3.11	6.73±0.89
Eye infection	1.15±0.68	0.00±0.00	0.61±0.61	0.00±0.00	6.79±2.16	4.93±1.79	12.48±3.09	4.12±0.69
Tick paralysis	11.01±1.54	1.99±1.02	11.17±2.04	10.42±2.64	12.78±2.93	10.56±2.69	11.85±3.10	10.51±0.95

Values are expressed as mean ± SE

4.2.3 Prevalence of Diseases and Risk Matrix for Life-Threatening Incidents

The probability-impact matrices for life-threatening conditions in camel calves are presented in Figure 4.2.1. Predation, tick paralysis, and pneumonia exhibited the highest incidence rates, exceeding 60%, and the highest mortality rates, over 8%, making them the most critical threats to calf growth and survival. Moderately risky conditions include diarrhoea, orf, diphtheria, worms, and pox, while eye infections pose the lowest risk.

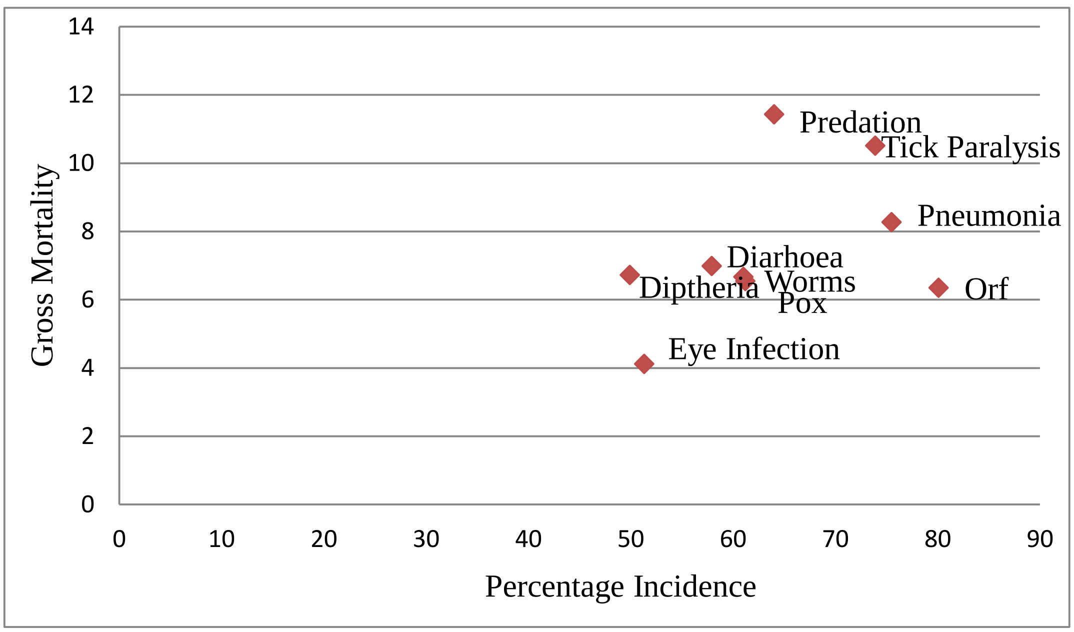

Figure 4.2.1: Risk Analysis of the common camel calf diseases

4.2.4 Disease predisposing factors

The routine herd, calf management, and milking practices are shown in Table 4.2.5. Among the routine management practices, the majority of Marsabit locations either do not perform external parasite control or do it at intervals beyond 2 weeks. On the contrary, Isiolo County pastoralists control external parasites either weekly or every two weeks. In Isiolo County, most pastoralists deworm camels every six months to one year, while in Marsabit, 55.1% deworm after one year or do not deworm at all. In calf management, 77.9% of the Isiolo suckle immediately, and 33.2% of the

Marsabit suckle immediately. In Marsabit, 59.9% suckle the calves 0 to 6 hours after they are born. In Isiolo, 77.1% sell milk after 1 to 2 months, and there are no pastoralists who start selling milk in less than a month. On the contrary, 41.3% of Marsabit herders start selling milk less than a month after calving. In Isiolo, 76.4% of Isiolo suckle one quarter, and 63.2% of Marsabit suckle one and 2 quarters. More herders in Marsabit than in Isiolo cannot quantify the milk that the calf suckles. In Marsabit, calves suckle for a shorter time, with 57.1% suckling for 7 to 12 months, while in Isiolo, 94.3% suckle for more than 13 months.

On the observance of hygiene at the milking time, Marsabit pastoralists had less incidence of subclinical mastitis, with only 25.9% having at least one quarter affected, while in Isiolo it was 62.9%. The majority in Marsabit washed only the udder before milking, while in Isiolo majority washed their hands and udder.

Table 4.2.5: Routine herd and calf management practices

	Isiolo N=137		Marsabit N=242		Total N=379			Isiolo N=137		Marsabit N=242		Total N=379	
	No	%	No	%	No	%		%	No	%	%	No	%
Frequency of controlling external parasites							**How soon after birth calf suckles**						
Weekly	6	4.3	47	19.4	53	14.0	Immediately	106	77.9	80	33.2	186	49.4
Two weekly	79	57.9	38	15.8	117	31.0	0-6 hrs	31	22.1	145	59.9	176	46.3
Beyond two	52	37.9	123	51.0	175	46.3	7-12 hours			16	6.5	16	4.1
None			34	13.8	34	8.8	Beyond 12			1	0.4	1	.3
Interval of administering dewormers							**Proportion of milk suckled**						
Less than 3 mon	1	.7	5	2.0	6	1.6	Two quarter	3	2.1	74	30.4	77	20.2
Every 3-6 mon	5	3.6	12	4.9	17	4.4	One quarter	104	76.4	78	32.8	182	48.6
6 mon to 1 year	67	49.3	56	23.5	123	32.8	Not quantified	13	9.3	73	30.0	86	22.5
Yearly	19	13.6	36	14.6	55	14.2							
Beyond one	23	17.1	78	32.8	101	27.1	None	17	12.1	17	6.9	34	8.8
None	22	15.7	55	22.3	77	19.9	**Sucking period in months**						
How soon milk is sold in months							19-24	73	53.6	42	17.4	115	30.5
Beyond 4	28	20.0	4	1.6	32	8.3	13-18	56	40.7	47	19.4	103	27.1
3-4 months	4	2.9	44	18.6	48	12.9	7-12	8	5.7	138	57.1	146	38.5

1-2 months	105	77.1	92	38.5	197	52.5
Less than 1			102	41.3	102	26.4
Activities before milking						
Hands and Udder	85	62.9	6	2.4	91	24.3
Udder	22	15.7	222	91.9	244	64.3
Nothing	30	21.4	14	5.7	44	11.4

0-6			15	6.1	15	3.9
Quarters affected by subclinical mastitis						
None	51	37.1	180	74.1	231	60.7
One	61	45.0	22	9.3	83	22.2
Two	24	17.1	9	3.6	33	8.5
Three			6	2.4	6	1.6
Four	1	.7	25	10.5	26	7.0

4.2.5 Risk factors affecting morbidities and mortalities

The regression for predisposing factors affecting disease morbidities for pneumonia and diarrhoea is shown in Table 4.2.6. Every unit increase in deworming interval increased the morbidity of calf diarrhoea by 16.7% ($p=0.056$), and every unit reduction in the time taken to start selling milk from a specific camel increased the morbidity of calf diarrhoea by 17.5% ($p=0.071$). Reduction of the proportion of milk suckled and months of suckling increased diarrhoea morbidity by 21.8% and 20.2%, respectively ($p<0.05$). Increasing the level of subclinical mastitis reduced diarrhoea morbidity by 14.4% at a 5% level of significance. Every unit in the reduction of the frequency of control of external parasites increased diarrhoea mortality by 28.6% ($p=0.075$). The reduction of the time taken to start selling milk and the reduction of the proportion of milk suckled increased diarrhoea mortality by 32.9% and 30.5%, respectively ($p<0.05$).

Every unit reduction in the deworming frequency, time taken to start selling milk, and months of calf suckling increased the morbidity of calf pneumonia by 17.9%, 29%, and 19.4%, respectively ($p<0.05$). Every unit in the reduction of the proportion of milk suckled increases pneumonia morbidity by 11.1% ($p<0.1$). Increasing the level of subclinical mastitis by one unit reduces the morbidity of pneumonia by 15.2 % ($p<0.05$). Reducing the time taken to start selling milk from a specific camel by one unit increased the camel calf mortality by 30.6% ($p=0.018$). Every unit reduction in months of calf suckling increased the mortality of pneumonia by 19.9 % ($p=0.080$).

Table 4.2.6: Risk factors associated with bacterial diseases' morbidity and mortality

	Morbidity					Mortality				
Disease-Associated Factors	Unstandardized Coefficients		Standardized Coeff			Unstandardized Coefficients		Standardized Coeff		
	B	SE	Beta	t	Sig	B	SE	Beta	t	Sig
			Diarrhoea							
(Constant)	10.26	.157		6.418	.000	5.18	.221		3.233	.002
Frequency of controlling external parasites	-.001	.027	-.003	-.035	.972	.067	.037	.286	1.804	.075
Interval of administering dewormers	.032	.016	.167	1.923	.056	-.009	.019	-.054	-.446	.657
Hours after birth the calf suckles	-.040	.037	-.101	-1.086	.279	-.017	.049	-.041	-.351	.726
Months after birth, milk is sold	.063	.035	.175	1.818	.071	.122	.051	.329	2.388	.019
Proportion of milk suckled	.067	.025	.218	2.642	.009	.082	.028	.305	2.898	.005
Months of calf suckling	.054	.021	.202	2.592	.010	.036	.028	.147	1.265	.209
Level of subclinical mastitis	-.032	.016	-.144	-1.982	.049	-.004	.018	-.025	-.239	.812
Activities before milking	.003	.024	.009	.113	.910	.001	.039	.004	.032	.975

	Pneumonia									
(Constant)	9.18	.128		7.507	.000	7.57	.190		4.634	.000
Frequency of controlling external parasites	-.030	.023	-.092	-1.323	.187	.032	.034	.131	.940	.349
State the interval of administering dewormers	.034	.013	.179	2.591	.010	-.011	.017	-.068	-.634	.527
How soon after birth calf suckles	.022	.032	.053	.694	.488	-.010	.052	-.023	-.189	.850
How soon after birth milk from a specific camel is sold	.095	.026	.290	3.642	.000	.103	.043	.306	2.405	.018
Proportion of milk suckled	.035	.021	.111	1.668	.097	.030	.026	.117	1.149	.253
Months of calf suckling	.055	.019	.194	2.914	.004	.046	.026	.199	1.766	.080
Level of subclinical mastitis	-.036	.014	-.152	-2.535	.012	-.014	.017	-.077	-.857	.393
Activities before milking	.009	.020	.030	.461	.645	.038	.025	.147	1.485	.141

The regression for disease and the predisposing factors for viral diseases are shown in Table 4.2.7. For Orf, reducing the time when milk from a specific camel was sold, and months of calf suckling increased the morbidity by 31.6% and 20.8% respectively ($p<0.01$). Increasing the level of subclinical mastitis by one unit reduced the morbidity of Orf by 23.5% ($p=0.000$). The mortality attributed to Orf was significantly affected by how soon milk from a specific camel was sold because every unit reduction in the months taken to start selling milk increased the mortality by 37.1% ($p=0.024$).

As regards pox morbidity, reducing the unit of time of selling milk after calving, the proportion of milk suckled, and months of calf sucking increased pox morbidity by 32.7%, 17%, and 24.3% ($p<0.05$) respectively. Increasing the level of subclinical mastitis reduces the morbidity of pox by 15.8% ($p<0.05$). Increasing the interval of controlling external parasites and the time to start the sale of milk increased the mortality of pox by 39.9% and 37.5 % respectively ($p<0.05$). An increasing number of teats affected by subclinical mastitis reduced the pox mortality by 24.2% ($p=0.038$).

Table 4.2.7: Risk factors associated with viral diseases' morbidity and mortality

	Morbidity					Mortality				
Disease-Associated Factors	Unstd C.		Std C.			Unstd C.		Std C.		
	B	SE	Beta	t	Sig	B	SE	Beta	t	Sig
					Orf					
(Constant)	9.40	.131		7.455	.000	8.34	.222		4.142	.000
Frequency of controlling external parasites	.010	.023	.032	.440	.660	.006	.038	.028	.146	.885
Interval of administering dewormers	.013	.013	.069	.980	.328	-.007	.020	-.053	-.369	.713
Hours after birth, a calf suckles	.017	.033	.041	.521	.603	.055	.053	.150	1.031	.306
Months after birth, milk is sold	.122	.029	.316	4.234	.000	.122	.053	.371	2.311	.024
Proportion of milk suckled	.014	.022	.044	.645	.519	.043	.028	.183	1.557	.124
Months of calf suckling	.059	.019	.208	3.183	.002	.012	.032	.045	.359	.72
Level of subclinical mastitis	-.055	.014	-.235	-3.901	.000	-.007	.017	-.048	-.427	.67
Activities before milking	-.001	.020	-.003	-.043	.966	-.007	.038	-.025	-.181	.86
					Pox					
(Constant)	5.65	.145		5.193	.000	6.64	.239		3.444	.001
frequency of controlling external parasites	.027	.026	.090	1.038	.301	.088	.038	.399	2.304	.024
State the interval of administering dewormers	.013	.016	.071	.826	.410	-.004	.023	-.028	-.183	.856

How soon after birth calf suckles	.041	.036	.104	1.143	.255	-.037	.061	-.081	-.605	.547
How soon after birth can milk from a specific camel was sold	.114	.032	.327	3.541	.001	.152	.061	.375	2.471	.016
Proportion of milk suckled	.051	.024	.170	2.109	.036	.018	.030	.065	.583	.562
Months of calf suckling	.068	.021	.243	3.171	.002	.037	.034	.155	1.115	.269
Level of subclinical mastitis	-.034	.015	-.158	-2.235	.027	-.044	.021	-.242	-2.118	.038
Activities before milking	.007	.023	.023	.281	.779	-.015	.036	-.047	-.414	.680

The regression for disease and the predisposing factors for helminthiasis and calf diphtheria were as shown in Table 4.2.8. Increasing the external parasite control interval increased worm infestation morbidity by 15.7% at a 10% significance level. Reducing the months before selling milk and the months of calf suckling increased the worm's morbidity by 32.5% and 30.3% respectively, at a 1% significance level. Worm mortality was affected by the months of calf suckling, in that every unit reduction in months of calf suckling increased the mortality by 26.6% at a 10% confidence level. Increasing intervals of deworming had a positive effect on worm morbidity and mortality, but it was not significant ($p>0.1$).

Tick paralysis morbidity was positively and significantly influenced by the interval of administering dewormers, proportion, and duration of calf suckling. Increasing interval of deworming, reducing proportion of milk suckled, and months of calf suckling increased tick paralysis morbidity by 19.7%, 16.7% and 24.2% respectively($p<0.05$). Increasing the interval of controlling external parasites increased mortality due to tick paralysis by 19.5% ($p=0.078$).

Incidence of calf diphtheria was significantly affected by administering a deworming regime, calf milk feeding, and hygiene at milking. Increasing the deworming interval, reducing the time taken to start selling milk and suckling period, and poor hygiene at milking increased morbidity by 18.5%, 17.7%, 23.2%, and 16.1% respectively, at 5% significance.

Table 4.2.8: Risk factors associated with helminthiasis and calf diphtheria morbidity and mortality

Disease-Associated Factors	Morbidity					Mortality				
	Unstd. C.		Std. C.			Unstd C.		Std. C.		
	B	SE	Beta	t	Sig	B	SE	Beta		Sig
					Worms					
(Constant)	5.64	.159		4.732	.000	8.73	.312		3.010	.004
Interval of controlling external parasites	.049	.027	.157	1.807	.073	.029	.044	.135	.664	.509
State the interval of administering de-wormers	.014	.016	.069	.848	.398	.003	.027	.018	.116	.908
How soon after birth calf suckles	.005	.039	.011	.118	.906	-.035	.065	-.089	-.540	.591
How soon after birth milk from a specific camel is sold	.109	.031	.325	3.547	.001	.073	.070	.190	1.052	.296
Proportion of milk suckled	.019	.024	.064	.797	.427	.048	.031	.201	1.524	.132
Months of calf suckling	.079	.022	.303	3.620	.000	.076	.042	.266	1.821	.073
Level of subclinical mastitis	.011	.014	.056	.816	.415	.009	.018	.062	.524	.602
Activities before milking	.003	.020	.010	.142	.887	-.016	.043	-.054	-.367	.715

Tick paralysis										
(Constant)	1.109	.137		8.100	.000	.815	.152		5.373	.000
Interval of controlling external parasites	-.026	.024	-.081	-1.073	.284	.047	.027	.195	1.775	.078
Interval of administering de-wormers	.036	.013	.197	2.720	.007	-.007	.013	-.048	-.544	.588
How soon after birth calf suckles	-.063	.034	-.156	-1.854	.065	-.016	.042	-.038	-.372	.710
How soon after birth milk from a specific camel is sold	.046	.029	.126	1.602	.111	.133	.031	.423	4.296	.000
Proportion of milk suckled	.054	.024	.167	2.261	.025	.033	.023	.117	1.405	.162
Months of calf suckling	.068	.020	.242	3.368	.001	.024	.021	.107	1.135	.258
Level of subclinical mastitis	-.016	.014	-.070	-1.092	.276	-.007	.014	-.037	-.465	.643
Activities before milking	.011	.021	.036	.511	.610	.020	.022	.085	.946	.346
Calf Diphtheria										
(Constant)	9.91	.164		6.087	.000	12.85	.257		4.319	.000
Frequency of controlling external parasites	-.039	.027	-.132	-1.440	.152	.046	.041	.201	1.120	.267
Interval of administering de-wormers	.033	.015	.185	2.145	.034	.003	.023	.019	.135	.893
How soon after birth calf suckles	-.003	.039	-.007	-.077	.938	-.043	.077	-.091	-.552	.583

How soon after birth milk from a specific camel is sold	.069	.035	.177	1.967	.051	.067	.060	.182	1.115	.269
Proportion of milk suckled	.029	.026	.091	1.110	.269	.053	.035	.193	1.521	.133
Months of calf suckling	.061	.022	.232	2.762	.006	.033	.038	.146	.874	.385
Level of subclinical mastitis	-.034	.015	-.168	-2.303	.023	-.028	.021	-.154	-1.326	.189
Activities before milking	.047	.023	.161	2.047	.042	-.028	.035	-.103	-.788	.433

4.3 Effects of camel feed supplementation on milk yield and reproduction during mating season

4.3.1 Ingredients and Supplement Proximate Composition

Results of the proximate nutrient composition of feed ingredients and supplements are shown in Table 4.3.1. Sunflower meal exhibited the highest crude protein (CP) content at 19.45%, followed by cottonseed meal at 14.21% and acacia pods at 11.68%. Regarding metabolizable energy, wheat bran (2884 kcal/kg), sunflower (2877 kcal/kg), and cottonseed meal (2868 kcal/kg) recorded the highest values, while Rhodes grass (1676 kcal/kg) and acacia pods (1853 kcal/kg) had the lowest values. Maize grain (2474 kcal/kg) and maize germ (2752 kcal/kg) demonstrated moderate metabolizable energy. Rhodes grass hay displayed the highest levels of crude fiber (CF), neutral detergent fiber (NDF), and acid detergent fiber (ADF) at 38%, 74%, and 42%, respectively. In contrast, maize grain exhibited the lowest values for CF, NDF, and ADF. These feed ingredients are required first for maintenance, production, and reproduction.

Table 4.3.1: Proximate composition (%) of feed ingredients and the supplement

Ingredients	Rhodes grass	Sunflower	Cotton seed	Acacia pods	Maize grain	Maize germ	Wheat bran	Mixed dry ration (supplement)
DM	89.67	91.18	90.59	86.98	88.54	87.95	88.01	88.87
CP	4.66	19.45	14.21	11.68	7.23	7.78	10.22	11.76
EE	1.03	16.67	12.91	1.07	3.69	8.86	6.79	7.93
ASH	6.27	4.64	10.52	7.47	0.94	2.47	4.40	5.07
NFE	39.52	17.88	28.12	47.03	74.17	63.44	57.07	47.95
CF	38.19	38.54	24.84	19.73	2.51	5.42	9.53	16.76

NDF	74.03	58.06	49.28	29.61	8.73	33.77	40.52	36.66
ADF	42.15	36.84	36.05	19.60	1.05	5.31	7.05	17.65
ADL	8.99	13.54	11.40	6.33	0.70	1.75	0.75	5.74
Estimated ME (kcal/kg)	1677	2877	2869	1854	2475	2753	2884	2897

Abbreviations: DM, Dry Matter; CP, Crude Protein; EE, Ether Extract; NFE, Nitrogen Free Extract; CF, Crude Fiber; NDF, Neutral Detergent Fiber; ADF, Acid Detergent Fiber; ADL, Acid Detergent Lignin; ME, Metabolizable Energy

The results of reproductive parameters, serum progesterone levels, and pregnancy status are shown in Table 4.3.2. All except one of the supplemented camels were mated within the first 14 days of supplementation, and one among the mated repeated after 21 days. The remaining one was mated on the 8th week. In the unsupplemented camels, seven were mated in the first 14 days, two repeated in the 5th week, one in the 6th week, and one mated for the first time in the 7th week. One was not mated at all (Barduu 2). This was an indication that supplementation improved the reproductive parameters, and camels were able to be in heat early in the mating season.

Pregnancy confirmation indicated that four of the supplemented and one of the unsupplemented were pregnant at the end of the mating season. Therefore, the conception rate for the supplemented and unsupplemented was 40% and 10% respectively. The camels were hence divided into four different statuses as follows: supplemented pregnant, supplemented and not pregnant; unsupplemented pregnant, and unsupplemented and not pregnant.

Table 4.3.2: Weekly reproductive parameters

Camel Name	Weeks									Progesterone levels(nmol/L)	Pregnancy Status
	1	2	3	4	5	6	7	8	9		
Supplemented camels											
Sumaya	*									26	Pregnant
Bordaga 3		*								0.6	Not- Pregnant
Dhugei 1	*									15.2	Pregnant
Dhugei 2	*									<0.6	Not- Pregnant
Pakistan	*									12.3	Pregnant
Frey 2	*									0.9	Not- Pregnant
Chongo	*									16.9	Pregnant
Afghor 2								*		1	Not- Pregnant
Bordaga 2		*								0.8	Not- Pregnant
Dhogonei	*			*						0.6	Not- Pregnant
Un-supplemented camels											
Wales	*									0.8	Not- Pregnant
Barduu 1	*				*					0.6	Not- Pregnant
Baryar 2							*			0.8	Not- Pregnant
Bordaga 1	*									1.1	Not- Pregnant
Dikidiki	*				*					1.2	Not- Pregnant
Barduu 2										0.9	Not- Pregnant
Baryar 1		*								11.9	Pregnant
Afghor 1	*					*					
Frey 1											
Kulamawe	*										

* Indicate the week when a specific camel was mated

4.3.2 Milk production

Daily milk production curves for the two groups for 63 days are shown in Figure 4.3.1. Mean daily milk production for supplemented and unsupplemented groups of 10 camels was 25.26±0.42 and 22.79±0.41 litres, respectively, with a difference of 2.46±0.52 liters (P=0.001).

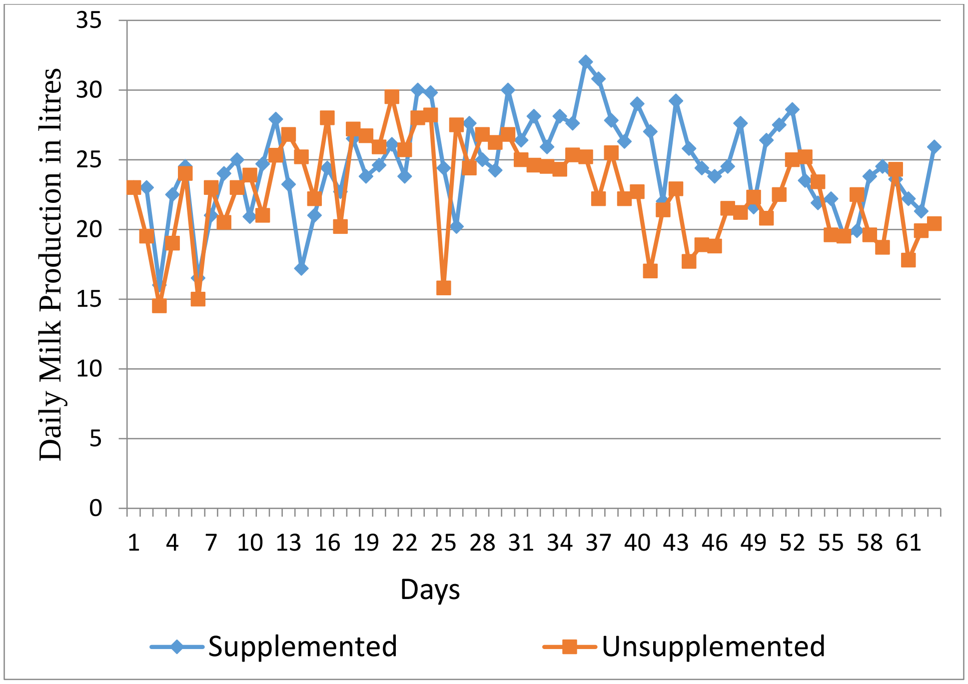

Figure 4.3.1: Total daily milk production for the supplemented and unsupplemented group

Mean weekly milk production after mating was 17.38±0.66 and 17.32±0.44 liters for the supplemented pregnant and supplemented not pregnant, respectively. Likewise, for unsupplemented camels, the weekly mean was 15.90±1.41 and 17.11±0.63 liters for the pregnant and not pregnant, respectively. Figure 4.3.2 shows weekly lactation curves for four camel groups.

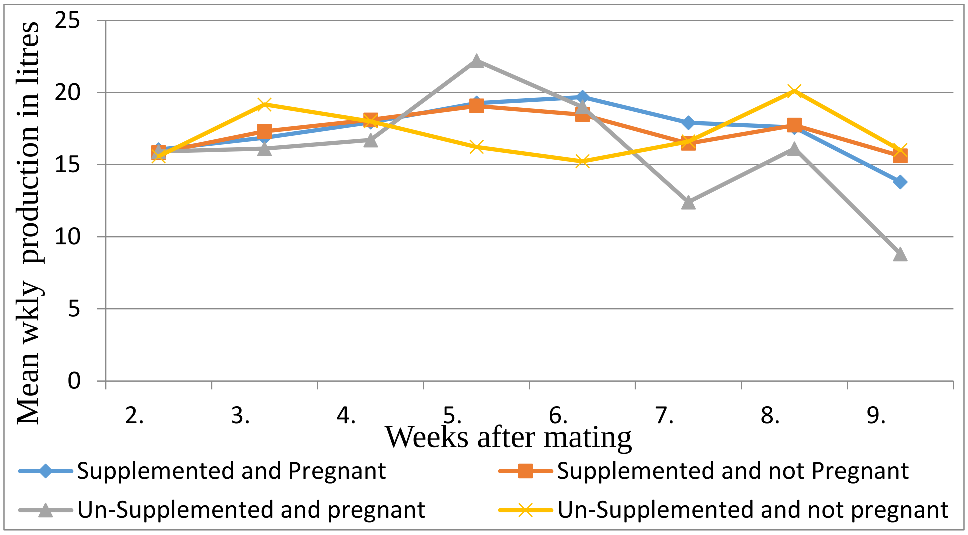

Figure 4.3.2: Weekly milk production in the four-camel groups

The paired mean comparison established there was no significant mean difference between the four groups. However, Table 4.3.3 showed the highest difference of 1.48±0.95 liters between pregnant supplemented and pregnant unsupplemented (Pair 2), though not significant (p=0.165). The lowest difference was 0.06±0.35 between supplemented pregnant and supplemented not pregnant (Pair 1) and was not significant (p=0.872).

Table 4.3.3: Paired mean weekly comparison for the four camel groups

Pairs	Status of Camels	Mean Difference	SE of Mean	t	Sig. (2-tailed)
1	Supplemented Pregnant & Supplemented not Pregnant	.06	.35	.167	.872
2	Supplemented Pregnant and unsupplemented pregnant	1.48	.95	1.551	.165
3	Supplemented Pregnant & Unsupplemented not pregnant	.27	.91	.293	.778

4	Supplemented not Pregnant & Un-Supplemented pregnant	1.42	1.06	1.342	.221
5	Supplemented not Pregnant & Un-Supplemented not pregnant	.21	.70	.297	.775
6	Un-Supplemented pregnant & Un-Supplemented not pregnant	-1.21	1.55	-.782	.460

4.3.3 Milk Percentage Protein and Fat

Milk protein content for the unsupplemented camels ranged from 4.98±0.13% to 5.03±0.03%. There was a significant difference in the supplemented camels starting immediately after the onset of supplementation (p=0.000). The levels of percentage protein increased every week as the camels continued feeding on the supplemented diet, ranging from 5.02±0.01 % in the first week to 5.39±0.13 % in the 9th week. The gap in the percentage protein levels increased continuously with supplementation (Figure 4.3.3).

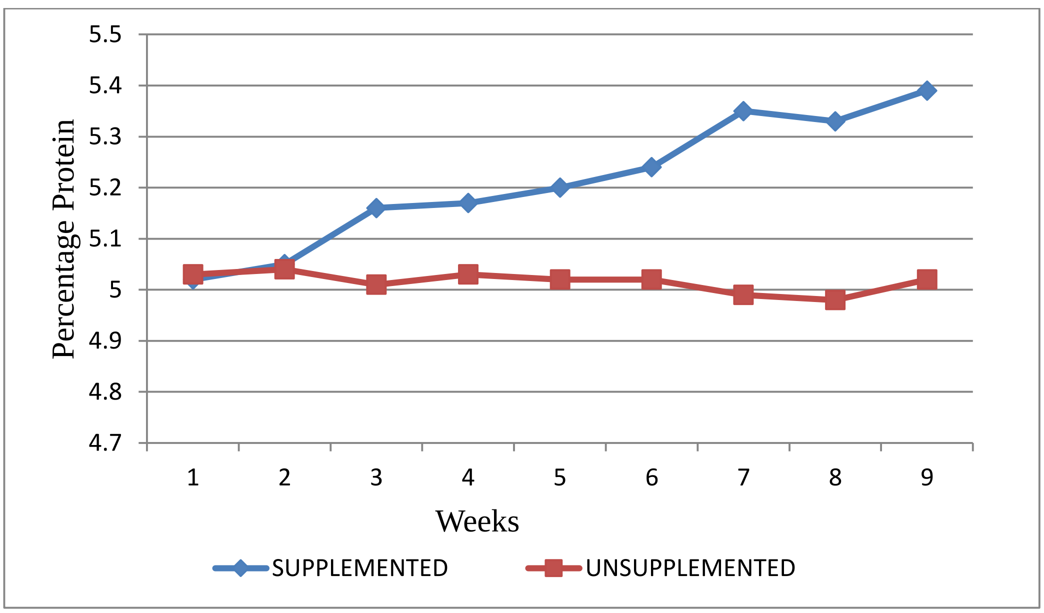

Figure 4.3.3: Milk percentage protein content

The milk fat content for the unsupplemented camels ranged from 3.07±0.07% to 3.57±0.03%. The supplemented camels' milk was higher in percentage fat than the unsupplemented. The difference in the percentage of fat in the milk was significant from the third week (P=0.018), however, it was not significant in the 6th week (P=0.180). The percentage of fat was higher in the supplemented and the difference was maintained (Figure 4.3.4).

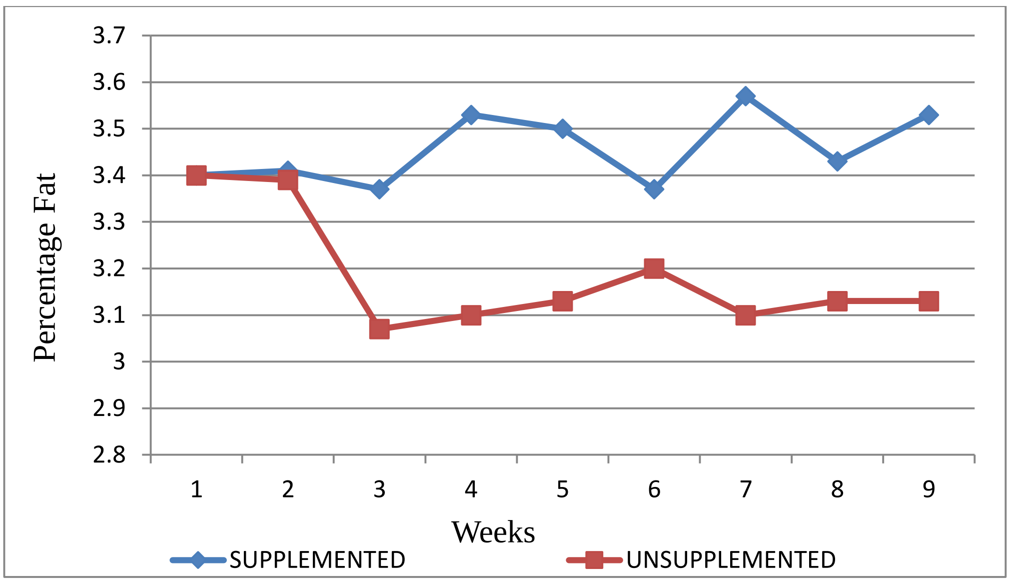

Figure 4.3.4: Milk percentage fat content

4.3.4 Serum Biochemical Profiles

Serum biochemical profiles are shown in Table 4.3.4. The paired mean comparison for total protein levels was 5.91±0.20 g/dl for supplemented and 5.33±0.14 g/dl for unsupplemented, showing a significant difference (p=0.016). Phosphorus levels were significantly different at 11.97±0.31 mg/dl (supplemented) and 9.17±1.01 mg/dl (unsupplemented) with p=0.040. Glucose levels in mmol/L were 7.8±0.61 (supplemented) and 6.00±1.01 (unsupplemented), with a significant difference (p=0.065). Serum albumin and magnesium were higher in supplemented camels with p=0.176 and 0.480, respectively. Calcium levels were lower in the supplemented camels but not significant (p=0.438).

Table 4.3.4:Serum biochemical elements mean differences in the blood of the supplemented and unsupplemented camels

(N=10)

Serum Biochemical elements	**Supplemented**	**Un-supplemented**	**P-Value**
Glucose mmol/l	7.80±0.61	6.00±1.01	0.065
Total Protein g/dl	5.91^{a}±0.20	5.33^{b}±0.14	0.016
Serum Albumin g/dl	3.12±0.35	2.50±0.03	0.176
Phosphorus mg/dl	11.97^{a}±0.31	9.17^{b}±1.01	0.040
Magnesium mg/dl	5.16±0.29	4.84±0.25	0.480
Calcium mg/dl	15.75±0.20	16.37±0.72	0.438

Values are expressed as mean ± SE. $^{a,\, b,}$ values in the same row having different superscript letters are significantly different ($p<0.05$).

4.3.5 Cost-Benefit analysis of Camel feed supplementation

4.3.5.1: Calculation of Incremental Benefit of Supplemental Feeding

Incremental benefit is defined as the value of the extra benefits added after supplementation. The difference in daily mean production for the supplemented and unsupplemented was 25.26-22.79=2.47 litres per day. Therefore, the average incremental production was (2.47 litres/10) =0.247 per day per camel. The price of camel milk at that time was Ksh 200 per liter; therefore, the incremental benefit of supplementation per camel was Ksh. (0.248*200) =49.6(0.41US$)

4.3.5.2: Calculation of Incremental Cost of Supplementation

Incremental cost is defined as the extra cost incurred in purchasing the feed ingredients, milling, mixing, and transportation. The following are the components of the incremental cost;

384 Kg maize germ@22=8432

210 kg Maize grain@30=6322

153kg Wheat bran@24=3678

134kg cotton seed cake@60=8040

383 kg sunflower cake @60=22995

190kg acacia pods @60=11490

766kg Rhodes grass @10=7660

200kg mollases @25=4788

30Kg urea @100=3000

20kg DCP @20=400

20 Kg limestone @30=600

20kg salt @10=200

Total cost of feed ingredients=77,605

Shredding boma Rhodes=Ksh 3,000

Milling cost of acacia and maize grain @ 10 Ksh per Kg=400*10=4,000

Mixing cost = 1,500*5= 7,500

Transportation cost (from Meru to Isiolo) = 5 per Kg 5*2500=12,500

Cost required to make and transport 2,500 kgs of concentrate =77,605+3,000+4,000+7,500+12,500=104,605

Therefore, the total cost of constituting 1 kg =104605÷2500=Ksh 41.84

Every camel consumed 3.5 Kgs per day=41.84*3.5=Ksh.146.44(1.22US$)

4.3.5.3: Benefit cost ratio

A benefit–cost ratio (BCR) is an indicator, used in cost–benefit analysis, that attempts to summarize the overall value for money of a an intervention or proposal. A BCR is the ratio of the benefits of a project, proposal or intervention expressed in monetary terms, relative to its costs, also expressed in monetary terms. All benefits and costs should be expressed in discounted present values. A BCR can be a profitability index in for-profit contexts. A BCR takes into account the amount of monetary gain realized by performing a project versus the amount it costs to execute the project. The higher the BCR the better the investment. The general rule of thumb is that if the benefit is higher than the cost the project is a good investment.

The Benefit-cost ratio of feed supplementation in this case is mathematically expressed as:

<u>BCR = the value of incremental benefit</u>/value of incremental cost

=US$0.41/US$1.22=0.34

Therefore, for every US$1 invested in supplementing camels, the return was US$0.34; hence, feed supplementation was not profitable considering milk production.

4.4 Factors affecting participation in camel milk input and output markets

4.4.1 Decision and Extent of participation in input and output markets

A very high number of Isiolo residents participated in milk sales. On the contrary, the number was extremely low in Marsabit with Laisamis and Koya locations having the lowest. The same was observed in the purchase of feed supplements, where the percentage was higher in Isiolo than in Marsabit. The level of mineral purchase was very high in Isiolo and negligible in Marsabit. More Isiolo pastoralists were hiring a workforce to take care of the camels than in Marsabit (Table 4.4.1).

Table 4.4.1: Decision to participate in output and input markets

County	Isiolo								Marsabit											
Location	Kulamawe n=62		Gotu n=30		Kinna n=45		Total n=137		Laisamis n=64		Lontolio n=60		Koya n=60		Merille n=58		Total n=242		Overall n=379	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
State if you participate in the sale of milk																				
Yes	62	100	22	74	44	98	128	94	4	6	17	28	4	7	33	58	58	24	186	49
No			8	26	1	2	9	6	60	94	43	72	56	93	25	42	184	76	193	51
Buying of feed supplement																				
Yes	25	40	30	100	15	33	70	49	8	12	3	5			6	10	17	93	87	23

No	37	60			30	67	67	51	56	88	57	95	60	100	52	90	225	7	292	77
Buying minerals																				
Yes	61	98	30	100	44	98	135	99	28	44	5	8			6	10	39	16	174	46
No	1	2			1	2	2	1	36	56	55	98	60	100	52	90	203	84	205	54
Hiring labor																				
Yes	62	100	30	100	39	87	131	96	43	67	14	23	8	13	32	56	97	40	228	60
No					6	13	6	4	21	33	46	77	52	87	26	44	145	60	151	40

The overall percentage of milk sold in the wet season was slightly higher than the percentage of milk sold in the dry season. The percentage of milk sold in both wet and dry seasons was higher in Isiolo than in Marsabit. There was a higher percentage of pastoralists who did not buy feeds at all in Marsabit than in Isiolo. Likewise, the percentage of pastoralists purchasing minerals for more than 4 months in a year was very high for Isiolo and extremely low for Marsabit. A very high percentage of Marsabit pastoralists did not buy mineral salts. Marsabit pastoralists hired fewer workers than in Isiolo County (Table 4.4.2).

Table 4.4.2: Extent of market input and output market participation

County	Isiolo								Marsabit											
Location	Kulamawe n=62		Gotu n=30		Kinna n=45		Total n=137		Laisamis n=64		Lontolio n=60		Koya n=60		Merille n=58		Total n=242		Overall n=379	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Percentage of milk sold																				
Wet season		95		51		98		87		53		29		19		97		48		62
Dry season		92		62		91		85		54		7		14		96		42		58
Months of buying feeds																				
Does not	37	60			30	67	67	49	56	88	57	95	60	100	52	90	225	93	292	77
Less than 4	3	5	21	71			24	18	5	7	3	5			5	9	13	5	37	10
4-6	14	22	9	29	12	26	35	25	2	3					1	2	3	1	38	10
7-9	7	11			3	7	10	7	1	2							1	0	11	3
More than 9	1	2					1	1											1	0

Months of buying minerals																				
Does not	1	2			1	2	2	1	35	56	55	92	60	100	52	90	202	84	204	54
Less than 4			29	97			29	21	14	21	4	7			6	10	24	10	53	14
4-6	35	57	1	3	31	70	67	49	15	23							15	6	82	22
7-9	25	40			13	28	38	27											38	10
More than 9	1	2					1	1			1	2					1	0	2	1
Number of hired workers																				
None					6	13	6	4	21	33	46	77	52	87	26	44	145	60	151	40
1-2	62	100	6	19	38	85	106	77	37	58	13	21	7	12	31	54	88	36	194	51
3-4			24	81	1	2	25	19	6	9	1	2					7	3	32	9
More than 4													1	2	1	2	2	1	2	1

4.4.2 Pastoralists' demographic characteristics

Pastoralists' demographics are shown in Table 4.4.3. In Isiolo County, 12% had been practicing camel rearing for more than 30 years, while in Marsabit it was 32%, which was the highest in the Koya location. In the Kulamawe and Kinna locations of Isiolo, 70% and 80% of pastoralists have practiced camel rearing for the last 11-20 years, respectively, and have not practiced beyond 30 years. More pastoralists were seeking advice on how to manage camels in Isiolo than in Marsabit County. In Isiolo, they were seeking advice from the Ministry of Agriculture staff, and in Marsabit from the neighbours. Distances to marketing centres were shorter in Marsabit than in Isiolo locations, ranging from 0-7.5 kilometers and 10.7-22.3 kilometers, respectively.

Table 4.4.3: Demographic Characteristics of Pastoralists

County	Isiolo								Marsabit											
Location	Kulamawe n=62		Gotu n=30		Kinna n=45		Total n=137		Laisamis n=64		Lontolio n=60		Koya n=60		Merille n=58		Total n=242		Overall n=379	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
How long they have practiced camel rearing																				
Below 10	11	18	1	3	3	7	15	11	26	41	14	23	1	2	13	22	54	22	69	18
11-20	43	70	5	16	36	80	84	61	28	44	9	15	2	3	20	36	59	25	143	38
21-30	8	13	8	26	6	13	22	16	9	14	17	27	14	23	14	24	54	22	76	20
Above 30			16	55			16	12	1	2	21	36	42	72	11	19	75	32	91	24
Distance to milk market marketing place																				
Mean	12.9±0.6		22.3±0		10.7±0.6		13.8±0.5		1.9±1.9		0±0		7.5±0		6±0.4		4.1±0.5		10.8±0.5	

4.4.3 Pastoralists' Physical Resources and Human Capital

The Pastoralists' physical resources and human capital status are shown in Table 4.4.4. Physical resources include the number of milking camels, herd size, transport infrastructure, and amount of milk produced. The motorbike was the most used marketing infrastructure. The majority of Isiolo herders owned it, while the number who own a motorbike in Marsabit was extremely low at only 8%. The percentage of milking camels and the total milk produced was higher in Isiolo than in Marsabit.

The most common groups where pastoralists were registered were the self-help groups. The level of registration in marketing groups was low in both counties but slightly higher in Isiolo than in Marsabit. Knowledge of the milk price was mainly from the buyers, and 84% of the Isiolo herders knew the price of milk before delivery, while in Marsabit, it was only 20%. Mostly, the marketing arrangement was verbal. Seeking extension services was more in Isiolo than Marsabit, with 69% and 54% respectively. Pastoralists in both counties get extension services from a combination of providers.

Table 4.4.4: Level of pastoralists' physical resources and acquisition of human capital in Isiolo and Marsabit Counties.

	Isiolo N=128		Marsabit N=58		Total N=186	
	No.	%	No.	%	No.	%
Marketing infrastructure						
None	3	2	37	15	40	11
Refrigerator	3	2	0	0	3	1
Motorbike	113	83	20	8	133	35
Both	9	6	1	0	10	6
Mean number of camels						
Total	53±2		45±2		47±2	
Milking Camels (%)	29±1		18±1		22±1	
Number Milking	13±0		11±0		13±0	

	Isiolo N=137		Marsabit N=242		Total N=379	
	No.	%	No.	%	No.	%
Registration in the milk marketing group						
Yes	23	16	23	9	46	12
No	114	84	219	91	333	88
Milk Marketing Group registered						
SHG	14	10	23	9	37	9
Coop	4	3			4	1
Other	5	4			5	1
Prior knowledge of milk price						
Yes	115	84	48	20	163	43
No	13	9	10	4	23	6

Milk production in liters per head per day during the wet season						
Below 10	3	2	131	53	134	35
10-19	45	32	81	33	126	33
20-29	65	46	27	11	92	24
Above 29	27	19	8	3	35	9
Milk production in liters per head per day during the dry season						
None	1	0.7	47	19	48	12
Below 10	42	30	160	65	202	52
10-19	70	50	35	14	105	27
20-29	27	19	5	2	32	8
Seeking extension services						
Yes	94	69	130	54	224	59
No	43	31	112	46	155	41

Source of the price information						
Brokers	29	21	5	2	34	9
Buyers	85	62	36	15	121	32
SHG	1	1	7	3	8	2
Type of agreement with the buyer						
Verbal	124	89	54	22	178	47
Contractual agreement	4	3	4	2	8	2
Source of Extension Services						
Livestock staff	7	5	2	0.8	9	2
Private			2	0.8	2	0.5
CDR			5	2	5	1
Neighbors			29	12	29	8
Combination of providers	130	95	204	84	334	88

4.4.4 Factors affecting the decision to sell milk and the percentage of milk sold in the wet and dry seasons

The decision of market participation in the sale of milk was positively and significantly different between the two counties. Being in Isiolo County increases the probability of participation in the sale of milk. Pastoralists in Isiolo were 6.148 times more likely to participate in milk sales than not to participate (p=0.000). The lack of extension services negatively and significantly influenced the decision to sell milk. The probability of selling milk was 18.6% if the pastoralists were not accessing extension services (p=0.000). Every one-unit increase in the total number of camels increases the probability of deciding to sell milk by 1.2% (p=0.081). Every unit increase in milk produced in the herd in the wet season reduces the chances of participation in the sale by 12% (p<=0.015) (Table 4.4.5).

Table 4.4.5: Factors affecting the decision to sell milk

Market Participation Factors	B	Sig.	Exp (B)
Constant	1.148	.145	3.151
County	6.148	.000	467.615
Sex	-.397	.295	.672
How long owner has practiced	-1.942	.360	.143
Indicate if the owner has another source of livelihood	.399	.341	1.490
Indicate if you ever seek advice on how to manage camel	-1.683	.000	.186
Total no of camels	.012	.081	1.012
Percentage milking camels	-.009	.544	.991
Herd milk prodtion in the wet season	-.120	.015	.887
Milk produced per camel in the wet season	-.105	.460	.900
Number of milking camels	-.014	.688	.986
Milk produced per camel in the dry season	.058	.739	1.059

Milk produced in the dry season	-.006	.923	.994

The probability decision to sell milk is shown in formula 4.4.1.

Probability of selling milk=3.151+468 (Isiolo County) +0.186(Failure of extension services) +1.012(herd size) +0.887(milk produced in wet season) 4.4.1

The variables that significantly contributed to the percentage of milk sold in the wet season are shown in Table 4.4.6. These were the pastoralists' county, length of practice, extension services, total number of camels, percentage of milking camels, and the market infrastructure owned. The extent was negative for the length of practice, percentage of milking camels, and total number of camels. Being in Marsabit County reduced the percentage of milk sold by 22.7% (p=0.059).

Increasing the number of years that the owner practices reduced the percentage of milk sold by 27.6% (p=0.000). Accessing extension services increases the percentage of milk sold by 28.9% (p=0.000). Increasing the number of camels and the percentage of milking camels by one unit reduces the percentage of milk sold in the wet season by 23.7% and 18.2% respectively (p<0.05). Owning a marketing infrastructure reduced the percentage of milk sold in the wet season by 15.5% (p=0.94).

Table 4.4.6: Factors affecting the percentage of milk sold in the wet season

	Unstd C.		Std C.	t	Sig.
	Beta	Std. E	Beta		
Constant	149.237	21.089		7.077	.000
County	-12.733	6.706	-.227	-1.899	.059
Sex	6.602	4.442	.097	1.486	.139
How long owner has practiced	-7.710	2.152	-.276	-3.583	.000

Indicate if the owner has another source of livelihood	-.926	4.437	-.013	-.209	.835
Indicate if you ever seek advice on how to manage camels	16.882	4.318	.289	3.910	.000
Total no of camels	-.195	.079	-.237	-2.460	.015
Percentage milking camels	-.367	.171	-.182	-2.145	.033
Milk produced per camel in the wet season	-2.180	1.857	-.097	-1.174	.242
Member of a registered group	-1.791	4.316	-.030	-.415	.679
Type of agreement	-2.953	8.388	-.023	-.352	.725
Marketing infrastructure owned	-4.545	2.702	-.155	-1.682	.094
Knowledge of milk prices before	-1.628	5.225	-.020	-.312	.756
Distance to the consumer	-.480	.393	-.126	-1.224	.223

The percentage of milk sold in the wet season is indicated by formula 4.4.2.

Percentage of milk sold in wet season=149.237-0.227 (Marsabit county)-0.276 (years of practice) +0.289(extension services)-0.237(herd size)-183(percentage of milking camels) *4.4.2*

The variables that significantly contributed to the percentage of milk sold in the dry season were the County, length of practice, extension services, total number of camels, and the type of marketing infrastructure. Being in Marsabit County reduced the percentage of milk sold by 39.1% (p=0.001). Increasing the number of years that the owner practices reduced the percentage of milk sold in the dry season by 18.5% (p=0.008). Accessing extension services increases the percentage of milk sold by 38.9% (p=0.000). Increasing the number of camels increased the percentage of milk sold in the dry season by 26.8%. Owning a marketing infrastructure reduces the percentage of milk sold in the dry season by 33.9% (p=0.000) (Table 4.4.7).

Table 4.4.7: Factors affecting the percentage of milk sold in the dry season

	Unstd C.		Std C.	t	Sig
Market Participation Factors	Beta	Std. E	Beta		
Constant	100.93	26.61		3.792	.000
County	-28.495	8.366	-.39	-3.406	.001
Sex	.616	5.553	.007	.111	.912
How long has practiced	-6.803	2.55	-.19	-2.672	.008
Indicate if the owner has another source of livelihood	-1.760	5.506	-.019	-.320	.750
Indicate if you ever seek advice on how to manage camels	29.751	5.333	.389	5.579	.000
Total no of camels	.291	.089	.268	3.261	.001
Percentage of milking camels	.258	.204	.098	1.269	.206
Milk produced per camel in the dry season	-2.141	2.339	-.058	-.915	.361
Member of a registered group	1.786	5.374	.022	.332	.740
Type of agreement	18.565	10.591	.111	1.753	.081
Marketing infrastructure owned	-12.964	3.219	-.339	-4.028	.000
Knowledge of milk prices before	1.255	6.456	.012	.194	.846
Distance to the consumer	.468	.491	.094	.952	.342

The formula for the percentage of milk sold is in equation 4.4.3.

Percentage of milk sold in dry season=100.93-0.391 (Marsabit County)-0.185 (years of practice) +0.389 (extension services) +0.268 (herd size)-339 (owning a marketing infrastructure). 4.4.3

4.4.5 Factors affecting the decision to purchase feeds and the months of purchasing feeds

The decision of market participation in the purchase of feeds was positive for Isiolo. A pastoralist in Isiolo was 3.404 times more likely to buy feeds than not to buy feeds. Every unit increase in the number of years that a pastoralist had practiced reduced the probability of buying feeds by 6.89 times (p=0.002). A pastoralist was 4.27 times more likely to buy feeds if he did not access extension services(p=0.001). Every unit increase in the total number of camels increases the probability of buying feeds by 1.8% (p=0.076). Failing to have extension services increases the chances of buying feeds by 1.453 (p=0.00). Milk produced per camel in the dry season reduced the probability of buying feeds by 35% (p=0.041). Total milk produced per herd in the dry season increased the probability of buying feeds by 10.1% (p=0.097) (Table 4.4.8).

Table 4.4.8: Factors affecting the decision to purchase feeds

Market Participation Factors	B	Sig.	Exp (B)
Constant	-3.153	.009	.043
County	3.404	.000	30.079
Sex	.239	.588	1.270
How long owner has practiced	-6.893	.002	.001
Owner has another source of livelihood	-.185	.691	.831
Seek advice on how to manage camels	1.453	.001	4.274
Total no of camels	.018	.076	1.018
Percentage milking camels	.026	.121	1.026

Milk produced per camel per day in the dry season	-.350	.041	.705
Herd milk production in the dry season	.101	.097	1.107
Sale of milk	-.361	.563	.697
Percentage of milk sold in the wet season	-.008	.254	.993
Percentage of milk sold in the dry season	.003	.603	1.003

The decision to purchase feed is shown in formula 4.4.4.

Probability of purchasing feeds=0.043+30.08 (Isiolo County)+0.001 (years of practice) + 4.27(Not seeking extension services) +1.018 (herd size)+0.705(milk produced per camel in the dry season) +1.107(total milk produced in the herd in the dry season) 4.4.4

The variables that significantly contributed to the months of purchasing feeds are the county, milk produced per camel in the dry season, and percentage of milk sold in the dry season (Table 4.4.9). Being in Marsabit reduced the months of purchasing feeds by 61.4% (p=0.000). A unit increase in milk produced per camel in the dry season and the percentage of milk sold in the dry season increased the months of purchasing feeds by 35.2% and 30.6% respectively ($p<0.05$).

Table 4.4.9: Factors affecting the months of purchasing feeds

Market Participation Factors	Uns d C.		Std C.	t	Sig.
	Beta	Std. E	Beta		
Constant	3.757	1.320		2.846	.006
County	-1.709	.451	-.614	-3.790	.000
Sex	-.182	.201	-.092	-.904	.370
How long owner has practiced	-.027	.106	-.038	-.253	.801
Indicate if the owner has another source of livelihood	.110	.212	.058	.521	.605

Indicate if you ever seek advice on how to manage camels	.092	.249	.063	.371	.712
Total no of camels	.000	.004	-.021	-.107	.915
Percentage of milking camels	.006	.008	.110	.700	.487
Milk produced per camel in the dry season	.596	.219	.352	2.728	.009
Percentage of milk sold in the wet season	.003	.004	.111	.686	.496
Percentage of milk sold in the dry season	.009	.004	.306	2.403	.020
Member of a registered group	.141	.180	.091	.781	.439
Type of agreement	-.205	.353	-.066	-.581	.564
Marketing infrastructure owned	-.163	.134	-.178	-1.221	.228
Knowledge of milk prices before	.305	.270	.135	1.130	.264
Distance to the consumer	-.028	.019	-.244	-1.453	.152

The equation for the months of purchase of feeds is shown in formula 4.4.5.

Months of purchasing feeds=3.757-0.614 (Marsabit County +0.352(Milk produced per camel in the dry season) +0.306(Percentage of milk sold in the dry season) 4.4.5

4.4.6 Factors affecting the decision and the months of purchasing mineral salts

The decision of market participation in the purchase of minerals was positively influenced by being in Isiolo County. Being in Isiolo County increased the chances of buying minerals was 9 times than not buying (p=0.000). The probability of purchasing minerals for a pastoralist who did not have another source of livelihood was 19.6% (p=0.048). Increasing the percentage of milking camels reduces the probability of buying minerals by 6% (p=0.022). Every unit increase in the percentage of milk sold in the wet season also reduces the probability of purchasing minerals by 2.6% (p=0.004) (Table 4.4.10). The equation for the months of purchase of minerals is shown in formula 4.4.6.

Table 4.4.10 : Factors affecting the decision to purchase minerals

Market Participation Factors	B	Sig.	Exp (B)
Constant	4.622	.001	101.655
County	9.060	.000	8608
Sex	-.306	.575	.736
How long has practiced	-3.254	.296	.039
Indicate if the owner has another source of livelihood	-1.630	.048	.196
Indicate if you ever seek advice on how to manage camels	.228	.706	1.256
Total no of camels	.007	.543	1.007
Percentage of milking camels	-.060	.022	.942
Sale of milk	-1.088	.152	.337
Percentage of milk sold in the wet season	-.026	.004	.974
Percentage of milk sold in the dry season	-.006	.486	.994

Probability of purchasing minerals=101.66+8608 (Isiolo County) +0.196 (No other source of income) + 0.942(Percentage of milking camels+0.974 (Percentage of milk sold in the wet season). *4.4.6*

Being in Marsabit County reduces the months of buying minerals by 43.8% (p=0.000). The access to extension services increased the months of buying minerals by 31.8% (p=0.003) (Table 4.4.11).

Table 4.4.11: Factors affecting the number of months of purchasing minerals in a year

Market Participation Factors	Unstd C.		Std C.	t	Sig.
	Beta	Std. E	Beta		
Constant	4.537	1.033		4.393	.000
County	-1.342	.345	-.438	-3.885	.000
Sex	.148	.159	.068	.932	.353
How long owner has practiced	-.098	.086	-.110	-1.140	.257
Indicate if the owner has another source of livelihood	.119	.155	.054	.766	.445
Indicate if you ever seek advice on how to manage camels	.530	.173	.318	3.070	.003
Total no of camels	-.004	.003	-.154	-1.258	.211
Percentage of milking camels	-.005	.005	-.079	-.836	.405
Percentage of milk sold in the wet season	-.001	.003	-.031	-.307	.760
Percentage of milk sold in the dry season	.003	.002	.121	1.465	.146
Member of a registered group	-.136	.143	-.075	-.948	.345
Type of agreement	-.451	.331	-.106	-1.365	.175
Marketing infrastructure owned	-.014	.118	-.012	-.115	.908
Knowledge of milk prices before	.206	.190	.084	1.081	.282
Distance to the consumer	.003	.012	.027	.266	.791

The equation for the months of purchase of minerals is shown in formula 4.4.7.

Months of purchasing minerals =4.54-0.438 (Marsabit County) + 0.318 (Seeking extension services). *4.4.7*

4.4.7 Factors affecting the decision to hire labour.

The factors considered to affect the decision to hire workforce to manage herds are positive for Isiolo. Being in Isiolo County increased the chances of hiring labour 32 times (p=0.000). Increasing the number of years of practice reduces the probability of hiring labour by 3.8 times (p=0.060). The probability of hiring a labour force for a pastoralist who did not have another source of livelihood was 36.1% (p=0.060). Every unit increase in the total number of milking camels and the percentage of milk sold in the dry season increased the probabilities of hiring the labour force by 2% and 1.5% respectively, at 5% significance (Table 4.4.12). The equation for the probability of hiring a workforce is shown in formula 4.4.8.

Table 4.4.12: Factors affecting the decision to hire labour

Market Participation Factors	B	Sig.	Exp(B)
Constant	-.346	.680	.708
County	3.469	.000	32.095
Sex	-.068	.848	.934
How long owner has practiced	-3.802	.060	.022
Indicate if the owner has another source of livelihood	-1.018	.016	.361
Indicate if you ever seek advice on how to manage camels	-.225	.540	.799
Total no of camels	.020	.005	1.020
Percentage of milking camels	.003	.853	1.003
Percentage of milk sold in the wet season	-.003	.408	.997
Percentage of milk sold in the dry season	.015	.001	1.015

Probability of hiring workers =0.708+32.1 (Isiolo County) +0.22 (years of practice). *4.4.8*

4.5 Summary of Significant Findings

Strategic adjustments in camel-rearing practices in Isiolo have focused on enhancing milk production despite camel-rearing being a relatively recent practice. This was evidenced by the preference for the Somali breed and the strategic balancing of herd sex ratios to favor productive females. The higher proportion of females over six years old significantly influences production, although it has resulted in increased calving intervals. Tail cocking was a commonly used method for confirming pregnancy, but it was, however, unreliable.

Predation emerged as the leading cause of mortality in both Isiolo and Marsabit counties, followed by tick paralysis. Microbial diseases were more prevalent in causing morbidity and mortality in Marsabit than in Isiolo. Predation rates, contributing to the highest mortality, were notably higher in Isiolo than in Marsabit. The riskiest diseases were tick paralysis, pneumonia, and the threat of predation. Key factors in reducing camel calf diseases included the proportion of milk suckled, extended lactation periods, and delaying the start of milk sales. Managing subclinical mastitis levels also played a role in decreasing the incidence of common bacterial and some viral diseases.

Conception rates post-mating were low, particularly in camels that did not receive feed supplementation. Supplementation positively impacted milk production and improved reproductive parameters, such as mating success, reducing repeat breeders, and confirmed conception rates. Additionally, supplementation increased milk protein and fat percentages, as well as serum biochemical elements.

Nearly all pastoralists in both counties had alternative sources of income. While motorcycles were commonly used for milk marketing, they did not significantly affect the percentage of milk sold. Market participation was significantly higher in Marsabit compared to Isiolo. Extension services played a role in influencing market participation, whereas years of practice negatively impacted it. The purchase of feeds was positively influenced by the amount of milk sold during the dry season, while the purchase of minerals was negatively affected by milk sales during the wet season. Addressing the major causes of mortality, improving feed supplementation, and leveraging extension services can further support the sustainability and productivity of camel herding in these regions.

CHAPTER FIVE: DISCUSSION

5.1 Camel Herd Structure and Performance

In the region under study, male camel ownership was predominantly reported, which was consistent with other studies. This was a common scenario in rural African settings where men are responsible for the most valuable assets, such as camels (Salamula et al., 2017). The relatively shorter history of camel rearing among pastoralists in Kulamawe and Kinna, along with the adoption of camel husbandry over the last three decades, suggests a response to the impacts of climate change. This is because of the frequent draughts, and the camels and goats, which are the browsers, are replacing cattle (Kagunyu & Wanjohi, 2014).

The majority of households with another source of livelihood were highest in Kinna and Kulamawe (Isiolo County) because it is an agro-pastoral livelihood zone (have other livestock and practice crop farming). The people who were available for interviews in both Counties were either owners or herders. The number of hired employees was low because camel owners relied on relatives who did not consider them to be hired.

Almost all camels reared in Isiolo were Somali type, and those reared in Marsabit were Rendille. This is attributed to the fact that the Somali camels are heavier and higher in milk yields than all the other Kenyan breeds (Kuria et al., 2016). Furthermore, most of the camel-keeping communities in Isiolo are of the Somali ethnicity, and those in Laisamis are of the Rendille tribe. Therefore, the respondents may have been referring to their own ethnic community. Some pastoralists in Marsabit County purchased feeds, probably because development partners facilitate this as a way of maintaining camels during drought

The average camel herd size in both Counties contrasted with Mwanyumba et al. (2015), who found the average herd size in Garissa County to be 7.1 camels. Probably at the time the study was carried out in Garissa, the climate had not taken a toll on the pastoralists to decide to replace cattle with camels. The proportions of females more than 4 years were higher in Isiolo than in Marsabit, and males more than 4 years were higher in Marsabit than in Isiolo. This was an indication that Isiolo was relatively more commercialized in terms of camel dairy milk production. In Marsabit, camel rearing was for other purposes and not dairy production. Female animals are preferred in any commercial dairy production because it is the sex that physiologically produces milk, the main product for the enterprise (Maher et al., 2021).

In Garissa, the ratio of males to females was almost the same as in Isiolo. Another study in the Somali region state of Ethiopia found the male-to-female ratio to be 1:13, which is a very high number of females (Keskes et al., 2013b). This shows that they are better at deliberate modification of the sex ratio in animal production to increase herd performance. In Botswana, the male-to-female ratio had a rather high percentage of males because the objective of camel rearing was a tourist attraction, not dairy production (Seifu et al., 2019).

The herd milk production in both wet and dry seasons was higher in Isiolo than in Marsabit because of the deliberate adjustment of the herd age and sex percentages. This finding aligns with other studies indicating improved technical efficiency in resource utilization with a higher proportion of dairy herds (Yilmaz et al., 2020). The larger the milking percentage means there was efficiency in the utilization of resources such as feed and labour, hence reducing cost per unit. The resources are utilized efficiently if the proportion of productive camels is high. This is especially in the dry season, where the constant was negative. This means that due to harsh climatic conditions in the ASALs, daily production per camel can stop completely in the dry season until age and sex percentages are adjusted to some level.

The majority of the households reported age at first calving to be 10-15 years in both Counties, which is not consistent with a study by Keskes et al. (2013), who found the mean age at first calving to be 5 years. This can be explained by the fact that in the Somali region state of Ethiopia, they do deliberate herd management with the objective of a dairy production enterprise. The larger the herd size in Marsabit had a negative the effect on milk production was because they were increasing the unproductive camels, which would interfere with resource utilization efficiency.

Calving intervals and lactation periods were relatively shorter in Marsabit compared to Isiolo. This finding is important because shorter calving intervals positively impact the productive lifespan of camels and promote herd growth. The observation that larger herd sizes negatively influence calving intervals contradicts results of other studies (Jago and Berry, 2011). This is as a result of seasonality in camel seasonal breeding(Gherissi et al., 2020) and this aligns with other studies in cattle where seasonal breeding takes place (Washburn et al., 2002).

The slightly long calving interval in Isiolo could be explained by the fact that in Isiolo, milk production was higher than in Marsabit. When resources are constrained, achieving production and reproduction simultaneously is not feasible (Rauw and Glazier, 2009). Further, there was relatively more pressure for production in Isiolo due to the sedentary method of production, motivated by demand. Further calving interval and lactation periods were both longer than what was reported in other studies, indicating diverse management practices (Keskes et al., 2013a). Increasing herd size in Isiolo increased the calving interval because they were exerting pressure for production, hence compromising reproduction.

Techniques like rectal palpation, commonly used in other large animals, are not feasible due to the height of the animal (Tripathi et al., 2022). Progesterone assays have been identified as the most reliable method (Kamoun and Jemmali, 2014). Pregnancy negatively impacts milk production (Nagy and Juhász, 2019) because limited resources make it difficult to achieve both production and reproduction simultaneously (Rauw and Glazier, 2009).

The traditional and scientific methods for pregnancy testing in this study were not correlated. This explains the findings in other studies showing that 21% of animals culled are pregnant (Benaissa et al., 2016). Furthermore, the tail cocking method was reported to be accurate when the camels are in a calm environment, and when agitated, they give false positives (Deen, 2008). However, there was a slight correlation, which shows that probably cocking the tail could be related to some levels of reproductive hormones in the oestrus cycle.

The number of false positives could be explained by levels of progesterone in the oestrus cycle, which is high after mating, but it was not maintained if mating was not successful. It has been established that cocking the tail can occur in unmated camels treated with exogenous progesterone (Skidmore, 2000). Furthermore, the camels show false positives when they have cystic ovarian disease due to high levels of progesterone (Purohit et al., 2020).

5.2 Camel calf diseases, life-threatening incidences, and predisposing factors

The overall mortality rate was different from what was established by other researchers (Ihuthia, 2010), who found the mortality of camel calves to be 50%. The highest contributor to calf mortality was predation, which was consistent with other studies (Onono et al., 2010). Tick paralysis also contributed significantly to the calf mortality (10.51%). Other researchers found that the highest contributors to mortality were septicaemia (3.4%), diarrhoea (2.42%), and Pneumonia (0.59%) (Tora et al., 2021). Furthermore, the mortality attributed to diarrhoea and pneumonia was very high in other studies compared to the current study, 6.99% and 8.27% respectively. Predation was the highest contributor to camel calf mortality. This is consistent with Onono et al. (2010), who established a camel calf mortality of 50% mainly attributed to predation. Calves are easy targets for predators because of their weakness and inability to defend themselves.

The number of camels with at least one quarter affected by subclinical mastitis in the two counties was not consistent with other studies. Compared to other studies, it was higher for Isiolo than for Marsabit County. Forty-six percent of the camels in Isiolo had at least one quarter affected by subclinical mastitis (Seligsohn et al., 2020). In Borena, Southern Ethiopia, it was 18.1% found to have at least one quarter affected by subclinical mastitis (Geresu et al., 2021). The level of subclinical mastitis in the quarters affected was 17.8% in the two counties. The incidence of mastitis was higher in Isiolo locations than in Marsabit locations. This finding was in contrast with what was reported by Geresu et al. (2021), who found the level of subclinical mastitis in the quarters tested was 22.4% and an extremely high number yielding mastitis-causing pathogens. The observation may have been predisposed by the high level of intensification in dairy production in Isiolo without accompanying animal health services and extension.

In dairy production, mastitis was predisposed by poor hygiene, especially at the time of milking, and poor access to extension services (Sinha et al., 2014). The incidence of mastitis was high in Isiolo because they kept high-yielding dairy camels, the Somali type. In another study, it was found that pure and crossbred camels giving high milk yields were more vulnerable to host factors that were at a higher risk of mastitis than moderately yielding dairy cattle (Cheng & Han, 2020). This finding was similar for the high-yielding camels (the Somali), which gave more milk and were more susceptible to mastitis than the moderately milk-yielding Rendille camels.

Feeding colostrum was different from what was established by Tadessee (2014), where colostrum feeding in Ethiopia was started after 3 days. In this study, colostrum feeding was started within 0 to 6 hours, if not immediately. In contrast, Kuria's (2016) study found that colostrum feeding was adequate, with 63.2% in Marsabit and 78.5% in Isiolo ensuring at least one quarter of colostrum was fed.

The overall households that reported calf diarrhoea was higher in Marsabit than in Isiolo. The highest incidence was in Merile location and the lowest was in Gotu. The factors that contributed to the morbidity were the interval of administering dewormers, how soon milk was sold after calving, the proportion of milk suckled in terms of the quarters sucked, and the months of suckling. This was expected because they all improve the immunity of the calf to be able to withstand infections. Unexpectedly, the level of subclinical mastitis was negatively influencing the morbidity and calf diarrhoea. Mortality was positively influenced by the interval of external parasite control, how soon milk from a specific camel was sold, and the proportion of milk suckled. Access to hygienic measures was poorer in Isiolo than in Marsabit because they were not washing the udder and hands before milking camels.

The level of subclinical mastitis was significantly and negatively contributing to the morbidity and mortality of common camel calf diseases such as diarrhoea, pneumonia, orf, and calf diphtheria. This finding contrasts with cattle calves, which are predisposed to diarrhoea by consuming milk from cattle with subclinical mastitis (Abb-Schwedler et al., 2014). It is explained by the fact that maintaining a stable microbiome is essential for good health. This maintained a stable balance that controls microbial flora and reduces the number of opportunistic pathogens, such as Escherichia, Enterococcus, and Shigella, and increases beneficial bacteria (Nayel et al., 2019).

Factors that positively influenced pneumonia morbidity were the frequency of deworming, how soon milk was sold, the proportion of milk suckled, and months of suckling. The level of subclinical mastitis negatively influenced it. Mortality was influenced positively by how soon milk was sold and the months of suckling. This was the same as diarrhoea. Calf Diphtheria morbidity was positively influenced by the interval of administering dewormer, how soon milk was sold, and the month of suckling and activities before milking. It was negatively influenced by the level of subclinical mastitis. All these were attributed to milk competition with calves for home consumption and sales, and they have an effect on calf immunity (Tura et al., 2020). It is noted that small quantities of bacteria in milk cause passive immunity to calves.

The gross mortality for pox was lower than what was established by Tadesse et al. (2018) of 25-100%. Mortality due to pox was positively influenced by increasing the interval of control of the external parasites. This can be explained by the fact that the pox virus is transmitted by insects such as mosquitoes. For that reason, it increases during the rainy season. This contributes to high mortality in calves because the camel calving season mostly coincides with the rainy season and high arthropod population. The virus that causes pox has been isolated in *Amblyoma dromedary* ticks, which were removed from the body of a camel severely having the clinical signs of pox (Achalu, 2019).

Worm infestation morbidity was influenced positively by the interval of control of external parasites, how soon milk is sold, and the months of suckling. Mortality was only influenced by months of suckling. Worms show signs if they are infested in a calf that is malnourished. The external parasite control interval had a positive influence on the morbidity due to worms. This was because some of the drugs, such as ivermectin, which is a broad-spectrum drug used to control ecto- and endo-parasites simultaneously (Hassan et al., 2005.). This drug was very popular with camel herders, especially those who were assisted by development partners.

Tick paralysis was found to be one of the riskiest diseases threatening the lives of camel calves. Interval of administering dewormers, proportion, and duration of calf suckling enhance the calf immunity, explaining why they significantly affect morbidity due to tick paralysis. Tick infestation was found to be high in other studies, especially in hot climatic conditions in the ASALs (Moshaverinia and Moghaddas, 2015). Therefore, reducing the frequency of controlling external parasites increased mortality due to tick paralysis.

The timing of milk sales post-calving significantly influenced mortality for diarrhoea, pneumonia, diphtheria or pox, and worms. The commencement of time taken to start the sale of milk was critical because this influenced the calves' immunity. Camel keepers in Isiolo took longer to start selling milk than Marsabit camel keepers, probably because they have a higher percentage of milking camels.

The months of calf suckling had the highest influence on all the bacterial, viral, and parasitic diseases. These were diarrhoea, pneumonia, diphtheria or pox, and worms. The period of suckling had a positive influence on the mortality of pneumonia and worms. The proportion of milk suckled had a positive influence on morbidity of pox, diarrhoea, and pneumonia, and a positive influence on mortality of diarrhoea. All those diseases were associated with poor immunity due to weaning, which further leads to poor nutrition.

The level of subclinical mastitis was very important in preventing camel calves from all microbial diseases and had a negative influence on pox mortality. This could be attributed to the fact that small quantities of pathogens given to an animal acquired immunity after exposure (Ximenez and Torres, 2017). Furthermore, early life colonization of the gastrointestinal tract with pathogens has an important impact on the maturation of the host immune system (Zheng et al., 2020).

Deworming interval had a positive influence on diarrhoea, pneumonia, and calf diphtheria morbidity. This can be attributed to the fact that helminths suck blood and adversely affect animal nutrition, which in turn affects the animals' immunity (Montout et al., 2021). Poor immunity therefore predisposes to microbial diseases.

5.3 Effects of Feed supplementation on Production, reproduction, and milk Quality

In the present study, the proximate composition of most ingredients fell below the established ranges observed in other studies. These were in dry matter (DM), crude protein (CP), ether extract (EE), and ash, respectively, whereas Kirimi et al. (2021) reported higher values for the same ingredients. Similarly, the proximate composition of maize germ was at the lower limit compared to the findings of Noor (2013), with values for crude protein (7.78 vs. 9.45), crude fibre (5.42 vs. 10.46), neutral detergent fibre (NDF) (33.77 vs. 40.6), and acid detergent fibre (ADF) (5.31 vs. 8.8).

The metabolizable energy for the mixed dry ration was slightly higher at 2,897.30 kcal/kg compared to the diet used by Moges et al. (2016) for camel supplementation (2,676.8 kcal/kg). Notably, the diet did not include Rhodes grass, which exhibited a lower metabolizable energy of 1,676.51 kcal/kg. It is worth noting that although sunflower meal and cottonseed cake are classified as protein feedstuffs, their protein content was markedly low, i.e. 19.45% and

14.21% respectively. This was probably due to adulteration of ingredients by unscrupulous dealers (Kirimi et al., 2021). The CP content in acacia pods (11.68%) and maize germ (7.78%) was extremely low compared with the findings of Noor (2013) of 17.45% and 9.46 % respectively. These differences can be explained by the fact that levels of the proximate composition of grains vary depending on the place where the grains were produced, the method of processing, and the level of infestation of the grain with insect pests (Osipitan et al., 2012). The CP for the mixed dry ration was low (11.76%) because urea and Rhodes grass were not included. Urea has a high level of Nitrogen, and the CP in Rhodes grass is 11.18% (Ondabu et al., 2008). Protein content is essential to provide the necessary amino acids for tissue growth, as well as to support the development of microorganisms for microbial fermentation (Qureshi & Al-Ani, 2008).

The difference in the mean daily milk production for 10 camels between supplemented and unsupplemented camels was 2.46±0.52 liters (10.79%). It is not consistent with other studies (Bakheit et al., 2017; Noor, 2013). This is because parameters that are important for milk production, such as energy, CP, and digestibility, are better in the wet than in the dry season (Noor, 2013) and were available to the experimental and control groups. It is possible that the unsupplemented camels were feeding on more shrubs compared to the supplemented camels. This was because when herbivores consume concentrate feeds, their nutritional needs can be fulfilled, eliminating the necessity of ingesting roughage. Indeed, animals that were fed on a combination of roughage and concentrate ruminate during the day, while those fed on roughage alone spend more time feeding during the day and ruminate at night (Moyo et al., 2019).

Low percentage levels of CP in the ingredients used in the supplemented feeds, compared to other studies, can explain the negligible difference in the mean daily milk production between supplemented and unsupplemented. Furthermore, the study was done during mating season, and camels were restless and not feeding well. The mean differences in the paired comparisons show that milk reduction is influenced more by nutrition than pregnancy. This is consistent with other studies (Khan et al., 2003; Nagy et al., 2015). There is a trade-off between production and reproduction in the event of limited resources (Rauw & Glazier, 2009). The drop in the first trimester due to the effect of resource availability contrasts with other studies (Idris et al., 2015).

The difference in milk protein levels increased linearly every week as the camels consumed the supplement diet. Urea, which was part of the constituents in the formulated ration causes an increase in the intake of the dry matter, crude protein, and the metabolizable energy, and improves digestibility (Ntiranyibagira et al., 2015). Further, microorganisms utilize the non-protein nitrogen to synthesize amino acids for their growth. Other studies have indicated that the levels of ruminal ammonia nitrogen are directly proportional to the supplemented non-protein nitrogen, which in turn affects the growth of microbial population (Wahyono et al., 2022). This further enhances the synthesis of fiber and synthesis of more protein, which was found to be high in the serum and is also excreted in the milk. The use of the Kjeldahl method determines the levels of total protein in the milk, relying on the levels of Nitrogen. Furthermore, camel milk has been found to have higher levels of Urea compared to other herbivores, which, in the Kjeldahl method, reflects as protein levels (Farah, 1993). Camels are pseudo ruminants, with the stomach having three compartments, each with both glandular and non-glandular sections to enhance nutrient utilization efficiency.

High levels of fat in the supplemented camels were due to the improved supplemented diet, which contained high fiber and urea in the ration. The addition of urea in the supplemented diet caused an increase in the ruminal pH, favoring the growth of microorganisms that produce acetic acid and butyric acid. These are the main volatile fatty acids that are the main precursors of milk fat (Paengkoum et al., 2010).

Levels of biochemical elements agree with Zaher et al. (2017) but were higher than what was established in other studies (Faye & Bengoumi, 2018; Elitok and Cirac, 2018). This could be due to high levels of mineral content in the shrubs during the wet season. The conception rate was low, especially for the unsupplemented (10%), and this contrasts with other studies (Jaji et al., 2017). This was attributed to the pregnancy testing method of progesterone assay compared to cocking the tail method found to give false positives (Deen, 2008). Supplementation plays a crucial role in enhancing reproductive indices during mating seasons. This was equivalent to flushing, which is done in sheep and goats to increase the chances of getting twins and triplets (Shaukat et al., 2020). The low conception rate in unsupplemented camels is consistent with other studies that found fertility to be correlated to high levels of energy in the diet (Beam and Butler, 1997; Butler & Smith, 1989). Minerals form part of elements that constitute reproductive hormones explaining why reproductive parameters were improved with supplementation (Rodney et al., 2018).

The intervention through supplementation was not profitable (the benefit cost ratio was 0.34), and this contrasts with other studies (Sagala et al., 2021). The current study only factored the changes in milk yield. Milking was done only once per day and the calves were allowed to browse with their mothers and suckle during the day. It is likely that the calves from the supplemented camels fed more milk during the day than the calves from the un-supplemented camels. It is also likely that milking once yielded less milk than would have been if the frequency of milking was increased. Though the increase in milk production was negligible, there were other advantages such as the improvement of reproductive parameters which have a bearing on the calving interval and hence herd growth. Furthermore, the increase in number of calves born after the intervention was not quantified. Also the growth rate of the calves due to increase in the milk suckled was not considered in the cost benefit analysis.

5.4 Factors Affecting Milk Input and Output Market Participation

In the study, the participation was overall 49% with a high difference between Isiolo and Marsabit. Isiolo County had an indication of having a changed attitude towards milk selling, and hence the percentage of milk sale participation was extremely higher than in Marsabit. This could be attributed to the cultural significance of camel milk in most pastoralist communities as it could be regarded as a taboo to sell camel's milk (Gebremichael et al., 2019). Sale of teff participation was 72.2% (Kifle, 2022) and 70% in Tana River (Lutta et al., 2021). In Zimbabwe market, participation for dairy cattle producers was found to be 87% (Chamboko et al., 2017). The high difference with Bekele's (2021) study is that it only considered the farmers who sold milk to the cooperative, and in the current study, all milk sale was considered, whether it was to the cooperative or not, and this was in cow's milk. The high participation in Isiolo was consistent with other studies (Bedilu et al., 2017), though it was, however, very low in Marsabit. It also depended on herd size and distance to the consumer.

Input and output market participation decisions were positive and significant for Isiolo County. This is an indication that Isiolo pastoralists are more commercial compared to Marsabit pastoralists. Likewise, the extent of market participation was negative and significant for Marsabit, meaning that being in Marsabit influences the extent of market participation negatively. Marsabit pastoralists are not commercially oriented, but rather, they are subsistence milk producers. Being in Isiolo County, there are more chances of participating in the purchase of fodder and other feed concentrates. This was because Isiolo is dominated by fodder producer groups who harvest and market to the camel owners (Sala et al., 2020).

The sex of the camel owner did not influence market participation. This is not consistent with Dube (2020), who found female-headed households to significantly contribute to smallholder farmer participation in the sale of agricultural products. Lack of off-farm income negatively influenced a decision to buy minerals and hire labour. This is consistent with the decision to sell milk in Ethiopia, where using the logit model is positively influenced by the off-farm income (Bekele, 2021). Off-farm income provides an alternative source of finances to purchase farm inputs, which in turn increases production and hence surplus for the market.

Distance to the consumer did not have any influence on milk sales in both wet and dry seasons because most milk was sold at a distance within reach. This is consistent with (Lutta et al., 2021). The distance did not determine the volumes of milk sold. In some instances, market participation was positively affected by the distance because the areas that are far produce and sell agricultural products due to the availability of land, and those that are near do not have production resources.

The herd size was significant and positive for the decision and the percentage of milk sold in the dry season. This is consistent with (Tilahun et al., 2023; Ordofa (2021), though they did not consider the season. The herd size was, however, significant and negative for the proportion of milk sold in the wet season. It could be attributed to the fact that in the wet season, everybody has milk, and most of what is produced is consumed at home because they target the local market. It is for the same reason that milk produced in the wet season has a negative and significant influence on the percentage of milk sold.

On the contrary, for the dry season, the local demand is high, and so they sell a high proportion (Lutta et al., 2021). The difference is as a result that camel milk goes to waste during the wet season because there is overproduction, and they may be relying only on the consumers who were there during the dry season. Furthermore, due to poor hygiene and time, milk may go bad and therefore cannot be sold to consumers (Odongo et al., 2016). The cause of this was that milk is consumed by specific communities, and consumption during the time of excess supply cannot be extended to non-consuming communities (Akweya et al., 2012). Due to that, about 50% of the camel milk produced, especially in the wet season, is wasted (Oselu et al., 2022). The herd size also positively and significantly affects the decision to purchase feeds and hire labour because a large herd size requires more feeds and more people to herd camels.

Herd size also influenced the decision to buy feeds and hire labour. This was because the larger the size, the more the need to buy feeds and the need to require people to take care of the camels. The amount of milk produced influences the percentage to be sold because it has satisfied home consumption, and there is a surplus for the market. This was consistence with other studies as the sale of chickpeas depends on the quantity produced (Worku et al., 2022).

The percentage of milk sold in the dry season positively influenced the decision to hire labour and the extent of purchasing feeds. Milk produced per camel and the percentage of milk sold in the dry season were the greatest contributors to the number of months for purchasing animal feeds because the production in times of feed scarcity had to be sustained by purchasing fodder, which becomes a rampant business in the ASALs during the dry season (Sala et al., 2020).

The percentage of milk sold in the wet season had a negative influence on the decision to purchase minerals because there was already no market, and feeds were plenty. Furthermore, the camels had access to salty shrubs, which were plentiful during the wet season (Kuria et al., 2004). Therefore, the money earned is not adequate to be utilized in the purchase of inputs. The percentage of milking camels has a negative and significant influence on minerals purchase because the percentage increases during the rainy season, which coincides with the calving season. This was related to the availability of nutritious shrubs and water, and therefore there was no need for purchasing minerals.

Owning a motorbike had a negative significance in the decision and percentage of milk sold in both wet and dry seasons. This finding contrasts with other studies (Chamboko et al., 2017) which indicated that having a marketing infrastructure for marketing agricultural products. In the current study, the common marketing infrastructure was a motorbike and/or a refrigerator. There was an indication that the motorbike used to transport milk need not be owned by the pastoralist. It may be hired and therefore used by several key farmers. Furthermore, owning a motorbike may not necessarily be used for marketing milk but for doing other activities, such as transporting people. It was, therefore, another source of income for the pastoralists.

The decision to sell milk and the percentage of milk sold in wet and dry seasons were positively and significantly affected by the herder seeking extension services. This is consistent with other studies by Belete and Nigatu (2023) and Ordofa et al. (2021). This was an indication that those who sought advice got more information on the production methods as well as the milk marketing channels than those who did not. However, the decision to purchase feeds was positively and significantly affected by the failure to seek extension services. Maybe with a lack of advice, camel keepers were unable to plan for the dry season and hence opted to purchase feeds without prior planning. Furthermore, a pastoralist who did not access extension services was more likely to purchase feeds that are deficient in economic advice. If they were more endowed with other resources, they would not seek extension services.

Months of purchasing minerals were positively and significantly affected by seeking extension services. This was because they were advised that for the camel to maintain good health and production, they should incorporate minerals in the feed ration, especially in the dry season. After all, the camels cannot get enough from the shrubs alone, especially during drought. Extension services educate farmers on the best practices in agricultural production, such that they produce sufficient for home use and sell a good proportion of their produce.

Having a contractual agreement positively and significantly affected the proportion of milk sold in the dry season. This was because milk production in the dry season was scarce, and therefore producers were forced to sell more than those who had not committed themselves to contractual agreements. They reduced the home consumption and probably also reduced the calf's consumption.

The length of practice had a negative and significant impact on the decision and the percentage of milk sold. This was not expected because with years of experience, farmers were expected to be efficient in production, hence having a surplus for the market. They should also be participating in the marketing networks due to their many years of experience. This contrasts with Tilahun et al. (2023), but it is consistent with Dube (2020). This can be explained by the fact that pastoralists in Isiolo have changed to camel production recently because of climate change, and it was in Isiolo where they have done commercial milk production. Marsabit pastoralists have been doing camel rearing for a longer time than those in Isiolo. Pastoralists in Marsabit may have maintained the cultural value of camel milk as a "Gift for visitors" and hence not commercialized.

Length of practice negatively influences the extent of mineral purchase and the decision to hire labour. This is an indication of a low level of commercialization in Marsabit County due to poor production and participation in milk sales. Pastoralists in Marsabit have been practicing longer than in Isiolo, and it hand they do not purchase feeds because they were not doing it for commercial purposes (Sala et al., 2020).

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

6.1.1 Camel herd structure and performance

Strategic adjustments in camel herd structure can enhance and sustain milk production without compromising reproduction. The research findings revealed notable differences in camel husbandry practices between Marsabit and Isiolo counties. Pastoralists in Marsabit had a longer history of camel rearing, primarily for subsistence purposes, attributed to the arid climate conditions. In contrast, Isiolo pastoralists, facing the effects of climate change, have entered the camel-rearing scene more recently and adopted a more commercial approach.

The shift towards a commercial approach in Isiolo was evident in their preference for high-producing dairy Somali camels and adjustments. The herd composition focuses on economically valuable female camels, aligning with market demands for milk supply in urban areas. Consequently, milk production in both wet and dry seasons was higher in Isiolo locations than in Marsabit locations. This, however, did not happen hand in hand with the institutional support for animal health and extension services. The calving interval and lactation period are longer in Isiolo than in Marsabit because in Isiolo, camels are under pressure to produce milk for the market. The long calving interval influences the herd growth and subsequent commercialization.

Herd composition adjustments need to be done from knowledge of pregnancy diagnosis, which is a crucial reproductive parameter. Cocking the tail method, though it had a positive correlation with the progesterone assay, is not effective. Progesterone assay is the best method in camel pregnancy diagnosis; however, it is expensive and can only be carried out in a specialized laboratory, which is far from the ASAL areas where camel rearing takes place.

6.1.2 Camel calf diseases and life-threatening incidences

The study highlights predation, tick paralysis, and microbial diseases such as pneumonia as the primary life-threatening incidents affecting camel calves. Isiolo had higher milk production than Marsabit, but it has a longer calving interval. Inadequate suckling practices, including milk quantity and duration, alongside immediate initiation of milk sales, contribute significantly to calf morbidity and mortality rates. This is because it compromises calf immunity and increases disease susceptibility. Drought reduces milk yield in mothers and limits forage availability; hence, calves often suffer from stunted growth and poor immunity.

Intensification of camel in Isiolo County without the accompanying animal health and extension services has resulted in a high incidence of subclinical mastitis cases. Increasing the frequency of control of internal and external parasites was key in controlling microbial diseases due to improved nutrition and, hence, the immunity. Control of ectoparasites improved the mortality of tick-transmitted diseases such as camel pox.

6.1.3 Effect of supplementation in the mating season

The study noted disparities in the quality of animal feed ingredients sourced from local traders across the two counties, impacting milk production outcomes. The proximate composition of most ingredients fell below the established ranges observed in other studies. This is an indication of the unscrupulous dealers, poor storage of grain, or grains cultivated in soils that are deficient in nutrients.

Supplementation with a nutritious diet during and after mating was essential to improve the conception rate. Furthermore, it prevents a sudden drop in milk production, especially in pregnant camels. The increase in milk production was lower than what was established in other studies because the study was carried out in the wet season. Improvements in milk quality, particularly protein and fat content, were observed after intervention with a supplemented diet.

6.1.4 Input and Output Market Participation

Despite cultural norms regarding camel milk consumption, Isiolo pastoralists have embraced commercialization, input, and output markets. However, Marsabit pastoralists have not embraced commercialization despite practising for a longer period. Milk market participation was influenced positively by the availability of extension services, though they were often provided by unqualified personnel. Enhancing market participation was also achieved through increasing the number of camels and the utilization of production inputs like feeds and minerals. However, milk market participation tends to be poorer during the wet season than during the dry season. Isiolo emerged as a more recent and commercially oriented hub for camel rearing, characterized by increased involvement in both milk sales and the procurement of production inputs. Interestingly, the distance to consumer markets did not hinder milk commercialization, indicating robust demand for camel milk in distant urban areas. Additionally, ownership of milk marketing infrastructure, such as motorcycles, did not affect commercialization. This was evidenced by the fact that the transportation infrastructure was shared by many pastoralists and still performed other activities to earn a living.

6.2 Recommendations from the study

The recommendations made from the study were as follows:

6.2.1 Camel herd structure and performance

- To optimize camel herd structure and milk production, planning must focus on balanced herd composition and improved breeding. There is a need to encourage herd growth through female retention and controlled male off-take. Marsabit pastoralists require empowerment through extension to identify the optimal herd structures that can enhance camel milk production and subsequent commercialization.
- The traditional tail cocking method for pregnancy diagnosis is not reliable, and efforts should be made to develop more reliable and cheap methods to maximize on productivity of the camel herd. Therefore, the method could probably be utilized together with other methods.

6.2.2 Camel calf diseases and life-threatening incidences

- Kenya's pending Agriculture and Livestock extension bill (2022) proposes the establishment of a board to identify extension services priorities. Incorporating camel calf care and disease prevention into these priorities is critical.

- Kenya's 2020 wildlife policy proposes compensation for wildlife-related losses requires allocation of resources to functionalize it.
- Encourage early colostrum intake within the first 6 hours of birth to boost immunity. Conduct awareness campaigns on disease prevention and nutrition.
- Plan for implementation of tick control and deworming programs and schedule routine vaccinations.
- The state of subclinical mastitis should be avoided because it always precedes clinical mastitis, therefore affecting the camel's productivity. Furthermore, the presence of pathogenic organisms in the milk affects the keeping time and hence increases milk post-harvest loss.

6.2.3 Effects of Camel supplementation on performance

- High-quality ingredients should be sourced from reputable suppliers. This needs to be in consultations with agronomists to ensure the best nutritional outcomes and grain storage.
- Plan for adequate forage and mineral supplements, especially during dry season and around the mating season, similar to practices with sheep and goats. It should be continued during the dry season following mating to avoid a sudden drop in milk production, particularly in pregnant camels.
- The developed feed standard can be advanced for commercialization.

6.2.4 Factors affecting input and output Market participation.

- There is a need to diversify the source of income in the ASALs because pastoralists can get an alternative source of income to purchase farm inputs.
- Formation of camel keepers' groups to share knowledge and pool resources for veterinary services is key. Support milk cooperatives and camel milk processors to improve value chains and arrange for selling milk in far markets.
- Group organizations for pastoralists should be encouraged to collectively plan for marketing in far markets and procuring inputs. This can also

facilitate the pastoralists in engaging in contractual agreements in order to participate in milk markets.

- Undertake camel milk value addition and make other camel milk products to reduce losses, especially during the wet season.

6.3 Recommendation for Further Study

Future research proposals based on gaps identified in this study can focus on refining and developing a more cost-effective camel-side method for pregnancy diagnosis.

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APPENDICES

Appendix 1: KU Research Approval

KENYATTA UNIVERSITY
GRADUATE SCHOOL

E-mail: kubps@yahoo.com
dean-graduate@ku.ac.ke
Website: www.ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 810901 Ext. 57530

Internal Memo

FROM: Dean, Graduate School

DATE: 4th May, 2021

TO: Ms. Florence K. Thiakunu
C/o Department of Animal Science
KENYATTA UNIVERSITY

REF: A99/38409/16

SUBJECT: APPROVAL OF RESEARCH PROPOSAL

This is to inform you that the Graduate School Board at its meeting 28th April, 2021 approved your Ph.D. Research Proposal **entitled "Camel Herd Growth and Commercialization in Arid and Semi-Arid Areas of Northern Kenya".**

You may now proceed with your Data collection, subject to clearance with the Director General, National Commission for Science, Technology & Innovation.

As you embark on your data collection, please note that you will be required to submit to Graduate School completed supervision Tracking and Progress Report Forms. The Forms are available at the University's Website under Graduate School webpage downloads.

By copy of this letter, the Registrar (Academic) is hereby requested to grant you substantive registration for your Ph.D. studies.

Thank you

REUBEN MURIUKI
FOR: DEAN, GRADUATE SCHOOL

c.c. Chairman, Department of Animal Sciences
Registrar (Academic) Att; Mr. Richard Chweya

Supervisors:

1. Prof. ~~David~~ Bernard Njehia
C/o Department of Agribusiness Mngt. & Trade
KENYATTA UNIVERSITY

2. Dr. Purity Nguhiu
C/o Department of Animal Sciences
KENYATTA UNIVERSITY

3. Dr. Joshua Arimi
Department of Food Science
Meru University of Science & Technology
C/o Department of Animal Sciences
KENYATTA UNIVERSITY

Appendix 2: KU Ethical Approval

KENYATTA UNIVERSITY
ETHICS REVIEW COMMITTEE

Fax: 8711242/8711575
Email: kuerc.chairman@ku.ac.ke

Website: www.ku.ac.ke

P. O. Box 43844,
Nairobi, 00100
Tel: 8710901/12

Our Ref: **KU/ERC/ COND. APPROVAL/VOL.1** Date: 22nd July, 2021

Florence Karimi Thiakunu

P.O Box 43844, 00100

Nairobi.

Dear Mr. Thiakunu,

APPLICATION NUMBER: PKU-2294/I1434 "CAMEL HERD GROWTH AND COMMERCIALIZATION IN ARID AND SEMI-ARID AREAS NORTHERN KENYA"

1. **IDENTIFICATION OF PROTOCOL**

The application before the committee is with a research topic **"Camel Herd Growth and Commercialization in Arid and Semi-Arid areas Northern Kenya "**. Received on June, 2021.

2. **APPLICANT**

Florence Karimi Thiakunu

3. **SITE**

Northern Kenya

4. **DECISION**

The committee has considered the research protocol in accordance with the Kenyatta University Research Policy (section 7.2.1.3) and the Kenyatta University Ethics Review Committee Guidelines and **APPROVED that the research may proceed ON CONDITION that you incorporate its advice as below**

5. **ADVICE/CONDITIONS**

1. Combining longitudinal and cross sectional study is okay but should indicate if experimental component is with randomization
2. Care and protection- state during experimental phase what would happen to camels that fall sick
3. Informed consent not provided also use KUERC format with contacts
4. state community considerations
5. Protection of researcher participants- not clear whether humans will be involved at all and if so care and protection, confidentiality need to be stated

The above specific conditions must be fulfilled in writing before an approval can be granted.

The manner of fulfilling these conditions should be outlined and submitted to Kenyatta University Ethical Review Committee.

When replying, kindly quote the application number above.

If you accept the decision reached and advice and conditions given please sign in the space provided below and return to KU-ERC a copy of the letter.

KENYATTA UNIVERSITY OFFICE OF THE CHAIRMAN 22 JUL 2021 ETHICS REVIEW COMMITTEE P. O. BOX 43844 - 00100 NAIROBI

Prof. Judith Kimiywe
CHAIRPERSON - ETHICS REVIEW COMMITTEE

I FLORENCE K. THIAKUNU accept the advice given and will fulfill the conditions therein.

Signature........................ Dated this day of 22nd July, 2021.

cc.

DVC-Research Innovation and Outreach

Appendix 3: NACOSTI Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **231759**

Date of Issue: **03/January/2022**

RESEARCH LICENSE

This is to Certify that Dr.. FLORENCE KARIMI THIAKUNU of Kenyatta University, has been licensed to conduct research in Isiolo, Marsabit on the topic: Camel Herd Growth and Commercialization in Arid and Semi-Arid Areas of Northern Kenya for the period ending : 03/January/2023.

License No: **NACOSTI/P/22/14910**

231759

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is Guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014

CONDITIONS

1. The License is valid for the proposed research, location and specified period
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4. Excavation, filming and collection of specimens are subject to further necessary clearence from relevant Government Agencies
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Appendix 4: Checklist for Focus Group Discussion

1. Preliminaries

   These were started by describing the objective of having the discussion. The group was given a chance to discuss the importance of the camel and the cultural value attached to the animal.

   The team then introduced themselves depending on the roles they played in the community.
2. Herd composition and how they select or remove animals from the herd.
3. Criteria for selecting male and female animals.
4. Criteria for culling male and female animals
5. List the common camel calf life-threatening incidences apart from disease
6. Describe how the feed colostrum and milk.
7. How soon do they sell milk?
8. How they milk
9. List the common camel calf diseases and the Animal health workers in the group interpreted them in the official names.
10. Common disease control measures such as deworming and control of external parasites
11. They listed if they do any preparation for drought, especially on animals in lactation or late pregnancy.
12. How do they manage the mating season and how do they confirm the conception?
13. How camel milk has been commercialized in terms of the decision to sell camel milk and the amount sold.
14. The purchase of roughage and concentrate feeds.
15. Where and how they get mineral supplements.
16. Source of labor and other people to attend to the camels.

Appendix 5: Study Questionnaire

I. GENERAL INFORMATION

1. Name of the interviewer

a) Sammy ☐	e) Legawat ☐	i) Julius ☐
b) Mary ☐	f) Milgichan ☐	j) Shukri Ali ☐
c) Letawa ☐	g) Galmagar ☐	k) Halkano ☐
d) Samuel ☐	h) Angelina ☐	l) Mwenda ☐

2. Questionnaire serial No................................
3. County

   (a) Isiolo ☐ (b) Marsabit ☐

4. Sex of the camel owner

   (a)Male ☐ (b) Female ☐

5. Your relationship with the owner

a) Self ☐	c) Child ☐	e) Employee ☐
b) Spouse ☐	d) Clan member ☐	f) Herder ☐

6. Indicate for how long the owner has practiced camel rearing

a) Less than 11 years ☐	c) 21- 30 ☐
b) 11-20 ☐	d)More than 30 years ☐

7. Indicate if the owner has another source of livelihood

   a) Yes ☐ b) No ☐

6. Indicate if you ever seek advice on how to manage camels

   a) Yes ☐ b) No ☐

7. State who gives the advice (extension services) on how to manage camels

a) CDR ☐	d) a and b ☐
b) Ministry of Agriculture/livestock ☐	e) a and c ☐
c) NGOs and faith-based organizations ☐	f) b and c ☐

8. Indicate the method mainly used in feed scarcity coping mechanisms-

a) Purchase roughage feeds ☐ c) purchase roughage and concentrate ☐

b) Purchase concentrate ☐ d) None of the above ☐

9. Name the most common external parasite control methods that you apply-

a) Pour on ☐ c) Both pour on and spray ☐

b) Spray ☐ d) None of the above ☐

10. State how often you control external parasites

a) None ☐ c) Once in two weeks ☐

b) Once per week ☐ d) Once in more than two weeks ☐

11. State the interval of administering de-wormers

a) Less than 3 months ☐ d) yearly ☐

b) Every 3 months ☐ e) more than one year ☐

c) Every 3-6 months ☐ f) More than one year ☐

d) Every 6 months to one year ☐ g) None ☐

12. A) Indicate if camels have suffered orf *Obitiro/Mburur, Humbururu* (Borana & Gabbra); *Lopedo, Non-kutukie* (Samburu); *Ambarrur*, *Mburur* (Somali); *Ngiborwok, Mburuwok* (Turkana) in last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐

b) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐

b) None ☐ e) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

13. A) Indicate if camels have suffered camel pox *Furuk*, (Somali); *Chito* (Gabbra); *Afturo* (Rendille); *Abturo* (Samburu); *Ekolimeri* (Turkana) in the last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐

b) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐

b) None ☐ e) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

14. A) Indicate if camel calves have suffered pneumonia *Qufa, Kufa', Furri* (Gabbra); *Dahassi, Yaharr* (Rendille); *Laxawgal, Ah, Dhugato, Dugub, Erghib, Kharid Dugub, Ooof* (Somali); *Loukoi, Lotai* (Turkana); *Nkorroget, Loroget, Lchama, Ibus bus* (Samburu) *Qaban*(Borana) in last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐

b) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐

b) None ☐ e) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

15. A) Indicate if camel calves have suffered mange *Lmacheri / Lpepedo*, (Samburu); *Emitina*, (Turkana); *Adho*, *Chitto*, *Addha* (Somali); *Haddo* (Rendille); *Simpirion* (Pokot) *Chitto* (Gabbra, Borana) in last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐
b) 1-5 ☐ e) 16-20 ☐
c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐
b) None ☐ e) 11-15 ☐
c) 1-5 ☐ f) More than 15 ☐

16. A) Indicate if camels have suffered abscess *Kharfat* (Rendille); *maala* (Gabbra,); *mala*, *mall*, *arno* (Somali); *ngubuthien*, *abus*, *adjumei*, *lobus*(Turkana); *ntubui*, (Samburu) in last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐
b) 1-5 ☐ e) 16-20 ☐
c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐
b) None ☐ e) 11-15 ☐
c) 1-5 ☐ f) More than 15 ☐

17. A) Indicate if camels have suffered trypanosomiasis *Ekarutut Gandi* (Gabbra); *Dukan* (Somali); *Omar* (Rendille); *Saar* (Samburu); *Ltorobwo*, *lokipi* (Turkana). in the last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐

b) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐

b) None ☐ e) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

18. A) Indicate if camels have suffered eye infection *Dhaasi* (Gabbra); *Moyian Yoonkouyek* (Samburu); *Kolumay* (Pokot) *Itwaren* (Somali); *Edeke Ankonyen* (Turkana) in the last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐

b) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐

b) None ☐ e) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

19. A) Indicate if camels have suffered predation *Ngamia kuliwa na wanyama wanjangwani*) in the last 12 months.

a) No ☐ b) Yes ☐

D) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐

b) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

E) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐

b) None ☐ e) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

20. A) Indicate if camels have suffered hemorrhagic septicemia *Dhofof, Ng'arng'ar/Efturo/Nkimet/Suug/Saar/Lchama/Nkimet/Homa ya ngamia*/*Madan-barar*/*Karabat* in last 12 months.

a) No ☐ b) Yes ☐

F) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐

b) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

G) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐

b) None ☐ e) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

21. A) Indicate if camels have suffered accidental poisoning *Laturdei* (Samburu); *Gomborlik, Goryafun, Gumbor* (Somali); *Ekorokoite* (Turkana); *Gorrahgel* (Rendille, Gabbra) in the last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐

b) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐

b) None ☐ e) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

II. HERD STRUCTURE AND COMPOSITION-PLEASE STATE

1. Number of camels per age and sex

	Males	Females	Total
a) Calves < 2 years			
b) Calves2-4 years			
c) Camels 4-6 years			
d) Camels 6-8 years			
e) Breeding Camels> 8 years			
f) Camels > 8 years and not breeding			
Total			

2. Types of camels reared

a) Somali ☐ d) Pakistan ☐

b) Turkana ☐ e) Mixture of all ☐

c) Rendille ☐ f) Cannot tell the breeds ☐

3. Number of camels in milk (milked and suckling calves) ………………

a) Less than 10 ☐ c) 20-30 ☐

b) 10-19 ☐ d) More than 30 ☐

4. Most common age of getting the first calf in years………………………

a) Less than 5 years ☐ c) 10-15 ☐

b) 5-9 ☐ d) More than 15 ☐

5. Milk produced in the herd per day in the wet season…………

a) Less than 10 liters ☐ c) 20-29 liters ☐

b) 10-19 litres ☐ d) 30 and above ☐

6. Milk sold per day in liters in the wet season
    a) Less than 10 litres ☐ c) 20-29 liters ☐
    b) 10-19 litres ☐ d) 30 and above ☐

7. Milk produced in the herd per day in the dry season…………
    a) Less than 10 litres ☐ c) 20-29 litres ☐
    b) 10-19 litres ☐ d) 30 and above ☐

8. Milk sold per day in liters in the dry season
    a) Less than 10 litres ☐ c) 20-29 litres ☐
    b) 10-19 litres ☐ d) 30 and above ☐

9. Average milking period in months
    a) Less than 24 ☐ c) 30-36 ☐
    b) 24-29 ☐ d) More than 36 ☐

10. Activities done before milking
    a) Wash hands ☐ c) Wash hands and udder ☐
    b) Wash udder ☐ d) None of the above ☐

11. Most common period between one calf to another for one camel in months……………
    a) Less than 18 ☐ c) 18-23 ☐
    b) 24-29 ☐ d) 30 and above ☐

III. CAMEL CALF MORBIDITY AND MORTALITY-INDICATE

1. The people who mostly attend to the sick camels
    a) Owner or family member ☐ c) Trained Animal Health workers ☐

b) Community Disease Reporter ☐ d) Herders ☐
c) Traditional Experts ☐ ☐

2. Number of calves born in the last year……………………
3. How soon calves are fed colostrum after birth
   a) Immediately ☐ c) 7-12 hrs ☐
   b) 0-6 hrs ☐ d) More than 12 hrs ☐
4. State how soon after giving birth milk from a specific camel is sold to the market
   a) Less than a month ☐ c) 3-4 months ☐
   b) 1-2 months ☐ d) More than 4 months ☐

5. Proportion of milk that a calf suckles to the total milk the mother produces
   a) None ☐ c) One quarter (*mastitis*) ☐
   b) Not quantified ☐ d) Two quarters (*mastitis*) ☐
6. How long calves suckle
   a) 0-6 months ☐ c) 13-18 months ☐
   b) 7-12 months ☐ d) 19-24 months ☐
7. State the commonly used Methods of weaning the calves
   a) Transfer to another herd ☐ e) a and c ☐
   b) To supplement feeds ☐ f) b and c ☐
   c) Gradually as the mother dries off ☐ f) None of the above ☐
   d) a and b ☐ ☐

8. A) Indicate if camel calves have suffered diarrhea (*Nkirata/Nkoritit Halbathi* (Gabbra); *Ngiriata* (Samburu); *Adeya*, *Har*, *Hardik* (Somali); *Eremonu*, *Colera*, *Loleo* (Turkana); *Haar* (Rendille)) in last 12 months.
   a) No ☐ b) Yes ☐

D) If yes indicate how many suffered

c) N/A (If above is a)	☐	d) 11-15	☐
d) 1-5	☐	f) 16-20	☐
c) 6-10	☐	f) More than 20	☐

E) Indicate how many of the sick died.

c) N/A (If above is a)	☐	d) 6-10	☐
d) None	☐	f) 11-15	☐
c) 1-5	☐	f) More than 15	☐

9. A) Indicate if camel calves have suffered pneumonia *Qufa, Kufa', Furri (Gabbra); Dahassi, Yaharr (Rendille); Laxawgal, Ah, Dhugato, Dugub, Erghib, Kharid Dugub, Ooof (Somali); Loukoi, Lotai (Turkana); Nkorroget, Loroget, Lchama, Ibus bus (Samburu) Qaban* (Borana)in last 12 months.

   a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a)	☐	d) 11-15	☐
b) 1-5	☐	e) 16-20	☐
c) 6-10	☐	f) More than 20	☐

C) Indicate how many of the sick died.

a) N/A (If above is a)	☐	d) 6-10	☐
b) None	☐	e) 11-15	☐
c) 1-5	☐	f) More than 15	☐

10. A) Indicate if camel calves have suffered orf *Mburur, Humbururu* (Borana & Gabbra); *Lopedo, Non-kutukie* (Samburu); *Ambarrur, Mburur* (Somali); *Ngiborwok, Mburuwok* (Turkana) in the last 12 months.

   a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐
b) 1-5 ☐ e) 16-20 ☐
c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐
b) None ☐ e) 11-15 ☐
c) 1-5 ☐ f) More than 15 ☐

11. A) Indicate if camel calves have suffered camel pox *Furuk,* (Somali); *Chito* (Gabbra); *Afturo* (Rendille); *Abturo* (Samburu); *Ekolimeri* (Turkana) in the last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐
b) 1-5 ☐ e) 16-20 ☐
c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐
b) None ☐ e) 11-15 ☐
c) 1-5 ☐ f) More than 15 ☐

12. A) Indicate if camel calves have suffered eye infection (*Dhaasi* (Gabbra); *Moyian Yoonkouyek* (Samburu); *Kolumay* (Pokot) *Itwaren* (Somali); *Edeke Ankonyen* (Turkana) in the last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐
b) 1-5 ☐ e) 16-20 ☐
c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐

b) None ☐ f) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

13. A) Indicate if camel calves have suffered worms *Ngipelei/ Ntumai* (Samburu); *Goryan, Bahala* (Somali); *Ngirtan, Nyiritan* (Turkana); Deyah (Rendille), *Mini* (Gabbra); *Chepturu* (Pokot); *Mnyoo* (Swahili) in last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐

b) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐

b) None ☐ e) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

14. A) Indicate if camel calves have suffered tick paralysis *Shilmi, Chilim, Yagar, Yakhal* (Gabbra); *Shilim, Chillim, Turdach* (Rendille); *Shilin, Yakhal* (Somali); *Ilmangeri, Lmanjeri, Imansher, ltunturi* (Samburu), *Ngimadang, Emadang* (Turkana), *Shini, Shelem* (Borana) in last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐

b) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐
b) None ☐ e) 11-15 ☐
c) 1-5 ☐ f) More than 15 ☐

15. A) Indicate if camel calves have suffered predation *Njau kuliwa na wanyama wa jangwani*) in the last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐
b) 1-5 ☐ e) 16-20 ☐
c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐
b) None ☐ e) 11-15 ☐
c) 1-5 ☐ f) More than 15 ☐

16. A) Indicate if camel calves have suffered excessive milk consumption (*Njau kunywa maziwa mingi*) in the last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

c) N/A (If above is a) ☐ d) 11-15 ☐
d) 1-5 ☐ e) 16-20 ☐
c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐
b) None ☐ e) 11-15 ☐
c) 1-5 ☐ f) More than 15 ☐

17. A) Indicate if camel calves have suffered calf diphtheria *bad smell and swelling in the mouth/njau kufura na kunuka mdomo*) in the last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐

b) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

c) N/A (If above is a) ☐ d) 6-10 ☐

d) None ☐ f) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

IV. MARKET PARTICIPATION/CALVING CONDITIONS

1. Indicate if you have participated in the sale of camel milk in the last 12 months.

a) No ☐ b) Yes ☐

2. Indicate the method of delivering camel milk to the buyer.

a) Not applicable (if a above) ☐ c) Farm-gate ☐

b) Transportation for sale ☐ ☐

3. Approximate the distance to the place you sell milk

a) Not applicable (if a or b above) ☐ d)11-15 ☐

b) Less than 5 km ☐ e) 16-20 ☐

c) 5-10 ☐ f) More than 20 ☐

4. Methods commonly used to transport milk

a) Lorry ☐ d) Public transport system ☐

b) On foot to the destination ☐ e) Lorry

c) Motorbike ☐

5. State if you are a registered member of any milk marketing groups

a) No ☐ b) Yes ☐

6. If yes, state the group registered
   a) Self-help group ☐ c) a and b ☐
   b) Cooperative ☐ d) ☐
7. Type of agreement you have made with your customers
   a) Not applicable (if a above) ☐ c) Signed contractual agreement ☐
   b) Verbal agreement ☐ d) None ☐
8. Marketing infrastructures available for your use
   a) Not applicable (if a above) ☐ d) b and c ☐
   b) Refrigerator ☐ e) None of the above ☐
   c) Motorbike ☐ ☐
9. Indicate if you know the price of milk before taking it to the market
   a) Not applicable (if a above ☐ c) Yes ☐
   b) No ☐ ☐
10. Main source of market price information
   a) Not applicable (if b above) ☐ e) Co-operative ☐
   b) Self-help group ☐ f) Brokers ☐
   c) The buyer ☐ g) Others ☐
   d) Social media ☐ ☐
11. Main source of minerals
   a) Naturally occurring salts on the ground. ☐ c) Combination of the two ☐
   b) Purchased minerals ☐ d) None of the above ☐
11. Most common sources of water
   a) Wells ☐ d) Water pans ☐
   b) Borehole ☐ e) Purchased water ☐
   c) Rivers ☐ ☐
12. Indicate how many months in a year you buy feed supplements

a) Less than 4 ☐ c) 7-9 ☐

b) 4-6 ☐ d) More than 9 ☐

13. Indicate how many months in a year you buy water

a) Less than 4 ☐ c) 7-9 months ☐

b) 4-6 months ☐ d) More than 9 ☐

14. Indicate how many months in a year you buy minerals

a) Less than 4 ☐ c) 7-9 ☐

b) 4-6 ☐ d) More than 9 ☐

15. Indicate how many people herding camels are hired

a) None ☐ c) 3-4 ☐

b) 1-2 ☐ d) More than 4 ☐

16. Indicate how many people herding camels are family members

a) None ☐ c) 3-4 ☐

b) 1-2 ☐ d) More than 4 ☐

17. A) Indicate if camels have suffered brucellosis/abortion *Dulab enani Dhies, d'ess, l'ess* (Somali); *nkiboroto* (Samburu); *akiyech, akiyechum, akiecium* (Turkana), *iralii* (Borana, Gabbra) at the time of pregnancy in last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐

b) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died

a) N/A (If above is a) ☐ d) 6-10 ☐

b) None ☐ e) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

18. A) Indicate if camels have suffered dystocia while giving birth *Ngamia kushidwa kutoa njau wakati anazaa*) in the last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

c) N/A (If above is a) ☐ d) 11-15 ☐

d) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐

b) None ☐ e) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

19. A) Indicate if camels suffered retained afterbirth after calving) in the last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐

b) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐

b) None ☐ e) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

20. A) Indicate if camels could not wake up/malnutrition after calving *Ngamia kushidwa kuamuka akiwa na mimba ama akiwa amezaa* in the last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

c) N/A (If above is a) ☐ d) 11-15 ☐

d) 1-5 ☐ f) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a) ☐ d) 6-10 ☐

b) None ☐ e) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

21. A) Indicate if camels failed to produce milk after calving *Ngamia kushidwa kutoa maziwa baada ya kuzaa* in the last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

a) N/A (If above is a) ☐ d) 11-15 ☐

b) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

c) N/A (If above is a) ☐ d) 6-10 ☐

d) None ☐ f) 11-15 ☐

c) 1-5 ☐ f) More than 15 ☐

22. A) Indicate if camels suffered mastitis after calving *Eoke ngakile Qanyara* (Gabbra); *Canda-barar* (Somali); *Loebeta* (Turkana); *Nolkina* (Samburu); *Ugonjwa wa kiwele* (Swahili); *Giid* (Rendille) in last 12 months.

a) No ☐ b) Yes ☐

B) If yes indicate how many suffered

c) N/A (If above is a) ☐ d) 11-15 ☐

d) 1-5 ☐ e) 16-20 ☐

c) 6-10 ☐ f) More than 20 ☐

C) Indicate how many of the sick died.

a) N/A (If above is a)
b) None
c) 1-5
d) 6-10
e) 11-15
f) More than 15

22. Do a random selection of any milking camel and test for the level of clinical or sub-clinical mastitis in the four quarters using CMT or mastitis indicator papers.

a) None
b) One quarter
c) Two Quarters
d) Three quarters
e) All four quarters

Appendix 6: Informed Consent form

KENYATTA UNIVERSITY

OFFICE OF THE CHAIRMAN ETHICS REVIEW COMMITTEE

My name is **FLORENCE KARIMI THIAKUNU**

I am a Ph.D student from Kenyatta University. I am conducting a study titled

"CAMEL HERD GROWTH AND MILK COMMERCIALIZATION IN ISIOLO AND MARSABIT COUNTIES, KENYA."

Procedures to be followed

Participation in this study will require that I ask you some questions. Some milk specimens will be taken from the teats of the milking camels for further tests. I will record the information you provide in an interview checklist.

Voluntarism

You have the right to refuse participation in this study.

Discomforts and Risks

You may refuse to answer questions that you find inappropriate. You may also stop the interview at any time. We will try our best to minimize camel discomfort by being gentle.

Benefits

If you participate in this study, you will help us to learn the factors that affect camel production, reproduction, and commercialization.

Reward

There are no rewards or any payment to you if you participate.

Confidentiality

The interviews and examinations will be conducted in a private field setting. Your name will not be recorded on the checklist. The checklists will be kept in a locked cabinet for safekeeping at Kenyatta University. Everything will be kept private and only shared with the study team.

Contact Information

If you have questions about the study, call the researcher Florence Karimi No. 0711386330 or the following supervisors: Prof. Bernard Njehia No. 0722488337, Dr. Purity Nguhiu No. 0722737711, and Prof Joshua Arimi No. 0717473736. However, if you have questions about your rights as a study participant: You may contact the Kenyatta University Ethical Review Committee Secretariat at chairman.kuerc@ku.ac.ke,

Participant's statement

The above information regarding my participation in the study is clear to me. The study has been explained to me and I have been given a chance to ask questions and my questions have been answered to my satisfaction. My participation in this study is entirely voluntary. I understand that my records will be kept private and that I can leave the study at any time.

Name of Participant: ____

Signature or Thumbprint Date

____

Name of Representative/Witness (where necessary) Relationship to Subject

……………………………………………………… ……………….

Investigators statement

I, the undersigned, have explained to the volunteer in a language s/he understands, the procedures to be followed in the study and the risks and benefits involved.

____

Name of Interviewer

____

____

Signature Date

Appendix 7: Signed Consent

APPENDIX E: INFORMED CONSENT FORM FOR THE EXPERIMENT

KENYATTA UNIVERSITY
OFFICE OF THE CHAIRMAN ETHICS REVIEW COMMITTEE

My name is **FLORENCE KARIMI THIAKUNU**

I am a Ph.D student from Kenyatta University. I am conducting a study titled

"CAMEL HERD GROWTH AND COMMERCIALIZATION IN ARID AND SEMI-ARID AREAS OF NORTHERN KENYA"

Procedures to be followed

Participation in this study will require that I give camels hormones to induce estrus as I monitor milk production with and without supplementation before and after conception. Urine specimen will be taken from the camels one month after mating to test for pregnancy. The data obtained will be recorded in a prepared checklist.

Voluntarism

Please remember the participation in this study is voluntary. You may ask questions related to the study at any time.

Benefits

If you participate in this study you will help us to learn how the effects of feed supplementation will help in productive and reproductive performance of camels and that can improve camel commercialization.

Reward

If you agree to participate in this study, two camel attendants will be given extraneous allowance of Ksh 4, 000 for three months. Camels will be dewormed and provided with the control of ecto-parasites at that period of the experiment. The investigator will bear the cost of treatment of camels that may get sick during the process of the experiment.

Confidentiality

The experiment will be conducted in a private setting within the Camel Centre at Gare Mara. The filled checklist will be kept in a locked cabinet for safe keeping at Kenyatta University. Everything will be kept private and only shared with the study team.

Contact Information

If you have questions about the study call the researcher Florence Karimi No. 0711386330 or the following supervisors; Prof. Bernard Njehia No. 0722488337, Dr. Purity Nguhiu No. 0722737711 and Prof. Joshua Arimi No. 0717473736. However, if you have questions about your rights as a study participant: You may contact Kenyatta University Ethical Review Committee Secretariat on chairman.kuerc@ku.ac.ke.

Participant's statement

The above information regarding my participation in the study is clear to me. The study has been explained to me and I have been given a chance to ask questions and my questions have been answered to my satisfaction. My participation in this study is entirely voluntary. I understand that my records will be kept private.

Name of Participant: **EWASO NG'IRO NORTH DEVELOPLMENT AUTHORITY**

Signature ______________________ Date 26/07/2021

EWASO NG'IRO NORTH DEVELOPMENT AUTHORITY P.O. Box 203 - 60300 ISIOLO

Official Stamp

Investigators statement

I, the undersigned, have explained to the volunteer in a language s/he understands, the procedures to be followed in the study and the risks and benefits involved

FLORENCE KARIMI THIAKUNU

Name of Interviewer

Signature ______________________ Date 26/7/2021

Appendix 8: Study Procedure Plates

Plate 1: FGD in Laisamis and Isiolo Towns

Plate 2: A community disease reporter collecting data from a herder in Kulamawe

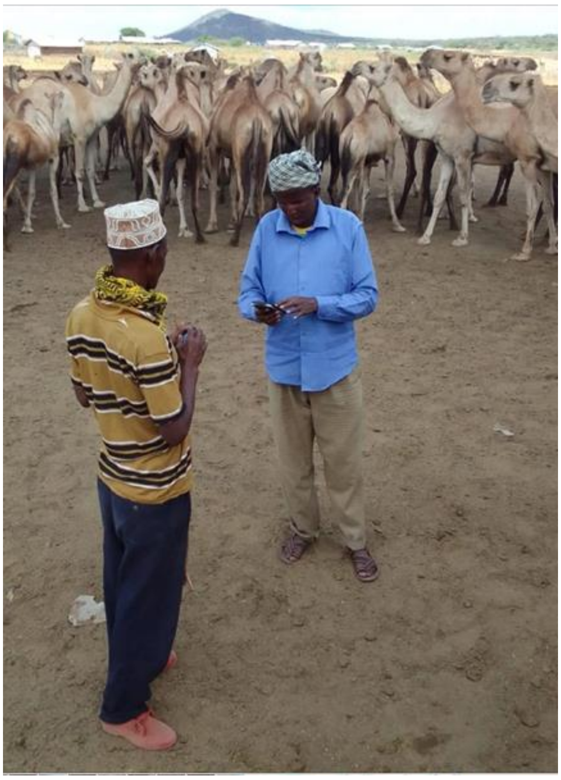


Plate 3: Animal health worker testing mastitis using indicator paper

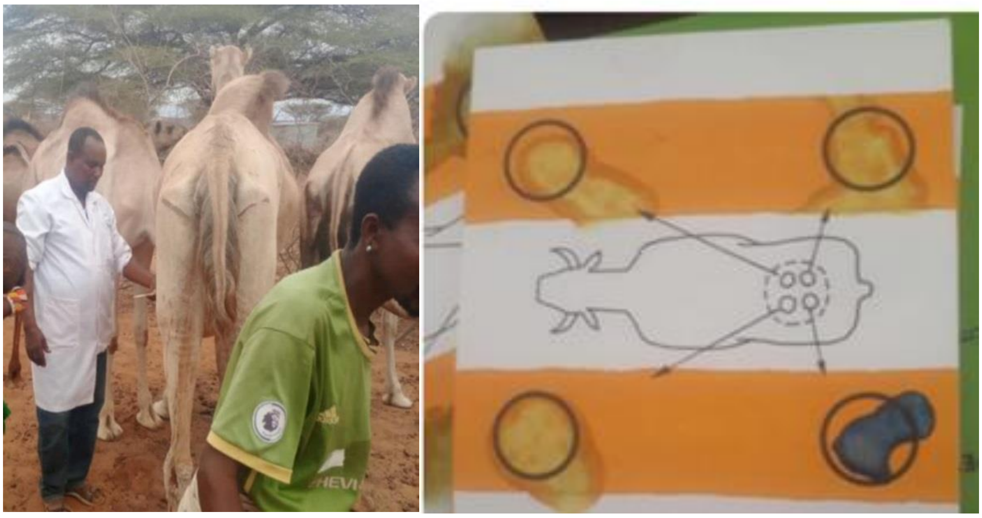
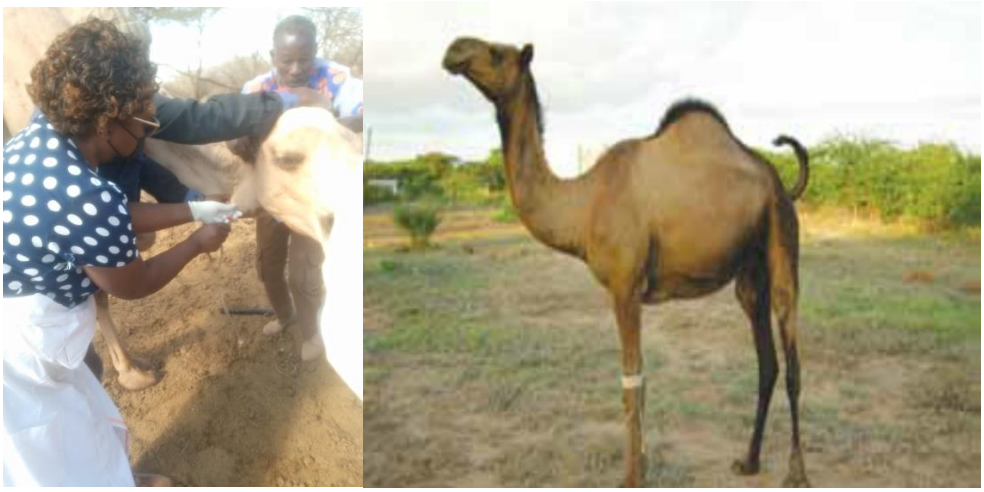


Plate 4: An assistant constituting feed and camel feeding from a trough

A B

Plate 5: Researcher collecting blood from a camel and camel tail cocking.



Appendix 9. References for Formulae

Appendix 10: Research Output Dissemination

Odessa centre | Pastoralism
Research, Policy and Practice

TYPE Original Research
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Camel calf diseases, life-threatening challenges, and associated risk factors in Isiolo and Marsabit counties, Kenya

Florence Karimi Thiakunu[1*†], Bernard Njehia[2], Purity Nguhiu[1], Joshua Arimi[3] and James Kirimi[4]

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A cross-sectional study was conducted in Isiolo and Marsabit counties, Kenya to investigate the challenges associated with high camel calf mortality. Data were collected through focus group discussions and scheduled interviews. Milk pH levels were used to ascertain subclinical mastitis. Statistical analysis was performed through recurring themes, comparing means, and multiple linear regressions. The null hypotheses for the coefficients were rejected at the $p < 0.05$ significance level. Gross camel calf mortality was found to be 44.11%, with the most significant risk factors being predation, tick paralysis, and microbial diseases. Increasing the suckling period and the amount of milk consumed, along with short deworming intervals were associated with reduced morbidity and mortality from microbial diseases ($p < 0.05$). This is attributed to improved calf immunity. Subclinical mastitis was associated with a reduction in microbial diseases. Camel pox was positively associated with long intervals between treatments for external parasites because it is tick-transmitted. The study recommends prioritising calf rearing and implementing security measures to protect calves from predators. A longitudinal study is recommended to confirm whether the associations identified are the cause of the morbidities and mortalities observed.

KEYWORDS
mortality, morbidity, immunity, predation, association

Introduction

Since the early 1970s, developing countries have undergone a *'livestock revolution'* driven by increased demand for animal products (Latino et al., 2020). Urbanisation and increased income in the majority of the middle-class population have led to a change in food preferences towards animal products. In Kenya, 80% of the landmass is arid or semi-arid and supports 60% of the country's livestock and wildlife which coexist and often cause human-wildlife conflict (Benka, 2023). The ecosystem is very fragile due to the effects of climate change and cannot support high natural resource-demanding livestock. Therefore, pastoralists have been replacing them with camels and goats. However, the

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Camel Herd Structure and Performance in Isiolo and Marsabit Counties, Kenya

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Abstract

Urbanization and improved middle-level class income have caused an increase in demand for animal products and allowed economic growth in developing countries. Arid and semi-arid lands (ASALs), which support high livestock populations have an opportunity to contribute to the economy. However, their potential may not be realized fully due to the effects of climate change. This study aimed to establish camel herd structure and performance in Isiolo and Marsabit Counties, Kenya. Focus Group Discussions (FGDs) and a cross-sectional study were conducted from July to August 2022 in each County. Data on the herd size and composition (the number of age and sex categories) was collected from 388 households through structured questionnaires. The pregnancy test was done on seventeen camels four months after the mating season by tail cocking and progesterone assay method. Analysis was done using descriptive, correlations, and linear regression statistics at a 0.05 significance level. There were more female camels over 4 years in Isiolo (above 12%) than in Marsabit

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Effects of concentrate supplementation on lactating Dromedary Camels during mating season in Isiolo, Kenya

Florence K. Thiakunu[1,2*], Bernard K. Njehia[3], Purity N. Nguhiu[2] & Joshua M. Arimi[4]

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KEY WORDS

Supplementation

Milk production

Progesterone

Tail cocking

Biochemical profiles

ABSTRACT

Camels are resilient and have a high potential to contribute to food security and economic development in arid areas. However, this potential is being limited by diminishing feed resources due to the effects of climate change. Further, there is an upcoming peri-urban camel production system where the animals are limited in their movement. Consequently, camels do not get enough browse forages in terms of biomass and quality to meet their nutritional requirement. This has resulted in decreased production and reproductive performance. The objective of this study was to determine the effect of concentrate supplementation on lactating camels on productive and reproductive performance during mating season. A diet containing 16.80% crude protein (CP) and a digestible energy of 8.44 MJ/Kg was formulated and supplemented in the evenings with a group of ten camels. Another

4. Effects of camel feed supplementation on milk yields and composition during early pregnancy period

Thiakunu, F.K[1]; Njehia, K.B[2]; Nguhiu, P.N[2] and Arimi, Joshua M[1]
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Subtheme: Food Safety, Security & Agribusiness

Abstract

A study was conducted between January and March 2022 which was the camel mating season at Ngaremara ward of Isiolo County. The objective was to determine the effect of feed supplementation on milk yield and composition in early pregnancy. It is documented that camels in pastoral environment drop milk production immediately after conception. There is limited information in literature on effects of supplementation on milk production at this stage. A complete randomized design was used to select ten camels which were supplemented with a formulated concentrate supplement made of locally available materials and ten un-supplemented which was the control. All camels were dewormed at the beginning of the study. Formulated feeds were gradually introduced to ten camels by adding 1 kg daily and enticing them with green acacia pods for 2 weeks until all supplemented were able to feed 3.5 kgs in the evening after grazing. Mating took place naturally using a bull between 6th January and 15th February 2022 and one supplemented and two un-supplemented camels were not mated. Milking was done in the mornings after allowing the calves to

Effects of feed supplementation in lactating camels during mating season in Isiolo, Kenya
By Florence Thiakunu.
Supervisors: Prof. B. Njehia, Dr. P. Nguhiu &Prof. J. Arimi

Parchment of Recognition

IN

International Research Conference Presentation

HELD AT

Dalhousie University (Virtual)

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Faculty of Agriculture
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FACULTY OF AGRICULTURE

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THEME: RESEARCH FOR INNOVATIVE SOLUTIONS IN THE 21ST CENTURY

Physical and Virtual

19TH – 21st MARCH, 2024
ARC HOTEL (AGRICULTURE RESOURCE CENTRE),
EGERTON UNIVERSITY,
NJORO, KENYA

Camel herd structure and performance in Isiolo and Marsabit Counties, Kenya

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[3]Department of Agricultural Economics, Kenyatta University, Kenya Kenya, [4]Department of Food Science, Meru University of Science and Technology, Kenya
Corresponding Author: karimithiakunu@gmail.com.

ABSTRACT
Urbanization and improved middle-level class income have caused an increase in demand for animal products and allowed economic growth in developing countries. Arid and semi-arid lands (ASALs), which support high livestock population have an opportunity to contribute to the economy. However, their potential may not be realized fully due to the effects of climate change. This study aimed to establish camel herd structure and performance in Isiolo and Marsabit Counties, Kenya. Focus Group Discussions (FGDs) and a cross-sectional study were conducted from July to August 2022 in each County. Data on the herd size and composition (the number of age and sex categories) was collected from 388 households through structured questionnaires. The pregnancy test was done on seventeen camels four months after the mating season by tail cocking and progesterone assay method. Analysis was done using descriptive, correlations, and linear regression statistics at a 0.05 significance level. There were more female camels over 4 years in Isiolo (above 12%) than in Marsabit (below 10%). In Isiolo, milk yield was above 20 and 10 liters per day in wet and dry seasons respectively, while Marsabit production was below 10 liters in both seasons. Milk production coefficients were significant for the females above four years ($p < 0.05$). There were more households in Marsabit (63%) with camels having a calving interval of 24 months and below than in Isiolo (50%). The tail cocking method did not correlate with the progesterone assay method in pregnancy diagnosis. The study concludes that, in Isiolo County, pastoralists are doing camel rearing with the objective of milk production unlike in Marsabit County. The recommendation is that pastoralists should be encouraged to adjust age and sex categories to increase milk production. Further, they need to apply an accurate cost-effective pregnancy testing method.

Keywords: Herd size, male-female ratio, performance, tail cocking, progesterone assay

Appendix 11: Tables of Results

1. SUPPLEMENTED GROUP										
DAY	SUMAYA 1801	BORDAGA 3 1803	DHUGEI 1 1805	DUGEI 2 1807	PAKISTAN 1808	FREY 2 1813	CHONGO 1815	AFGHOR 2 1817	BORDAGA 2 1819	DHOGONEI 1820
JANUARY,2022										
13.	1	1	1.45	1	0.75	2	1.5	1	1	1
14.	1.5	1	1.25	1	1	1.75	1	1	1	1
15.	1.25	1	1	1	0.75	2	1.5	1	1	1
16.	1	1	-	1	0.75	1.5	-	1	0.75	1
17.	1.25	1.5	1	1	1	1	1.5	1	1	1
18.	1.5	1.75	1	1	1	1	1.5	1	1	1.5
19.	1.5	0.75	0.5	-	1	1	1	1	0.75	0.75
20.	1.5	1	1	1	1	0.75	1.25	1	1	1
21.	1.5	1.75	1.5	1	1	1.25	1	1	1	1
22.	1.75	1	1.5	1	1.25	1	1.75	1.5	0.75	1
23.	1.5	1.45	1	0.3	1.3	0.7	1.4	1	1	0.8
24.	1.25	1	1.1	1.05	1.1	1	1.5	2	1.1	1.25

25.	1.5	1.5	1.2	1.2	1.1	1.7	1.75	2	1	1
26.	1.45	1.46	1	1	1.4	1	1.5	1	0.8	1
27.	1	1	1.3	0	1	1	1	1.3	1	0
28.	1.5	1	1	1	1	1.5	1.5	1	1	0.8
29.	**1.75**	1	1	1.15	1	1.2	1.45	1.3	1.15	1.2
30.	**1**	1	1.2	1	1.3	1	0	1	1	105
31.	**1.75**	1	1.2	1	1.4	1	1.5	2.1	1.2	1.1
FEBRUARY, 2022										
1.	1.5	1.5	1.3	0.5	1.4	2	1.5	1.2	1	0
2.	1	1.65	1.45	1.1	1.5	1	1.4	1.2	1	1
3.	1.3	1.3	1	1.25	1.1	2	1.5	1.5	1	1.1
4.	1.8	0	1.3	1.2	1.3	1.2	1.6	1.3	1.2	1
5.	2	1.1	2	1.3	1.5	1	1.7	1.3	1.3	1.8
6.	1.7	1.1	1.75	1.25	1.4	2.3	1.65	1.5	1.15	1.1
7.	1	1.5	1.1	1.2	1	2	1.2	1.2	1	1
8.	1.3	1.5	0.4	0.6	1	1.2	1	1.1	1	1
9.	1.7	1.6	1	1.2	1.1	1.35	1.7	1.45	1.3	1.4
10.	1.6	1.9	1	0.85	1.25	1.1	1.4	1.4	1	1
11.	1.4	1.4	1.2	0.77	1.05	1.2	1.7	1	1	1.4

12.	2	1.5	1.2	1	1.5	1.25	1.75	1.6	1.2	2
13.	2	1.3	1.1	1	1.2	1.1	1.5	1	2	1
14.	2	1.4	1.7	1.1	1.2	1.6	1.4	1.5	1.4	0.75
15.	1.8	1.55	1	1.4	1.4	1.8	1.7	1.4	1.2	1.1
16.	1.8	1.4	1.3	0.5	1.5	1.85	1.8	1.3	1.1	1.5
17.	1.9	1.4	1	0.7	1.3	1.5	2	1.2	1.3	1.5
18.	2.2	1.3	1.9	1.4	1.3	1.3	2	1.4	1.5	1.7
19.	2	1.5	1.3	1.4	1.4	2.4	1.5	1.2	1.3	1.4
20.	1.75	1.2	1.1	1.2	1.4	1.5	1.5	1.1	1.4	1.75
21.	1.5	1	1.75	1	1.5	1.2	1.4	1.4	1.2	1.2
22.	2	1.5	2	1.4	1.4	1.2	1.35	1.45	1	1.2
23.	2	1.25	1.8	1.3	1.75	1	1.2	1.4	0	1.8
24.	1.5	1	1.2	0.5	1.4	1.15	0	1.3	1.2	1.75
25.	1.5	1.7	1.3	1.3	1.4	1.2	1.3	1.9	1.5	1.5
26.	1.7	1.4	1.2	1.2	1.5	1	1	1.5	1.2	1.2
27.	1.5	1	1.2	1.35	1.45	0.9	1	1.3	1	1.5
28.	1.2	1.5	1.5	0.9	1.5	1	1	1.1	1	1.2
MARCH, 2022										
1.	1.4	1.5	1.5	1.4	1.65	1	0	1.2	1.2	1.4

2.	1.3	1.1	1.2	1.1	1.2	2	1.4	1.6	1.5	1.4
3.	1	1	2	0.7	1.4	0.6	1.2	1.4	0	1.5
4.	1.6	0.8	1.1	0.45	1.5	0.85	1.2	2.3	1.2	1.4
5.	2	0	1	1.1	1.3	1.8	1.5	1.45	1	1.2
6.	1.1	0	1.1	1.5	1.3	1	1.4	1.9	1.3	1.4
7.	1.05	0	1.1	0.45	1.2	1.6	1.2	1.3	1	1.4
8.	1.8	0	1	0.5	1.25	0.75	0	1.2	1.2	1.35
9.	1.3	0	0.6	1	0.8	0.75	1.2	2.1	0.75	1.3
10.	1	0	0.6	1	0.95	1	1.1	1.1	0.8	1
11.	1.1	0.2	1	0.5	1.3	0.75	0	1.1	1.2	0.9
12.	1.45	0	1.15	0.75	1.1	1	1.4	1.15	1.3	1.5
13.	1.6	0.2	1.1	1.3	1	1.4	1.45	1.3	1	1
14.	1	0	1.5	0.75	1.3	0.9	1.2	1.5	1.3	1.2
15.	1.15	0.2	1.2	0.75	0.9	1.6	1.1	1	1	1.1
16.	1	0.3	1.2	0.6	1.2	1	0.2	1.5	1.05	1.4
17.	2	0.4	1.6	1.3	1.3	0.75	1.45	1	1.05	1.2
18.	1	0.6	1.1	1.2	1.3	1	0.75	1.2	1.3	1.1
19.	2	0.75	1	0.4	1.3	1.8	1.34	1.4	1.1	1.2

2. CONTROL GROUP……..………………										
JANUARY, 2022										
DAY	WALE I 1802	BARDU -1 1804	BARYA R 2 1806	BORDA GA 1 1809	AFGHOR 1 1810	FREY 1 1811	DIKIDI KI 1812	KULAMAW E 1814	BARDU 2 1816	BARY AR 1 1818
JANUARY, 2022										
13.	1.5	1	2	1.75	-	1	0.75	0.75	1	1
14.	1	1	1.5	1	0.5	1.5	1	1	1	0.5
15.	1	0.75	1.75	1	-	1	1.25	1	1	1
16.	0.5	0.5	1	1	1	1	1	0.25	1	-
17.	0.5	0.5	1	1	1	1	1.5	1	1	1
18.	1.5	1	1.25	1.5	1.25	1.5	1	1	1	1
19.	1	0.75	1	1	-	1	0.75	1	1	-
20.	1.25	1	1.5	1	1	0.75	1	1	1.5	1.5
21.	1	0.75	1	1.25	1	1	1	1	1	1.25
22.	1	1	1.5	1.75	1	1	1.25	1	1	1
23.	1.65	0.65	1.8	1.8	1.1	0.75	1	0.7	1	1.5
24.	1.1	1	1.8	1.4	1.4	1.15	0.85	0.8	1	0
25.	1.2	1	1	1.3	1.5	1.25	1.6	1.4	1	1.4

26.	2	0.75	1.1	1.9	1.45	0.75	1.75	1.2	1.2	1.3
27.	2	1	1	2	1.4	1	1	1	1.2	1
28.	1	1.6	1.5	1	1.2	1	0.8	1	1	1
29.	1.2	1.1	2	1.5	1.3	1.75	1.3	1.3	1.2	1.35
30.	1	1	1.2	1	0	1	1.2	1	1.5	1.2
31.	1	2	1.9	1.1	1.5	1	1	1	2	1.1
FEBRUARY, 2022										
1.	1	1.9	2	1.4	0.75	1.9	1	1.3	1.1	1
2.	1.5	0.3	1.5	1.6	1.4	1	1.5	1	1.75	1.4
3.	2	1	2.1	2	0	1.5	1.6	1.1	2.25	1.2
4.	1.4	2	2	1.5	1.1	1.3	0	1.1	1	1.45
5.	1.1	2	2.4	1.5	1	1	1	1	2.4	1.6
6.	1.5	2.1	1.3	1.55	1	0.75	2	1.3	1	1.6
7.	1	1.2	1.2	1	0.5	1	0.5	1.2	1.5	
8.	1	2	1.3	2	1.2	0.75	1.5	1.5	1.2	1.3
9.	0.8	1	1.5	1.8	1.3	1.1	1	1.2	1.3	1.2
10.	1	1.7	2.2	1.2	1.4	1.1	0.5	1	1.8	1.5
11.	1.2	1	2.1	1.2	1.3	0.81	1	1	2	1.5
12.	1.2	1	2.4	1.3	0	1.2	1.9	1.4	1.5	1.5

13.	1	1.3	2	1.5	0	1.1	0.5	1.1	2	2
14.	1.4	1.75	1.5	1.3	1	0.8	0.75	1.3	1.2	1.3
15.	1.3	1.6	1.3	1.7	1.3	0.6	0.75	1	1	1.7
16.	1	1.6	0.95	2	1.1	0.8	1	1.1	1	1.6
17.	1	0.7	1.9	1.5	1.35	0.82	1.9	1.1	1	1.4
18.	1	1	1.4	1.7	0	0.8	2	1.3	1.4	2
19.	1.4	1.2		1.15	1.45	0.5	1	1.2	2	1.2
20.	1.45	1	1.3	1.4	1.5	0.6	1	1.2	1.4	1.9
21.	1	1	1.4	2	1.2	0.5	1	1	1	1
22.	1	0.5	2	1.5	1.45	0.45	1	1.2	1.25	1
23.	1.5	0.3	1.3	1.3	0.25	0.5	0	1	1.35	1
24.	1.2	0	1.5	1.2	0.9	0.4	1	1.1	2	1.4
25.	2.1	0.3	1	1.35	0.4	1	1.2	1	2.3	0.8
26.	1	0	1.2	1.3	1	1	1.2	0.65	1	0.5
27.	1.5	0	1.2	1.4	1.1	0.75	1	0.5	1	1
28.	1	0	1.1	1.5	1.1	0.4	0.8	1	1.4	1.1
MARCH, 2022										
1.	1	0	2	1.4	1.2	1	1	0.75	1	1.4
2.	1.8	0	1.5	1.3	1	1	0.9	1	2.1	0

3.	2	0.3	1	1.45	1	1.4	1	1	1	1
4.	1.1	0.5	1.2	1.25	1	1.2	1.1	0.85	1.2	1
5.	2	0	1.1	1.25	1.1	1.3	1	1	1.5	1
6.	2	0.75	1.6	1.4	1.2	1.2	1	1	1.5	0.85
7.	2	0.9	1.3	1.2	1	0.8	0.8	1	2.1	1.5
8.	1.1	0.9	1.1	1.3	1	1	0.85	1.05	2	1.4
9.	1	1	1	1.3	1	1.7	0.75	0	0.75	1.3
10.	1	1.2	1.1	1	0.75	1	1	0.5	1.2	1
11.	1.2	1	1.75	1.1	0.8	0.85	1	0.65	2.1	0.8
12.	1.2	1	1.2	1.4	1.1	1	0.75	0.85	1.3	0
13.	1.1	1	1.1	1.4	0.8	1	1	0.55	1.4	0
14.	1.4	1.2	1.05	1.6	1	1	1.15	1	1.45	1.3
15.	1.15	0.5	1.1	1	0.6	1	0.85	0.75	1.2	0.75
16.	0.2	0.4	2	1.5	0.75	1.4	0.95	1	1.2	0.55
17.	1.3	1.3	1	1.2	1.2	0.5	0.8	0.9	1.3	0.7
18.	1	0.7	1.1	1.4	0	0.95	1	0.6	1.2	0.75
19.	0.4	0.75	1.15	1.3	1.15	1	0.7	1.1	2.2	0.75