Journal of Agricultural Science; Vol. 16, No. 1; 2024
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

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

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Received: October 27, 2023 Accepted: November 28, 2023 Online Published: December 15, 2023

doi:10.5539/jas.v16n1p75 URL: https://doi.org/10.5539/jas.v16n1p75

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 (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%) 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, age sex percentage, milk yield, calving interval, tail cocking, progesterone assay

1. Introduction

Agriculture provides the most basic need for human survival in the form of food security. It is a major driver of economic development in the developing countries. Since the early 1970s the developing countries have been undergoing a '*livestock revolution*' motivated by the demand for animal products (Latino et al., 2020). Urbanization and increased income in the majority of the population middle class leads to changes in food preferences toward demand for animal products. Therefore, if developing countries especially arid lands where livestock production is their main activity can seize the opportunity and produce for market they can get out of poverty. Some developing countries such as Brazil are leading in response to this demand (Latino et al., 2020).

Due to the effects of climate change which is impacting negatively on the environment, the anticipated economic development however may not be realized. This is because it is impacting negatively on livestock production in all livelihood zones. During drought, animals die in large numbers due to competition for meagre resources. This makes them vulnerable and can suffer hunger leading to poor growth and production. It takes time for the pastoralists to replace the stock when there is plenty of feed (Githu et al., 2022). In response to this, pastoralists employ a combination of strategies which include moving to other areas and changing livestock species (Habte

et al., 2022). Most of them are replacing cattle with sheep and goats to distribute the risk and camels due to their resilience (Faye, 2015; Shuiep et al., 2012; Yosef et al., 2013). This is how the camel has gained increasing importance in the ASALs. They are resilient, survive, and still produce some milk in a situation where other animals succumb. The ASALs however, are under threat of climate change unless efforts are made to adjust animal husbandry practices (Godde et al., 2020).

The approximate world camel population was 19 million (FAO, 2013) and 27 million (Faye, 2015). The recent approximation was 35 million (FAO, 2022). In sub-Saharan Africa, Livestock production contributes 18% of agricultural GDP compared with 45-50% in the developed countries (Erdaw, 2023). According to Hurst et al., (2012), destocking reduces the grazing pressure and hence improves milk yields in wet and dry seasons, age at first calving, and calving interval. If unproductive animals are reduced in the herd, it can have a positive effect on productivity and hence reduce the vulnerability by participating in markets. This can be used for deliberate modification of camel herd structure and result in a substantial increase in herd performance (FAO, 2011).

In Somalia and the Afar region of Ethiopia, pastoralists select males for breeding where they consider the pedigree and individual animal characteristics. The size, hardiness, good body conformation colour, and large testicles are the preferred phenotypic characteristics (Marshall et al., 2016). Female camels are never selected in most ASALs because they have never been satisfied with the female population to have a wide selection. However, they cull female animals that have failed to reproduce due to habitual abortions, and stillbirths which is quite high under pastoral conditions (Keskes et al., 2013b). The most important method of testing a female's ability to reproduce is by confirmation of pregnancy after mating.

In Kenya, ASALs make up 90% of Kenya's landmass and the home to more than 50% of domesticated livestock including camels (Nyariki & Amwata, 2019). Agriculture contributes 18% of GDP and a further 27% through linkages along the production and supply chain (FAO, 2022). For a long time, pastoralists in the ASALs have practiced livestock production because it is the only good method of utilizing scarce natural resources (Ndathi et al., 2013). Production has been mainly for subsistence and is controlled by natural forces. Due to the remoteness of the ASALs, pastoralists do not access extension and animal health services and therefore utilize indigenous knowledge for livestock management (Nkuba et al., 2021). Animal health and extension workers are few and disease surveillance is done by community disease reporters (CDRs) under the guidance of a few qualified animal health workers.

Several pregnancy testing methods can be applied in camels, including observation, clinical manipulation, and hormonal analysis. Scientifically progesterone hormone analysis has been proven to be the most reliable in camels (Kamoun & Jemmali, 2014). Progesterone levels range from 0 to 2.73 mmol/L in a non-pregnant state increasing to more than 7.4 nmol/L two days after a successful mating and is maintained throughout gestation. Any camel serum progesterone level that is more than 3.5 nmol/L is considered pregnant (Mostafa et al., 2016; Kamoun & Jemmali, 2014). In the ASALs they utilize the observation indigenous method of cocking the tail which was proven to be 95% accurate (Purohit, 2010).

There is scanty information on whether pastoralists deliberately control the age and sex percentages in the herd to improve performance. Correlation of the indigenous tail cocking method with the scientific method of progesterone analysis has never been done. It is with this background that this study was done. The objectives therefore were to: characterize camel herd structure and determine its effect on milk yields and reproductive parameters. Further, the indigenous method of pregnancy confirmation and the scientific method of progesterone analysis were compared.

2. Materials and Methods

2.1 Study Area

The study was conducted in Isiolo and Marsabit Counties (Figure 1). These are among the traditional camel-keeping Counties in Kenya. The proportion of households keeping camels is 12% and 29% for Isiolo and Marsabit respectively. 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 five 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 200 mm and 1000 mm per annum (p.a.). The arid and very arid area forms the most extensive part of Marsabit below 700m above sea level with rainfall below 300 mm p.a. Marsabit has 215,234 camels distributed among 22,093 households in four Sub-Counties (KNBS, 2019).

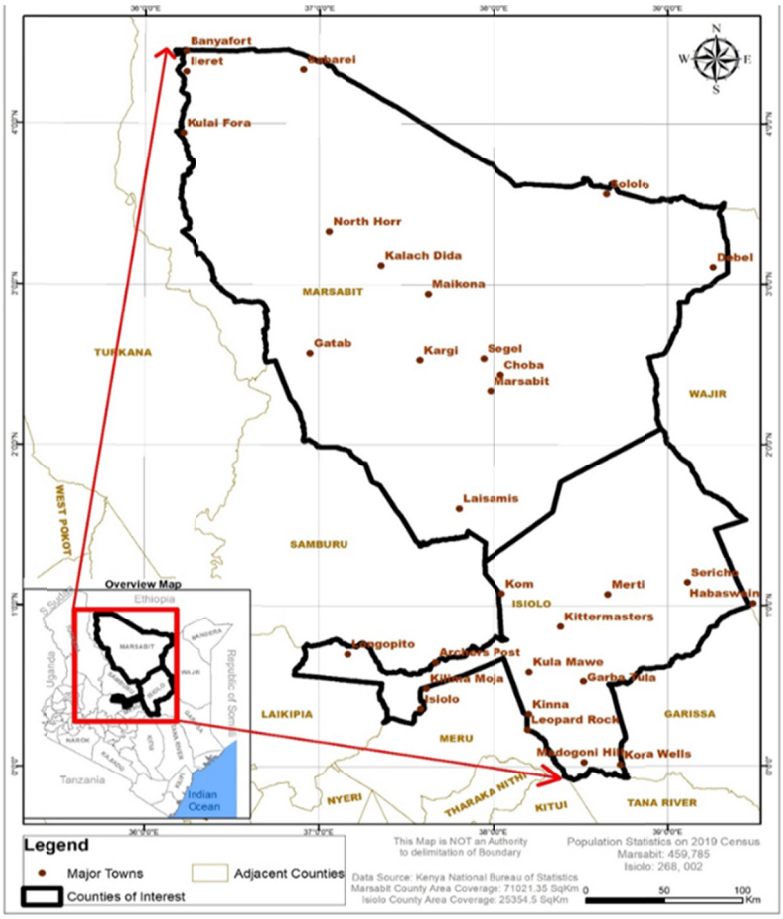

Figure 1. Map of Kenya showing the position of Isiolo and Marsabit Counties (KNBS, 2019)

2.2 Research Design

The research design was cross-sectional relying on the recall for one year before the study. Focus Group Discussions were composed of 14 people including community disease reporters, staff from the Ministry of Livestock, and pastoralists. Data was collected through a questionnaire which was uploaded in the Kobocollect toolbox. Through the questionnaire, the herd structure and performance were determined. The research variables included the actual numbers of every age and sex category. Performance was assessed as the average milk production per day per herd in liters during the wet and dry seasons. Age at first calving was measured in years while the lactation period and calving interval as a reproductive parameter were measured in months.

2.3 Sample Size Determination

The sample population was all the camel-keeping households in Isiolo and Marsabit Counties totaling 28,864. The sample size was determined in two stages by using formulae 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,

$$N = Z^2pq/L^2 \quad (1)$$

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 no sufficient knowledge of the population with the attribute being measured and therefore a value of 0.5 is recommended hence the sample was,

$$1.96^2 \times 0.5^2/0.05^2 = 384 \quad (2)$$

For a target population of 28,864 households, the sample size was then adjusted using the formula;

$$n' = 1/(1/n + 1/N) \quad (3)$$

(Pfeiffer, 2010) where n'=adjusted sample size for finite population; n=sample size for infinite population; N = population size hence the sample size was

$$n' = 1/(1/384 + 1/28{,}864) = 379 \quad (4)$$

Data collection was started with the objective of getting at least 390 completed questionnaires. This is taking into consideration the non-responses, inconsistent, and incomplete answers (Kelley, 2003) which were estimated to be about 10 but finally there were 388 completed questionnaires.

2.4 Sampling Design

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 Sub-Counties were purposively sampled due to their potential in milk production. 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. 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. Respondents were 140 drawn from Kulamawe, Gotu, and Kinna locations in Isiolo County and 248 from Laisamis, Lontolio, Koya, and Merile locations in Marsabit County (Table 1).

2.5 Data Collection

Initial data was obtained from key informants who included the staff from the Livestock Departments in the two Counties. They were selected because they have daily contact with the community rearing camels and have knowledge and experiences related to camel herd structure and milk production. The information given prompted further exploration through the questionnaire. Two FGDs were held in Isiolo and Laisamis to get an insight into the camel herd dynamics and to familiarize with the community. The group comprised the investigator, a staff from the Ministry of Livestock in the respective Counties, CDRs, and pastoralists. The data collection tool was a questionnaire administered by CDRs in specific local languages which include Somalia, Turkana, Rendille, Samburu, and Boran.

Questionnaires were administered using a Kobocollect toolbox. Blood was drawn from seventeen camels 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. Camel herders made a sudden approach through the rear of the female camel and observed for tail cocking. This was done every morning before the camels went out to browse. Tail cocking was traditionally confirmatory that the camel was pregnant. The study process had some challenges and limitations notably because Isiolo and Marsabit Counties are vast with poor road communication infrastructure. Furthermore, the study was conducted in 2022 when there was a high level of insecurity in certain Sub Counties of Marsabit. The dusk-to-dawn curfew had been imposed by the Kenya government. This led to focusing the data collection only in Laisamis Sub-County for Marsabit County. The enumerators had to spend a few hours collecting data to have time to travel and retreat to their resting places before 6 p.m.

2.6 Blood Analysis

Sampled blood from seventeen camels was analysed at Lancet laboratories, in Nairobi, Kenya. Blood was centrifuged to separate the serum and analysed for progesterone levels using Abbott Alinity I Analyzer. This was through electro-chemiluminescent microparticle immunoassay as described by Deguchi et al. (2004) and Zaher et al. (2017). 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 mmol/L. Pregnancy was confirmed based on the progesterone levels and more than 3.5 mmol/L is considered pregnant (Mostafa et al., 2016; Kamoun & Jemmali, 2014).

2.7 Data Analysis

Descriptive statistics was used to determine age and sex percentages as well as 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 herd 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 per camel per day in the wet and dry seasons. Medians were used as measures of central tendency for milk production in wet and dry seasons as recommended by Chyung et al. (2017) and Tsang (2012). It is recommended that in ordinal data only median or mode can be

used as a measure of central tendency (Kusmaryono et al., 2022) and 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 in the model. Results were given in narrations, tabulations, figures and tables, and a linear regression model. A cross-tabulation was done to establish the correlation of cocking the tail method of pregnancy diagnosis and the scientific method of progesterone assay with a null hypothesis that the population correlation coefficient = 0.

3. Results

3.1 General Information

Table 1 shows pastoralists' 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 (96%), Kulamawe (92%), and Lontolio (81%) and lowest in Merille (59%) and Gotu (58%). 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. In Isiolo County, 24% have been practicing camel rearing for more than 30 years while in Marsabit it is 32% which was highest in Koya location. In 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.

Table 2 shows the general camel herd management. Most Isiolo pastoralists kept the Somali camel (86%) while the majority of Marsabit kept the Rendille type (77%). In both Counties, the most commonly used method in feed scarcity coping mechanism is migrating to other areas and 9% of Marsabit purchase feeds. More pastoralists were seeking advice on how to manage camels in Isiolo (69%) than in Marsabit (54%). In Isiolo, they were seeking advice from Ministry staff, and in Marsabit from the neighbours.

Table 1. Number and percentage of the households' general information per location

Counties	Isiolo								Marsabit											
Locations	Kulamawe n=63		Gotu n=31		Kinna n=46		Total n=140		Laisamis n=66		Lontolio n=62		Koya n=61		Merille n=59		Total n=248		Overall n=388	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Gender of the owner																				
Male	55	87	25	81	41	89	121	86	47	71	38	61	50	82	45	76	180	73	301	77
Female	8	13	6	19	5	11	19	14	19	29	24	39	11	18	14	24	68	27	87	22
Relationship with the owner of the camel																				
Self	3	5	1	3	1	2	5	4	46	70	21	34	46	75			113	46	118	30
Spouse	7	11	2	7	4	9	13	9	13	20	15	24	14	23	23	39	65	26	78	20
Child	2	3	4	13	1	2	7	5	4	6	2	3	1	2	25	42	32	13	39	10
Herder	51	81	7	23	40	87	98	70	2	3	23	37			8	14	33	13	131	34
Hired			17	55			17	12	1	2	1	2			3	5	5	2	22	6
State if the owner has any other source of income																				
Yes	58	92	18	58	44	96	120	86	66	100	50	81	44	72	35	59	195	79	315	81
No	5	8	13	42	2	4	20	14			12	19	17	28	24	41	53	21	73	19
State how long they have practiced camel rearing																				
Below 10	11	18	1	3	3	7	15	11	27	41	14	23	1	2	13	22	55	22	70	18
11-20	44	70	5	16	37	80	86	61	29	44	9	15	2	3	21	36	61	25	147	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			17	55			17	12	1	2	22	36	44	72	11	19	78	32	95	24

Table 2. Number and percentage of households with general camel management characteristics per location

County	Isiolo								Marsabit											
Location	Kulamawe n=63		Gotu n=31		Kinna n=46		Total n=140		Laisamis n=66		Lontolio n=62		Koya n=61		Merille n=59		Total n=248		Overall n=388	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Type of camels																				
Somali	63	100	28	90	44	96	135	86											135	35
Rendille							5	14	48	73	55	89	47	77	45	76	195	77	195	50
Turkana									1	2							1	0.4	1	0.3
Mixture			3	10	2	4			17	26	7	11	14	23	13	22	51	21	56	14
Can't tell															1	2	1	0.4	1	0.3
Feed scarcity coping mechanisms																				
None	18	29	31	100	2	4	51	36	1	1	4	7			14	24	19	8	70	18
Migrate	40	64			28	61	68	49	65	99	56	90	61	100	22	37	204	82	272	70
Combination	4	6			15	33	19	14			1	2			1	2	2	0.8	21	5
Buy feeds	1	2			1	2	2	1			1	2			22	37	23	9	25	6
Do they seek advice on how to manage camels?																				
Yes	51	81			45	98	96	69	42	64	18	29	29	48	45	76	134	54	230	59
No	12	19	31	100	1	2	44	31	24	36	44	71	32	52	14	24	114	46	158	41
Indicate the person who gives advise																				
GK	6	10	-	-	1	2	7	5					2	3			2	0.8	9	2
Private			-	-			133	95			2	3					2	0.8	2	0.5
CDR			-	-					3	5			2	3			5	2	5	1
Neighbours			-	-					17	26			13	21			30	12	30	8
Combination	57	91	-	-	45	98			46	70	60	97	44	72	59	100	209	84	342	88

Note. GK: Government of Kenya, CDR: Community disease reporter.

3.2 Camel Herd Structure

The average herd sizes are 52 and 45 camels in Isiolo and Marsabit respectively (Table 3). In Isiolo County, Gotu location has the highest average herd size of 85 followed by Kulamawe and Kinna with 46 and 40 camels respectively (Table 4). In Marsabit County, Merile location, the highest herd size is Merile with 74 camels, and the lowest is Laisamis with 32 camels (Table 5).

Table 3. Herd size, composition, number, and percentage of milking camels in the overall study area.

Counties	Isiolo		Marsabit		Total	
Herd structure	Mean	Range	Mean	Range	Mean	Range
Herd size	52	16-204	45	3-171	48	3-204
No milking camels	17	8-35	10	8-35	13	8-35
Percentage of milking camels	29	12-74	18	0-91	22	0-91
Male calves below 2 years	5	0-17	4	0-20	5	0-20
Female calves below 2 years	6	0-13	4	0-22	5	0-22
Male 2-4 years	4	0-14	3	0-25	3	0-25
Female 2-4 years	5	0-16	4	0-16	4	0-16
Male 4-6 years	3	0-15	3	0-18	2	0-18
Female 4-6 years	7	0-36	4	0-25	5	0-36
Male 6-8 years	2	0-21	3	0-21	3	0-21
Female 6-8 years	8	0-49	5	0-45	6	0-49
Males above 8 years breeding	1	0-5	3	0-29	2	0-29
Female above 8 years and breeding	9	0-73	4	0-20	6	0-73
Male above 8 years and not breeding	1	0-8	3	0-26	2	0-26
Females above 8 years and not breeding	4	0-15	4	0-21	4	0-21

Table 4. Herd size, composition, number, and percentage of milking camels in locations in 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 of 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 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

Table 5. Herd size, composition, number, and percentage of milking camels in locations in 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 of 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 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

The number of milking camels was more than 8 in all locations with Gotu recording 23 and only 9 in Merille despite the large herd size (Tables 4 and 5). The number of camel age and sex categories was almost the same but Isiolo showed a notable reduction in the number of male adult camels. The mean number of males more than 8 years old and breeding ranged from 1-3 across all the locations in the two Counties.

3.3 Herd age and sex percentages.

The overall ratio of males to females was 1:1.87 with a difference in the ratio for Isiolo (1:2.8) and Marsabit (1:1.7). Figure 2, 3, and 4 shows the camel herd age and sex percentages in Isiolo and Marsabit Counties, locations in Isiolo County and locations in Marsabit County respectively. Isiolo County has higher percentages of all female camels from four years old excluding those beyond 8 years and not breeding. On the contrary Marsabit County has the highest percentage of males more than 4 years old including those that are not used for breeding (Figure 2).

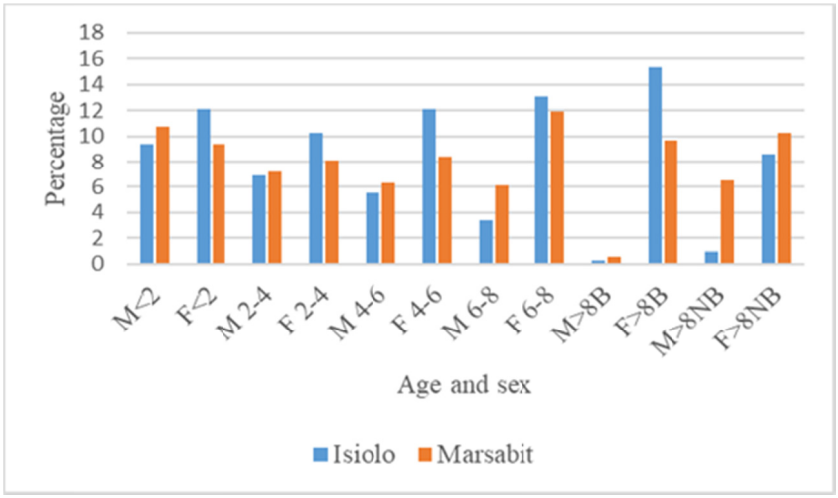

Figure 2. Camel herd age and sex percentages in Isiolo and Marsabit Counties

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.

In Isiolo County, the highest percentage of female camels above 4 years is found in the Gotu location (Figure 3). Marsabit shows uniformity in age and sex percentage distribution except for Lontolio location which has the highest percentage of females 6-8 years (Figure 4). The percentage of male calves less than 4 years in both Counties was 17.32% and females 19.24% with the highest in Kinna and Kulamawe. In both Counties the percentage of males more than 8 years and breeding is very low.

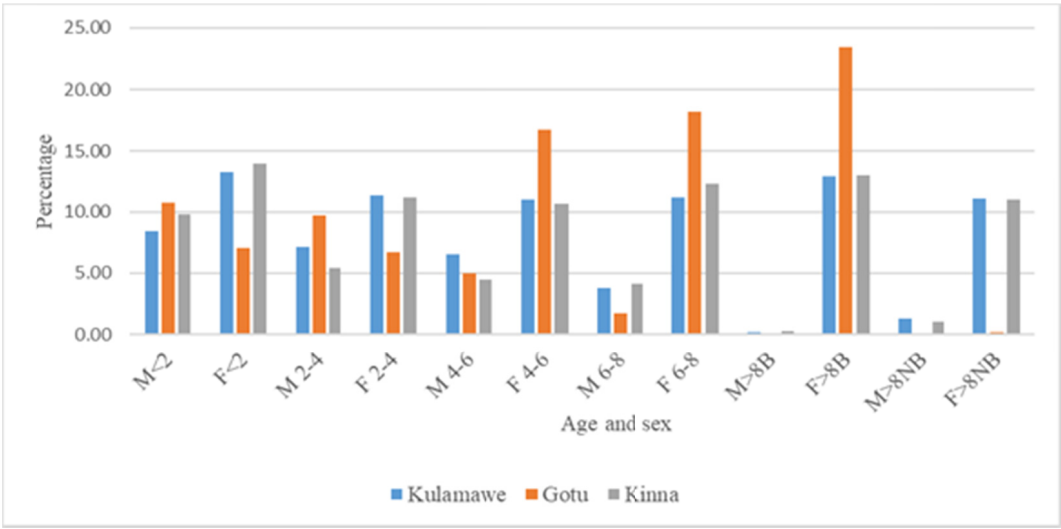

Figure 3. Camel herd age and sex percentages in Kulamawe, Gotu, and Kina locations of Isiolo County

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.

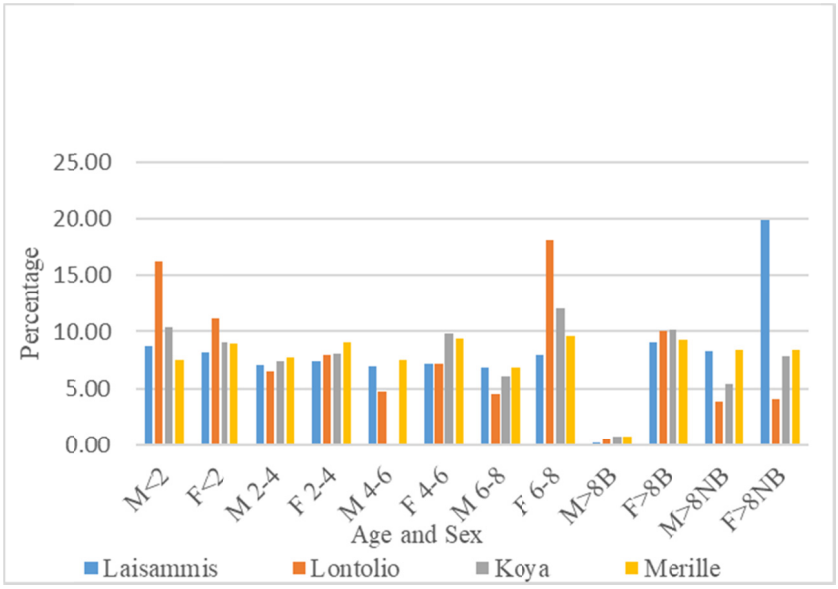

Figure 4. Camel herd age and sex percentages in the locations of Marsabit County

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.

3.4 Camel Milk Production and Reproductive Performance

Table 6. Camel herd milk production and reproductive performance

County	Isiolo								Marsabit											
Location	Kulamawe n=63		Gotu n=31		Kinna n=46		Total n=140		Laisamis n=66		Lontolio n=61		Koya n=61		Merille n=59		Total n=247		Overall n=387	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Milk production in liters per herd per day during the wet season																				
Below 10					3	7	3	2	29	44	54	89	8	13	40	68	131	53	134	35
10-19	24	38	1	3	20	44	45	32	37	56	6	10	20	33	18	31	81	33	126	33
20-29	37	59	6	19	22	48	65	46			1	2	26	43			27	11	92	24
Above 29	2	3	24	77	1	2	27	19					7	12	1	2	8	3	35	9
Milk production in liters per herd per day during the dry season																				
None					1	2	1	0.7	9	14	35	57	2	3	1	2	47	19	48	12
Below 10	21	33	1	3	20	44	42	30	55	83	26	43	25	41	54	92	160	65	202	52
10-19	37	59	10	32	23	50	70	50	2	3			29	48	4	7	35	14	105	27
20-29	5	8	20	65	2	4	27	19					5	8			5	2	32	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	51	81	31	100	39	85	121	86	63	96	44	72	38	62	33	56	178	72	299	77
Calving Interval																				
Below 18	2	3					2	1			16	26	3	5	11	19	30	12	32	8
18-24	35	56	11	36	23	50	69	49	33	50	33	54	37	61	22	38	125	51	194	50
24-29	26	41	20	65	23	50	69	49	33	50	12	20	21	34	23	39	89	36	158	41
Above 29															3	5	3	1	3	0.8
Lactation Period																				
Below 24	21	33	1	3	16	35	39	27	63	96	39	64	39	64	32	54	173	70	211	55
24-29	37	59	30	97	28	61	95	68	3	5	20	33	9	15	25	42	57	23	152	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

Table 6 shows the performance in all the locations in Isiolo and Marsabit Counties. In Isiolo, only 7 % of the households produce less than 10 liters per herd per day in the wet season while in Marsabit, 53% produce less than 10 liters per herd per day. In the dry season, 69% of Isiolo pastoralists produce more than 10 liters per day while 65% in Marsabit, produce less than 10 liters per day. Age at first calving is the same for the two Counties with the majority of the households having 10-15 years of the age at first calving. The calving interval is 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 is also shorter in Marsabit with 70% (below 24 months) than in Isiolo where 68% (24-29 months). Age at first calving is 10-20 years for 86% and 72% in Isiolo and Marsabit Counties respectively.

3.5 Effect of Herd Proportions on Performance

Table 7. Regression model for 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 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

Table 7 shows a regression result for the effect of age and sex percentages on performance. The milk production model in the wet and dry seasons was the same. In the regression model, the coefficients for the proportion of females 6-8 years and females above 8 years and not breeding were positive and significant ($p < 0.05$). Therefore, they were significant contributors to the model. The variable female above 8 years and breeding was 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 liters' production by calculating the antilogarithm. The constant therefore for wet and dry seasons is 1.68 and -1.69 respectively. Models for the wet season and dry seasons are shown in equations 5 and 6 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 liters 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 liters in the wet and dry seasons respectively.

$$P = 1.68 + 0.18\ (PF\ 6\text{-}8) + 0.324\ (PF > 8NB) \quad (5)$$

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

where, P is the average production per camel per day; PF6-8 is the proportion of females 6-8 years old, and PF > 8NB proportion of females more than 8 years old and not breeding.

3.6 Traditional and Scientific Pregnancy Confirmation

Table 8 shows the comparison of the progesterone assay method and the traditional method of cocking the tail. Four camels confirmed pregnant through progesterone assay were also confirmed pregnant by the traditional method. However, there were eight camels confirmed pregnant by the traditional method and found not pregnant through the scientific method (false positive). Table 9 shows the cross-tabulations and the correlation coefficients of traditional and scientific methods.

Table 8. Progesterone levels and the cocking the tail comparisons

Camel tag 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	+	-

Note. Symbols: +, Pregnant; -, Not pregnant.

Table 9. Correlations of scientific and traditional methods of testing pregnancy

		Science	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

The correlation coefficient is 0.054 which is very weak though positive and is also not significant ($p > 0.05$).

4. Discussion

4.1 Camel Herd Structure

More male than female camel owners were reported in the study area which is consistent with other studies. This is normal in a rural African setup where men are responsible for the most valuable assets such as camels (Salamula et al., 2017). The majority of households with another source of livelihood was highest in Kinna and Kulamawe (Isiolo County) because they are agro-pastoral livelihood zones. They have other livestock species 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 themselves to be hired. Pastoralists in Kulamawe and Kinna have been practicing camel rearing for a shorter period than in other locations. This and the fact that they have not done it for more than 30 years is an indication that they adopted camel rearing due to the effects of climate change. Almost all camels reared in Isiolo are Somali type and in Marsabit are Rendille type. This could be attributed to the fact that the Somali camels are heavier and produce more milk than all the other Kenyan breeds (Kuria et al., 2016). Furthermore, most of the camel-keeping pastoralists in Isiolo County and Laisammis Sub-County in Marsabit County are of Somali and Rendille communities respectively, and may have been referring to their own ethnic community. Some pastoralists in Marsabit County purchase feeds probably because development partners facilitate them 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, climate change had not taken a toll on the pastoralists to decide to replace cattle with camels. The proportions of females more than 4 years are higher in Isiolo than in Marsabit and bulls more than 4 years higher in Marsabit than in Isiolo. This is an indication that Isiolo is relatively more commercialized in terms of camel dairy milk production.

In Marsabit, camel rearing is for other purposes and not dairy production. In Garissa, the ratio of males to females was 1:3 (Mwanyumba et al., 2015) which was almost the same as in Isiolo (1:2.8). 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., 2013 a). 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 was 1:1.3 which is a rather high percentage of males because the objective of camel rearing was for tourist attraction, not dairy production (Seifu et al., 2019).

4.2 Herd Performance

Milk production in both wet and dry seasons is better in Isiolo than in Marsabit because of the deliberate adjustment of the herd age and sex percentages. This is consistent with a study that confirmed the technical efficiency in the utilization of resources improves when the proportion of dairy cattle in the herd increases (Yilmaz et al., 2020). The larger the milking percentage means there is 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. The linear regression model indicated that milk production was extremely low, 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 dry season until age and sex percentages are adjusted to an appropriate 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 a) who found the mean age at first calving to be 5 years. Calving interval and lactation periods were also both longer than what was reported in other studies (Keskes et al., 2013a). This is significant because a short calving interval has a positive impact on the productive life of camels and improves herd growth. A long calving interval translates to a long milking period because camels suddenly drop in milk production on day 35 after conception and stop completely in the first gestation trimester (Nagy et al., 2015). The slightly long calving interval in Isiolo could be explained by the fact that in Isiolo milk production is higher than in Marsabit. When resources are constrained, achieving production and reproduction simultaneously is not feasible (Rauw & Glazier, 2009). Further, there is relatively more pressure for milk production in Isiolo due to the sedentary method of production motivated by demand.

4.3 Pregnancy Testing Methods

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 is 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 is not maintained if mating is not successful. It has been established that cocking the tail can occur in unmated camels treated with exogenous progesterone (Skidmore, 2000). Therefore, the method could probably be utilized together with other managerial practices. Indeed, in Algeria, they do pregnancy testing using the tail cocking method 21 days after mating when they expect the non-pregnant camels to be on oestrus and this is done through a male parade (Gherissi et al., 2020). This however may not work in the Kenyan ASALs situation where there are no organized breeding programs.

5. Conclusion and Recommendation

This study generated new knowledge on the identification of optimal herd structures that can enhance camel milk production and subsequent commercialization. Herd composition adjustments can be done from knowledge of pregnancy diagnosis which is a crucial reproductive parameter. Isiolo County pastoralists kept the highest milk-yielding type of camel and adjusted the herd ratios towards the females of economic importance. This has a positive effect on milk yields however calving interval and lactation period are longer in Isiolo than Marsabit. Though expensive, progesterone assay is the best method in camel pregnancy diagnosis, and cocking the tail method is not effective. The recommendation to camel owners is to strategically implement herd structure adjustments aiming to increase and sustain milk production. Further, the study recommends the formulation of comprehensive policies addressing an appropriate number of camels and the provision of extension services. Future research can focus on refining and developing more cost-effective methods for pregnancy diagnosis.

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Acknowledgments

The authors would want to acknowledge Ewaso Ng'iro North Development Authority for availing their camels for the study. The services of Kenyatta University, Meru University of Science and Technology, and Lancet Laboratories Nairobi are recognized. We greatly appreciate the services of Dr. Michael Baariu, Mr. Raphael Basele, and Mr. Wallace King'ori for coordinating the data collection exercise.

Funding

This work was supported by the National Research Fund (NRF) multi-disciplinary multi-institutional research grants. (Project: Development of value-added camel milk products to enhance food security in arid and semi-arid areas of Northern Kenya).

Competing Interests

The authors declare that they have no known competing interests to influence the work reported in this paper.

Informed Consent

Obtained.

Ethics Approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and Peer Review

Not commissioned; externally double-blind peer-reviewed.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data Sharing Statement

No additional data are available.