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Traditional practices of camel husbandry, their drivers and role in promoting camel health and productivity across five communities in northern Kenya

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Abstract

Camel rearing is one of the most versatile livelihoods in northern Kenya because of its ability to sustain production in the often-dry pastoral rangelands. However, the capacity of pastoral households to adopt and expand camel herds is constrained by several factors. These include (i) a low knowledge of control of camel diseases that leads to high morbidities and mortalities, (ii) poor milking practices that predicate high competition for milk between calf and man leading to high camel-calf mortalities, (iii) inadequate herding labour that limits capacity to effectively exploit the expansive range ecosystem, and (iv) high prices and unwillingness to trade in female animals that reduces access to replacement stock. This study surveyed 340 camel keeping households from five communities in northern Kenya (*viz*. Borana, Gabbra, Rendille, Somali and Turkana) to assess their traditional practices of camel husbandry and the extent to which they mitigate these constraints. The study also sampled and examined 847 camels belonging to the households to evaluate the potential effect of the husbandry practices on production performance and health of camels. The results showed significant differences across the communities in traditional practices of camel husbandry including the selection of herd structures, herd dynamics practices, sourcing and utilisation of grazing labour, knowledge and control of camel diseases, milking practices and sharing of milk between camel-calf and man. Similarly, significant differences were observed in production performance and health of camels including herd-level disease prevalence, anaemia, body condition scores, calf mortalities, herd sizes, and milk production and sale. This study delineates the traditional practices of camel husbandry with potential to improve camel herd health and production performance. The study also identifies the herders' socioeconomic circumstances that preclude implementation of the practices and suggests recommendations that may increase uptake of the good husbandry practices for increased uptake of camels.

Keywords: *Camel trypanosomiasis control; herd dynamics; herd structure; husbandry practices*

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Introduction

Pastoral communities in northern Kenya are taking up camels (*Cemelus dromedaries*) as an adaptation to climate change and a means of building climate resilience (Watson et al., 2016). Several studies have documented this progressive uptake across different camel rearing communities. Examples include, Sato (1980) focusing on the Rendille, Sperling (1987) on

Samburu, Hussein (1989) and Guliye et al. (2007) on Somali, Bollig (1992) on Pokot, and Kagunyu and Wanjohi (2014) among Borana. These studies have identified four broad constraints that pastoral households face in their endeavour to adopt and expand their camel holdings. First, inadequate herding labour has forced many to fit camels in their cattle and small stock rearing culture thereby limiting their productivity. Second, a low knowledge of camel diseases has led to high morbidities and mortalities and slowed herd growth. Third, inability by herders to acquire adequate skills in managing camel calves has reduced calf survival rates, and lastly, limited trade in female animals due to high prices and unwillingness to sell has constrained access to breeding and replacement stock.

While a few studies have examined the traditional practices of animal husbandry employed by these communities to ease some of these constraints, far fewer have evaluated the impact of the husbandry measures on camel production performance and health. These include, Kaufmann (1998) assessed differences in camel-calf management practices and their impact on mortalities among the Rendille, Gabbra and Somali. Kuria et al. (2011) evaluated the status of camel-calf management practices among the Gabbra, Rendille, Somali and Sakuye communities without delving into the impact of the practices. Kuria et al. (2016) investigated the relationship between market decisions and market margins among the Samburu, Borana, Gabbra and Somali. Wanjala et al. (2021) assessed the management practices for *Surra* among the Borana, Gabbra, Rendille, Somali and Turkana, but failed to provide information on the extent to which the variegated practices influenced *Surra* prevalence in camel herds. This study contributes to this growing body of knowledge by assessing livestock herds of five camels keeping communities in northern Kenya (Borana, Gabbra, Rendille, Somali and Turkana), to assess how their traditional practices in camel husbandry mitigate the aforementioned constraints, and the effect of the mitigation measures on the productive performance and health of camels. The study is motivated by the need to identify and promote the best traditional practices in camel husbandry as a way of strengthening and expanding camel production in Kenya's northern pastoral economy. Among the traits that make camel increasingly appreciated in these areas are its hardiness and ability to provide quality milk all year round, even in the long dry seasons (Dahl and Hjort, 1976; Watson et al., 2016). In addition to the prolonged lactation, camel milk is valued for its longer shelf life compared to that of cow and goat, and if the milk gets sour, it is still sold at about 75% of the fresh value (Nori, 2023). For all these reasons, camel milk fetches higher prices than other animals' milk (Elhadi et al. 2015), and generates about 40.9% and 35.7% of household income during wet and dry seasons respectively (Oselu et al., 2022). Besides these household level benefits; adoption of camels contributes to the sustenance of the environment. For example, replacing camels with cattle has the potential to contribute to lowering of greenhouse gas emissions. Rahimi et al. (2022) states that, increasing camels by approximately 1.2 million heads, while reducing the cattle population by approximately 5.9 million heads, is estimated to result in approximately 0.14 Mt increase in milk output, 1,683.6 million cubic metres reduction in water needs, about 404.3 Mt decrease in biomass consumption by grazers, and 1,224.6 MtCO2e drop in greenhouse gas emissions.

Materials and methods

Selection of the study area

Isiolo and Marsabit Counties in northern Kenya were purposively sampled for implementation of this survey because unlike other counties, they are re inhabited by diverse communities. Isiolo covers 25,700 square km land size with a population of 268,002 people from the Ameru who are Bantu, the Cushitic Borana and Somali, and Nilotic Turkana. The county has 253,000 cattle, 45,000 camels and 1,087,000 sheep and goats. On the other hand, Marsabit County covers 66,923 square kilometres with a population of 459,785 people, 217,360 camels, about 420,000 cattle and 3,880,942 sheep and goats. It is inhabited by the Rendille, Gabbra, Borana, Samburu and Turkana (Kenya, 2019).

Sampling

The target population comprised all camel keeping households among the Borana, Somali, Turkana, Rendille and Gabbra. First, a listing of all administrative wards and villages in both Isiolo and Marsabit was obtained from the

County Governments in Isiolo and Marsabit. Isiolo has nine wards with 46 village units, while Marsabit has 20 wards with 60 village units. A two-stage sampling approach was used in obtaining the list of households to interview. In the first stage, for every community, one ward with the highest population of camels was purposively sampled. These were Ngaremara Ward inhabited by Turkana, Bula Pesa Ward for Somali and Kinna Ward for Borana, all in Isiolo County. Others were Turbi for Gabra and Laisamis for Rendille in Marsabit County. In the second stage, two village units were randomly sampled from every ward. The selection of two villages was solely dictated by budgetary considerations. A listing of all camel keeping households residing in the sampled villages was generated with the assistance of the local ward administrators from the County Government. All the listed households were visited and interviewed by trained enumerators using a questionnaire that had been prepared and pre-tested a priori. The total sample of interviewed households was 353, of whom 111 were of Somali ethnic community, 41 were Turkana, 46 Borana, 83 Gabbra and 72 Rendille. A household was defined as a set of (related or unrelated) people habitually sharing the same dwelling (whether it is their main residence or not) and who had a joint budget. The habitual residence was the dwelling in which they usually lived. The household was therefore composed of the people who shared the same budget, by either contributing resources towards the expenses made for the life of the household or by merely benefiting from those expenses (UN, 1998). Where the head was not available, an appointment for an interview date was made. If the head of the sampled household resided in an area that could not be reached, then the interview was conducted with the senior-most member in the household. All the households were interviewed between November 2021 and February 2022 using a pre-tested questionnaire. Information from completed questionnaires was stored in MS Access and analysed descriptively using SPSS.

Type of data collected

Data was collected on social and economic parameters of the household, livestock inventories, production and sale of camel milk, sale of live animals, grazing practices, sources of grazing labour, camel herd structure, camel herd dynamics and *Surra* knowledge and prevalence.

Camel herd structure encompassed the proportion in numbers formed by different age and sex classes (Faye et al., 2017), and was imputed to be represent households' camel keeping objectives (Hussein 1989). Such objectives included milk production or wealth storage. On the other hand, herd dynamics entailed the changes in herd size arising from inflows and outflows over time, denoting stability of herd structures over that time (Negassa and Jabbar 2007). A comparative analysis of herd structure and herd dynamics across different communities enabled estimation of calf survival rates as a productivity indicator (Wilson 1984). Lastly, *Surra* was selected as a case study to exemplify communities' capacity to manage camel diseases. The choice of *Surra* was informed by past studies that listed it as the most common disease affecting camels in northern Kenya (Lamuka 2017). The disease is caused by a protozoan parasite, the trypanosome (*Trypanosoma evansi*) and transmitted mechanically by biting flies. Specifically, Oyieke (2003) reported *Surra* past and present prevalence of 72-95% in camel herds in northern Kenya using the enzyme linked immunosorbent assay (ELISA). However, active infections using mouse inoculation (MI) and blood smear (BS) techniques were 19.2 and 11.5 percent, respectively. On the other hand, Njiru et al (2002) reported mean prevalence ranging from 11.1% by microhaematocrit centrifugation technique to 28.1% using a monoclonal antibody-based card latex agglutination test (Suratex®) and 37.9% using CATT/*T.evansi*. Njiru et al (2002) further noted that the Surra infections reduced the daily milk off-take by 57.1, and was associated with mortality rates of 5.5% in adults and 19.09% in young stocks. The cost of veterinary care was on average US$ 2.36 per camel per year.

Data collection approach

Herd structure: Respondents were required to provide information on the current number of camels in their herds belonging to the following age categories: calves (one year old or less), young males and females (pre-breeding), adult females (breeding and dry), adult females

(breeding but lactating), adult males (entire) and, adult males castrated. These numbers were used to compute herd ratios.

Herd dynamics: Information was collected on the different forms of inflows and outflows in a one-year period preceding the survey (Sato 1997). This included births, gifts, exchanges, purchases, sales, loan and trust. Gift transaction entailed transferring one's personal camel to another for no direct return, whereas an exchange transaction was undertaken for a direct return. Loan transaction meant transferring a camel to another on condition that the transferred camel itself was returned on a future date according to a prescribed convention, and trust transaction meant transferring female camels in accordance with the rules of the trust system. Calf mortalities in the last one year was computed as:

$$M = B + P \pm L \pm T \pm G - C - S \quad \text{.. (1)}$$

Where, $\boldsymbol{M}$ = calf mortalities that occurred in the last one calendar year from date of survey; $\boldsymbol{P}$ = calves aged one year and below purchased into the herd in the last one calendar year from date of survey; $\boldsymbol{L}$ = calves aged one year and below loaned into (+) or out of (-) the herd in the last one calendar year from date of survey; $\boldsymbol{T}$ = calves aged one year and below brought into (+) or out of (-) the herd in the last one calendar year from date of survey; $\boldsymbol{G}$ = calves aged one year and below gifted away in the last one calendar year from date of survey; $\boldsymbol{C}$ = Current number of calves aged one year and below in herd; $\boldsymbol{S}$ = calves aged one year and below sold out from the herd in the last one calendar year from date of survey.

Knowledge of *Surra* was captured by evaluating herders' awareness of the 12 clinical signs of the disease as explained in Desquesnes et al. (2013) and Kula et al. (2017), possible causes of the symptoms and options for appropriate treatment of the syndrome. The disease symptoms used were: (i) fever with shivering and elevation of body temperature at the initial stages of the disease; (ii) teary eyes and discharge from nose (lacrimation, nasal and ocular discharge); (iii) marked depression, dullness, reduced appetite and general loss of condition (iv) diarrhoea; (v) loss of colour in mouth and nose (pale mucosa); (vi) drooping hump; (vii) inability to walk long distances; (viii) swelling of the feet, brisket, underbelly and eyelids; (ix) rough hair-coat; (x) loss of weight; (xi) abortion in pregnant camels; and, (xii) significant drop in milk in lactating females. Appropriate treatment comprised of six aspects –choice of the correct drug, choice of the correct reconstitution diluent type, volume of diluent, dose rate, route of administration, and frequency of treatment. Herders were scored on each of the three areas and those adjudged to have good knowledge of *Surra* had to describe at least six correct clinical symptoms, identify at least one vector and describe appropriate treatment using at least one drug.

Lastly, *Surra* prevalence was determined through epidemiology surveys. A total of 847 camels belonging to 49 of the 353 interviewed farmers from the 10 study villages were screened for trypanosome infection in blood and PCV determination using the dark ground/phase contrast buffy-coat technique (BCT) (Murray et al 1977). This number represented approximately 14% of all the camels owned by the interviewed farmers, which were estimated at 12,092 based on the household survey results. There was no objective sampling since all the animals that were presented at the sampling site were screened. Briefly, the animals were restrained and blood samples aseptically collected from the jugular vein into EDTA-laced vacutainer tubes. The blood was then transferred into to heparinized capillary tubes, sealed on one end and centrifuged at 12,000 rpm for five minutes and the haematocrit, expressed as packed cell volume (PCV) recorded. The capillary tube was cut and buffy coat expelled onto a clean microscope slide and examined for trypanosomes under a light microscope. Data on each animals' age, sex and body condition score was also collected and recorded. The body condition was scored on a scale of 1-5 (where 1 was poor and 5 was excellent) through visual observation taking into account the extent to which fat and muscle deposition occurs in various places on the animal's body. The sampled camels were distributed as follows: 146 belonged to Somali, 162 to Borana, 241 Rendille, 200 Gabbra and 98

Turkana. In terms of age, 425 (50.2%) were categorised between 1-2 years, 180 (21.3%) 2-5 years, and 237 (28%) above 5 years. Five camels could not be conclusively categorised by age.

Data analysis

Questionnaire survey data: Information from completed questionnaires was stored in MS Access and analysed descriptively using IBM SPSS Statistics. Descriptive statistics was used to describe and summarize household and herd level characteristics. Analysis of variance and chi-square tests were used to compare parameter differences across communities. The difference-in-differences analytical approach was used to delineate the traditional practices of camel husbandry and herders' socioeconomic circumstances with the highest impact on camel health and productivity performance. After analysis of the data, feedback workshops were organised with respondents to share the findings and gain understanding on trends recorded across communities.

Animal data: *Surra* prevalence was calculated as the number of trypanosome-positive animal(s) divided by the total number of examined animals and then multiplied by 100 (with an assumption that the animals sampled had not received any prophylactic treatment and were thus all at risk). Descriptive statistics were computed, and results were presented as mean with their standard deviations (mean ± SD). Least Significance Difference (LSD)-test was used to determine differences in the body condition scores and PCV of infected vs non-infected, of male and female camels and of animals across different communities. Pearson Chi-square was used to detect statistical differences in trypanosome infection based on sex, age categories, sampling sites, body condition, and anaemic status. Analysis of variance (ANOVA) was performed by one and two-way ANOVA to show the statistical differences, if any, in PCVs and BCS between the age categories and sampling sites. All significant levels were stated at $p< 0.05$. The PCV was considered anaemic if it was ≤23, while BCS (BCS ≤ 2.5) was considered poor while (BCS > 2.5) was considered above average to good.

Ethical approval and informed consent

The study was approved by the Kenya Agricultural and Livestock Research Organization (KALRO)-Institutional Animal Care and Use Committee (KALRO-IACUC) while the survey of camel owners was approved by Kenya Agricultural and Livestock Research Organization Scientific Review Committee. The camel keepers who participated in this study signed a written informed consent form before camel sampling and questionnaire administration. The process entailed providing the camel keepers with adequate information about the study, outlining the possible benefits and consequences of participating in the study, responding to the farmers' questions, making it clear that they were free to discontinue the interview at any point, providing adequate time for them to make informed decision and then getting their permission before proceeding with the study.

Results

Livestock species reared

Table 1 summarises the social and economic parameters of the surveyed households.

Table 1

Social and economic parameters of households rearing camels

Parameter (μ)	Community				
	Somali (n=111)	**Rendille (n=72)**	**Gabbra (n=83)**	**Borana (n=46)**	**Turkana (n=41)**
Age of household head (years)	54.8±15.1	52.9±12.3	55.5±14.8	47.6±15.5	46.6±15.6

Size of household (number)	9.9±4.4	10.0±5.5	7.6±2.7	9.3±3.7	10.5±5.1
Formal education of household head (years)	2.59±4.0[a]	0.32±2.0	1.1±3.5	2.7±4.6 [a]	1.3±3.2
Camel owned (heads)	46.2±29.3[a]	26.4±17.1[bc]	26.2±23.6[c]	49.9±34.2[a]	16.2±15.2[b]
Cattle owned (heads)	11.4±26.8[a]	12.0±19.1[a]	3.5±9.36	9.32±12.7[a]	9.5±13.7[a]
Small ruminants owned (heads)	71.8±94.5[a]	111±111[a]	108±113[a]	55.6±54.3	63.6±118[a]

Figures without the same superscript across rows are significantly different (LSD, P<0.05)

Camel keeping households owned smaller cattle herd sizes, but relatively larger flocks of small ruminants. The proportion of households rearing camels alone was significantly higher (20%) among the Somali and Borana, compared to Turkana at 9.8%, Gabbra 3.7% and 1.4% for Rendille (p<0.001; χ2=22.80; df=4). The Borana and Somali households also had a significantly higher mean for years of formal education attainment.

Camel herd structure

Table 2 summarises the camel herd structure and milk offtake across the different communities.

Table 2

Camel herd structure and milk offtake across different communities

Number of animals (Mean)	**Community orientation**				
	Somali (N=110)	**Rendille (N=64)**	**Gabbra (N=66)**	**Borana (N=33)**	**Turkana (N=34)**
Calves	6.62[a] ±5.4	3.35±3.1	1.61±2.0	6.11[a] ±5.1	1.36±1.7
Young females	8.17±7.7	4.42±4.1	3.59±3.1	11.23±11.9	2.51±2.9
Young males	5.20±5.1	2.95±2.3	3.44±3.1	5.43±7.1	1.85±2.7
Mature females (dry)	14.2±12.4	5.68±6.2	6.17±8.4	17.1±17.9	5.62±7.5
Lactating females	8.68±7.4	4.23±3.7	4.35±5.8	7.6±6.9	2.85±3.7
Mature males (entire)	2.66±3.4	3.65±4.6	5.06±6.1	2.31±2.9	1.15±1.6
Mature males (castrates)	0.11±0.6	1.98±2.7	1.85±2.9	0.06±0.24	0.65±1.8
Ratios					
Females to males (Herd)	6.0[a] ±9.4	2.9±2.9	2.0±1.5	6.4[a]±4.9	4.7 [a] ±3.9
Breeding females to breeding males	14.57[a]±12.1	4.87±4.9	2.62±3.5	20.8[a]±22.3	7.1±5.6

Pre-breeding females to Pre-breeding males	1.84[a]±1.6	1.44[a]±1.2	1.17±0.73	2.41[a]±1.6	1.46[a]±1.7

Figures without the same superscript across rows are significantly different (LSD, P<0.05)

The herd level ratio of female to male animals was significantly higher in herds owned by the Borana, Somali and Turkana, compared to those of Gabbra and Rendille. There were no significant differences in female to male ratios of the pre-breeding age group across communities, perhaps to ensure a balanced source of replacement stock for breeding and continued reproduction, and for fast rapid recovery after drought, disease or other disasters. However, the ratio tilted in favour of females in the breeding age group among the Borana, Turkana and Somali, an indication of more offtake of young male adults. The milk output/household/day was significantly higher among the Borana and Somali households compared to the rest. However, households from these two communities milked significantly lower quantities of milk/dam/day. A further analysis of the data showed that a significantly higher proportion (78%) of Somali herders as well as Borana (71.4%) participated in camel milk markets, compared to the Turkana, Rendille and Gabbra at 38.4%, 19.5% and 14.6% respectively (p<0.001; χ2=60.94; df=4).

Grazing management and sources of labour

Table 3 summarises information on grazing management and sourcing of labour.

Table 3

Proportion (%) of camel keepers affirming to selected husbandry practices

Parameter (% yes)	**Community**				
	Somali (n=107)	**Rendille (n=68)**	**Gabbra (n=82)**	**Borana (n=35)**	**Turkana (n=40)**
Graze camels separately from of other livestock	93.5	86.8	64.6	77.1	90.0
Camel herd is split into different groups during grazing	38.0	40.6	51.2	57.1	26.8
Family members are main source of grazing labour	67.3	94.1	91.5	77.1	92.7
Employ experienced herders as main source of grazing labour	32.7	5.9	8.5	22.9	7.3

Majority (82.8%) of the households grazed camels separately from other livestock, while a few (42.4%) took additional steps to split the camel herd further into different age groups. Although the practice of herd splitting was observed across all communities, it was more common among households that owned significantly larger herd sizes (μ =33.2; σ=26), compared to those who did not (μ =29.0; σ=30) (F=9.1; p<0.001). There was no strict code guiding how the herd was split, but more often, majority of the weaned stock (both male and female), the breeding stock (male and female) and male castrates were grazed in extensive areas away from the homesteads, either jointly or as separate herds. On the other hand, the lactating dams and calves were grazed in areas that were close to the homesteads. On sourcing of grazing labour, the proportion of herders relying on hired labour was also significantly higher among the Borana and Somali households compared to the rest (p<0.001; χ2=32.5; df=4).

Camel herd dynamics

Table 4 summarises the different forms of inflows and outflows reported in camel herds during the one-year period preceding the survey.

On average, the number of animals sold was higher than the number purchased for restocking across all communities. However, these sales were significantly higher among Somali and Borana compared to other communities. Whereas pre-breeding males dominated the sales, purchases were mainly composed of pre-breeding females. Lastly, calf mortality rates reported among Borana and Somali were 10% and 11% respectively, lower than those reported by Gabbra, Rendille and Turkana that ranged from 27-28%.

Table 4

Camel herd dynamics across communities within last one year

Parameter (heads)	**Community**				
	Somali (N=111)	**Rendille (N=69)**	**Gabbra (N=82)**	**Borana (N=35)**	**Turkana (N=41)**
Sales	1.61[a] ±2.8	0.62±2.0	0.35±0.9	2.17[a] ±4.0	0.60±1.7
Births	7.21[a] ±5.3	3.44[b]±3.2	2.72[b]±2.6	6.7[a] ±5.0	1.95[b]±2.1
Purchase	0.92[a] ±2.2	0.09±0.4	0.48[a] ±1.3	0.29[a] ±0.84	0.23[a] ±0.53
Exchange/Gifts -in	0.22[a] ±0.7	0.14[a] ±0.5	0.55±1.2	0.11 [a] ±0.7	0 [a]
Exchange/ Gifts -out	0.07[a] ±0.3	0.04[a] ±0.3	0.71±3.1	0.03 [a] ±0.2	0.02[a] ±0.2
Surviving calves	6.62[a] ±5.4	3.35[b]±3.1	1.61[b]±2.0	6.11[a] ±5.1	1.36[b]±1.7
Proportion of non-surviving calves	0.10	0.28	0.27	0.11	0.28

Figures without the same superscript across rows are significantly different, LSD (P<0.05)

Knowledge of Surra

Table 5 gives results on knowledge of *Surra* that encompassed three components, namely correct disease diagnosis, knowledge on transmission and appropriate treatment.

Table 5

Proportion (%) of herders with knowledge of Surra symptoms, its vectors, and treatment drugs across different communities

Proportion (%) of respondents able to:	**Community**				
	Somali (n=111)	**Rendille (n=69)**	**Gabbra (n=84)**	**Borana (n=35)**	**Turkana (n=41)**
Describe 6 correct symptoms	71.2	59.4	47.6	45.7	51.2
Explain correct use of at least 1 drug	80.0	17.4	78.6	82.4	64.1
Identify one vector	98.2	94.2	97.6	100	97.6

Correct knowledge of *Surra*	60.9	11.6	40.5	54.3	46.2

Based on this classification, knowledge of *Surra* was significantly different across communities (p<0.001; χ2=44.26; df=4) being highest among Somali herders and lowest for Rendille. All communities demonstrated good knowledge of the disease vectors, but significant variation was observed in knowledge on diagnosis and treatment. Majority (88.4%) of Rendille herders were unable to identify and describe correct use of at least one drug. Additional information revealed that 20.9% of Rendille camel owners solely relied on herbal remedies to treat *Surra*, a practice that was likely to result in high disease prevalence and chronic diseases cases if at all the herbal remedies turned out to be ineffective.

In order to gain insight on administration of treatment drugs, all respondents were requested to ascertain whom, more often than not, treated their camels once diagnosed with *Surra*. The results are given in Table 6.

Table 6

Frequencies (%) of different labour sources used in treatment of infected camels

Person who treats camels infected with Surra	**Community**					
	Somali (n=111)	**Rendille (n=69)**	**Gabbra (n=84)**	**Borana (n=35)**	**Turkana (n=41)**	**Total (n=340)**
Trained Veterinary personnel	3.6	15.9	10.7	2.9	0	7.7
Self	54.9	69.6	54.8	65.7	90.2	63.2
Experienced herders	40.5	14.4	32.1	31.4	9.8	29.1

The results indicate that whereas a large portion (35.9%) of herders from the Turkana community had improper knowledge on correct use of trypanocidal drugs, the community, relied almost entirely on self-treatment. This practice, coupled with the relatively low knowledge in *Surra* diagnosis (at 46.2% of herders) could potentially lead to improper drug use and high incidences of chronic form of the disease in herds. Among the Somali, Borana and Gabbra, treatment was mainly undertaken by experienced herders.

Prevalence of Surra in camel herds across different communities

Table 7 summarises *Surra* point prevalence, packed cell volume (PCV), and body condition scores (BCS) of all sampled camels segregated by sex and age, across the five communities.

Table 7

Surra prevalence levels, packed cell volume (PCV) and body condition scores (BCS) segregated by sex and age of cattle

Parameter	**Sex/Age**	**Community**				
		***Somali* (n=143)**	***Rendille* (n=241)**	***Gabbra* (n=200)**	***Borana* (n=160)**	***Turkana* (n=97)**
Prevalence by sex	Males	0	24.1	3.2	0	16
	Females	0	12.3	2.9	1.6	11.1
	0-2 years	0	21.9	0	0	12.9

Prevalence by age	2-5 years	0	15.2	0	2.2	14.3
	> 5 years	0	15.6	4.4	1.4	11.3
PCV score by sex (± SD)	Females	27.0±2.8	23.6±4.1	26.0±4.2	27.5±3.1	24.2±5.4
	Males	27.2±3.2	23.1±4.7	26.7±3.6	27.7±2.6	22.6±5.1
PCV score by age (± SD)	0-2 years	28.0±3.0	22.6±5.0	28.6±3.4	27.5±2.7	22.9±5.1
	2-5 years	26.6±2.7	23.1±3.8	26.3±5.0	27.5±3.1	22.7±5.7
	> 5 years	26.2±2.5	24.0±4.5	26.1±3.6	27.6±3.1	24.5±5.4
BCS score by sex (± SD)	Females	3.3±0.5	2.9±0.8	3.3±0.6	3.5±0.6	3.2±0.6
	Males	3.0±0.4	2.5±0.6	3.1±0.7	3.3±0.5	2.7±0.5
BCS score by age (± SD)	0-2 years	3.0±0.3	2.2±0.4	2.6±0.5	3.4±0.5	2.8±0.5
	2-5 years	3.5±0.5	2.6±0.5	2.9±0.5	3.5±0.5	2.9±0.3
	> 5 years	3.5±0.6	3.1±0.8	3.4±0.7	3.6±0.6	3.2±0.7

Table 8

Classification of communities based on traditional practices of camel husbandry and socioeconomic factors

Traditional practices of camel husbandry and their typologies		Socio-economic parameters			
Traditional practices	Typologies	Centralised and well developed camel milk marketing market channel		Non-centralised and under-developed camel milk marketing market channel	
		High herder education	Low herder education	High herder education	Low herder education
Choice of herd structure	High female-to-male ratio	Borana; Somali	-	-	-
	Low female-to-male ratio	-	Turkana	-	Gabbra; Rendille
Milking volumes and sharing of milk between man and calf	Less milk drawn during milking	Borana; Somali	-	-	-
	More milk drawn during milking	-	Turkana	-	Gabbra; Rendille
Knowledge of disease management	Fairly good knowledge on disease diagnosis, transmission and control	Borana; Somali	-	-	-
	Lower knowledge on disease diagnosis, transmission and control	-	Turkana	-	Gabbra; Rendille
Use of experienced herding labour	Moderate use of experienced labour in grazing and treatment	Borana; Somali	-	-	Gabbra
	Minimal use of experienced labour in grazing and treatment	-	Turkana	-	Rendille

Mean *Surra* prevalence was 7.1% and varied significantly across communities (p<0.001; χ2=61.58; df=4). It was highest in camels owned by the Rendille at 16.6%, followed by Turkana (12.2%), Gabbra (3%), Borana (1.2%) and Somali (0%). The infections across three age categories were 6.1 % in calves, 7.6 % (young adults) and 7.1 % (adults), and were different across communities for both male and female animals (p<0.001). Infection levels were livider in males (11.0 %) compared to females (5.5 %) within communities where the disease was reported. This could be explained by the herding practices, where males were exposed to higher risk of infection compared to females. Most of the male and the non-lactating females (which comprised of between 55-63% of the mature female herd) were often grazed in far-off extensive areas with higher risk of exposure to vectors, increasing the likelihood of infection. However, it is important to note that herd splitting and grazing in risky areas alone could not be construed to lead to higher infection levels, because the same grazing practice was observed among the Somali and Borana, yet the disease prevalence in both sexes was absent or minimal.

The mean PCV values, an indicator of anaemia, were lower in infected animals. The values were lowest in herds owned by Rendille and highest in Borana herds, reflecting the same trend of BCS and *Surra* prevalence. Of the animals surveyed, 34.5% (292 animals) were anaemic (PCV < 25). Of these, 112 (13.3%) had severe anaemia (PCV < 20), with significant proportion belonging to Rendille and Turkana households. The mean PCV values of infected animals was 20.1 $\pm$ 4.3, and significantly lower than that of non-infected animals (25.9$\pm$ 4.0). About 77 of severely anaemic animals had no infection detected. Anaemia is widely regarded as a pathognomonic sign of *Surra*.

Discussion

Livestock species mix and potential for increasing camel uptake

Analysis of livestock species mix among households that have adopted camels shows that camels are replacing cattle much faster than small ruminants in pastoral livestock herds in northern Kenya. However, extrapolating these results across all households rearing livestock in Isiolo and Marsabit counties reveals that the proportion of households owning camels is still low compared to cattle and small ruminants. With Isiolo and Marsabit Counties having approximately 141,318 households and 262,360 heads of camels (Kenya 2019), and a mean camel holding of 34.3 heads per household, it can be estimated that approximately 7,649 households (5.4%) rear camels. This is less than 73,312 households (52%) rearing cattle, and 57,767 (41%) keeping small ruminants. The low proportion of camel herders notwithstanding, the population of camels in Kenya has been increasing at a much faster annual average rate of 5.2% from 3 million in 2010 to 4.7 million in 2020, compared to cattle at 2.1% and goats, 3.3% (FAOSTAT). Several studies have reported similar results (see Kanyungu and Wanjohi, 2014; Mwaura et al., 2015; Watson et al., 2016; Mohamed 2022; Nori 2023). These studies associate the rapid increase in camels compared to cattle to the shifting agro-ecological dynamics. Even though a comparatively large proportion of households still rear cattle, there has been a decline in the average herd size per household arising from the general increase in pressure of the natural grazing resource (Nori, 2023).

Evidence from this study shows that the intensity of uptake of camels (in terms of herd size) and their burgeoning health and productivity, varies across communities. These differences are attributed to the inherent traditional practices in camel husbandry (that are learned based on cultural patterns), as well as the socioeconomic circumstances of the herders (see also Schlee, 1989 and Watson et al., 2016 for similar arguments). This study delineates four traditional practices in camel husbandry and two socioeconomic parameters that interact to influence uptake and productivity of camels. These are discussed next.

Access to camel milk market, choice of camel herd structure and use of experienced herding-labour

The results of this study shows that the higher milk production and the comparatively larger camel herd sizes among the Somali and Borana

communities were partly linked to implementation of two husbandry practices, namely, selection of a herd structure dominated by dams and hiring of experienced herding labour. This was in addition to residing in an area served by a centralised milk-marketing channel. Before expounding on these linkages, a brief background on the types of camel milk marketing channels faced by the five communities under study is necessary.

The marketing of camel milk in Isiolo and Marsabit Counties can be differentiated in two main channels (Nori, 2023). The first channel is centred in Isiolo town and is managed by cooperatives that operate informally by collecting and bulking raw milk in Isiolo, which is then chilled and transported to mostly Somali consumers in Eastleigh, Nairobi. The main areas that supply milk to this channel include the peri-urban settings in the central portion of Isiolo County that is inhabited by Somali and Turkana communities, including the Isiolo holding ground, Mlango and Ngaremara. Others are the more distant open rangelands in its eastern parts of the county including the Kulamawe corridor that spans from Kinna to Buji, inhabited by the Borana. Milk produced in these rangelands reaches Isiolo through an organised chain of community-networks supported by rural collectors and motorbike transporters. At the heart of these community-networks, are two cooperatives based in Isiolo town, managed by women and characterised by different ethnic configurations, market management and institutional arrangements (Nori, 2023). The second channel is not centralised, and serves the other areas of Isiolo not served by the first channel, as well as the whole of Marsabit County. It comprises of milk collectors who gather milk from the rangelands and sell it to open-air retail traders for final sale to urban consumers. This channel serves most of the Rendille and Gabbra herders. However, it is important to point out that in the diverse rangelands served by this channel; some pockets of centralised milk marketing are emerging. An example includes the nascent Moyale Cooperative that started in 2018 and comprises about 20 members. The cooperative processes pasteurised camel milk for sale in Moyale town and other parts of Marsabit County. The areas that supply milk to this emerging centralised channel include the villages along the Bubisa-Moyale corridor that is mostly inhabited by Gabbra community (Oselu et al., 2022).

From the foregoing, it is clear that whereas the Borana, Somali and Turkana access a milk market with a value chain that is stable, centralised, whose progress is linear and with a well-defined modernising direction, the same does not apply to the Gabbra and Rendille. This phenomenon seemed to influence the nature of traditional practices of animal husbandry embraced by these communities. First, the ratio of female to male camels in herds reared across communities varied from a low of two (i.e. two females for every male) among the Gabbra to a high of 6.4 among the Borana. Hussein (1989) observed that the ratio of females to males in herds that is capable of providing for the mix of multiple products derived from camels in communities rearing these animals in the Horn of Africa is 5:1. However, this ratio can be varied based on the objectives of rearing camels. It is increased to above five (as observed in the Borana and Somali herds) where the objective is milk production, or below five (like in the Gabbra and Rendille herds) when objective is wealth storage. In the current study, this dairying versus wealth storage dichotomy was reinforced by the observation that a significantly larger proportion of Somali (78%) and Borana (71.4%) households participated in camel milk markets, compared to 38.4% for Turkana, 19.5% for Rendille and 14.6% for Gabbra. The differences in level of development of the two camel milk channels perhaps explain why the Somali and Borana herders embraced a herd-structure dominated by female animals, which enabled them exploit the existing market opportunity. It is however important to point out that whereas the Turkana herders, whose herd ratio was 4.7, and which was not significantly different from that of the Borana and Somali, were also served by the organised and centralised marketing channel, but appeared slow in responding to the market stimuli due to additional socioeconomic circumstances discussed later in this paper.

The second husbandry practice that was linked to the level of development of the milk value chain was the use of hired experienced herding labour.

To cope with increasing demands of grazing and tendering camels, households resorted to use of hired labour, a practice that was significantly higher among the Borana and Somali compared to other communities. Hired labour comprised of experienced herders, and this practice of relying on experienced herders in pasturing and treatment of camels is not new and has been recorded as an age-old practice, particularly among the Somali and Gabbra, who have kept camels for a much longer period (Dahl and Hjort, 1976; Stiles 1992; Saafo and Kaarhus, 2011, Nori 2023). These experienced herders mostly comprised of the young men and some of the married men, as well as widowed women who are sent out to satellite camps called *fora*, to graze and tender camels particularly during dry seasons, when camels are more vulnerable to infections. Whereas such *fora* largely remain a social cooperation responsibility among the Gabbra, it had evolved towards a form of paid employment within the Somali and Borana. In most cases, part of the income generated from the sale of milk is used to cover the herder salary, rental of grazing plots (Nori, 2023), and cost of drugs; which had a positive contribution to better health outcomes, faster herd growth and higher productivity.

Linkages between camel keeper formal education attainment, milking practices and herd health

Households rearing camels among the Somali and Borana reported a significantly higher mean for years of formal education compared to the Turkana, Gabbra and Rendille. This seemed to enable the two communities make judicious decisions during camel milking that minimised human and calf competition for milk, that in turn led to higher camel-calf survival rates. The two communities also demonstrated better knowledge of treatment of camel diseases that translated to low disease prevalence, low anaemia levels and superior body condition scores. On the one hand, during milking, the Borana and Somali drew significantly less milk per lactating dam per day compared to the Turkana, Gabbra and Rendille. The amount of milk drawn per lactating dam per milking session is not necessarily an indicator of productivity, but a critical volume that entails balancing between the twin objectives of meeting household nutritional and income needs as well as leaving sufficient volumes in the udder to support calf survival and health. In their day-to-day operations, household heads made several critical decisions that included frequency of milking, number of udder-quarters to milk, and the specific quarters that are milked. Studies have shown that rear half-quarters produce significantly more milk than fore half, and milk from rear quarters is richer in fats, proteins and total solids percentage, suitable for calf's healthy growth. Therefore, the decision on which quarters to milk and the amount of milk to draw plays a key role in calf feeding and survival in camels (Faraz et al., 2021). Besides, competition between man and calf for milk is recorded as one of the key causes of camel-calf mortalities that eventually constraints herd growth (Schwartz et al 1991). More importantly, it has been reported that calf survival contributes to not only to high milk output per lactation, but also to longer lactation period since the milking dam only lets down milk in the presence of its calf (Simpkin 1998; Farah et al., 2007; Gebremichael et al., 2019). In case the calf dies, a portion of the skin is recovered, dried and stored for use in aiding in milk let down during milking.

On the other hand, the proportion of herders who were able to correctly diagnose and treat, as well as understand transmission mechanisms of the most important camel disease in the locality (*Surra*), were significantly higher among Somali and Borana households, compared to Turkana, Rendille and Gabbra. Similarly, *Surra* prevalence within camel herds was lowest among the Somali and Borana households' camel herds. Lastly, good herd health, denoted by the good body condition and low anaemia was highest among the Borana and Somali. These herd health scores are good indicators of management and more often lead to increased reproductive success and faster herd growth (Faye et al., 2017).

Therefore, one may infer that the higher education among Borana and Somali could have potentiated them to offer better husbandry practices to their camel herds leading to lower calf mortalities and disease incidences, which in turn led to faster herd growth and larger camel herds when compared to Turkana, with whom they shared similar product market conditions. Literature is replete with studies that document

the crucial role that education plays in enabling people become effective and productive economic agents. In agriculture, in particular, most of the studies on the subject have established that the education and skills of the agricultural workers are significant factors in explaining the inter-farm, inter-regional and inter-country differences in agricultural performance (Singh 2000). This study provided evidence to support this body of knowledge.

Conclusion and recommendations

This study has shown that although camels are slowly replacing cattle as a means of building climate resilience among communities in northern Kenya, their uptake is still low, with differences observed across communities on health and productivity parameters such as calf survival rates, disease prevalence, body condition scores, anaemia levels, herd sizes, live animals offtake and milk output. By applying the difference-in differences framework to analyse these results, the observed differences were attributed to differences in traditional practices of husbandry practices and herders' socioeconomic circumstances. The herders' husbandry practices included selection of camel herd structure, hiring of experienced labour in herding and treating camels, knowledge on proper control of camel disease, and use of milking practices that minimised competition for milk between man and calf. On the other hand, herders' socioeconomic circumstances included access to centralised camel milk market channels and level of formal educational attainment of the household head. The interaction of these factors and how communities are arranged therein, is summarised in Table 8.

Even without more nuanced econometric estimations to quantify the magnitude and significance of the aforementioned relationships between parameters, it is acknowledged that application of the difference-indifferences framework in research has been useful in undertaking impact studies for policy formulation. Therefore, the following recommendations are derived:

- It is apparent that the Turkana community was unable to fully exploit the existing market opportunities for camel milk due to lower education attainment levels. In this regard, the Kenya Agricultural and Livestock Research Organisation should work with the veterinary services department of the county governments of Isiolo and Marsabit to develop and operationalise a training curriculum to improve the knowledge of Turkana herders on the specific traditional practices of camel husbandry that promote herd health and growth. The curriculum should include: (i) choice of a herd structure that will ensure production of sufficient quantities of milk; (ii) good milking practices that will minimise completion for milk between man and camel-calf; (iii) diagnosis and control of important camel disease; and, (iv) importance of use of experienced labour in grazing of camel herds.
- Whereas significant investments have been made in upgrading and modernising markets for live animals and meat in northern Kenya, limited attention has been given to marketing infrastructures for milk. The county governments should therefore consider investing in camel milk bulking and cooling facilities in strategic areas, as this will most likely provide more impetus for increasing uptake of camels as a climate change resilient livelihood option for pastoral households in northern Kenya.

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