ORIGINAL RESEARCH ARTICLE

Risk factors predisposing dromedary camels and pastoral communities to zoonotic diseases in Kenya

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ABSTRACT
Dromedary camels have coexisted with humans throughout civilizations providing versatile life-sustaining benefits and serving as heritage in the Arabian Peninsula and the Horn of Africa belt. Like other livestock that show close resilience to harsh environmental conditions, camelids suffer from tropical diseases, which jeopardize their productivity. This study aimed at assessing the potential risk factors predisposing dromedary camels to tropical diseases and the vulnerability of key populations to zoonotic diseases in Kenya. We conducted a stratified random sampling aiming for at least 15% of the camel population in the area (for camel herd > 20 camels). For small herds (<20 camels) every camel was considered for inclusion. Attempts were made to evenly represent the sex distribution of camels. Live camels (n=1625) were randomly selected across the 13 counties and checked for the presence or absence of clinical signs indicative of the disease state. Human respondents (n=602) were also randomly selected for interviews to assess the level of interaction between humans, camels and other livestock. The study showed that 80% of the respondents were unaware of zoonoses and 20% of those who knew about it did not consider it as a significant risk.

Sixty-three percent of the respondents interacted directly with camels at home, while 37% had no camels in their homestead but reported to have interacted with camels and have used their products. Additionally, a significant correlation between migrations (OR=0.8, p=0.01) and acquisition of diseases was identified. Camels that used wells as the source of drinking water showed an increased risk of acquiring an infection (OR=1.49, p=0.01), while grazing camels mixed with other livestock increased the likelihood of disease transmission by 13-15%. Taken together, the findings suggest existence of significant risk factors that drive zoonoses across the camel rearing ecosystems.

Keywords: Climate change, Herders, Horn of Africa, Livestock, One-Health, Zoonoses.

1.0 INTRODUCTION

Camel rearing practices have rapidly taken a new dimension in Kenya in the last three decades, revolutionizing livestock production in a way other animals have failed to achieve in their domestication history (Watete et al., 2016). The dromedary camel population has increased significantly to about 3 million. Resilience to hot climate and tolerance to tropical diseases preferentially make camels ideal livestock of choice in the drier part of Kenya (Kagunyu & Wanjohi, 2014; Kuria et al., 2016; Watson et al., 2016).

Traditionally, camel husbandry is practiced in the northern part of the country's low-altitude areas characterized by arid and semi-arid climate. However, new frontiers are opening in higher altitude-wetter areas non-traditional for nomadic and transhumance lifestyles in Kenya (Watson et al., 2016).

There are a couple of reasons burgeoning this new paradigm but two events are conspicuous in accelerating the transformation; the desertification process and food insecurity (Dijkstra, 2017). Pastoral communities in Eastern and North-Eastern regions of Kenya have begun diversifying cattle with camels to cushion themselves from economic losses encountered during drought and endemic disease outbreaks where herders are left impoverished when cattle succumb to deaths (Kagunyu & Wanjohi, 2014). Through the government and non-governmental organizations (NGOs) camels were introduced and distributed to wetter southern rangelands and higher altitudes areas in an initiative aimed at bettering food security in the arid and semi-arid lands (ASALs) of the country (Bukachi & Njiru, 2003; Kipsang, 2013). These two reasons have increased the camel population into new environments.

Traditional camel rearing areas of Kenya are contiguous with the Horn of Africa where several diseases outbreaks both zoonotic and non-zoonotic with life-threatening outcomes have been reported (Doosti et al., 2012; Erster et al., 2018). For instance, Acute Camel Death Syndrome first reported in Ethiopia and Somalia was also identified as an outbreak with temporal pattern that indicates seasonal risk in the Northern part of Kenya (Gitonga, 2017). Kenya has been identified as the epicenter for rift valley fever; a mosquito-transmitted viral disease that infects livestock and humans (Mario et al., 2008). Studies have demonstrated that apparent healthy camels are carriers of zoonotic diseases and act as reservoirs for endemic diseases of livestock (El-Sayed et al., 2008; Lamuka et al., 2018). Also, they carry pathogens with zoonotic potential. A study by Ommeh et al. (2018*)* identified widespread seroprevalence of Middle East respiratory syndrome coronavirus (MERS-CoV) in Kenyan dromedary camels. Moreover, camels also harbour pathogens transmissible between con-specific and hetero-specific species. A possibility of pathogen co-circulation in the herd and multiple virus co-infection with novel viruses was observed in camels (Zhang et al., 2019). A recent study by Browne et al. (2017) confirmed the existence of *Coxiella burnetii*, a zoonotic pathogen in camels living in Laikipia County.

Pressure on scarce resources has triggered the pastoralists from larger ASALs regions to migrate southwards in search of water and pastures (Dijkstra, 2017). Invasion of camel to new environments has profoundly increased camel-human-wildlife interactions. The migration paths involve stopovers at various national parks, conservancies, and spill-over into private farms where herders graze and water their camels (Mghenyi, 2018). Camels interact with wildlife in national parks and ranches, with a possibility of contracting and carrying wild disease pathogens. Apart from the occasional conflicts between the pastoralists and the locals, the residents are forced to share water sources with camels (Mghenyi, 2018; Mkanyika, 2018; Nzengu, 2013). Camel can easily spread diseases to other livestock and humans through drinking water contaminated with camel urine and feces, consumption of raw and unpasteurized milk products, and improperly cooked camel meat (Njeru et al., 2016). In communities, where the drawing of blood from the live animal is common, the introduction of camels as livestock in the area compound this risk of zoonosis. Until recently, dromedaries were considered hardy animals which are resistant to diseases affecting herbivores in the same ecological zone. This notion propagated abandonment of research in camel diseases, a trend that is currently reversing, owing to the realization of the significance camels have in the region (Mochabo et al., 2006; Watson et al., 2016).

Epidemiological data on the probable risk factors for zoonotic diseases in ASALs of Kenya is scanty. And where there are considerable efforts, the research is directed at assessing the zoonotic vulnerability of humans stemming from human-camel-interaction. One study by Dirie and Abdurahman (2003), presented a perspective of pastoralists on common diseases in northern Kenya and their veterinary knowledge in a cultural setting. Another review by Njeru et al. (2016), presented

factors fostering pathogen transmission, prevalence and spread of Q-fever. However, this review only focused on *Coxiella burnetii* and disregarded other important zoonotic diseases in circulation. At present, no country-wide study focusing on camel vulnerability to diseases has been done in the Kenyan camel rearing ecosystem. Unfortunately, the camel-rearing counties are also mapped as hot-spots for outbreaks of livestock diseases hence putting camels at greater risks (Bird et al., 2008; Gikonyo et al., 2018; Gitao, 1994, 1997; Oyas et al., 2018). Prescient knowledge of disease transmission patterns in camels is quintessential to decipher risk factors likely to compromise dromedary camel husbandry in Kenya.

2.0 MATERIAL AND METHODS

2.1 Study Area

The study was done in thirteen (13) counties of Kenya where camel husbandry is practiced on a large scale (*Table 1*). The selected counties are subsets of Northeastern, Rift Valley and Eastern regions of Kenya characterized by nomadic lifestyle. The camel rearing regions in the ASALs are contiguous with South Sudan, Ethiopia, and Somalia, forming a single ecosystem where camels rearing is a cherished way of life (*Fig. 1*).

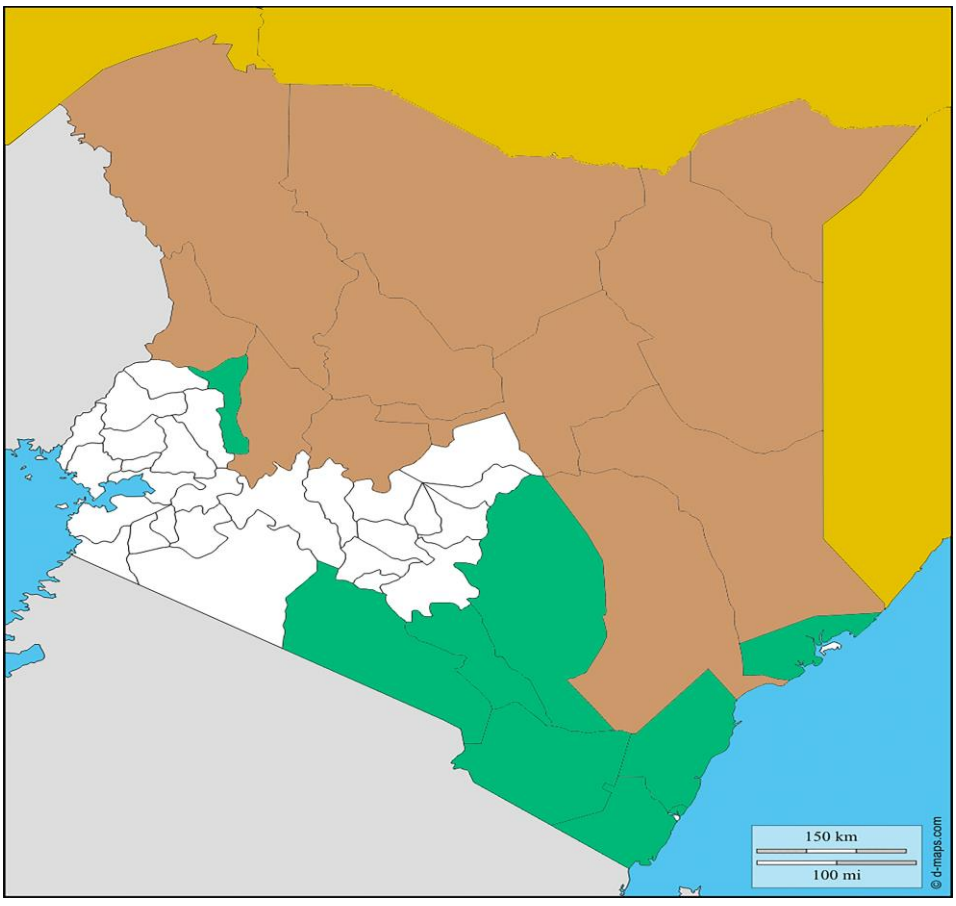

Figure.1: A map of Kenya. Brown color show counties that traditionally keep camels. Green color indicates nontraditional camels rearing counties. Yellow color indicates contiguous neighboring countries known for camel keeping.

2.1.1 Data collection

The data was collected using semi-structured questionnaires from selected pastoralists and people who had interacted with camels in their day-to-day life. A study consent was also sought from each respondent. For human respondents, the sample size was calculated using infinite population, where 20 samples are required to detect a disease with 95% chance when the actual prevalence is < 5% (Simpson et al., 2018). The distribution of respondents was based on interaction capacity with camels and willingness to participate. Six hundred and two respondents across 13 counties were interviewed for their interaction capacity with camels *(Table 1*).

Table 1. Displays the sampling sites grouped according to county and sub-counties both for camels selected for the study and human respondents.

County	Sub-county	Sampling Site	Camel	Human
Turkana	Turkana central	Lorengelop	45	25
	Turkana central	Nang'urichutu	31	13
West Pokot	Kacheliba	Serewo	20	14
	West Pokot	Chepkerem	10	15
	West Pokot	Simatu	16	12
	West Pokot	Chepruporko	24	-
Isiolo	Isiolo	Chumbiere	104	48
Laikipia	Laikipia north	Loll-Daiga Ranch	50	-
	Laikipia west	Rumuruti	36	6
Samburu	Samburu central	Camel Derby association	17	-
	Samburu central	Barsaloi	97	44
Baringo	Tiaty	Barbello	15	-
Marsabit	North Horr	Uranura	13	-
	North Horr	Galasa	50	14
	North Horr	North Horr	56	5
Mandera	Mandera west	Tabaka	151	18
Wajir	Wajir west	Argane	144	46
Garissa	Lagdera	Eloy-Modogashe	131	6
	Dadaab	Arango Arba	16	33
	Dadaab	Hagadeera	47	22
	Garissa	Garissa market	55	-
	Garissa	Iftin	100	52
Tana River	Tana North	Boka wells	100	62
	Tana north	Bangali open market	211	135
	Tana north	Bangali watering dam	60	32
Kitui	Kitui south	Thua	20	-
Kibwezi	Kibwezi west	Kiboko	6	-

Three respondents did not complete the interview process. We conducted a stratified random sampling aiming for at least 15% of the camel population in the area (for camel herd > 20 camels). For small herds (<20 camels) every camel was considered for inclusion. Attempts were made to evenly represent the sex distribution of camels. A total of 1625 live camels were selected for clinical observation regarding disease symptoms. The symptoms considered were nasal discharge, coughing, lacrimation, diarrhoea, cases of abortion, emaciation, and elevated body temperatures. In cases where the diseases are known to be present in an area, the use of clinical signs coupled with indigenous knowledge for diagnosis can be considered, especially in rural areas (Dirie & Abdurahman, 2003). The data was collected from March 2016 to April 2019.

2.1.2 Statistical analysis

Data from the questionnaires were entered into spreadsheets and organized using Microsoft Excel software (Microsoft office 2013). Three respondents who did not complete the interview were excluded from the analysis *(Table 2)*. Downstream analyses were done in python (anaconda version 3.7.1). Descriptive statistics were expressed as frequencies and percentages. A logistic regression model was used to assess the possible relationships between potential risk factors and the observed potential disease symptoms on both humans and camel health.

2.1.3 Ethical approval and considerations

Permission for studying camels was granted by the Directorate of Veterinary Services under the State Department of Livestock, Ministry of Agriculture Livestock and Fisheries of Kenya. Permission was also sought from the Chief Officers and County Veterinary departments, and study area chiefs of the 13 counties. The Kenyatta National Hospital/University of Nairobi Ethics and Research Committee approved this study and granted permission for researching human subjects under permit reference number P210/04/2017. Informed consent was obtained from camel owners, handlers, and family members or their guardians (in case of underage children) from whom questionnaires were administered. All institutional and national guidelines for care, handling and use of animals were followed.

3.0 RESULTS

3.1 Human Demographics and univariate analysis

Female respondents constituted 53.8% (n=322) and males 42.2% (n=277). The mean age of the respondent was 36 and 42 years for females and males respectively. Seventy-three percent of all the respondents reported having had a pathogen related illness within one month and 23% reported no illness and were healthy. The majority of the respondents had no formal education (76%), 13% attained primary education (n=76), 9% reached secondary school, and only 2% had attained tertiary education. Fifty-nine percent of the respondents interacted directly with camels at home, while 41% had no camels in their homestead but reported to have interacted with camels in their neighbourhood or have used their products. Results identify sharing water source with camels, camel rearing practice, migration from one place to another, and direct interaction with camels ($p<0.05$) as significant risk factors that increases the vulnerability of herders to zoonotic diseases (*Table 2*).

Table 2: Displays humans-camels interactions and potential risk factors for zoonotic diseases transmission.

Potential Risk Factors	proportions	Odd Ratios (OR)	P value
Gender of the respondent			
Male	277(42.2)	1.2995	0.118
Female	322 (53.8)	1.3000	0.020
Level of Education			
None	455 (76%)	1.823	0.516
Primary	76 (13%)	0.869	0.611
Secondary	56 (9%)	0.968	0.924
Tertiary	12 (2%)	0.354	0.773
Any knowledge of zoonoses in camels or human			
Yes	120 (20%)	0.578	0.072
No	399 (80%)	0.623	0.083
Sharing water sources with camel			
Yes	479 (80%)	0.8135	0.004
No	120(20%)	0.0364	0.033
Migration or long-distance travel			
Yes	48(8%)	1.6882	0.029
No	551(92%)	0.7431	0.002
Animals interacted with in the homestead			
Camels	375 (62.6%)	1.0649	0.035
Cows	338 (56.4%)	0.9292	0.664
Goats	297 (49.6%)	1.1481	0.409
Sheep	328 (54.8%)	1.0543	0.753
Donkeys	331 (55.3%)	1.2305	0.218
Chickens	454 (75.8%)	1.0130	0.947
Others (dogs, cats, rats, bats)	398 (66.4%)	1.1430	0.448
Direct interaction with camels			
Often milked camels	287 (48%)	1.4132	0.000
Occasionally consumes raw milk	351 (57%)	1.0836	0.024
Often treat sick camel	179 (30%)	0.4274	0.035

The possible relationships are predicted as odd ratios and the significance values expressed as p values.

3.1.1 Human Interaction with Livestock

Camel herders had a 6% increased chance of manifesting disease symptoms as opposed to people who reared other livestock animals. Herders who often milk camels and people who occasionally consume raw unpasteurized camel milk are 1.4 and 1.08 times at risk respectively as compared to those who do not while involvement in treating sick camels increases the risk of contracting the disease by 42%. The gender of respondents and interaction with other animals whether at home in the neighbourhood showed no significant association.

3.1.2 Camel characteristics and univariate analysis

From the results, female camels constituted 66% versus males 34%. The proportions of camel age categorized as adults was 69.3 %, sub-adult 7.3% and juvenile 23.5%. Among the female adult camels that were scrutinized for any disease symptoms, 39.5% was pregnant at the time of the survey. Camels that showed disease syndromes were 78.6% versus 21.4% which manifested no noticeable symptoms *(fig. 2*).

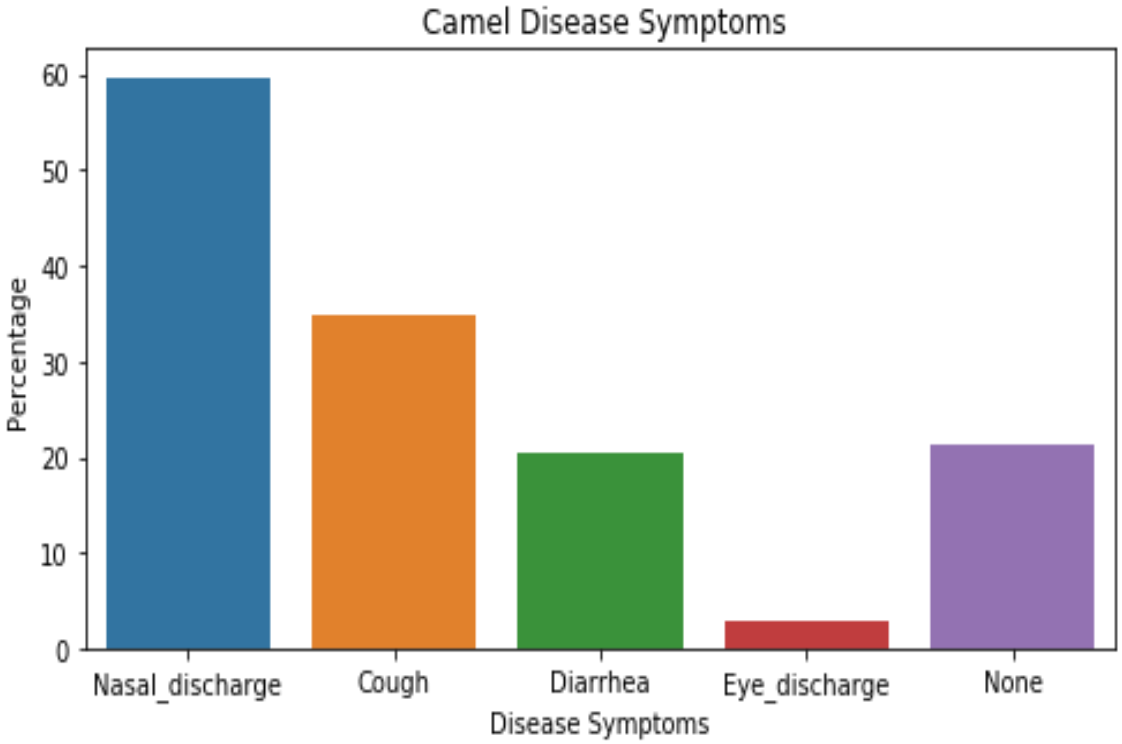

Figure. 2: Bar graph showing percentages of observed disease symptoms in camel

All variables under consideration showed a significant association ($p<0.05$) except the age of camels that were classified as sub-adults, interaction with goats in grazing areas, pregnancy status and the source of camels (*Table 3*).

Table 3: putative risk factors predisposing camels to diseases, Odd ratios and their p-values.

Potential Risk Factors	**Proportions**	**Odd Ratio (OR)**	**P value**
Sex of the camel			
Male	553(34%)	0.5994	0.000
Female	1072(66%)	4.4416	0.000
Age of camels			
Adults (> 2 years)	1126(69.3)	3.398	0.000
Sub-adults (6 months–2 years)	117(7.3%)	0.8163	0.359
Juvenile (≤6 months)	382(23.5)	1.5484	0.005
Pregnancy status:			
Yes	317(29.6%)	2.273	0.554
No	485(70.4%)	2.509	0.622
Sources of drinking water			
Rivers	406(25%)	0.7206	0.029
Dams	1314(80.9%)	0.6081	0.013
wells	350(21.5%)	1.4899	0.043
Migration or long-distance travel			
Yes	1177(72%)	0.7950	0.000
No	448(28%)	0.5361	0.0652
Other animals in homestead			
Cows	1156(71.2%)	0.4089	0.000
Goats	1078(66.3%)	1.1334	0.498
Sheep	691(42.5%)	1.5231	0.021
Donkeys	588(36.25%)	0.3497	0.000
Chickens(poultry)	847 (52.15%)	1.3274	0.047
Camel (intercept)		7.27	-
Source of individual camel:			
Restocking	1516(93.3%)	0.6533	0.522
Purchase from the open market	52(3.2%)	1.0421	0.642
Purchase from friend/gifts	57(3.55)	0.6642	0.965
Mode of treating sick camels			
Self-medicate camels	1568(96.5%)	0.6902	0.005
Friends in the neighborhood	1059(65.2%)	0.6403	0.001
Trained vet services personnel	1032(63.5%)	0.2225	0.013
Spraying of camels to combat ticks			
Yes	299(18.4%)	0.538	0.045
No	1326(81.6%)	0.764	0.032

3.1.3 Putative Risk Factors for Disease transmission in camels

In the current study, 72% proportion of the camels migrated or travelled traveled for long distances and this increased the chances of disease manifestation by 80%. Dromedary camels are constantly on move to regions inaccessible by veterinary personnel, hence necessitating herders to self-medicate their sick camel or to assistance from fellow pastoralists. Although this seemed to reduce the transmission rate by 30-36%, the use of trained personnel showed a significant reduction by 78%. Camels grazed separately showed an odds ratio of 7.3 suggesting that disease transmission is from camel to camel as opposed to interaction with other livestock animals in the households or neighbourhood. The alternative explanation can suffice that symptoms manifested are for diseases exclusive for to the Camelidae family. Camels that drink water fetched from wells had 49% (OR 1.49) increased chances of showing disease symptoms than other water sources while camels watered through rivers and dams are 28% and 39% less likely to become infected with diseases respectively. It was noted that some pastoralists fetched water from wells into drinking troughs to water camels while others reused these watering troughs hence increasing the risk factors for disease transmission.

This study has shown a positive correlation between goats (OR=1.13), sheep (OR=1.52), and chickens (OR=1.33) with a disease incidence rate in the studied region. The study also showed 46% increased chances of a camel to withstand persisting with the disease following spraying and improving hygiene.

4.0 DISCUSSION

Mixed grazing of cattle, sheep, goats, donkeys, and camel have been practiced for many years in rural open fields (Kagunyu & Wanjohi, 2014; Paling et al., 1979). However, this tradition always has pros and cons, in which the latter is devastating especially in a disease outbreak, which may wipe out an entire herd. Most diseases in animals are transmissible across livestock species (Libeau et al., 2011; Megersa, 2010). A study conducted by Chengula et al. 2014 showed that camel has contracted rift valley virus from goats in Eastern Africa belt. Foot and mouth disease, which previously infected cloven-hooved animals, has now acquired both Bactrian and dromedary camel species as new hosts. Mixed grazing predisposes camel to diseases and provides a rich reservoir for pathogens in the herd (Doosti et al., 2012; Megersa, 2010). Grazing livestock together complicates disease control strategies as evidenced by the emergence of the PPR virus in unusual camel's host, which ought to be eradicated from small ruminants by 2030 (Omani et al., 2019). Camels ingesting chicken droppings as a source of urea supplementation can explain a positive correlation between chicken and transmission of disease to camels. Chicken droppings from infected poultry may contain enteric viruses, bacteria, and protozoans and worms, which may develop enteric diseases in camels especially calves (Kagunyu & Wanjohi, 2014; Ogali et al., 2018). Identification of Astroviruses and Circovirus in poultry faces in various parts of the world underscores this risk in livestock and camel husbandry in general (Li et al., 2010).

Herders who kept camels alone also kept them in huge herds. Overstocked animals rarely receive proper attention such as vaccination and proper hygiene partly due to the costs involved and the rigorous nature of the exercise (Kuria et al., 2016). In Qatar and Saudi Arabia, overstocking of camels is an issue, where everyone wants to keep camels because other livestock animals are harder to keep due to a hot climate (El Wathig & Faye, 2016). A similar reality is observed in southern Ethiopia, Sudan, and Algeria (El-Sayed et al., 2008; Ghoneim et al., 2017; Mohammed et al., 2014).

Kenyan camel population is in constant migration and traverse a wide area across counties and may contract infections from areas that are endemic for certain diseases. Disease outbreaks in particular regions leave behind etiological agents in the soil that may persist for a long time such as anthrax, *rift valley fever phlebovirus*, and *small ruminant morbillivirus* previously called *Pestes des petits ruminants (PPR) virus* (Libeau et al., 2011). When camels traverse through disease-endemic areas they may acquire new infections and possibly introduce them to new destinations and this may bolster disease incidence rate.

Diseases and theft were both identified as the most significant challenges experienced by pastoralists with 93.3%. Communities rearing camels in Kenya are associated with cultural practices such as raiding, which may introduce infected camels into a clean herd (Kagunyu & Wanjohi, 2014). It is surmised that these stolen animals are kept in pastureland for a long time and are rarely vaccinated against disease (Bett et al., 2009). Noteworthy, 4.7% who did not cite theft or veterinary services as problems also happened to rear their camels in fenced ranches. A low number of pastoralist consulting trained personnel correlate with observation that the majority of people cited veterinary services as one of their main challenges. Also, pastoralists seldom seek immunization services unless camels show clinical symptoms of diseases. Poor hygiene was correlated with camel mastitis in Marsabit and Wajir County (Lamuka et al., 2017).

A hundred percent of respondents that cited water scarcity, drought and disease outbreaks underscores the vulnerability of camel in arid areas. ASALs areas receive sporadic rain, and therefore water and pastures are always scarce. However, flash floods in deserts and plains when it occurs leads to loss and spread of diseases to new areas that were devoid of outbreaks (Chengula et al., 2014). After the flood deluge, a great expanse of land become infected with pathogens that were previously unknown in that region. Floods also facilitate the reproduction and spread of disease vectors such as mosquitoes. Water bodies and pastures become contaminated with waterborne diseases. Arthropod vectors such as tick and fleas create integument breaches that act as a route of entry for internal pathogens hence paving way for infections. The increased population of mosquitoes, biting flies, and ticks at a particular period of the year has been associated with certain disease outbreaks (Gitonga, 2017).

5.0 CONCLUSION

This study found that diseases risk factors in traditional and emerging camel-rearing areas were commonplace. Migration behaviours of camel herders, neglect of physical hygiene, sharing of drinking water sources, lack of proper control of external parasites fundamentally increased the incidences and transmission rate of disease pathogens. Moreover, camel herders had little knowledge not only of the potential risks posed by disease circulation in the herd but also the zoonotic potential of the livestock diseases. Hence, camel handlers, their families, veterinarians among others who interact closely with camels are at a higher risk of contracting zoonotic diseases in camel rearing regions. The results outlined in this work are important to Kenya, a low middle-income economy, where the camel is categorized as emerging livestock with a promising potential to avert food insecurity by producing milk and meat against a backdrop of climate change. Although the camel population has increased tremendously, and new lifestyles such as sedentarisation and peri-urban camel husbandry are emerging, the disease challenge and the underlying factors will continue to undermine camel productivity and threaten human health. The outputs in this work will go a long way in informing sound management practices and evolving strategies for a healthy population to realize the full potential of camel productivity.

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