Camel Production in Kenya; Do they have *Ehrlichia*?

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**Abstract**

The global population of camels is approximately 30 million and 80% of this is found in Africa whereby 60% occupy the horn of Africa. Kenya is the third country in Africa with the largest population of dromedary camels and 57% of this population is found in Arid and Semi-arid lands (ASALs) of the Northern region. They are a source of livelihood to the pastoral communities in terms of milk, meat, transport and income through sale and because they are hardy and resilient to climate change, they are likely to replace other livestock in these regions. Despite their contribution to the Gross Domestic Product (GDP) and per capita income, they are faced with many challenges including tick infestation and Tick Borne Diseases (TBDs). *Ehrlichia* infections are tick-borne bacterial diseases that have been reported in camels elsewhere but there are no studies that have been carried out in Kenya to confirm them and provide information on their clinical manifestation. This paper highlights camel population and distribution, adaptation, economic significance and the studies that have reported *Ehrlichia* infections, risk factors, clinical presentation as well as diagnosis of this condition in camels. There is therefore need to carry out research on this disease to describe clinical and molecular presentation in dromedary camels in Kenya.

**Keywords:** Dromedary Camels; Tick Infestation; *Ehrlichiosis*; Kenya

**Introduction**

The camel belongs to camelidae family in the order of Artiodactyles sub-order of tylopoda (animals with padded feet). They comprise two main types (large and small camelids) distributed into three genus: *Camelus*, *Lama* and *Vicugna* [1]. The small type originated from Andin Mountains of South America includes two domestic species (*lama* and *alpaca*) and two wild species (guanaco in genus *lama* and *vicuna* in genus *vicugna*). The large type are represented by two domesticated species, the one-humped camel (dromedary) and the two-humped camel (Bactrian camel), the first living in the hot arid lands from North of Africa and eastern part of Asia, the second in the cold steppes and deserts in Central Asia [1]. There is a new large camelids that has been described in very remote areas between Mongolia and China, called Tartary camel (*C. bactrianus ferus*) which was distinguished from the domestic double humped camel [2]. Camels occupy the remote areas, arid or semi-arid lands or high mountains and this has been linked to the high adaptation of those species to their ecosystem [1]. The population of camels worldwide is difficult to exactly determine because they are mainly animals of nomadic people and pastoralists who are moving frequently and secondly because there is no obligatory vaccination therefore the exact number is not known. Food and Agricultural Organization in 2011, estimated around 25 million heads though there has been adjustments in the Sahelian countries (Mauritania, Mali, Niger, Chad, Sudan, Ethiopia) and this has changed this figure. For example in Chad, Ministry of Animal Resources readjusted the camel population from 800,000 to more than 1.3 million heads after appropriate census therefore the current camel world population is probably around 30 million heads [1]. More than 80% of global camel population is found in Africa with around 60% in the...
Horn of Africa. The order of countries with camels as an important part of their economy has been ranked; Somalia, Sudan, Kenya, Ethiopia, Niger, Mauritania, Chad, Mali and Pakistan with estimated increase of 3.4% per annum even though this growth rate is not similar with all the countries [1]. Globally and within the continent, Somalia holds the highest dromedary camel population with over 7 million herd followed closely by Sudan (4.7 million), Kenya (2.9 million), Niger (1.7 Million) and Mauritania (1.4 Million) [1].

Camel farming depend on the climatic and agro-ecological conditions, desert countries like Mauritania the farming is all over the country but in semi-arid regions, specific small areas are devoted to camel keeping like in Ethiopia, where only the lowlands are occupied by dromedary camels and arid lands of China are occupied by Bactrian camels [1]. Introduction of camels to countries which did not have them was either for leisure (e.g. in circus or zoo gardens) or for rearing for various purposes including tourism attraction, walking in beaches or milk production [3].

The camel is a multipurpose animal that can provide milk, meat, wool, transport, race, tourism, agricultural work, and beauty contest and there is no other animal that can provide varied services to humans [1]. Milk and meat production are the principal purposes for camel rearing in many countries especially for Dromedaries. The camel meat represents 0.13% of the total meat produced in the world and 0.45% of red meat from Herbivorous [1]. Camels have slow reproductive cycles long gestation (13 months), late precocity for reproduction (rarely before 3 years), and long intercalving interval (generally 2 years) [1]. Moreover, the survival rate of the young being low (the young mortality could reach 20% and even more), the numerical productivity is weak, even if the longevity of the camel could compensate it [1].

Adaptation of camels

Camels are hardy animals that can walk for up to 60 km carrying 250 kg on their back in a day. They survive in hot and dry conditions of the desert with anatomical and physiological adaptations [1]. The features such as hump act as a reserve of fatty tissues that is broken down to energy and water preventing starvation and dehydration. They also have third eyelid, double layered eyelashes, and nostrils that can close completely that protect them from sand storms and dust [1]. They also have large heavily padded flat feet that provide cushioning and a thick sandy colored skin for insulation and camouflage. Physiologically the camel can withstand variation of ambient temperature by losing too little water in feces and urine.

Milk from camels is highly nutritious and thus more superior to milk from other species however, it contributes less than 1% of the global amount of milk. The high protein level (4.02%) also increases the keeping quality especially in marginalized regions with poor hygienic measures in milk production [1]. Moreover, the milk contains insulin-like substances that boosts immunity, reduces blood sugar levels, reduce lactose intolerance and it improves blood circulation. In typically dry areas of Afar in Ethiopia, Dankil camels (4 - 5 liters) have been documented to produce more milk compared to local Afar zebu cattle breeds (1 - 1.5 liters) [1]. Generally, a healthy camel with proper feeding and management produces an average of 2000 liters of milk in each lactation period [1]. Camel meat consumption has increased of late and camel butcheries are on the rise in Northern, Eastern and Western Africa. An adult camel carcass can weigh between 250 and 400 kg. The camel meat has low cholesterol level, high protein contents and a peculiar taste [1].

In Kenya, camel population was estimated in 2009 by the Kenya National Burea of Statistics at 2.9 million in 2009 placing it the third largest camel population in Africa, behind Somalia (7M) and Sudan (4.7M). There are four breeds of camels reared in Kenya; Turkana, Somali, Rendille/Gabbra and the Pakistani breeds though this was based on phenotypic characteristic rather than molecular genetics [4]. The total camel milk production was estimated at 200 million liters and meat at 700 tonnes per year, worth of around KES 2 and 1 billion respectively. In Kenya, processed camel milk has been packaged and is available in the supermarkets. However, other processed products such as yoghurt, cheese and ghee as well as traditional fermented products are also available elsewhere [1].
However, camel production in Kenya has been faced with a number of challenges ranging from poor nutrition, infectious and non-infectious diseases to inadequate veterinary services. In a study to determine community perception on the common disease affecting dromedary camels in Turkana district, Trypanosomosis (11.4%), mange (10.8%), tick infestation (7.9%), hemorrhagic septicemia (7.7%) and non-specific diarrhea (7.6%) were reported [5]. Similarly [6] reported predation (50.9%), drought (28.7%), and diseases (20.4%) as the major challenges facing camels in Samburu district. Therefore, the existence of ticks and reports of infectious diseases in dromedary camels in Northern Kenya warrant research to single out the presence of *Ehrlichia* bacteria and associated determinant factors.

The *Ehrlichia* infection

*Ehrlichiae* are tick-borne small, nonmotile, pleomorphic, gram-negative, obligatory intracellular bacteria that infect leukocytes appearing as minute cocci in the cytoplasm [7]. *Ehrlichiae* and *Anaplasma* are bacteria from the order *Rickettsiales* and family *Anaplasmataceae* with four genera of veterinary importance namely: *Ehrlichia*, *Anaplasma*, *Neorickettsia* and *Wolbachia*. The new reorganization has been based on the identification of 16s rRNA phenotypic similarities [8]. All bacteria in the *Anaplasmataceae* family are obligate intracellular organisms that replicate within cytoplasmic membrane-bound vacuoles of vertebrate mature or immature blood cells with invertebrate vector hosts except *Wolbachia* bacteria [9]. The new nomenclature of these organisms that is considered globally fall in the above four genera with expansion to accommodate other species. *Anaplasma* comprises of *Anaplasma (Ehrlichia) phagocytophila* (including *E. equi* and Human Granulocytic Ehrlichiosis agent (HGE), *Anaplasma (Ehrlichia) bovis* and *Anaplasma (Ehrlichia) platys*, *Ehrlichia* genus to comprise *E. ruminantium*, *E. canis*, *E. chaffeensis*, *E. ewingii* and *E. muris*, *Neorickettsia* genus to include *E. risticii* and *E. senettasus* while *Wolbachia* genus has *W. pipientis* species [8].

The five species in the *Ehrlichia* genus have been grouped as ‘*E. canis* genogroup’ and have been implicated to infect ruminants, horses, dogs, cats and even humans.

*Ehrlichia* and *Anaplasma* have long been documented in domestic and wild animals but their identification in humans has raised an alarm [10]. The high occurrence of these bacteria could be attributed to advances in technology in regards to diagnosis, surveillance and climate change that has affected the reservoir host and vector dynamics [10].

Pathogenesis

The *Ehrlichia* bacteria enter the host cell through phagocytosis and are enveloped within the cytoplasmic vacuoles of mononuclear phagocytic cells (leukocytes) where they form endosomes (membrane bound loci) that ensure their survival in the cytoplasm [11]. In the host cells, they multiply within the endosomes through binary fission to form elementary clusters called initial bodies and further growth and replication form vacuole-bound colonies commonly known as morulae (Latin word for mulberry meaning clusters of dividing cells). An infected monocyte can contain 1 or 2 morulae that has/have the ability to survive within the host cell by suppressing the host signal transduction pathways that would lead to their recognition [7]. The morula stains dark blue with Romanovsky-type stains and the presence of these clusters in the cytoplasm is characteristic for this bacterial infection [11]. The multi-systemic nature of Ehrlichial infection in both human and dogs has been illustrated as the cause of multiple organ infection [12]. In human, infected mononuclear cells with this bacteria have been isolated in the spleen chords, liver, lymph nodes and periartheriolar sheaths [11] whereas in canine, *Ehrlichia* DNA have been extracted from the lymph, spleen and kidneys cells and in chronic cases from the bone marrow [7].

Transmission

The transmission of this bacterium to both animals and humans is through the bite of an infected tick and therefore is one of the plethora zoonoses. The cyclic transmission of this bacterium maintains it in the tick population and ensures continuous transmission be-
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There is a wide range of vertebrate hosts and therefore a large source of infected blood for ticks [12]. White tailed deer (*Odocoileus virginianus*) has been documented as the primary reservoir for *E. chaffeensis* because it is naturally infected and can sufficiently maintain the transmission cycle [11]. However, dogs and goats have also been recognized as important reservoirs for *Ehrlichia*. These three hosts have been implicated as sources of infection to humans as they are regularly exposed to tick and their close proximity to humans [11]. Ticks play an important role in the transmission process as they carry bacteria to and from multiple hosts when they are feeding. The lone star tick *Amblyomma americanum* and the brown dog tick *Rhipicephalus sanguineus* have been documented as the common transmitting agents for *E. chaffeensis* and *E. canis*, respectively [12]. The newly hatched larvae of these ticks are not infective because transovarian transmission is inefficient but they become infected by feeding on an infected host and the subsequent nymphal and adult stages can mount an infection in naïve reservoir, canine or human hosts [11,12].

Ehrlichial infection in camels

Serological studies have shown that dromedary camels are infected with *Anaplasmataceae* bacteria (*A. marginale* and *A. phagocytophilum*) in Tunisia [13] but molecular characterization of the species involved in East Africa is scanty. In a molecular study carried out in Saudi Arabia on spleens of dromedary camels, *Ehrlichia* (4%) and *Anaplasma* (26%) lineages closely related to *E. canis* and *A. platys* respectively were identified [14]. Elsewhere, a camel bull has been reported to have died from a mixed infection of *E. ruminantium* and trichuriosis in National Animal Production Research institute farm in Nigeria [15]. *Ehrlichia ruminantium* infection was diagnosed when purple colonies were identified from capillary endothelia cells in the hematoxylin/eosin stained histopathological sections of the brain [15]. This infection in camels is rare and the literature is scarce though there are reports that they could be infected but the results are not proven as stated by the Centre of Food security and Public Health (2015). However, *Ehrlichia ruminantium* was thought to be restricted to cattle, sheep and goats [16] but it has been diagnosed in other species [15]. Clinical diagnosis for this infection is difficult through conventional means and therefore postmortem [15], serology and molecular methods [16] have proven to be significant in identifying these bacteria.

Other *Anaplasmataceae* bacteria have also been documented in dromedary camels. *Anaplasma platys* was identified in 61% of camels sampled in a study in Nigeria [17], a bacterium that has been considered as a dog pathogen. However, it has been documented in other species, cattle [18], sheep [19], cats [20], camels [14,17] and even in humans [21].

The tick, *Rhipicephalus sanguineus* has been implicated to play a huge role in the transmission of this bacterium [22] and even though it is a dog tick, it has been found in other animals including camels [23]. The cross-infestation of ticks in multiple hosts has led to identification of pathogens that were initially considered to have host specificity in other species that had been documented before. For example, *Theileria ovis* (12.6%) has been detected in dromedary camel blood in Egypt [24] and in North Central Nigeria; DNA extracted from blood of a dog has shown 98% identity with *Theileria ovis* [25]. *Theilolarai ovis* is transmitted by *Hyalomma* and *Rhipicephalus* ticks which both have a wide range of hosts including camels [23]. Even though female camels have been found to harbor more ticks than males [26], sex has not been documented to influence the establishment of TBDs in this species [13]. Therefore, the co-existence of dogs, sheep, goats, cattle and camel together with different species of ticks could be implicated as a cause of identification of new diseases in livestock and even in humans. The 61% prevalence of *A. platys* in Nigeria was attributed to the higher sensitivity of Reverse Line Blot (RLB) PCR method that was used as well as small sample size [17]. Interestingly, *A. platys* has also been isolated from blood from Bactrian camels and ticks (*Rhipicephalus sanguineus* group) in China indicating that even double-hump camels could be infected with this bacteria [27].

The presence of *Anaplasmataceae* bacteria in camels with no apparent clinical manifestation could suggest the possible role of camel as the carrier host of these bacteria [17].

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Risk factors of tick borne diseases (TBDs) infection in camels

Camels are infested with different genera of ticks that feed on their blood and cause anemia, irritation, skin injuries and sometimes tick paralysis [28] in addition to acting as vector for transmission of TBDs [29]. Viral (Crimean-Congo Hemorrhagic Fever Virus (CCHFV) and Bacterial (Ehrlichiosis/Anaplasmosis) diseases have been documented to be transmitted by ticks in camels and have fatal zoonotic potential [17, 28, 29]. Hard ticks including *Amblyomma, Dermacentor, Rhipicephalus* and *Hyalomma* have been isolated from camels and have been implicated in the transmission of Ehrlichial infection [22]. In temperate regions, camel tick population has been found to differ from one season to the other with high levels during summer but in tropical climate they are found all round the year [28].

Sex has been reported to influence the number of ticks on the animal body though it does not necessarily correlate with an Ehrlichial infection [13,26]. Species of the animal has been documented to influence the level of tick infestation and the possible transmission of TBDs as reported in Egypt that cattle (60.5%) were the most infested compared to goats (25.9%), buffaloes (17.8%), sheep (14.8%), and Camels that were free from infestation [30].

Interaction amongst different species of animals and wide variety of tick populations have been attributed to the emergence of new diseases that were initially considered specific to particular species. The identification of *Ehrlichia canis* and *Anaplasma platys* in camels [14], and *Theileria ovis* in dogs [25] is an indication of cross-infection of animals by bacteria from other species. The herd size, age and the use of camels (meat, milk, or transport) have been incriminated as some of the risk factors that influence establishment and spread of diseases. In a serological and virological study of Middle East respiratory syndrome coronavirus (MERS-COV) in camels in Burkina Faso, Morocco and Ethiopia countries indicated that these factors influenced the level of seropositivity [31]. The antibodies were higher in middle/large herd, young animals and in those kept for meat or milk compared to transport camels [31]. Literature on the effects of these factors in establishment and spread of Ehrlichial infection in camel is currently unavailable and therefore is a gap.

Acaricide application in terms of chemical composition, frequency, source and dilution ratio are the main factors that influence efficacy and effectiveness of acaricides in controlling tick population [32]. Chemical composition and dilution ratios have been cited to influence tickicidal activity of acaricide used to control tick infestation in dromedary camels in Ethiopia. Indiscriminate use of acaricide without following the prescribed manuals on dosage and application could be one of the factors that could lead to ticks developing resistance toward acaricides [32]. Amitraz in double concentration revealed 99.1% efficacy in eliminating ticks 72 hours post application in dromedary camels [32]. In extension, these factors influence the tick population on camels and in the environment and therefore have a correlating effect on the establishment of TBDs including Ehrlichial infections.

Pasture management and farming systems have been documented to affect tick population and distribution and have been reported to influence establishment of MERS-COV in dromedary camels in Africa [31]. Farming systems such as intensive, semi-intensive or extensive and pasture management e.g. paddocking, rotational or continuous use have effects on camel immunological status as well as vector development and therefore may play a role in development of Ehrlichial infection.

Therefore, there is need to carry out a research to determine the relationship between these factors and Ehrlichial infection in dromedary camels Kenya.

Clinical manifestation of Ehrlichial infection in camels

Though there are well-documented clinical manifestation of Ehrlichial infections in other species; sheep [19], cattle [18], cat [20], dogs [33] and humans [21]. There is scarce information on the clinical signs and pathogenesis of Ehrlichial infections in camels. This is despite that there have been identification of these bacteria in dromedary camels [14,15,17]. Some literature has identified asymptomatic cases of Ehrlichial infection in camels and has implicated camel as a possible carrier host of the bacteria [17]. In the ASALs with high popula-
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The production of camels, TBDs including Ehrlichial infection, have been associated with a number of clinical signs and have been incriminated as a major challenge to camel health, production, and reproduction [34]. Since little is known about camel Ehrlichial infection, authors have indicated clinical signs of heavy tick infestation in camels as potential clinical manifestation of ehrlichiosis in camels. These include pale mucous membranes, weakness, rough hair coat, stunted growth, emaciation, reduced milk production, and high calf mortality [15, 34]. However, diarrhea was reported in bull camel that died in Nigeria but it had trichuris infection making it difficult to tell the origin of diarrhea [15].

**Post mortem**

Ruminants with ehrlichiosis especially *E. ruminantium* generally have effusions in the body cavities (chest and pericardial), congestion and oedema of lungs and associated lymph nodes as well as the brain [15]. The heart muscles are flabby whereas liver, spleen and kidneys are slightly swollen. Histologically, squashed brain tissue from an infected bull camel in Nigeria showed cytoplasmic purple staining inclusions in the capillary endothelial cells [15].

**Hematological picture of Ehrlichial infection**

An experimental study in naïve sheep inoculated with *E. ruminantium* infected blood in Sudan showed significant reduction in Hemoglobin (HB), Erythrocytes and Packed Cell Volume (PCV) with a gradual reduction of White Blood Cells (WBC) [15]. Thrombocytopenia has been reported as the most consistent sign in both animals and humans infected with *Ehrlichia* bacteria [35] though it has not been documented in camel ehrlichiosis. This has been attributed to a number of factors in the dog including autoimmune reaction [36] pooling of blood in the spleen [37] and suppression of thrombopoiesis in the bone marrow [38]. So far, to my knowledge there is no literature on the hematological and biochemical picture of Ehrlichial infections in dromedary camels.

**Biochemical changes in Ehrlichial infection**

Similar to hematological changes, literature is lacking on the biochemical changes that could be seen in Ehrlichial infection in camels. However, this has been described in other species both in experimental [15] and naturally infected studies [34]. Generally, the following parameters are assessed in serum; serum proteins (albumins, gamma globulins), serum enzymes (alkaline phosphate, alanine aminotransferase), blood urea and creatinine [15].

**Diagnosis of Ehrlichial infection in camels**

Different approaches have been employed in diagnosis of *Ehrlichia* infection in animal and have been found that molecular identification of the bacteria is the most superior method [16]. Giemsa stained blood smear examination to identify cytoplasmic morulae is diagnostic of ehrlichiosis especially in facilities that do not have adequate capacity to carry out advanced approaches. However, the outcome of this method may be unrewarding because of low parasitemia that is frequently observed [38]. Modified Nyindo culture test has been documented to be diagnostic but is expensive for clinical diagnosis and therefore suitable only for research purposes [39]. Post mortem and histopathological examination have shown characteristic pathologic lesions and cytoplasmic inclusion in the capillary endothelial cells in a bull camel that died of *E. ruminantium* [15]. Serological tests have been used to detect antibodies against these bacteria in blood. The first test used peritoneal macrophages from *E. ruminantium* infected mice to check for antibodies of this bacterium from sera of infected animals [40]. However, current serological tests detect immunodominant antibodies of *E. ruminantium* outer membrane proteins (MAP1) using an indirect enzyme-linked immunosorbent assay (ELISA) [41]. Most of these tests have reported false-positive results that have been attributed to presence of closely related members of *Anaplasmataceae* family [42,43]. On the other hand, false negatives have also been documented in cattle due to low levels of antibodies as a result of continuous mild natural challenge such that the tests cannot pick these antibodies presence [44]. Therefore, molecular identification has taken a centre stage in making correct diagnosis and proper characterization of Ehrlichial infection in animals [16].

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Polymerase Chain Reaction (PCR) can be employed either as conventional/direct [45], nested format [46], Reverse Line Blott (RLB) [17], quantitative real-time [47], or loop-mediated isothermal amplification (LAMP) format [48]. The PCR has been used to detect Ehrlichia bacteria in different species of animals; Dogs [33], cats [20], cattle, sheep and goats [16] and in dromedary camels [14,17].

There are gene markers that have been developed to identify bacteria from the two genera, Ehrlichia and Anaplasma and even primers for specific species in animals [14,16,17,33], and humans [21]. Ehrlichia and Anaplasma species related to E. canis and A. platys respectively have been detected in camels in Saudi Arabia [14] and A. platys in camels reared in Sokoto State, North-West of Nigeria [17]. The specific primers, EHR16SD and EHR16SR targeting a 345 bp region of the 16S rRNA of Anaplasma and Ehrlichia genomes respectively have been used to detect the presence of these bacteria from spleen of slaughtered camels in Unizah abattoir; Saudi Arabia [14]. This study detected 26% and 4% prevalence of Anaplasma and Ehrlichia lineages respectively. [17] used the same primers in Nigeria on EDTA blood from camels and found that 61% of the sampled dromedary camels were positive for A. platys. However, in a molecular study to detect Ehrlichia canis in dogs around Nairobi, Kenya, ECC and ECB primers were used to identify Anaplasma and Ehrlichia genera with HE5 and ECANS5 specific primers for E. canis [33] and EHR16SD and EHR16SR have been used to detect Anaplasma platys [9]. The modified pCS20 HHIF and HH2R were used in a molecular study in Sudan to identify E. ruminantium in ruminants [16].

However, there is currently no data available on clinical, hemato-biochemical and molecular presentation of Ehrlichial infections in Kenya despite being the third country in Africa with the highest population of camels. There is therefore need to carry out such studies to fill these gaps as well as to understand the epidemiology of these zoonotic bacteria.

Conclusion

Camels are a source of livelihood to the ASALs communities in terms of milk, meat, transport and income through sale and because they are hardy and resilient to climate change, they are likely to replace other livestock in these regions. Despite their contribution to the Gross Domestic Product (GDP) and per capita income, they are faced with many challenges including tick infestation and Tick Borne Diseases (TBDs). From the review of several documents, Ehrlichial infections in camels have been reported elsewhere but there is no solid findings in Kenya of the same despite the country having around three million heads. This then calls for studies to identify and characterize TBDs (including Anaplasmataceae species) in dromedary camels in Kenya.

Conflict of Interest

None.

Bibliography

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