بسم الله الرحمن الرحيم

كلية الدراسات العليا

SUDAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

College of Graduate Studies

A Cross-Sectional Study on Ticks Infesting Cattle, Sheep and Goats and Associated Risk Factors in Khartoum North, Khartoum State, Sudan

دراسة مقطعية للقراد الذي يصيب الأبقار والضان والماعز وعوامل الخطر المصاحبة في منطقة بحري بولاية الخرطوم- السودان

A thesis submitted in partial fulfillment of the requirements of the degree of Master in Preventive Veterinary Medicine (MPVM)

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March 2020

Dedication

To my family and friends

Acknowledgements

First of all, thanks and praise are to Almighty Allah, The Compassionate and The Most Merciful for giving me strength and health during the period of the study.

I would like to express my deep appreciation to my supervisor **Dr. Naglaa Abd El Hakeem Abass** for her advices, guidance and continuous support.

I would like to thank **Professor Yasir Osman** for his assistance in tick identification. My thanks extended also to **Prof. Mohammed Tajeldin** for his help in data analysis.

I am very grateful to the Ministry of Agriculture, Animal Resources and Irrigation–Khartoum State, especially **Dr. Sir Alkhatim Fadlalmawla** (General Directorate of Animal Health and Epidemic Diseases) for facilitating the collection of samples during the field investigation. I also owe my great thanks to **Professor Shawgi Mohammed Hassan** for his help in tick identification.

ABSTRACT

Tick infestation has direct impact on animal health and production in many parts of the world, including sub-Saharan Africa. Tick infestation causes important economic losses, particularly in tropical and subtropical countries.

A cross-sectional study was conducted from December 2017 to April 2018 to determine the prevalence of tick infestation in cattle, sheep and goats in Khartoum North, investigate the potential risk factors associated with tick infestation in these livestock species. A total of 277 animals of different species (182 cattle, 60 sheep and 35 goats) were selected randomly and examined for tick infestation at 44 farms in Bahri and Sharg Alneel in Khartoum North (Algaili, Wadramli, Wawissi, Samrab, Shigla, Silait, Kafouri, Ailafoon and Kuku). Predesigned questionnaire was used for each examined animal to identify possible risk factors associated with tick prevalence prior to tick collection and collected ticks were further morphologically identified using taxonomic keys.

The highest prevalence of tick infestation was recorded in Bahri area 88.8% and 52.6% was in Sharg Alneel. About 68.9% (191/277) of total observed animals were found infested by ticks with the highest rate in cattle (74.2%) followed by sheep (66.7%) and goats (45.7%). Regarding the associated risk factors, tick infestation was found significant ($P < 0.004$) different among the three species of animals. Old animals (<5 years old of cattle) and (< 3years old of sheep and goats) had the highest prevalence of 87.8% compared with adults (2–5 years old of cattle) and (>6 months–3 years old of sheep and goats) 66.1% and young (> 2 years old of

cattle) and (1-6 months in sheep and goat) 56.1%. Females had slightly higher prevalence of 71.1% compared with the males 59.2%. Crossbred and foreign breed had the highest prevalence of tick infestations of 72.4% compared with local breed 62.0%. Medium herd size had the highest prevalence of tick infestation of 80.7% compared with the small herd size 67.6 % and the lowest reported in the large herd size of 20.8%. Animal kept in semi closed registered the highest prevalence of tick infestation of 95.7% compared with those kept in closed one 59.9%. The prevalence of tick infestation in farms where control of ticks was practiced was greatly less (55.1%) than farms without tick control (90%).There was significant association between tick infestation prevalence and different methods of tick control. Weekly removing of manure decreased the tick infestation prevalence (48.3%) much better than the monthly removing of manure (94.5%). The highest prevalence of tick was reported in summer (83.1%) compared with autumn (60.6%). Distribution of the tick species in different livestock revealed that, cattle were more infested by *Hyalomma. anatolicum,* sheep were more infested by *Rhipicephalus sanguineous* and goats were more infested by *Rhipicephalus e. evertsi*.

From the total count of 2367 ticks (male 1591, female776) collected, three genera and five species were identified of which the dominant tick species was *Hyalomma anatolicum*, *Rhipicephalus e. evertsi*, *Rhipicephalus Sangiuanus* group, *Hyalomma rufipes* and less frequently *Amblyomma lepidum.* Udder was the most tick infested site in cattle (54.5%), ears were the most tick infested site in sheep (70.6%) and tail was the most tick infested site in goats (77.5%).

High prevalence of tick infestation reported among examined cattle, sheep and goats population was in Khartoum North. Animal species, age, herd size, housing type, tick control, control method, removing of manure and season were considered risk factors for tick infestation prevalence. *Hyalomma anatolicum* was the most common tick species infesting ruminants in the study area.

ملخص

تؤثر الإصابة بالقراد تأثيراً مباشراً على صحة الحيوان وإنتاجه في أجزاء كثيرة من العالم ، بما في ذلك أفريقيا جنوب الصحراء الكبرى. الاصابة بالقراد تتسبب في أضرار اقتصادية كبيرة خاصة في البلدان المدارية وشبه المدارية .

أجريت دراسة مقطعية في الفترة من ديسمبر 2017 إلى أبريل 2018 لتحديد مدى انتشار الإصابة بالقراد في الأبقار والأغنام والماعز في منطقة الخرطوم بحري ، واستقصاء عوامل الخطر المحتملة المرتبطة بالإصابة بالقراد في هذه الأنواع من الحيوانات. تم اختيار 277 من الحيوانات من الأنواع المختلفة (182 من الأبقار و 60 من الأغنام و 35 من الماعز) بشكل عشوائي وفحصها لوجود القراد في 44 مزرعة في بحري (الجيلي ، ودرملي واوسي و السامراب) وشرق النيل (الشقلة ، السليت ، كافوري ، العيلفون وكوكو). تم تصميم استبيان لكل الحيوانات التي تم فحصها لمعرفة العوامل التي يحتمل ان تؤثر على انتشار القراد ومن ثم تصنيف القراد الذي تم جمعه.

سُجّل أعلى معدل للإصابة بالقراد في منطقة بحري بنسبة 88.8% و 52.6% في منطقة شرق النيل. هنالك حوالي 68.4٪ (277/191) من الحيوانات التي تم فحصها، وُجدت مصابة بالقراد بأعلى معدل في الأبقار (74.2٪) يليها الضأن (66.7٪) والماعز (45.7٪). فيما يتعلق بعوامل الخطر المرتبطة بانتشار القراد، تم تسجيل اختلافات إحصائية $P < 0.004$ بين أنواع الحيوانات الثلاث. سجلت الحيوانات الأكبر عمراً(> 5 سنوات في الأبقار و > 3 سنوات في الضأن والماعز) أعلى معدل انتشار للقراد بنسبة 87.8٪ مقارنة مع الحيوانات الأقل منها عمراً(2-5 سنوات في الأبقار و> 6 أشهر في الضأن و الماعز) و التي سجلت نسبة66.1 ٪ ،والأعمار الصغيرة (أقل من عامين في الأبقار و 1-2 أشهر في الضأن و الماعز) سجلت 56.1%. كان معدل انتشار القراد في الإناث أعلى بقليل 71.1٪ مقارنة مع انتشاره في الذكور 59.2%٪. سجلت السلالات المهجنة والأجنبية معاً أعلى معدل انتشار للإصابة بالقراد بنسبة 72.4٪ مقارنة مع السلالات المحلية 62.0٪. سجلت الحيوانات بالقطيع المتوسط الحجمأعلى معدل لانتشار القراد بنسبة 80.7٪ مقارنة مع الحيوانات بالقطيع الصغير الحجم 67.6٪ وأدنى معدل إصابة تم تسجيله في حيوانات القطيع كبير الحجم 20.8٪. سجلت الحيوانات في المزارع

شبه المغلقة أعلى نسبة انتشار للإصابة بالقراد بنسبة 95.7 ٪ مقارنة مع الحيوانات في المزارع المغلقة بنسبة 59.9 ٪. معدل الإصابة بالقراد في المزارع التي تم فيها استخدام وسائل للتحكم في القراد أقل بكثير (55.1٪) من المزارع التي لا توجد بها أي نوع من أنواع السيطرة على القراد (90٪) كما كشفت الدراسة عن وجود ارتباط كبير بين الإصابة بالقراد واختلاف طرق السيطرة عليه. قللت الإزالة الأسبوعية لفضلات الحيوانات كثيراً من انتشار الإصابة بالقراد حيث سجلت (43.3٪) بينما تم تسجيل معدل أعلى عندما كانت إزالة الفضلات شهرية (94.5٪). تم تسجيل أعلى نسبة انتشار للقراد في فصل الصيف (83.1٪) مقارنة بالخريف (60.6٪).

كشفت الدراسة أن الأبقار أكثر إصابة بنوع هيالوما أناتوليكوم ، بينما الأغنام أكثر اصابة بريبيسفالس سانقوينس والماعز مصابة أكثر بريبيسفالس ايفرتسي ايفرتسي.

من عدد 2367 من القراد الذي تم جمعه (ذكور 1591 ، أناث 776)، تم التعرف على ثلاثة أجناس وخمسة أنواع من القراد ، وكانت أكثر أنواع القراد تواجداً هي هيالوما أناتوليكوم ، ريبليسيفالوس إيفرتسي إيفرتسي ، مجموعة ريشيبسفالس سانغيوانوس و هيالوما روفايبس. سجل الضرع أكثر المواقع المصابة بالقراد في الأبقار (54.5 ٪) ، بينما الأذن أكثر المواقع المصابة بالقراد في الأغنام (70.6 ٪) وكانت منطقة تحت الذيل أكثر المواقع المصابة بالقراد في الماعز(77.5٪).

سجلت منطقة بحري أعلى معدل إصابة بالقراد في الأبقار والأغنام والماعز. تم اعتبار عوامل الخط مثل أنواع الحيوانات، العمر، حجم القطيع، نظام التربية، مكافحة القراد، طريقة المكافحة، إزالة فضلات الحيوانات والموسم عوامل خطر لانتشار القراد. و سجلت هيالوما اناتوليكوم أكثر أنواع القراد انتشارا في منطقة الدراسة.

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INTRODUCTIO

Ticks are small arachnids; they are ectoparasites, feeding on the blood of mammals, birds, and sometimes reptiles. Economically, ticks are the most important pests of livestock in tropical and subtropical areas (Jongejan and Uilenberg, 1994).

Ticks of animals are considered harmful to livestock not only due to tick bite and blood loss but also by transmission of many species of pathogens, as well as reducing wool and hides value (De Castro, 1997). Ticks feeding in large numbers can cause a systemic suppression of their host's immunity and this may predispose animal to secondary infections. Ticks and tick-borne diseases (TBDs) are major constraints to livestock improvement in many parts of the world including the Sudan (Osman, 1992; Walker *et al*., 2003).

In Sudan, the estimated cattle population is 31million and there are 40 million sheep and 31 million goats (MoAR, 2019). On the other hand, ticks and tick-borne diseases are widespread and cause great economic losses in the animal productivity (Gamal and El Hussein, 2003; El Hussein *et al*., 2004) and the main ticks found belong to genera*Hyalomma*, *Rhipicephalus*, *Rhipicephalus* (*Boophilus*) and *Amblyomma* (El Hussein *et al*., 2012).

In several parts ofSudan, numbers of published data are available on tick species from different livestock animals and tick-borne diseases (TBDs).Salih *et al*., (2004) recorded different tick species of cattlein 17 locations in the country. Hassan *et al.,* (2016) identified two tick genera and six species in sheep and goats in Khartoum State and recorded high tick load in Khartoum North followed by Khartoum and Omdurman (3.82±0.76, 1.0±0.30 and 0.85±0.23 respectively). In White Nile State,the genera belong to *Amblyomma, Hyalomma* and *Rhipicephalus* species were identified by Gumaa *et al.,* (2015).

Moreover, numerous studies from the regional countries reported the tick infestation prevalence. In Ethiopia, Desalegn *et al.,* (2015) found that 16.6% of examined domestic ruminants were infested by one or more tick species. Mohammed*et al.,* (2014) revealed that the prevalence and distribution of tick infestation in different animal species in Egypt was 30.1%. Few studies were addressed the tick infestation prevalence and associated risk factors in the Sudan. Investigation of frequency and distribution of ticks infesting livestock animals are crucial for the diagnosis of different tick borne diseases and their respective control programs.

Objectives:

1.To determine the prevalence of tick infestation in cattle, sheep and goats in Khartoum North.

2.To investigate the potential risk factors associated with tick infestation in these livestock species in the study area.

CHAPTER I

LITRITURE REVIEW

1.1 Ticks

Ticks are small arachnids; they are harmful, blood-sucking external parasites of mammals, birds, reptiles and amphibians. Tick infestation has direct impact on animal health and production in many parts in the world, including sub-Saharan Africa (Jongejan and Uilenberg, 2004).Bowman *et al.,* (1996) estimated more than 80% of the world cattle population is infested by ticks, which transmit a wide range of viral, bacterial and protozoan pathogens causing tick borne diseases (TBDs).

There are at least 866 described species of tick in the world, and ticks are major obstacle to the livestock industry in Africa since this part of the world is particularly affected because of the large number of tick species and variety of diseases caused (Walker *et al.,* 2003).

1.2 Taxonomy of tick

Ticks belong to the Kingdom Animalia, the phylum Arthropoda, class Arachnida, sub class Acari and sub order Ixodida. Ixodida contains three families, theIxodidaeor hard ticks (692 species), the Argasidae or soft ticks (186 species) and Nuttalliellidae (one species) (Nava *et al.,* 2009). The major genera of Ixodidae family are *Rhipicephalus (Boophilus), Amblyomma, Hyalomma, Dermacentor, Haemaphysalis, Ixodes, Margaropus* and *Rhipicephalus* and the major genera of Argasidae are *Argas, Ornithodoros* and *Otobius* (Horak*et al*., 2002). There are many distinct features between hard ticks and soft ticks, but the main feature is that Ixodid ticks have scutum or a conscutum as a hard shield on their dorsal surface unlike Argasid ticks (Walker *et al.,*2003).

1.3 Tick life cycle

Ticks have four stages in their life cycle, namely eggs, larvae, nymphs and adults (Hoogstraal, 1956). In hard ticks, mating occurs on the host except Ixodes where it may also take place when the ticks are still on the vegetation. Male ticks attempt to mate with many females as they are feeding, while females mate only once, before they are ready to engorge fully with blood. Then they detach from the host and have enough sperm stored to fertilize all their eggs. They lay many eggs (2,000 to 20,000) in a single batch. Eggs are laid in the physical environment, never on the host. The common type of life cycle is the Three-host tick life cycle, in which case it requires a new host for each developmental stage such as *Amblyomma* species and *Rhipicephalusappendiculatus* (Soulsby, 1982). The life cycle of three-host ticks is slow, from six months to several years. Larvae hatch, usually in several weeks and they feed once on a host, then detah and hide in soil or vegetation. They moult to nymphs, which feed once and moult in the similar way as larvae and moult to adult tick (Walker *et al.*, 2003).

In The two-host life cycle, the larvae and nymphs feed on the same individual host, and the adults feed on another host. *Hyalomma scupense* and *Rhipicephalus e. evertsi*have two-host life cycles (Kettle, 1995).

One-host tick life cycle is a less common type of life cycle but it occurs in *Rhipicephalusannulatus*. All three feedings of any individual tick occur on the same individual. The adults will change position on the same host for mating. The life cycle of the one-host ticks is usually rapid host (Walker *et al.,* 2003).

1.4 Ecology of ticks

Ticks are widely distributed throughout the world particularly in tropical and subtropical countries. However, each species of tick is adapted to different macro and microclimates (Soulsby, 1982). Air temperature and relative humidity are critical factors determining longevity of host-seeking ticks which decreases with increasing temperature. Rapid death of ticks at high temperature is most probably due to very high rates of water loss or heat stress (Tukahriwa, 1976; Utech *et al*., 1983). Tatchell and Easton (1986) stated that host density, host susceptibility, vegetation type and host grazing behavior are important factors in tick regulation and distribution.

Ticks vary in their response to ambient temperature within sex, age and host species. Each species has critical temperature above which its survival is greatly influenced. This critical temperature generally varies with different genera. Environmental conditions such as temperature, relative humidity are critical for the longevity and survival of unfed stages in the vegetation (Tukahriwa, 1976; Dark, 1995).

1.5 Distribution of ticks in the world

Ixodes species have reported in Europe and North America (Jongejan and Uilenberg, 2004;Jaenson *et al.,* 2012); and they are responsible for transmitting zoonotic diseases likeLyme borelliosis. Bugmyrin*et al.,* (2013) considered southern Karelia (Russia) as a zone of *Ixodes. ricinus* and *I. persulcatus*, without a clear geographic boundary between the two species. *Ixodes persulcatus* was detected in 9 of 36 field localities in the Bothnian Bay area (Jaenson, *et al.,* 2016). *I.scapularis* is the most common *Ixodes* in North America (Jongejan and Uilenberg 2004).

Rhipicephalus microplus is the most important species of *Rhipicephalus* that occurs in the tropics including Australia, East and Southern Africa, and South and Central America. *B. annulatus* is found in the Mediterranean region, southern Russia and also distributed in Africa in a belt from West Africa to Southern and Central Sudan (Hoogstraal, 1956). *B. decoloratus* and *B. geigyi* are also common in Africa (Jongejan and Uilenberg, 2004).

Haemaphysalis species are important to livestock animals in Europe and Asia and have been introduced into Australia, New Zealand and New Caledonia (Jongejan and Uilenberg, 2004). Du *et* *al.,* (2018) reported that *Haemaphysalis (Alloceraea) kolonini* as a new species in Southwestern province Yunnan, China.

Haemaphysalis longicornis, Dermacentor silvarum, Ixodes persulcatus, Haemaphysalis conicinna, Rhipicephalus microplus and *Rhipicephalus sanguineus senus lato* are the most frequently tick species in China (Zhang *et al.,* 2019).

Rhipicephalus turanicus was the most abundant species in an urban park in Rome, Italy, followed by *Ixodes ricinus*, *Dermacentor marginatum* and *Haemaphysalis punctata,* respectively (Manici *et al.,* 2014).

Hyalomma speciesare abundant in semi-arid zones and have been reported in Iran (Ganjali*et al.,* 2014). *Hyalomma marginatum* is found in Southern and Eastern Europe and is responsible for transmitting Cremean-Congo Hemorrhagic fever virus, which an emerging pathogen in Europe (Jongejan and Uilenberg, 2004).*H. anatolicum* is the most common tick species infesting ruminants in Pakistan, and *Hyalomma dromedarii* was also reported in the same area (Rehman *et al.,* 2017).

Amblyomma hebraeum,*Rhipicephalus appendiculatus*,*Rhipicephalus decoloratus* and *Ixodes rubicundus* are reported in cattle and wildlife in South Africa (Hoogstraal,1956) as well as *Ixodes rubicundus*, *A. hebraeum*, *R. microplus*, *R. evertsi mimeticus*, *H. silacea* (Horak *et al.,* 2015).*Amblyomma variegatum* is the most important species on the African continent throughout tropical sub-Saharan Africa and *A. hebraeum* is present in the south-eastern part of the African continent (Jongejan and Uilenberg 2004).

Rhipicephalus spp. are common on mammals in Africa, particularly the brown ear tick *R. appendiculatus*, which is the most important *Rhipicephalus* species. of domestic and wild ruminants in East and Southern Africa (Jongejan and Uilenberg, 2004). It is responsible for transmitting the parasite *Theileria parva* in eastern, central and southern Africa, where it causes East Coast fever, Corridor disease and January disease in cattle (Perry *et al.,* 1991).

The most common ticks infesting cattle and goats in the eastern region of the Eastern Cape Province, South Africa and Maputo Province, Mozambique were *Amblyomma hebraeum*, *Rhipicephalusmicroplus*, *Rhipicephalus appendiculatus* and *Rhipicephalus evertsi evertsi*and the dominant species on dogs were *Haemaphysalis elliptica* and *Rhipicephalus simus* (Horak *et al.,* 2009).

In Egypt, *Hyalomma anatolicum*, *Rhipicephalus microplus*, *Rhipicephalus sanguineus*,*Rhipicephalus annulatus* and *Haemaphysalis* spp. were present in Beni-Suef (Mohammed*et al.,* 2014).

Several *Amblyomma* species including; *A. lepidum*, *A. astrion,A. gemma,A. pomposum*, A. *cohaerens* and *A. variegatum* have been introduced into the Caribbean region from West Africa. *A. americanum*, *A. cajennense* and *A. maculatum* have economic significance in the American continent (Jongejan and Uilenberg, 2004).

1.6 Distribution of ticks in Sudan

According to previous reports fromSudan, *Hyalomma dromedarii* is distributed in area with annual rainfall below 250 mm and may be found in desert and semi-desert areas. Osman and Hassan, (2003) described that *Amblyomma lepidum* is generally concentrated in the central of the eastern part of the country from Torit and Kapoeta in the south to Kassala in the north, but absent in Northern provinces.Abdallah (2007) confirmed that *A. lepidum* has spread from eastern parts of country to Darfur State, as well as *H. anatolicum* which is commonly found in the State.*H. impeltatum* was also reported as the most dominant species in Kosti province (El Imam, 1999).

A. lepidum, *A. variegatum*, *R. decoloratus*, *R. annulatus*, *Hyalomma rufipes*, *H. truncatum*, *Rhipicephalus* and *Haemaphysalis* spp. were reported in Southern Kordofan (Sowar, 2002). Osman *et al.,* (1982) stated that *H. impeltatum* was the most dominant tick of sheep in arid area of Kordofan.

Karrar *et al.,* (1963) reported that tick species that infest domestic animals in Kassala, Eastern Sudan are *H. anatolicum,H. excavatum*, *H. dromedarii*, *H. impeltatum,H. rufipes*, *H. truncatum*, *Rhipicephalus e. evertsi*, *R. sanguineus*, *R. praetextatus*, *Rhipicephalusdecoloratus* and *A. lepidum.*

According to Food and Agriculture Organization(FAO, 1983), *H. rufipes* and *Rhipicephalus e. evertsi* are present in the Central Sudan and *H. anatolicum* in the northern parts of central Sudan, and *A. lepidum* in central grassland, semi desert, rare in mixed forests and forest savanna and disappear in desert area. *R. guilhoni* is the most common species of ticks infesting sheep in Sennar State (Suleiman, 2004).

Salih *et al.,* (2004) identified *Hyalomma anatolicum*from cattle in Atbara and Eldamer, and *H. dromedarii* from all localities (Atbara, El Damer, Khartoum, Madani, Sennar, Um Benin, Damazin, El Dieum, Rabak, Kosti, El Obeid, Fasher, Nyala and Geneina). *Rhipicephalus decoloratus*, *H. impeltatum*, *H. truncatum*, *H. rufipes*, *R. evertsi evertsi*, *R. praetextatus* and *R. sanguineus* group collected from several localities.

In Khartoum, Latif *et al.,* (1994) identified*H. anatolicum, H. truncatum*, *B. decoloratus*, and *R. sanguineus.*Hassan *et al.,* (2016) identified *H. anatolicum, H. impeltatum, R. camicasi, R. evertsi evertsi, R. guilhoni* and *R. sanguineus* in sheep and goats in Khartoum State.

Altigani and Mohammed (2010) reported that *H. dromedarii*as the predominant tick species in El Butana area mid-eastern Sudan, followed by *H. rufipes,H. impeltatum, H. anatolicum*, *H. truncatum*, *A. lepidum* and *R. sanguineus*.

1.7 Risk factors associated with tick infestation

The effect of host characteristics has informing various degrees of resistance to tick infestation (Berman, 2011).Tick infestation depends on species, the region, host population and developed control measures (Solis, 1991). Rehman *et al.,* (2017) reported that absence of rural poultry, not performing acaricide treatments, traditional rural housing systems and grazing were important risk factors associated with higher tick prevalence in livestock farms. Age, gender, breed and animal species significantly affected the intensity of tick infestation.Tick presence and tick loads vary with seasons, geographic location, vegetation type, breed, habitation and age of the animal (Mtshali *et al.,* 2004).

The impact of environmental factors such as climate (Estrada-Pena, 2009) and habitat type (Thamm *et al.,* 2009) on the patterns of tick prevalence have been investigated in various parts of the world.

1.8Important tick species in Sudan

A total of 72 tick species have been identified in Sudan (Hassan and Salih, 2013). The most economically important ticks of livestock in Sudan belong to the genera *Hyalomma*, *Rhipicephalus* and *Amblyomma,*14 of which infestlivestock and five are vectors of very important tick-borne disease. *Hyalomma anatolicun* is the vector of *Theileria annulata* which causes 30% calf mortality in exotic dairy herds, *T. ovis* which causes high mortality in sheep and *Babesia cabali*and*Theileria equi* which causes equine babesiosis. *Rhipicphalus e. evertsi* transmits *T. ovis* and is a potential candidate for *T. annulata* transmission. *Rhipicephalus* species transmit cattle babesiosis and anaplasmosis. *Amblyoma Iepidum* and *A. variegatun* transmit Erhlichiosis in sheep (El Hussein *et al.,* 2012).

1.9Tick-borne diseases in Sudan

Tick-borne illnesses are caused by infection with a variety of pathogens, including rickettsia and other types of bacteria, viruses, and protozoa.Theimportant tick- borne disease in Sudan are:

1.9.1 Tropical theileriosis

Tropical theileriosis is a tick-borne disease of cattle caused by *Theileria annulata*. In Sudan, the pathogen is transmitted mainly by *Hyalomma anatolicum*(Salih *et al.,* 2005). It is highly fatal in exotic breeds and their crosses, while little or no mortality in local breeds. Latif *et al.,* 1994) reported that 85 % of dairy farms investigated inKhartoum Province experienced clinical theileriosis and mortalities among newly born calves and heifers, which 22% and 30%, respectively. Bashir*et al.,* (2018) detected an infection with *T. annulata* in 63% of examined cattle from Sennar State. Recently, Mohammed-Ahmed,*et al.,* (2018) reported that 68.3% (164/240) of serum sample from cattle in North Kordofan State were positive for antibodies against *T. annulata* using IFA test.

1.9.2 Malignant Ovine Theileriosis

Malignant Ovine Theileriosis (MOT) is caused by highly pathogenic species of *Theileria* (Ali *et al.,* 2017).*Theilerialestoquardi*is transmitted by *Hyalomma* ticks (Levine, 1973).MOT considered as an important cause of morbidity and mortality among sheep in the Sudan. Recently, the result of the estimation of the prevalence of MOT in five States in Sudan, indicated a sero- prevalence of 33.8% from serum samples of clinically asymptomatic sheep (Hassan *et al.,* 2019). An average of 17 % of sheep admitted for treatment at Atbara Veterinary Clinic, Northern Sudan, was diagnosed as MOT. The prevalence of *T. lestoquardi*antibodies using IFA test based on schizont antigen. Antibodies were found in all sheep grazing areas ofSudan (Elhussein *et al.,* 2004).

1.9.3 Erhlichiosis

This disease caused by *Ehrlichia ruminantium* and transmitted by *Amblyomma* species (Semu and Mahn 2001).Erhlichiosis was reported as a considerable disease of sheep and goats in Eastern

Sudan (Karrar, 1960). It is identified in other parts of the country including Western Sudan (Abdel Wahab *et al.,* 1998).A serological survey indicated high prevalence of *E. ruminantium* antibodies in cattle, sheep and goats (83%, 69% and 75.2%, respectively) (Abdel Rahman*,* 2006). In Sennar State, (Mohammed*,*2003) found that 76.6% (230/300) of sheep sera in five localities namely Sennar, Singa, Dinder, Um Benin and Abu Naama were positive for*E. ruminantium* antibodies by ELISA Test.

1.9.4 Equine Piroplasmosis

The causative agents of this disease are two protozoan parasites *Babesia caballi* and *Theileria equi*. They are transmitted by *Dermacenter, Hyalomma* and *Rhipicephalus* (Kamyingkird *et al.,* 2014). The prevalence of the disease among horses and donkeys in Sudan was 35.95% using molecular techniques (Salim *et al.,* 2013). Recently the overall prevalence of Equine Piroplasmosis in Khartoum State was 27.4% (Abdel Nasir, 2017).

1.9.5 Avian Spirochaetosis

Avian Spirochaetosis is caused by *Borrella anserina* and transmitted by *Argas* spp. An investigation in River Nile State revealed that the disease wasthe second most significant bacterial disease of chickens in the area (a 5-year average relative Incidence of 25 % of the diseases of poultry diagnosed) (El Hussein *et al.,* 2004). Khalifa*et al.,* (2013) reported a low occurrence of Spirochaetosis in Sudan in a retrospective study (2000-2005) of poultry diseases diagnosed at Department of Avian diseases and Veterinary Research Institute in Khartoum.

1.10 Economic impact of ticks

Losses due to tick-borne diseases are incurred by mortality, abortion, reduction in milk yield and weight gain, reduce productive life and cost of treatment (El Hussein and Atta Elmanan2003). Mohammed, (2003) found that there is a heavy loss in live weight gain which is attributed to tick infestation. Tick may harm their hosts by injuries caused by their bites which may predispose the host to attacks by blowflies, screwworm, or by sucking blood and by transmission of viruses, bacterial protozoal or rickettsial diseases. These effects together may vary from situation where it is impossible to raise livestock to one where great expense is incurred in control of ticks. Anemia caused by loss of blood is another important impact of ticks on livestock industry. The amount of blood taken by a particular vector is epidemiologically important (Rechav *et al*., 1994).

1.11 Diagnosis of Tick-borne diseases

For effective control and treatment of tick-borne diseases, sensitive, reliable and rapid diagnostic tests are important. Provisional diagnosis includes history, clinical signs, postmortem findings and knowledge of disease and vector distribution (OIE, 2000). Several techniques for detection of tick-borne diseases have been applied.

Microscopic techniques are used in detecting *Theilieria* schizonts in the lymph node smear, piroplasms in blood smear and Babesiosis in blood or organ smear stained with Romansky stain as well as acute form of *Anaplasma* infection in Giemsa stained thin smears (Callow *et al.,* 1993; Bose *et al.,* 1995).

Diagnosis of tick-borne diseases using microscopic examination requires intensive labor and well-trained technicians. In carriers where the parasitemia is low, microscopic examination is not sensitive method (Friedhoff and Bose 1994; Bose *et al*., 1995). Adam *et al.,* (2017) diagnosed Theileriosis in the dairy farms around Nyala town, South Darfour State by using blood smear technique. Microscopic examination was also used to detect *Theileria* spp piroplasms in sheep in Al Huda National Sheep Research Station (Ahmed*et al.,* 2018).

Rapid development of heart water Disease, Lack of clinical signs and total absence of lesions, made the diagnosis of Erhlichiosis in live animal difficult (Camus *et al.,* 1996).

Serological tests are used when parasites occur in low numbers or cannot demonstrated in a sample due to the life cycle of the host. Complement fixation test (CFT), Indirect Fluorescent Antibody Technique(IFAT), Enzyme Linked Immunosorbent Assay(ELISA) were used in numerous previous studies. Hassan *et al.,* (2016) used Indirect Fluorescent Antibody (IFA) test to assess antibodies of *Theileria. lestoquardi* in sheep and goats in Khartoum State.

Conventional PCR, RAPID- PCR, RFLP-PCR, multiplex PCR, real-time PCR, Reverse Line Blot (RLB) and reverse transcriptase PCR were also reported in molecular diagnosis of tick-borne diseases. RLB was used to detect and simultaneously differentiate between *Theileria* and *Babesia* species infecting sheep in six different localities (Atbara, Khartoum, Kosti, Medani, Damazin and Nyala) in Sudan (El Imam *et al.,* 2016).

1.12 Tick Control

Tick control on livestock is very essential to reduce tick population and consequently prevent diseases caused by tick- transmitted pathogens. Eradication of ticks is mostly not possible except in Islands, where effective campaigns have sometimes been applied (Jongejan and Uilenberg, 1994). The control of tick-borne diseasesdepends on intensive using acaricides **(**Drummond, 1976). However, these chemicals are toxic, leave residues in meat and milk, and cause environmental pollution (Hassan, 2003; Butox, 2017). Moreover, acaricides are not only expensive but also the resistance of ticks to different acaricides is reported (Aziz, 2003). Treatment of animals by dipping or spraying with acaricides is more efficient than using them in pasture (FAO, 1984).

Acquired resistance of the host after repeated infestation by ticks to Ixodid ticks has been recognized as a biological control method (Trager, 1939). Acquired immunity varies with the tick species, the host breed and between the individuals of the host. Reduction in the number of ticks attached the host, reduce engorgement weights and reduce egg and larval production resulting in reduced tick population (Willadsen, 1980). Generally, *Bos indicus* have a much higher proportion of acquiring resistance to ticks than *Bos taurus* breed (European)(Wambura, *et al.,* 1998). In the Sudan, crossbred carried 4.5 times more ticks than Kenana and Butana (Latif, 1984).A major new approach in the control of ticks in Australia is the development of an anti-tick vaccine against *B. microplus* (Jongejan and Uilenberg, 1994).

Biological control of ticks relies on natural enemies, many rodents, ants, and birds feed on ticks reducing tick population (Hoogstraal, 1956) Samish and Rehacek, 1999, Samish and Glazer, 2001). Domestic chickens considered to be a natural tick predator in open system (Hassan *et al.,* 1992). In a trial in the Western Kenya, Mwangi *et al.,* (1997) reported that *Ixodiphagus hookei* which lays its eggs in nymphs of *A. variegatum* reduce tick infestation in cattle by 95%.

CHAPTER II

MATERIALS AND METHODS

2.1 Study area

The current survey was carried out in Khartoum North (includes Bahri and Sharg Alneel localities) which situated in Khartoum State, the capital of Sudan. The area is located in the centre of Sudan at the confluence between latitude 15.5518° N and longitude 32.5324° E and shares borders with Khartoum to its south and Omdurman to its west (Figure2.1). Khartoum North features a hot arid climate. The area has the largest livestock population in Khartoum State comprises of 223,131 cattle, 457,270 sheep and 592,905 goats (Ministry of Agriculture, Animal Resources and Irrigation-Khartoum State -2018).

2.2 Study design, sampling, and study population

The study was carried out during December 2017 to April 2018 to determine the prevalence of tick infestation in livestock population in Khartoum State.

A cross-sectional study deign was selected and the sample size was calculated using the formula described by Thrusfield, (2007) assuming 50% prevalence, 95% confidence interval and 5% desired absolute precision. Accordingly, 277 ruminants including 182 cattle, 60 sheep and 35 goats of both sexes and different age groups were examined in the area of Khartoum North.

To select study animals, the two localities Bahri and Sharg Alneel within the area were chosen at the first level and villages were further conveniently selected at the second stage,in Bahri, the livestock farms were selected in four villages, namelyAlgaili, Wadramli, Wawissi and Samrab and in Sharg Alneel, the livestock farms were selected in five villages namely Shigla, Silait, Kafouri, Ailafoon and Kuku. In each selected village, animal herds were visited for tick sampling and the total number of animals examined in Khartoum North was proportionally allocated to the number of animals in each locality. Animals were randomly selected from 44 farms; 30, 8 and 6 for investigating cattle, sheep and goats, respectively and a minimum of five and a maximum of ten animals were examined in each herd.Animals are divided into three age groups; young (< 2 years old of cattle) and (1-6 months in sheep and goat), adults (2–5 years old of cattle) and (>6 months–3 years old of sheep and goats) and old (>5 years old of cattle) and (> 3years old of sheep and goats). Local, crossbred and foreign breeds as well as livestock with 4 coat colors (white, black, brown and mixed) were investigated in the study area.Examinedanimals were kept into two housing types; closed and semi closed with two raising types; one species and mixed species and there were three herd sizes; small (10-50) animals, medium (51-100) and large (101-150).Studied animals were fed two feeding types; either roughages or roughages mixed with concentrates.

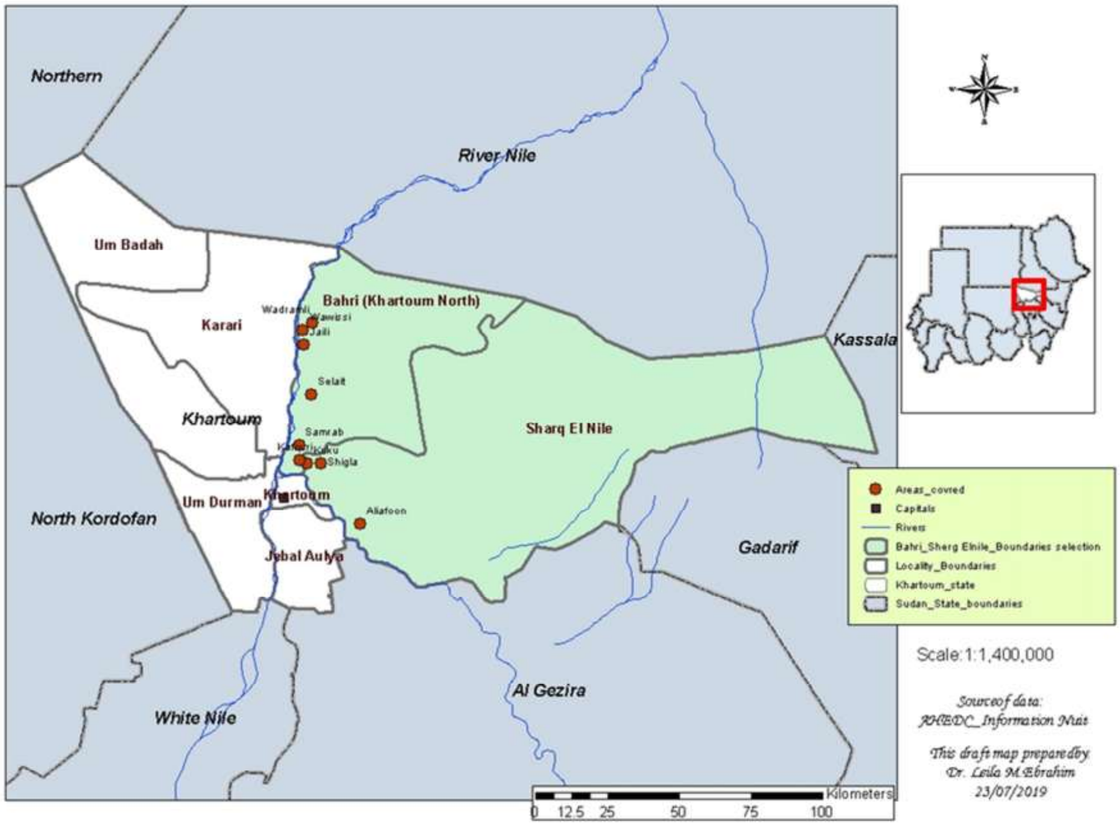

Figure 3.1: The study area, Khartoum North

2.3 Collection and preservation of ticks

The selected animals of different species were properly restrained then ears, brisket, withers, knees, udder, testes, tail and around eyes were examined for the presence of ticks. All attached adult ticks were collected by rotating the tick by hand to avoid losing the mouth parts and transferred for each animal in labeled universal bottles containing (70%) ethanol. The information was written in the label including; locality, village, farm number, animal species and predilection site.

2.4 Potential risk factors associated with tick prevalence

Prior to tick collection, a pretested questionnaire containing closed and open questions was used to identify possible risk factors associated with tick prevalence. The questionnaire was divided into three parts: host-related information, farm-related information and management and environment-related information. The data were collected from all visited farms with the help of the owners of animals and they were obtained in (Appendix 1).

2.5 Identification of ticks

In Parasitology Department of Central Veterinary Research Laboratory, ticks were morphologically identified according to taxonomic keys described bywalker*et al.,*(2003) to the species level under a stereomicroscope.

2.6 Data Analysis

The prevalence of tick infestation in individuals and herds were determined by dividing the number of positive samples by the total investigated animal, and was expressed as percentages. Initially collected data were analyzed by SPSS version 20.0 and Chi-squaretest was used to evaluate association between hypothesized risk factors and tick infestation status of the animal and the level of significance was set as *P-value* ≤ 0.05. Finally, significant risk factors were entered and analyzed using the logistic regression to assess the association between tick infestation and the interaction between risk factors, variables with *P-value* ≤ 0.25 in univariate analysis were entered in the logistic regression model.

CHAPTER III

RESULTS

3.1 Prevalence of tick infestation

Out of the total 277 examined domestic ruminants, 191 were infested by varying numbers of tick genera leading to an overall individual prevalence of 68.9%.

The overall prevalence of tick infestation in different herds was 88.6%. In herds of cattle, sheep and goat, the prevalence were (93.3%, 87.5 % and 66.7%, respectively) (Table 3.1).

3.2 Risk factors analysis

3.2.1 Districts

Within the region of Khartoum North, Bahri was recorded the highest prevalence of tick infestation in examined livestock (88.8%) compared with Sharg Alneel (52.6%). The prevalence of tick infestation was statistically significant different ($X2= 42.0$, $P = 0.000$) among livestock of different areas (Table 3.2).

3.2.2 Host characteristics

Concerning the effect of host characteristics, animal species revealed that cattle had the highest prevalence of tick infestations of 74.2% followed by sheep 66.7% and then goats 45.7%. The difference in the prevalence of tick infestation was found to be statistically significant among the three species of animals ($X2 = 11.3$, $P=0.004$) (Table 3.3).

Based on age, older animals aged (<5 years old of cattle) and (< 3years old of sheep and goats) had the highest prevalence of

87.8% compared with the prevalence (66.1%) in the adult ages (2–
5 years

Table 3.1: Prevalence of tick infestation in different herds of different animal species in Khartoum North

Animal species	Examined farms	Positive farm (%)
Cattle	30	28 (93.3)
Sheep	8	7 (87.5)
Goats	6	4 (66.7)
Total	44	39 (88.6)

Table 3.2: Prevalence of tick infestation in domestic ruminants within the districts of Khartoum North

Locality	No. of examined	No. of infested (%)	X^2	p- value
			42.0	**.000***
Bahri	125	111 (88.8)		
Sharg Aneel	152	80 (52.6)		
Total	277	191 (68.9)		

old of cattle) and (<6 months–3 years old of sheep and goats). The lowest prevalence of tick infestation was seen in younger animals aged (> 2 years old of cattle) and (1-6 months in sheep and goat) with 56.1%. The prevalence of tick infestation was significantly different (X2 = 19.1, P=0.000) among the different age groups (Table 3.3).

Sex–wise prevalence revealed that females had slightly higher prevalence of 71.1% compared with the males 59.2% and there is no significant association between tick infestation prevalence of tick infestation and sex of animals (X^2 = 2.7, *P* = 0.103) (Table 3.3).

Regarding the livestock breeds, crossbred and foreign breed had the highest prevalence of tick infestations of 72.4% compared with local breeds 62.0%. Accordingly, no significant association was found between the prevalence of tick infestation and breeds of examined ruminants (X^2 = 3.2, *P* = 0.07) (Table 3.3).

Based on our results, the difference was not significant among tick infestation prevalence and different coat color of examined animals (X^2 = 3.5, *P*=0.316) (Table 3.3).

Table 3.3: Effect of host characteristics on tick infestation prevalence in livestock animals in Khartoum North

Risk factors	**No.of examined**	**No.of infested (%)**	**X^2**	**p- value**
Animal species			11.3	**.004***
Cattle	182	135 (74.2)		
Sheep	60	40 (66.7)		
Goat	35	16 (45.7)		
Age			19.1	**.000***
Young	82	46 (56.1)		
Adult	121	80 (66.1)		
Old	74	65 (87.8)		
Sex			2.7	.103
Male	49	29 (59.2)		
Female	228	162 (71.1)		
Breed			3.2	.07
Local	92	57 (62.0)		
Cross and foreign	185	134 (72.4)		
Coat color			3.5	.316
White	89	55 (61.8)		
Black	61	43 (70.5)		
Brown	42	32 (76.2)		
Mixed	85	61 (71.8)		

3.2.3 Managemental and environmental factors

Regarding the effect of managemental risk factors, medium herd size (51-100) had the highest prevalence of tick infestation of 80.7% compared with the small herd size (10-50) 67.6 % and the lowest reported in the large herd size (101-150) of 20.8%. The prevalence of tick infestation was significantly different (X^2 =33.4, P = 0.000) among livestock of different herd size (Table 3.4).

In the current survey, the semi closed housing reported the highest prevalence of tick infestation of (95.7%) compared with closed one (59.9%). The difference in the prevalence of tick infestation between the two types of housing found to be statistically significant (X^2 =31.3, P=.000) (Table 3.4).

Our data showed that both raising and feeding type were not considered as risk factors for tick infestation among cattle, sheep, and goats (Table 3.4).

The prevalence of tick infestation in animals subjected to tick control were greatly less than those not exposed to any method of controlling ofticks (55.1% and 90.0%, respectively) and the difference of tick infestation prevalence was significant between the two groups (X^2 =37.8, P=0.000) (Table 3.4).

Regarding tick prevalence based on methods of control, rearing chickenscombined with using acaricides and rearing chickens only were effective methods of tick control (41.5% and 60.0%) compared by using of acaricides only (64.1%). The prevalence of tick infestation was statistically different (X^2 =47.0, P = 0.000) among livestock with different methods of control (Table 3.4).

The prevalence of tick infestation among livestock when the removing of manure occurred monthly was greatly higher 94.5% and tick infestation prevalence in animals exposed to weekly manure removing 48.3%. The difference in the prevalence of tick infestation was found to be statistically significant (X^2 =29.0, P = 0.000) (Table 3.4).

The highest prevalence of tick was in summer (83.1%) compared with autumn (60.6%). 76.2% prevalence was recorded among animals that their owners had no answer about the season. The prevalence of tick infestation was statistically different (X^2 =12.0, P = 0.002) among livestock in different seasons (Table 3.4).

Table 3.4: Effect of Managemental and environmental risk factors in tick infestation prevalence in livestock animals in Khartoum North

Risk factors	**No. of examined (%)**	**No. of infested (%)**	**X^2**	**p-value**
Herd size			33.4	**.000***
Small	139	94 (67.6)		
Medium	114	92 (80.7)		
Large	24	5 (20.8)		
Housing type			31.3	**.000***
Closed	207	124 (59.9)		
Semi closed	70	67 (95.7)		
Raising type			1.3	.253
One species	143	103 (72.0)		
Mixed species	134	88 (65.7)		
Feeding type			.27	.605
Roughages	70	50 (71.4)		
Mixed	207	141 (68.1)		
Control of tick			37.8	**.000***
Yes	167	92 (55.1)		

No	110	99 (90.0)		
Method of Control			47.0	**.000***
Acaricides	92	59 (64.1)		
Chickens	10	6 (60.0)		
Combined Methods	65	27 (41.5)		
None	110	99 (90.0)		
Removing of manure			29.0	**.000***
Weekly	60	29 (48.3)		
Monthly	55	52 (94.5)		
Other	162	110 (67.9)		
Seasons			12.0	**.002***
Autumn	155	94 (60.6)		
Summer	59	49 (83.1)		
No answer	63	48 (76.2)		

3.3 Tick species

From the total count of 2367 ticks (male 1591 and female776) collected from 44 livestock herds, three genera and five species were identified. The dominant tick species was *Hyalomma anatolicum* 1764 (74.5%), followed by *Rhipicephalus e. evertsi* 383 (16.2%), *Rhipicephalussangiuanus*group 214 (9.04), *Hyalomma rufipes* 4 (0.2%) and lastly *Amblyomma lepidum* 2(.09%) (Table 3.5). While *H. anatolicum* was the most common tick species in all districts, *Amblyomma lepidum* was only found in one cattle herd in Silait village (Sharg Alneel). Moreover, *Hyalomma rufipes* was found in one herd in Alsamrab (Bahri).

3.4 Predilection sites

Different body parts of the investigated animals were examined to determine the predilection sites of tick infestation. Analysis revealed that udder was the most tick infested site in cattle (54.5%) and under the tail (perineum) (38.5%), followed by external genitalia (3.11%), knee (2.3%), brisket (1.2%), ear (0.4%) and around eyes (0.04%).

In sheep, ears were the most infested predilection site of tick (71%), followed by under the tail (26%), around eyes (1.9%) and udder (1.1%) %).

In goats, the tail was the most tick infested site (77.5%) followed by ears (21.3%) and around eyes (1.3%) (Table 3.6).

Table 3.5: Tick species identified in the domestic ruminants in Khartoum North

Tick species	Male (%)	Female (%)	Total count(%)
Hyalomma anatolicum	1241 (70.4)	523 (29.6)	1764 (74.5)
Hyalomma rufipes	4 (100)	0	4 (0.17)
Rhipicephaluse.evertsi	237 (62)	146 (38.1)	383 (16.2)
Rhipicephalus sangiuanus group	107 (50)	107 (50)	214 (9.04)
Amblyommalepidum	2 (100)	(0)	2 (0.09)
Total	1591 (67.2)	776 (32.8)	2367

Table 3.6: Distribution of ticks in different predilection sites in livestock ruminants in Khartoum North

Body parts	Cattle (%)	Sheep (%)	Goats (%)
Udder	1103 (54.5)	3 (1.1)	0
Tail	779 (38.5)	68 (26)	62 (77.5)
Ear	8 (0.4)	186 (71)	17 (21.3)
Brisket	25 (1.2)	0	0
Knee	46 (2.3)	0	0
Around eye	1 (0.04)	5 (1.9)	1(1.3)
Testes	63 (3.1)	0	0
Total	2025 (85.6)	262 (11)	80 (3.4)

3.5Male to female ratio

At the species level, the male to female ratio in cattle was (2.3:1) for *H. anatolicum,* (1.4:1) for *R. e. evertsi,* (0.4:1) for *R. sanguineus* group and (2:0) for *A. lepidum*. In sheep, the male to female ratio was (3:1) for *H. anatolicum*, 4:0 for *Hyalomma rufipes,*(1.9:1) for *R. e. evertsi* and (1.3:1) for *R. sanguineus* group. In goats, the ratio was (10:1) for *H. anatolicum*, (2.4:1) for *R.e. evertsi* and 0.75:1 for *R. sanguineus.*

Distribution of the tick species in different livestock animals revealed that, cattle were more infested by *H. anatolicum* (84.4%) compared with sheep that were more infested by *R. sanguineus* (59.5%) and goats were more infested by *R.e. evertsi*(68.7%). Favorable predilection sites of each species of ticks were illustrated in (Table 3.7).

Table 3.7: Distribution of tick species and male to female ratio with predilection sites in livestock ruminants in Khartoum North

Host	Tick spp.	No of ticks (%)	M	F	Sex ratio M:F
Cattle	*H.a*	1709 (84.4)	1198	511	2.3:1
	R.e	270 (13.3)	159	111	1.4:1
	R.s	44 (2.2)	12	32	0.4:1
	A.l	2 (0.1)	2	-	2:0
Sheep	*H.a*	44 (16.8)	33	11	3:1
	H.r	4 (1.5)	4	0	4:0
	R.e	58 (22.2)	38	20	1.9:1
	R.s	156 (59.5)	89	67	1.3:1
Goats	*H.a*	11 (13.8)	10	1	10:1
	R.e	55 (68.7)	39	16	2.4:1
	R.S	14 (17.5)	6	8	0.75:1

**H. a=Hyalomma anatolicum*
R. e= Rhipicephalus e. evertsi
R. s= Rhipicephalus sangiuanus
A. l= Amblyoma lepidum
H. r= Hyalomma rufipes

3.6 Tick burden

Regarding tick burden, out of 135 infested cattle, 93 (69.4%) were infested by (1-20) Ixodid ticks, 30 (22.4%) were infested by (21-40) ticks and 11(8.2%) were infested by (≥41) ticks. Among 40 infested sheep, there were 36 (90.0%) infested by (1-20) ticks, 4(10.0%) were infested by (21-40) ticks. From 16 infested goats, there were 15 (93.8%) infested by (1-20) ticks, 1 (6.3%) was infested by (21-40) ticks (Table 3.8).

3.7 Multivariate Analysis

In the logistic regression model, animal species was significantly (OR =7.8, *P* = 0.03, CI=1.279-47.474) affected the tick infestation prevalence, and goats were 7.8 times less infested than cattle.

The tick prevalence was significantly lower (OR =6.6, *P*=0.02, CI: 1.258-34.159) in animals where control measure had been used, and the prevalence was lower 6.6 times than the prevalence in uncontrolled animals. The tick prevalence was significantly lower (OR =5.4, *P*=0.002, CI: 1.842-16.087) in animals where two methods of control had been used (present of rural poultry and using of acaricides) and the prevalence was lower more than 5 times than the prevalence when using of acaricides only. The logistic regression analysis was presented in Table (3.9)

Table 3.8: Tick load in livestock ruminants in Khartoum North

Number of ticks	Cattle (%)	Sheep (%)	Goat (%)
1-20	93 (69.4)	36 (90)	15 (93.8)
21-40	30 (22.4)	4 (10)	1 (6.3)
≥41	11 (8.2)	0 (0)	0 (0)

Table 3.9: Multivariate logistic regression analysis of potential risk factors for livestock animals in Khartoum North

Risk factor	**Odds ratio**	***P*-value**	**95% CI**	
Area			Lower	Upper
Bahri (ref)				
Sharg Aneel	0.182	0.078	.27	1.207
Animal species				
Cattle (ref)		0.017		
Sheep	.688	0.706	.099	4.800
Goat	7.793	0.026	1.279	47.474
Animal age				
Young (ref)		.000		
Adult	.130	.000	.044	.383
Old	.046	.000	.012	.177
Animal gender				
Male(ref)				
Female	2.387	.130	.774	7.360
Animal breed				
Local (ref)				
Cross	.176	.059	.029	1.450
Herd size				
Small (ref)		.007		
Medium	.455	.133	.107	2.137

Large	6.115	.017	.732	50.508
Housing type				
Closed (ref)				
Semi closed	.018	.000	.002	.150
Control of tick				
No(ref)				
Yes	6.554	.026	1.258	34.159.
Method of control				
		.009		
Acaricides(ref)	1.701	.566	.277	10.449
Natural predators Two methods	5.444	.002	1.842	16.087
Removing of manure				.
Weekly(ref)		.792		
Monthly	.692	.724	.023	12.318
Other	1.259	.714	.368	4.303
Season				
Autumn(ref)		.033		
Summer	.125	.014	.034	.685
No answer	1.270	.682	.406	3.973

CHAPTER IV

DISCUSSION

The observed prevalence in the present study was lower than that reported byNateneal *et al*., (2015)(82%) in bovine in Bedele district, Oromiyia Regional State, Western Ethiopia and Jelalu *et al*., (2016) who recorded 75.5% in cattle in Arbegona District, Southern Ethiopia. This difference in tick infestation could be due to several factors associated with tick survival such as climate, location, tick control and husbandry system as well as some host determinants.

Within the studied area, tick infestation was significantly different among livestock of different locations. The prevalence of tick infestation in Bahri area was (88.8%) and (52.6%) in Sharg Alneel area. Difference of tick prevalence according to the location was also confirmed by different authors (Gumaa *et al*., 2015; Rehman *et al*, 2017). This difference could be due to the variation in husbandry practices including tick control methods such as using of acaricides regularly, removing of manure and existence of rural poultry in farms within the investigated livestock.

This study showed that the tick infestation prevalence was high in cattle (74.2%) followed by sheep (66.7%) and finally goats (45.7%). It is evident that the tick prevalence differed significantly among the three animal hosts (X^2 = 11.3, P=0.004). This finding is in agreement with other reports of Ghosh*et al*., (2007) in Bangladesh, India and Pakistan, Irshad *et al*., (2010) in Bangladesh, Mohammed*et al*., (2014) in Benisuef district, Egypt and Sultana *et al*., (2015) in

Pakistan. Observed higher tick prevalence in cattle as compared to sheep and goats might link to host genetics (Jonsson *et al.,* 2014).

Compared to older animals, younger ones had lower tick burden and this result agrees with some previous studies (Swai *et al*., 2005; Lorusso *et al.,* 2013; Rehman *et al*., 2017). Okello-Onen*et al*., (1999) stated that the young animals protect themselves from ticks by innate and cell-mediated immunity. In contrast,higher tick loads were observed in cattle younger than 1 year in a previous study conducted by Manaswini *et al.,* (2017).

Although there was no association between tick infestation and the sex as a risk factor, this study found that the tick infestation was higher in female animals compared to males which is agreed with previous studies (Igbal *et al.,* 2013 and Mohammed*et al.,* 2014). This is might be due to the sample size of females examined. Moreover, pregnancy and lactation could decrease the resistance in females, and therefore become more susceptible to any infection (Sutherst *et al.,* 1983).

Our study revealed that tick infestation was highest in (crossbred andforeign) cattle followed by local breed (Zebu) which is in line with previous reports from White Nile State in the Sudan (Guma *et al*., 2015), Egypt (Mohammed*et al*., 2014) and Ethiopia (Solomon and Kaaya, 1996; Desalegn *et al.,* 2015). In contrast, Belew and Mekonnen (2011) recorded that local breeds were more infested by tick (44.96%) than cross breeds (15.83%). Wambura *et al*., (1998) indicated that Zebu (*Bos indicus*) was reported to show some levels of relative resistance to tick infestation compared with *Bos indicus* and *Bos taurus* crosses. The resistance acquired by the local breed could be due to pre-immunity against ectoparasites as a result of frequent contact with the parasites at an early stage of life (Ahmed *et al.,* 2012).

Our finding that there is no association between tick infestation prevalence and the coat color of examined livestock animals is not consistent with the finding of Gasparin *et al.,* (2007), who recorded that lighter colored animals are more resistant than dark colored ones.Moreover, Hassan, (1997) found that white colored cattle carried more ticks than brown ones, while black cattle carried few number of ticks. He suggested that the dark coat color raising temperature of the host and consequently the tick die or leave the host.

Herd size was found to be significantly associated with tick infestation. Herds with medium numbers of animals had the highest tick infestation compared with those of small numbers, and the lowest prevalence reported in herds with high livestock density. This result could be due to the fact that the higher stocking density increases the chance of tick to infest large number of animals. The recorded prevalence of tick infestation in large herds examined could be attributed to their small sample size.

Regarding the housing type, animals kept in semi closed recorded the highest tick infestation compared with those kept in closed system. This is similar to the work of Igbal *et al*., (2013) and Rehman *et al*., (2017) who confirmed that grazing animals were more prone to tick infestation in a pasture than those animals kept in closed system with zero-grazing.

It was observed that farms, where control of ticks was practiced, had lower tick prevalence compared to farms without control methods. Within the used control methods, using of acaricides resulted in low tick prevalence but ticks were commonly found on a majority of studied farms. This might suggest occurrence of acaricides resistance. Such resistance has been reported in a previous study by Abbas *et al.,* (2014).The results showed that rearing of chickens reduced tick prevalence in the investigated livestock herds. Hassan *et al*., (1992) reported that hens are used in different locations as a mean of biological tick control as chicken are picking ticks from animal bodies as well as their surroundings.

The present survey revealed that regular removing of manure in investigated farms reduced the tick infestation prevalence. It is obviously that the weekly removing of manure decreased the tick infestation prevalence much better than the monthly manure removing.

According to this study, tick infestation was higher in summer season compared to autumn, this observation is in agreement with that recorded by Rehman *et al.,* (2017) who observed that both tick prevalence on an animal level and median tick burden were higher in the arid zone with high annual mean temperatures. In addition, thisresult goes in accordance with Rony *et al*., (2010) and Kabir*et al.,* (2011), who reported that tick load was significantly higher during summer season compared with winter and wet season. In contrast, Stuti *et al.,* (2008) revealed that the animals were infested with ticks during the rainy season more than summer and winter.

This study revealed that the udder (54.5%) and perineum (38.5%) of examined cattle were the most attaching sites of ticks, followed by external genitalia (3.11%), knee (2.3%), brisket (1.2%), ears (0.4%) and around eyes (0.04%). Mohammed*et al*. (2014) reported that udders and external genitalia were the most tick infested sites (70.7% each) followed by neck and chest (63.0% each), inner thighs (61.1%), perineum (41.7%), ears (14.6%) and around eyes (11.7%). This finding could be attributed to the fact that the udder is characterized by thinner skin that allows easy penetration of mouthparts of ticks into the skin area as well as the wide surface of udder with high blood supply.

In sheep, ears were the most tick infested site (70.6%), this is in agreement with that reported by Mohammed, *et al.,* (2014) in Egypt. On the other hand, tail was the most tick infested site (77.5%) in goats, followed by ears and around eyes.In contrast, they reported from Egypt that ears were the most predilection site infested by ticks in goats. The reason of ticks in ears of sheep is not known.

From 2367 ticks (male 1591, female776) collected, three genera and five species were identified. *Hyalomma anatolicum* were found to be the most dominant tick species (74.5%) in Khartoum North, followed by *Rhipicephalus e. evertsi* (16.1%), *Rhipicephalus sangiuanus* group (9.04%), *Hyalomma rufipes* (0.2%) and less frequently *Amblyomma lepidum*(0.09) *H. anatolicum* was the most common tick species in all districts. Salih *et al*., (2004) reported that *Hyalomma anatolicum*, the exophilic tick was the most abundant species in Atbara, El Damer and Khartoum and the highest mean was recorded in Khartoum. This species is thriving in semi-desert conditions in

Northern Sudan, and is spreading southwards in the Central Sudan (Jongejan *et al*., 1987).

In cattle four species of ticks were recorded; *Hyalomma anatolicum*, *Amblyomma lepidum*, *Rhipicephalus e. evertsi*, *Rhipicephalus sanguineus* group. *H. anatolicum* was the most abundant species in cattle in the area, which agrees with previous reports from Wad Medani and Khartoum, respectively (Lazarus, 2002; Mohammed *et al*., 2004; Salih *et al*., 2004). Only two males of *A. lepidum* were found in one cattle farm in Al Silait in this study, this tick species is abundant in eastern parts of the Sudan as reported by earlier studied (Karrar *et al*., 1963; Walker *et al*., 1987). Factors such as animal movement, habitat change, drought, desertification and global climatic changes may force ticks to extend their distribution ranges beyond their known geographic regions (El Ghali and Hassan, 2012).

Likewise, four species of ticks were identified in sheep;*Hyalomma anatolicum*, *Hyalomma rufipes*, *Rhipicephalus e. evertsi*and *Rhipicephalus sanguineus* group. These species have been reported previously in Khartoum by Gad Elrab (1986). *R. sanguineus* group was the highest tick burden in sheep.*Rhipicephalus e. evertsi* was the most prevalent tick species in examined goats followed by *Rhipicephalus sanguineus* groupand *H. anatolicum.*

Regarding the sex of ticks identified in this study, the numbers of male ticks were more than female ticks (67.2 %, 32.8%). This finding is logic because the females mate only once, then detaches from the host, while male ticks remain on the host and will attempt to mate with many females before dropping off (Walker *et al.,* 2003). In addition, host grooming could easily remove partially-engorged or engorged females as compared to males (Solomon *et al.,* 1998).

Conclusions

This study revealed high prevalence of tick infestation among cattle, sheep and goat's populations in Khartoum North. *H. anatolicum* is the most common tick species infesting ruminants in the study area, which transmitting Tropical Theileriosis in livestock animals that lead to a great loss in animal production.*Rhipicephalus e. evertsi*, *Rhipicephalus sangiuanus* group, *Hyalomma rufipes* and *Amblyomma lepidum* were also reported.Animal species, age, location, herd size, housing type, tick control, method of controlling ticks, removing of manure and seasonare the risk factors associated with tick infestation prevalence in the livestock prevalence in Khartoum North.

Recommendations

According to data generated from the present survey,we recommend to map TBDs and plan of combined control strategies for ticks and TBDs inSudan.

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Appendix 1

QUESTIONAIRE

Date: ………………………………

Owner name: ……………………..................

Telephone……………………

District: ……………………………

Coordinate: N …………………………E ……………………………

Herd size………………...

Housing type:

closed ☐ open ☐ semi closed ☐

Raising system:

one species ☐ mixed species ☐

Feeding types:

roughages ☐ concentrates ☐ mixed ☐

Animal species:

cattle ☐ sheep ☐ goats ☐

Animal breeds:

local ☐ crossbred ☐ foreign ☐

Animal sex:

male ☐ female ☐

Animal age: ………………….

Coat color:

white ☐ black ☐ brown ☐ other ☐

Tick infestation:

presence ☐ absence ☐

Predilection site:

ear ☐ udder ☐ tail ☐ knees ☐ brisket ☐ testes ☐ wither ☐

High tick infestation period in the year:

wet hot ☐ dry hot ☐ dry cold ☐ no answer ☐

Control of tick:

yes ☐ no ☐

If yes, specify the control method:

acaricides ☐ …………… interval…………….

natural predator ☐ both ☐

Removing of manure:

weekly ☐ monthly ☐ other …………

INTRODUCTION

Ticks are small arachnids; they are ectoparasites, feeding on the blood of mammals, birds, and sometimes reptiles. Economically, ticks are the most important pests of livestock in tropical and subtropical areas (Jongejan and Uilenberg, 1994).

Ticks of animals are considered harmful to livestock not only due to tick bite and blood loss but also by transmission of many species of pathogens, as well as reducing wool and hides value (De Castro, 1997). Ticks feeding in large numbers can cause a systemic suppression of their host's immunity and this may predispose animal to secondary infections. Ticks and tick-borne diseases (TBDs) are major constraints to livestock improvement in many parts of the world including the Sudan (Osman, 1992; Walker *et al*., 2003).

In Sudan, the estimated cattle population is 31million and there are 40 million sheep and 31 million goats (MoAR, 2019). On the other hand, ticks and tick-borne diseases are widespread and cause great economic losses in the animal productivity (Gamal and El Hussein, 2003; El Hussein *et al*., 2004) and the main ticks found belong to genera*Hyalomma*, *Rhipicephalus*, *Rhipicephalus* (*Boophilus*) and *Amblyomma* (El Hussein *et al*., 2012).

In several parts ofSudan, numbers of published data are available on tick species from different livestock animals and tick-borne diseases (TBDs).Salih *et al*., (2004) recorded different tick species of cattlein 17 locations in the country. Hassan *et al.,* (2016) identified two tick genera and six species in sheep and goats in Khartoum State and recorded high tick load in Khartoum North followed by Khartoum and Omdurman (3.82±0.76, 1.0±0.30 and 0.85±0.23 respectively). In White Nile State,the genera belong to *Amblyomma, Hyalomma* and *Rhipicephalus* species were identified by Gumaa *et al.,* (2015).

Moreover, numerous studies from the regional countries reported the tick infestation prevalence. In Ethiopia, Desalegn *et al.,* (2015) found that 16.6% of examined domestic ruminants were infested by one or more tick species. Mohammed*et al.,* (2014) revealed that the prevalence and distribution of tick infestation in different animal species in Egypt was 30.1%. Few studies were addressed the tick infestation prevalence and associated risk factors in the Sudan. Investigation of frequency and distribution of ticks infesting livestock animals are crucial for the diagnosis of different tick borne diseases and their respective control programs.

Objectives:

1.To determine the prevalence of tick infestation in cattle, sheep and goats in Khartoum North.

2.To investigate the potential risk factors associated with tick infestation in these livestock species in the study area.

CHAPTER I

LITRITURE REVIEW

1.1 Ticks

Ticks are small arachnids; they are harmful, blood-sucking external parasites of mammals, birds, reptiles and amphibians. Tick infestation has direct impact on animal health and production in many parts in the world, including sub-Saharan Africa (Jongejan and Uilenberg, 2004).Bowman *et al.,* (1996) estimated more than 80% of the world cattle population is infested by ticks, which transmit a wide range of viral, bacterial and protozoan pathogens causing tick borne diseases (TBDs).

There are at least 866 described species of tick in the world, and ticks are major obstacle to the livestock industry in Africa since this part of the world is particularly affected because of the large number of tick species and variety of diseases caused (Walker *et al.,* 2003).

1.2 Taxonomy of tick

Ticks belong to the Kingdom Animalia, the phylum Arthropoda, class Arachnida, sub class Acari and sub order Ixodida. Ixodida contains three families, theIxodidaeor hard ticks (692 species), the Argasidae or soft ticks (186 species) and Nuttalliellidae (one species) (Nava *et al.,* 2009). The major genera of Ixodidae family are *Rhipicephalus (Boophilus), Amblyomma, Hyalomma, Dermacentor, Haemaphysalis, Ixodes, Margaropus* and *Rhipicephalus* and the major genera of Argasidae are *Argas, Ornithodoros* and *Otobius* (Horak*et al*., 2002). There are many distinct features between hard ticks and soft ticks, but the main feature is that Ixodid ticks have scutum or a conscutum as a hard shield on their dorsal surface unlike Argasid ticks (Walker *et al.,*2003).

1.3 Tick life cycle

Ticks have four stages in their life cycle, namely eggs, larvae, nymphs and adults (Hoogstraal, 1956). In hard ticks, mating occurs on the host except Ixodes where it may also take place when the ticks are still on the vegetation. Male ticks attempt to mate with many females as they are feeding, while females mate only once, before they are ready to engorge fully with blood. Then they detach from the host and have enough sperm stored to fertilize all their eggs. They lay many eggs (2,000 to 20,000) in a single batch. Eggs are laid in the physical environment, never on the host. The common type of life cycle is the Three-host tick life cycle, in which case it requires a new host for each developmental stage such as *Amblyomma* species and *Rhipicephalusappendiculatus* (Soulsby, 1982). The life cycle of three-host ticks is slow, from six months to several years. Larvae hatch, usually in several weeks and they feed once on a host, then detach and hide in soil or vegetation. They moult to nymphs, which feed once and moult in the similar way as larvae and moult to adult tick (Walker *et al.*, 2003).

In The two-host life cycle, the larvae and nymphs feed on the same individual host, and the adults feed on another host. *Hyalomma scupense* and *Rhipicephalus e. evertsi*have two-host life cycles (Kettle, 1995).

One-host tick life cycle is a less common type of life cycle but it occurs in *Rhipicephalusannulatus*. All three feedings of any individual tick occur on the same individual. The adults will change position on the same host for mating. The life cycle of the one-host ticks is usually rapid host (Walker *et al.,* 2003).

1.4 Ecology of ticks

Ticks are widely distributed throughout the world particularly in tropical and subtropical countries. However, each species of tick is adapted to different macro and microclimates (Soulsby, 1982). Air temperature and relative humidity are critical factors determining longevity of host-seeking ticks which decreases with increasing temperature. Rapid death of ticks at high temperature is most probably due to very high rates of water loss or heat stress (Tukahriwa, 1976; Utech *et al*., 1983). Tatchell and Easton (1986) stated that host density, host susceptibility, vegetation type and host grazing behavior are important factors in tick regulation and distribution.

Ticks vary in their response to ambient temperature within sex, age and host species. Each species has critical temperature above which its survival is greatly influenced. This critical temperature generally varies with different genera. Environmental conditions such as temperature, relative humidity are critical for the longevity and survival of unfed stages in the vegetation (Tukahriwa, 1976; Dark, 1995).

1.5 Distribution of ticks in the world

Ixodes species have reported in Europe and North America (Jongejan and Uilenberg, 2004;Jaenson *et al.,* 2012); and they are responsible for transmitting zoonotic diseases likeLyme borelliosis. Bugmyrin*et al.,* (2013) considered southern Karelia (Russia) as a zone of *Ixodes. ricinus* and *I. persulcatus*, without a clear geographic boundary between the two species. *Ixodes persulcatus* was detected in 9 of 36 field localities in the Bothnian Bay area (Jaenson, *et al.,* 2016). *I.scapularis* is the most common *Ixodes* in North America (Jongejan and Uilenberg 2004).

Rhipicephalus microplus is the most important species of *Rhipicephalus* that occurs in the tropics including Australia, East and Southern Africa, and South and Central America. *B. annulatus* is found in the Mediterranean region, southern Russia and also distributed in Africa in a belt from West Africa to Southern and Central Sudan (Hoogstraal, 1956). *B. decoloratus* and *B. geigyi* are also common in Africa (Jongejan and Uilenberg, 2004).

Haemaphysalis species are important to livestock animals in Europe and Asia and have been introduced into Australia, New Zealand and New Caledonia (Jongejan and Uilenberg, 2004). Du *et* *al.,* (2018) reported that *Haemaphysalis (Alloceraea) kolonini* as a new species in Southwestern province Yunnan, China.

Haemaphysalis longicornis, Dermacentor silvarum, Ixodes persulcatus, Haemaphysalis conicinna, Rhipicephalus microplus and *Rhipicephalus sanguineus senus lato* are the most frequently tick species in China (Zhang *et al.,* 2019).

Rhipicephalus turanicus was the most abundant species in an urban park in Rome, Italy, followed by *Ixodes ricinus*, *Dermacentor marginatum* and *Haemaphysalis punctata,* respectively (Manici *et al.,* 2014).

Hyalomma speciesare abundant in semi-arid zones and have been reported in Iran (Ganjali*et al.,* 2014). *Hyalomma marginatum* is found in Southern and Eastern Europe and is responsible for transmitting Cremean-Congo Hemorrhagic fever virus, which an emerging pathogen in Europe (Jongejan and Uilenberg, 2004).*H. anatolicum* is the most common tick species infesting ruminants in Pakistan, and *Hyalomma dromedarii* was also reported in the same area (Rehman *et al.,* 2017).

Amblyomma hebraeum,*Rhipicephalus appendiculatus*,*Rhipicephalus decoloratus* and *Ixodes rubicundus* are reported in cattle and wildlife in South Africa (Hoogstraal,1956) as well as *Ixodes rubicundus*, *A. hebraeum*, *R. microplus*, *R. evertsi mimeticus*, *H. silacea* (Horak *et al.,* 2015).*Amblyomma variegatum* is the most important species on the African continent throughout tropical sub-Saharan Africa and *A. hebraeum* is present in the south-eastern part of the African continent (Jongejan and Uilenberg 2004).

Rhipicephalus spp. are common on mammals in Africa, particularly the brown ear tick *R. appendiculatus*, which is the most important *Rhipicephalus* species. of domestic and wild ruminants in East and Southern Africa (Jongejan and Uilenberg, 2004). It is responsible for transmitting the parasite *Theileria parva* in eastern, central and southern Africa, where it causes East Coast fever, Corridor disease and January disease in cattle (Perry *et al.,* 1991).

The most common ticks infesting cattle and goats in the eastern region of the Eastern Cape Province, South Africa and Maputo Province, Mozambique were *Amblyomma hebraeum*, *Rhipicephalusmicroplus*, *Rhipicephalus appendiculatus* and *Rhipicephalus evertsi evertsi*and the dominant species on dogs were *Haemaphysalis elliptica* and *Rhipicephalus simus* (Horak *et al.,* 2009).

In Egypt, *Hyalomma anatolicum*, *Rhipicephalus microplus*, *Rhipicephalus sanguineus*,*Rhipicephalus annulatus* and *Haemaphysalis* spp. were present in Beni-Suef (Mohammed*et al.,* 2014).

Several *Amblyomma* species including; *A. lepidum*, *A. astrion,A. gemma,A. pomposum*, A. *cohaerens* and *A. variegatum* have been introduced into the Caribbean region from West Africa. *A. americanum*, *A. cajennense* and *A. maculatum* have economic significance in the American continent (Jongejan and Uilenberg, 2004).

1.6 Distribution of ticks in Sudan

According to previous reports fromSudan, *Hyalomma dromedarii* is distributed in area with annual rainfall below 250 mm and may be found in desert and semi-desert areas. Osman and Hassan, (2003) described that *Amblyomma lepidum* is generally concentrated in the central of the eastern part of the country from Torit and Kapoeta in the south to Kassala in the north, but absent in Northern provinces.Abdallah (2007) confirmed that *A. lepidum* has spread from eastern parts of country to Darfur State, as well as *H. anatolicum* which is commonly found in the State.*H. impeltatum* was also reported as the most dominant species in Kosti province (El Imam, 1999).

A. lepidum, *A. variegatum*, *R. decoloratus*, *R. annulatus*, *Hyalomma rufipes*, *H. truncatum*, *Rhipicephalus* and *Haemaphysalis* spp. were reported in Southern Kordofan (Sowar, 2002). Osman *et al.,* (1982) stated that *H. impeltatum* was the most dominant tick of sheep in arid area of Kordofan.

Karrar *et al.,* (1963) reported that tick species that infest domestic animals in Kassala, Eastern Sudan are *H. anatolicum,H. excavatum*, *H. dromedarii*, *H. impeltatum,H. rufipes*, *H. truncatum*, *Rhipicephalus e. evertsi*, *R. sanguineus*, *R. praetextatus*, *Rhipicephalusdecoloratus* and *A. lepidum.*

According to Food and Agriculture Organization(FAO, 1983), *H. rufipes* and *Rhipicephalus e. evertsi* are present in the Central Sudan and *H. anatolicum* in the northern parts of central Sudan, and *A. lepidum* in central grassland, semi desert, rare in mixed forests and forest savanna and disappear in desert area. *R. guilhoni* is the most common species of ticks infesting sheep in Sennar State (Suleiman, 2004).

Salih *et al.,* (2004) identified *Hyalomma anatolicum*from cattle in Atbara and Eldamer, and *H. dromedarii* from all localities (Atbara, El Damer, Khartoum, Madani, Sennar, Um Benin, Damazin, El Dieum, Rabak, Kosti, El Obeid, Fasher, Nyala and Geneina). *Rhipicephalus decoloratus*, *H. impeltatum*, *H. truncatum*, *H. rufipes*, *R. evertsi evertsi*, *R. praetextatus* and *R. sanguineus* group collected from several localities.

In Khartoum, Latif *et al.,* (1994) identified*H. anatolicum, H. truncatum*, *B. decoloratus*, and *R. sanguineus.*Hassan *et al.,* (2016) identified *H. anatolicum, H. impeltatum, R. camicasi, R. evertsi evertsi, R. guilhoni* and *R. sanguineus* in sheep and goats in Khartoum State.

Altigani and Mohammed (2010) reported that *H. dromedarii*as the predominant tick species in El Butana area mid-eastern Sudan, followed by *H. rufipes,H. impeltatum, H. anatolicum*, *H. truncatum*, *A. lepidum* and *R. sanguineus*.

1.7 Risk factors associated with tick infestation

The effect of host characteristics has informing various degrees of resistance to tick infestation (Berman, 2011).Tick infestation depends on species, the region, host population and developed control measures (Solis, 1991). Rehman *et al.,* (2017) reported that absence of rural poultry, not performing acaricide treatments, traditional rural housing systems and grazing were important risk factors associated with higher tick prevalence in livestock farms. Age, gender, breed and animal species significantly affected the intensity of tick infestation.Tick presence and tick loads vary with seasons, geographic location, vegetation type, breed, habitation and age of the animal (Mtshali *et al.,* 2004).

The impact of environmental factors such as climate (Estrada-Pena, 2009) and habitat type (Thamm *et al.,* 2009) on the patterns of tick prevalence have been investigated in various parts of the world.

1.8Important tick species in Sudan

A total of 72 tick species have been identified in Sudan (Hassan and Salih, 2013). The most economically important ticks of livestock in Sudan belong to the genera *Hyalomma*, *Rhipicephalus* and *Amblyomma,*14 of which infestlivestock and five are vectors of very important tick-borne disease. *Hyalomma anatolicun* is the vector of *Theileria annulata* which causes 30% calf mortality in exotic dairy herds, *T. ovis* which causes high mortality in sheep and *Babesia cabali*and*Theileria equi* which causes equine babesiosis. *Rhipicphalus e. evertsi* transmits *T. ovis* and is a potential candidate for *T. annulata* transmission. *Rhipicephalus* species transmit cattle babesiosis and anaplasmosis. *Amblyoma Iepidum* and *A. variegatun* transmit Erhlichiosis in sheep (El Hussein *et al.,* 2012).

1.9Tick-borne diseases in Sudan

Tick-borne illnesses are caused by infection with a variety of pathogens, including rickettsia and other types of bacteria, viruses, and protozoa.Theimportant tick- borne disease in Sudan are:

1.9.1 Tropical theileriosis

Tropical theileriosis is a tick-borne disease of cattle caused by *Theileria annulata*. In Sudan, the pathogen is transmitted mainly by *Hyalomma anatolicum*(Salih *et al.,* 2005). It is highly fatal in exotic breeds and their crosses, while little or no mortality in local breeds. Latif *et al.,* 1994) reported that 85 % of dairy farms investigated inKhartoum Province experienced clinical theileriosis and mortalities among newly born calves and heifers, which 22% and 30%, respectively. Bashir*et al.,* (2018) detected an infection with *T. annulata* in 63% of examined cattle from Sennar State. Recently, Mohammed-Ahmed,*et al.,* (2018) reported that 68.3% (164/240) of serum sample from cattle in North Kordofan State were positive for antibodies against *T. annulata* using IFA test.

1.9.2 Malignant Ovine Theileriosis

Malignant Ovine Theileriosis (MOT) is caused by highly pathogenic species of *Theileria* (Ali *et al.,* 2017).*Theilerialestoquardi*is transmitted by *Hyalomma* ticks (Levine, 1973).MOT considered as an important cause of morbidity and mortality among sheep in the Sudan. Recently, the result of the estimation of the prevalence of MOT in five States in Sudan, indicated a sero- prevalence of 33.8% from serum samples of clinically asymptomatic sheep (Hassan *et al.,* 2019). An average of 17 % of sheep admitted for treatment at Atbara Veterinary Clinic, Northern Sudan, was diagnosed as MOT. The prevalence of *T. lestoquardi*antibodies using IFA test based on schizont antigen. Antibodies were found in all sheep grazing areas ofSudan (Elhussein *et al.,* 2004).

1.9.3 Erhlichiosis

This disease caused by *Ehrlichia ruminantium* and transmitted by *Amblyomma* species (Semu and Mahn 2001).Erhlichiosis was reported as a considerable disease of sheep and goats in Eastern

Sudan (Karrar, 1960). It is identified in other parts of the country including Western Sudan (Abdel Wahab *et al.,* 1998).A serological survey indicated high prevalence of *E. ruminantium* antibodies in cattle, sheep and goats (83%, 69% and 75.2%, respectively) (Abdel Rahman*,* 2006). In Sennar State, (Mohammed*,*2003) found that 76.6% (230/300) of sheep sera in five localities namely Sennar, Singa, Dinder, Um Benin and Abu Naama were positive for*E. ruminantium* antibodies by ELISA Test.

1.9.4 Equine Piroplasmosis

The causative agents of this disease are two protozoan parasites *Babesia caballi* and *Theileria equi*. They are transmitted by *Dermacenter, Hyalomma* and *Rhipicephalus* (Kamyingkird *et al.,* 2014). The prevalence of the disease among horses and donkeys in Sudan was 35.95% using molecular techniques (Salim *et al.,* 2013). Recently the overall prevalence of Equine Piroplasmosis in Khartoum State was 27.4% (Abdel Nasir, 2017).

1.9.5 Avian Spirochaetosis

Avian Spirochaetosis is caused by *Borrella anserina* and transmitted by *Argas* spp. An investigation in River Nile State revealed that the disease wasthe second most significant bacterial disease of chickens in the area (a 5-year average relative Incidence of 25 % of the diseases of poultry diagnosed) (El Hussein *et al.,* 2004). Khalifa*et al.,* (2013) reported a low occurrence of Spirochaetosis in Sudan in a retrospective study (2000-2005) of poultry diseases diagnosed at Department of Avian diseases and Veterinary Research Institute in Khartoum.

1.10 Economic impact of ticks

Losses due to tick-borne diseases are incurred by mortality, abortion, reduction in milk yield and weight gain, reduce productive life and cost of treatment (El Hussein and Atta Elmanan2003). Mohammed, (2003) found that there is a heavy loss in live weight gain which is attributed to tick infestation. Tick may harm their hosts by injuries caused by their bites which may predispose the host to attacks by blowflies, screwworm, or by sucking blood and by transmission of viruses, bacterial protozoal or rickettsial diseases. These effects together may vary from situation where it is impossible to raise livestock to one where great expense is incurred in control of ticks. Anemia caused by loss of blood is another important impact of ticks on livestock industry. The amount of blood taken by a particular vector is epidemiologically important (Rechav *et al*., 1994).

1.11 Diagnosis of Tick-borne diseases

For effective control and treatment of tick-borne diseases, sensitive, reliable and rapid diagnostic tests are important. Provisional diagnosis includes history, clinical signs, postmortem findings and knowledge of disease and vector distribution (OIE, 2000). Several techniques for detection of tick-borne diseases have been applied.

Microscopic techniques are used in detecting *Theilieria* schizonts in the lymph node smear, piroplasms in blood smear and Babesiosis in blood or organ smear stained with Romansky stain as well as acute form of *Anaplasma* infection in Giemsa stained thin smears (Callow *et al.,* 1993; Bose *et al.,* 1995).

Diagnosis of tick-borne diseases using microscopic examination requires intensive labor and well-trained technicians. In carriers where the parasitemia is low, microscopic examination is not sensitive method (Friedhoff and Bose 1994; Bose *et al*., 1995). Adam *et al.,* (2017) diagnosed Theileriosis in the dairy farms around Nyala town, South Darfour State by using blood smear technique. Microscopic examination was also used to detect *Theileria* spp piroplasms in sheep in Al Huda National Sheep Research Station (Ahmed*et al.,* 2018).

Rapid development of heart water Disease, Lack of clinical signs and total absence of lesions, made the diagnosis of Erhlichiosis in live animal difficult (Camus *et al.,* 1996).

Serological tests are used when parasites occur in low numbers or cannot demonstrated in a sample due to the life cycle of the host. Complement fixation test (CFT), Indirect Fluorescent Antibody Technique(IFAT), Enzyme Linked Immunosorbent Assay(ELISA) were used in numerous previous studies. Hassan *et al.,* (2016) used Indirect Fluorescent Antibody (IFA) test to assess antibodies of *Theileria. lestoquardi* in sheep and goats in Khartoum State.

Conventional PCR, RAPID- PCR, RFLP-PCR, multiplex PCR, real-time PCR, Reverse Line Blot (RLB) and reverse transcriptase PCR were also reported in molecular diagnosis of tick-borne diseases. RLB was used to detect and simultaneously differentiate between *Theileria* and *Babesia* species infecting sheep in six different localities (Atbara, Khartoum, Kosti, Medani, Damazin and Nyala) in Sudan (El Imam *et al.,* 2016).

1.12 Tick Control

Tick control on livestock is very essential to reduce tick population and consequently prevent diseases caused by tick- transmitted pathogens. Eradication of ticks is mostly not possible except in Islands, where effective campaigns have sometimes been applied (Jongejan and Uilenberg, 1994). The control of tick-borne diseasesdepends on intensive using acaricides (Drummond, 1976). However, these chemicals are toxic, leave residues in meat and milk, and cause environmental pollution (Hassan, 2003; Butox, 2017). Moreover, acaricides are not only expensive but also the resistance of ticks to different acaricides is reported (Aziz, 2003). Treatment of animals by dipping or spraying with acaricides is more efficient than using them in pasture (FAO, 1984).

Acquired resistance of the host after repeated infestation by ticks to Ixodid ticks has been recognized as a biological control method (Trager, 1939). Acquired immunity varies with the tick species, the host breed and between the individuals of the host. Reduction in the number of ticks attached the host, reduce engorgement weights and reduce egg and larval production resulting in reduced tick population (Willadsen, 1980). Generally, *Bos indicus* have a much higher proportion of acquiring resistance to ticks than *Bos taurus* breed (European)(Wambura, *et al.,* 1998). In the Sudan, crossbred carried 4.5 times more ticks than Kenana and Butana (Latif, 1984).A major new approach in the control of ticks in Australia is the development of an anti-tick vaccine against *B. microplus* (Jongejan and Uilenberg, 1994).

Biological control of ticks relies on natural enemies, many rodents, ants, and birds feed on ticks reducing tick population (Hoogstraal, 1956) Samish and Rehacek, 1999, Samish and Glazer, 2001). Domestic chickens considered to be a natural tick predator in open system (Hassan *et al.,* 1992). In a trial in the Western Kenya, Mwangi *et al.,* (1997) reported that *Ixodiphagus hookei* which lays its eggs in nymphs of *A. variegatum* reduce tick infestation in cattle by 95%.

CHAPTER II

MATERIALS AND METHODS

2.1 Study area

The current survey was carried out in Khartoum North (includes Bahri and Sharg Alneel localities) which situated in Khartoum State, the capital of Sudan. The area is located in the centre of Sudan at the confluence between latitude 15.5518° N and longitude 32.5324° E and shares borders with Khartoum to its south and Omdurman to its west (Figure2.1). Khartoum North features a hot arid climate. The area has the largest livestock population in Khartoum State comprises of 223,131 cattle, 457,270 sheep and 592,905 goats (Ministry of Agriculture, Animal Resources and Irrigation-Khartoum State -2018).

2.2 Study design, sampling, and study population

The study was carried out during December 2017 to April 2018 to determine the prevalence of tick infestation in livestock population in Khartoum State.

A cross-sectional study deign was selected and the sample size was calculated using the formula described by Thrusfield, (2007) assuming 50% prevalence, 95% confidence interval and 5% desired absolute precision. Accordingly, 277 ruminants including 182 cattle, 60 sheep and 35 goats of both sexes and different age groups were examined in the area of Khartoum North.

To select study animals, the two localities Bahri and Sharg Alneel within the area were chosen at the first level and villages were further conveniently selected at the second stage,in Bahri, the livestock farms were selected in four villages, namelyAlgaili, Wadramli, Wawissi and Samrab and in Sharg Alneel, the livestock farms were selected in five villages namely Shigla, Silait, Kafouri, Ailafoon and Kuku. In each selected village, animal herds were visited for tick sampling and the total number of animals examined in Khartoum North was proportionally allocated to the number of animals in each locality. Animals were randomly selected from 44 farms; 30, 8 and 6 for investigating cattle, sheep and goats, respectively and a minimum of five and a maximum of ten animals were examined in each herd.Animals are divided into three age groups; young (< 2 years old of cattle) and (1-6 months in sheep and goat), adults (2–5 years old of cattle) and (>6 months–3 years old of sheep and goats) and old (>5 years old of cattle) and (> 3years old of sheep and goats). Local, crossbred and foreign breeds as well as livestock with 4 coat colors (white, black, brown and mixed) were investigated in the study area.Examinedanimals were kept into two housing types; closed and semi closed with two raising types; one species and mixed species and there were three herd sizes; small (10-50) animals, medium (51-100) and large (101-150).Studied animals were fed two feeding types; either roughages or roughages mixed with concentrates.

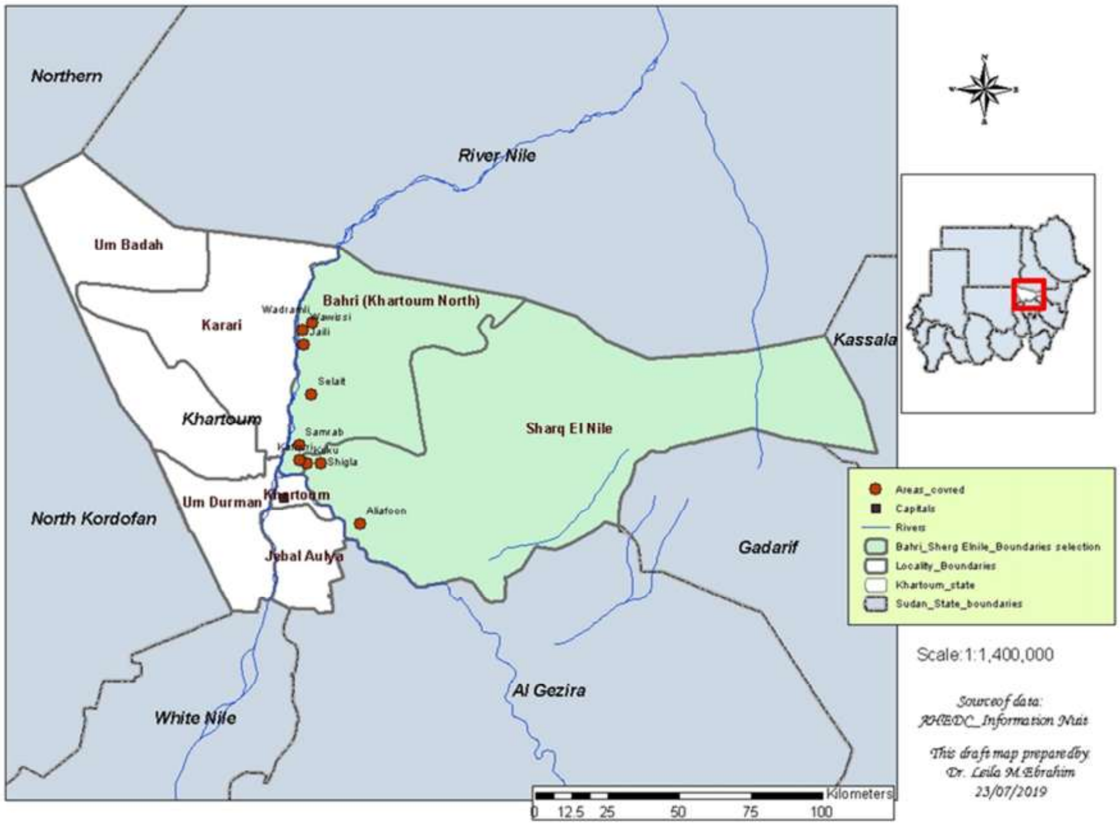

Figure 3.1: The study area, Khartoum North

2.3 Collection and preservation of ticks

The selected animals of different species were properly restrained then ears, brisket, withers, knees, udder, testes, tail and around eyes were examined for the presence of ticks. All attached adult ticks were collected by rotating the tick by hand to avoid losing the mouth parts and transferred for each animal in labeled universal bottles containing (70%) ethanol. The information was written in the label including; locality, village, farm number, animal species and predilection site.

2.4 Potential risk factors associated with tick prevalence

Prior to tick collection, a pretested questionnaire containing closed and open questions was used to identify possible risk factors associated with tick prevalence. The questionnaire was divided into three parts: host-related information, farm-related information and management and environment-related information. The data were collected from all visited farms with the help of the owners of animals and they were obtained in (Appendix 1).

2.5 Identification of ticks

In Parasitology Department of Central Veterinary Research Laboratory, ticks were morphologically identified according to taxonomic keys described bywalker*et al.,*(2003) to the species level under a stereomicroscope.

2.6 Data Analysis

The prevalence of tick infestation in individuals and herds were determined by dividing the number of positive samples by the total investigated animal, and was expressed as percentages. Initially collected data were analyzed by SPSS version 20.0 and Chi-squaretest was used to evaluate association between hypothesized risk factors and tick infestation status of the animal and the level of significance was set as *P-value* ≤ 0.05. Finally, significant risk factors were entered and analyzed using the logistic regression to assess the association between tick infestation and the interaction between risk factors, variables with *P-value* ≤ 0.25 in univariate analysis were entered in the logistic regression model.

CHAPTER III

RESULTS

3.1 Prevalence of tick infestation

Out of the total 277 examined domestic ruminants, 191 were infested by varying numbers of tick genera leading to an overall individual prevalence of 68.9%.

The overall prevalence of tick infestation in different herds was 88.6%. In herds of cattle, sheep and goat, the prevalence were (93.3%, 87.5 % and 66.7%, respectively) (Table 3.1).

3.2 Risk factors analysis

3.2.1 Districts

Within the region of Khartoum North, Bahri was recorded the highest prevalence of tick infestation in examined livestock (88.8%) compared with Sharg Alneel (52.6%). The prevalence of tick infestation was statistically significant different (X2= 42.0, *P* = 0.000) among livestock of different areas (Table 3.2).

3.2.2 Host characteristics

Concerning the effect of host characteristics, animal species revealed that cattle had the highest prevalence of tick infestations of 74.2% followed by sheep 66.7% and then goats 45.7%. The difference in the prevalence of tick infestation was found to be statistically significant among the three species of animals (X2 = 11.3, P=0.004) (Table 3.3).

Based on age, older animals aged (<5 years old of cattle) and (< 3years old of sheep and goats) had the highest prevalence of

87.8% compared with the prevalence (66.1%) in the adult ages (2–5 years

Table 3.1: Prevalence of tick infestation in different herds of different animal species in Khartoum North

Animal species	Examined farms	Positive farm (%)
Cattle	30	28 (93.3)
Sheep	8	7 (87.5)
Goats	6	4 (66.7)
Total	44	39 (88.6)

Table 3.2: Prevalence of tick infestation in domestic ruminants within the districts of Khartoum North

Locality	No. of examined	No. of infested (%)	X^2	p- value
			42.0	**.000***
Bahri	125	111 (88.8)		
Sharg Aneel	152	80 (52.6)		
Total	277	191 (68.9)		

old of cattle) and (<6 months–3 years old of sheep and goats). The lowest prevalence of tick infestation was seen in younger animals aged (> 2 years old of cattle) and (1-6 months in sheep and goat) with 56.1%. The prevalence of tick infestation was significantly different (X2 = 19.1, P=0.000) among the different age groups (Table 3.3).

Sex–wise prevalence revealed that females had slightly higher prevalence of 71.1% compared with the males 59.2% and there is no significant association between tick infestation prevalence of tick infestation and sex of animals ($X^{2\,=}$ 2.7, *P* = 0.103) (Table 3.3).

Regarding the livestock breeds, crossbred and foreign breed had the highest prevalence of tick infestations of 72.4% compared with local breeds 62.0%. Accordingly, no significant association was found between the prevalence of tick infestation and breeds of examined ruminants ($X^2 = 3.2$, $P = 0.07$) (Table 3.3).

Based on our results, the difference was not significant among tick infestation prevalence and different coat color of examined animals ($X^2 = 3.5$, P=0.316) (Table 3.3).

Table 3.3: Effect of host characteristics on tick infestation prevalence in livestock animals in Khartoum North

Risk factors	No.of examined	No.of infested (%)	X^2	p- value
Animal species			11.3	**.004***
Cattle	182	135 (74.2)		
Sheep	60	40 (66.7)		
Goat	35	16 (45.7)		
Age			19.1	**.000***
Young	82	46 (56.1)		
Adult	121	80 (66.1)		
Old	74	65 (87.8)		
Sex			2.7	.103
Male	49	29 (59.2)		
Female	228	162 (71.1)		
Breed			3.2	.07
Local	92	57 (62.0)		
Cross and foreign	185	134 (72.4)		
Coat color			3.5	.316
White	89	55 (61.8)		
Black	61	43 (70.5)		
Brown	42	32 (76.2)		
Mixed	85	61 (71.8)		

3.2.3 Managemental and environmental factors

Regarding the effect of managemental risk factors, medium herd size (51-100) had the highest prevalence of tick infestation of 80.7% compared with the small herd size (10-50) 67.6 % and the lowest reported in the large herd size (101-150) of 20.8%. The prevalence of tick infestation was significantly different (X^2 =33.4, P = 0.000) among livestock of different herd size (Table 3.4).

In the current survey, the semi closed housing reported the highest prevalence of tick infestation of (95.7%) compared with closed one (59.9%). The difference in the prevalence of tick infestation between the two types of housing found to be statistically significant (X^2 =31.3, P=.000) (Table 3.4).

Our data showed that both raising and feeding type were not considered as risk factors for tick infestation among cattle, sheep, and goats (Table 3.4).

The prevalence of tick infestation in animals subjected to tick control were greatly less than those not exposed to any method of controlling ofticks (55.1% and 90.0%, respectively) and the difference of tick infestation prevalence was significant between the two groups (X^2 =37.8, P=0.000) (Table 3.4).

Regarding tick prevalence based on methods of control, rearing chickenscombined with using acaricides and rearing chickens only were effective methods of tick control (41.5% and 60.0%) compared by using of acaricides only (64.1%). The prevalence of tick infestation was statistically different (X^2 =47.0, P = 0.000) among livestock with different methods of control (Table 3.4).

The prevalence of tick infestation among livestock when the removing of manure occurred monthly was greatly higher 94.5% and tick infestation prevalence in animals exposed to weekly manure removing 48.3%. The difference in the prevalence of tick infestation was found to be statistically significant (X^2 =29.0, *P* = 0.000) (Table 3.4).

The highest prevalence of tick was in summer (83.1%) compared with autumn (60.6%). 76.2% prevalence was recorded among animals that their owners had no answer about the season. The prevalence of tick infestation was statistically different (X^2 =12.0, *P* = 0.002) among livestock in different seasons (Table 3.4).

Table 3.4: Effect of Managemental and environmental risk factors in tick infestation prevalence in livestock animals in Khartoum North

Risk factors	**No. of examined (%)**	**No. of infested (%)**	**X^2**	**p-value**
Herd size			33.4	**.000***
Small	139	94 (67.6)		
Medium	114	92 (80.7)		
Large	24	5 (20.8)		
Housing type			31.3	**.000***
Closed	207	124 (59.9)		
Semi closed	70	67 (95.7)		
Raising type			1.3	.253
One species	143	103 (72.0)		
Mixed species	134	88 (65.7)		
Feeding type			.27	.605
Roughages	70	50 (71.4)		
Mixed	207	141 (68.1)		
Control of tick			37.8	**.000***
Yes	167	92 (55.1)		

No	110	99 (90.0)		
Method of Control			47.0	**.000***
Acaricides	92	59 (64.1)		
Chickens	10	6 (60.0)		
Combined Methods	65	27 (41.5)		
None	110	99 (90.0)		
Removing of manure			29.0	**.000***
Weekly	60	29 (48.3)		
Monthly	55	52 (94.5)		
Other	162	110 (67.9)		
Seasons			12.0	**.002***
Autumn	155	94 (60.6)		
Summer	59	49 (83.1)		
No answer	63	48 (76.2)		

3.3 Tick species

From the total count of 2367 ticks (male 1591 and female776) collected from 44 livestock herds, three genera and five species were identified. The dominant tick species was *Hyalomma anatolicum* 1764 (74.5%), followed by *Rhipicephalus e. evertsi* 383 (16.2%), *Rhipicephalussangiuanus*group 214 (9.04), *Hyalomma rufipes* 4 (0.2%) and lastly *Amblyomma lepidum* 2(.09%) (Table 3.5). While *H. anatolicum* was the most common tick species in all districts, *Amblyomma lepidum* was only found in one cattle herd in Silait village (Sharg Alneel). Moreover, *Hyalomma rufipes* was found in one herd in Alsamrab (Bahri).

3.4 Predilection sites

Different body parts of the investigated animals were examined to determine the predilection sites of tick infestation. Analysis revealed that udder was the most tick infested site in cattle (54.5%) and under the tail (perineum) (38.5%), followed by external genitalia (3.11%), knee (2.3%), brisket (1.2%), ear (0.4%) and around eyes (0.04%).

In sheep, ears were the most infested predilection site of tick (71%), followed by under the tail (26%), around eyes (1.9%) and udder (1.1%) %).

In goats, the tail was the most tick infested site (77.5%) followed by ears (21.3%) and around eyes (1.3%) (Table 3.6).

Table 3.5: Tick species identified in the domestic ruminants in Khartoum North

Tick species	Male (%)	Female (%)	Total count(%)
Hyalomma anatolicum	1241 (70.4)	523 (29.6)	1764 (74.5)
Hyalomma rufipes	4 (100)	0	4 (0.17)
Rhipicephaluse.evertsi	237 (62)	146 (38.1)	383 (16.2)
Rhipicephalus sangiuanus group	107 (50)	107 (50)	214 (9.04)
Amblyommalepidum	2 (100)	(0)	2 (0.09)
Total	1591 (67.2)	776 (32.8)	2367

Table 3.6: Distribution of ticks in different predilection sites in livestock ruminants in Khartoum North

Body parts	Cattle (%)	Sheep (%)	Goats (%)
Udder	1103 (54.5)	3 (1.1)	0
Tail	779 (38.5)	68 (26)	62 (77.5)
Ear	8 (0.4)	186 (71)	17 (21.3)
Brisket	25 (1.2)	0	0
Knee	46 (2.3)	0	0
Around eye	1 (0.04)	5 (1.9)	1(1.3)
Testes	63 (3.1)	0	0
Total	2025 (85.6)	262 (11)	80 (3.4)

3.5Male to female ratio

At the species level, the male to female ratio in cattle was (2.3:1) for *H. anatolicum,* (1.4:1) for *R. e. evertsi,* (0.4:1) for *R. sanguineus* group and (2:0) for *A. lepidum*. In sheep, the male to female ratio was (3:1) for *H. anatolicum*, 4:0 for *Hyalomma rufipes,*(1.9:1) for *R. e. evertsi* and (1.3:1) for *R. sanguineus* group. In goats, the ratio was (10:1) for *H. anatolicum*, (2.4:1) for *R.e. evertsi* and 0.75:1 for *R. sanguineus.*

Distribution of the tick species in different livestock animals revealed that, cattle were more infested by *H. anatolicum* (84.4%) compared with sheep that were more infested by *R. sanguineus* (59.5%) and goats were more infested by *R.e. evertsi*(68.7%). Favorable predilection sites of each species of ticks were illustrated in (Table 3.7).

Table 3.7: Distribution of tick species and male to female ratio with predilection sites in livestock ruminants in Khartoum North

Host	Tick spp.	No of ticks (%)	M	F	Sex ratio M:F
Cattle	*H.a*	1709 (84.4)	1198	511	2.3:1
	R.e	270 (13.3)	159	111	1.4:1
	R.s	44 (2.2)	12	32	0.4:1
	A.l	2 (0.1)	2	-	2:0
Sheep	*H.a*	44 (16.8)	33	11	3:1
	H.r	4 (1.5)	4	0	4:0
	R.e	58 (22.2)	38	20	1.9:1
	R.s	156 (59.5)	89	67	1.3:1
Goats	*H.a*	11 (13.8)	10	1	10:1
	R.e	55 (68.7)	39	16	2.4:1
	R.S	14 (17.5)	6	8	0.75:1

**H. a=Hyalomma anatolicum*
R. e= Rhipicephalus e. evertsi
R. s= Rhipicephalus sangiuanus
A. l= Amblyoma lepidum
H. r= Hyalomma rufipes

3.6 Tick burden

Regarding tick burden, out of 135 infested cattle, 93 (69.4%) were infested by (1-20) Ixodid ticks, 30 (22.4%) were infested by (21-40) ticks and 11(8.2%) were infested by (≥41) ticks. Among 40 infested sheep, there were 36 (90.0%) infested by (1-20) ticks, 4(10.0%) were infested by (21-40) ticks. From 16 infested goats, there were 15 (93.8%) infested by (1-20) ticks, 1 (6.3%) was infested by (21-40) ticks (Table 3.8).

3.7 Multivariate Analysis

In the logistic regression model, animal species was significantly (OR =7.8, *P* = 0.03, CI=1.279-47.474) affected the tick infestation prevalence, and goats were 7.8 times less infested than cattle.

The tick prevalence was significantly lower (OR =6.6, *P*=0.02, CI: 1.258-34.159) in animals where control measure had been used, and the prevalence was lower 6.6 times than the prevalence in uncontrolled animals. The tick prevalence was significantly lower (OR =5.4, *P*=0.002, CI: 1.842-16.087) in animals where two methods of control had been used (present of rural poultry and using of acaricides) and the prevalence was lower more than 5 times than the prevalence when using of acaricides only. The logistic regression analysis was presented in Table (3.9)

Table 3.8: Tick load in livestock ruminants in Khartoum North

Number of ticks	Cattle (%)	Sheep (%)	Goat (%)
1-20	93 (69.4)	36 (90)	15 (93.8)
21-40	30 (22.4)	4 (10)	1 (6.3)
≥41	11 (8.2)	0 (0)	0 (0)

Table 3.9: Multivariate logistic regression analysis of potential risk factors for livestock animals in Khartoum North

Risk factor	Odds ratio	*P*-value	95% CI	
Area			Lower	Upper
Bahri (ref)				
Sharg Aneel	0.182	0.078	.27	1.207
Animal species				
Cattle (ref)		0.017		
Sheep	.688	0.706	.099	4.800
Goat	7.793	0.026	1.279	47.474
Animal age				
Young (ref)		.000		
Adult	.130	.000	.044	.383
Old	.046	.000	.012	.177
Animal gender				
Male(ref)				
Female	2.387	.130	.774	7.360
Animal breed				
Local (ref)				
Cross	.176	.059	.029	1.450
Herd size				
Small (ref)		.007		
Medium	.455	.133	.107	2.137

Large	6.115	.017	.732	50.508
Housing type				
Closed (ref)				
Semi closed	.018	.000	.002	.150
Control of tick				
No(ref)				
Yes	6.554	.026	1.258	34.159.
Method of control				
		.009		
Acaricides(ref)	1.701	.566	.277	10.449
Natural predators Two methods	5.444	.002	1.842	16.087
Removing of manure				.
Weekly(ref)		.792		
Monthly	.692	.724	.023	12.318
Other	1.259	.714	.368	4.303
Season				
Autumn(ref)		.033		
Summer	.125	.014	.034	.685
No answer	1.270	.682	.406	3.973

CHAPTER IV

DISCUSSION

The observed prevalence in the present study was lower than that reported byNateneal *et al*., (2015)(82%) in bovine in Bedele district, Oromiyia Regional State, Western Ethiopia and Jelalu *et al*., (2016) who recorded 75.5% in cattle in Arbegona District, Southern Ethiopia. This difference in tick infestation could be due to several factors associated with tick survival such as climate, location, tick control and husbandry system as well as some host determinants.

Within the studied area, tick infestation was significantly different among livestock of different locations. The prevalence of tick infestation in Bahri area was (88.8%) and (52.6%) in Sharg Alneel area. Difference of tick prevalence according to the location was also confirmed by different authors (Gumaa *et al*., 2015; Rehman *et al*, 2017). This difference could be due to the variation in husbandry practices including tick control methods such as using of acaricides regularly, removing of manure and existence of rural poultry in farms within the investigated livestock.

This study showed that the tick infestation prevalence was high in cattle (74.2%) followed by sheep (66.7%) and finally goats (45.7%). It is evident that the tick prevalence differed significantly among the three animal hosts (X^2 = 11.3, P=0.004). This finding is in agreement with other reports of Ghosh*et al*., (2007) in Bangladesh, India and Pakistan, Irshad *et al*., (2010) in Bangladesh, Mohammed*et al*., (2014) in Benisuef district, Egypt and Sultana *et al*., (2015) in

Pakistan. Observed higher tick prevalence in cattle as compared to sheep and goats might link to host genetics (Jonsson *et al.,* 2014).

Compared to older animals, younger ones had lower tick burden and this result agrees with some previous studies (Swai *et al*., 2005; Lorusso *et al.,* 2013; Rehman *et al*., 2017). Okello-Onen*et al*., (1999) stated that the young animals protect themselves from ticks by innate and cell-mediated immunity. In contrast,higher tick loads were observed in cattle younger than 1 year in a previous study conducted by Manaswini *et al.,* (2017).

Although there was no association between tick infestation and the sex as a risk factor, this study found that the tick infestation was higher in female animals compared to males which is agreed with previous studies (Igbal *et al.,* 2013 and Mohammed*et al.,* 2014). This is might be due to the sample size of females examined. Moreover, pregnancy and lactation could decrease the resistance in females, and therefore become more susceptible to any infection (Sutherst *et al.,* 1983).

Our study revealed that tick infestation was highest in (crossbred andforeign) cattle followed by local breed (Zebu) which is in line with previous reports from White Nile State in the Sudan (Guma *et al*., 2015), Egypt (Mohammed*et al*., 2014) and Ethiopia (Solomon and Kaaya, 1996; Desalegn *et al.,* 2015). In contrast, Belew and Mekonnen (2011) recorded that local breeds were more infested by tick (44.96%) than cross breeds (15.83%). Wambura *et al*., (1998) indicated that Zebu (*Bos indicus*) was reported to show some levels of relative resistance to tick infestation compared with *Bos indicus* and *Bos taurus* crosses. The resistance acquired by the local breed could be due to pre-immunity against ectoparasites as a result of frequent contact with the parasites at an early stage of life (Ahmed *et al.,* 2012).

Our finding that there is no association between tick infestation prevalence and the coat color of examined livestock animals is not consistent with the finding of Gasparin *et al.,* (2007), who recorded that lighter colored animals are more resistant than dark colored ones.Moreover, Hassan, (1997) found that white colored cattle carried more ticks than brown ones, while black cattle carried few number of ticks. He suggested that the dark coat color raising temperature of the host and consequently the tick die or leave the host.

Herd size was found to be significantly associated with tick infestation. Herds with medium numbers of animals had the highest tick infestation compared with those of small numbers, and the lowest prevalence reported in herds with high livestock density. This result could be due to the fact that the higher stocking density increases the chance of tick to infest large number of animals. The recorded prevalence of tick infestation in large herds examined could be attributed to their small sample size.

Regarding the housing type, animals kept in semi closed recorded the highest tick infestation compared with those kept in closed system. This is similar to the work of Igbal *et al*., (2013) and Rehman *et al*., (2017) who confirmed that grazing animals were more prone to tick infestation in a pasture than those animals kept in closed system with zero-grazing.

It was observed that farms, where control of ticks was practiced, had lower tick prevalence compared to farms without control methods. Within the used control methods, using of acaricides resulted in low tick prevalence but ticks were commonly found on a majority of studied farms. This might suggest occurrence of acaricides resistance. Such resistance has been reported in a previous study by Abbas *et al.,* (2014).The results showed that rearing of chickens reduced tick prevalence in the investigated livestock herds. Hassan *et al*., (1992) reported that hens are used in different locations as a mean of biological tick control as chicken are picking ticks from animal bodies as well as their surroundings.

The present survey revealed that regular removing of manure in investigated farms reduced the tick infestation prevalence. It is obviously that the weekly removing of manure decreased the tick infestation prevalence much better than the monthly manure removing.

According to this study, tick infestation was higher in summer season compared to autumn, this observation is in agreement with that recorded by Rehman *et al.,* (2017) who observed that both tick prevalence on an animal level and median tick burden were higher in the arid zone with high annual mean temperatures. In addition, thisresult goes in accordance with Rony *et al*., (2010) and Kabir*et al.,* (2011), who reported that tick load was significantly higher during summer season compared with winter and wet season. In contrast, Stuti *et al.,* (2008) revealed that the animals were infested with ticks during the rainy season more than summer and winter.

This study revealed that the udder (54.5%) and perineum (38.5%) of examined cattle were the most attaching sites of ticks, followed by external genitalia (3.11%), knee (2.3%), brisket (1.2%), ears (0.4%) and around eyes (0.04%). Mohammed*et al*. (2014) reported that udders and external genitalia were the most tick infested sites (70.7% each) followed by neck and chest (63.0% each), inner thighs (61.1%), perineum (41.7%), ears (14.6%) and around eyes (11.7%). This finding could be attributed to the fact that the udder is characterized by thinner skin that allows easy penetration of mouthparts of ticks into the skin area as well as the wide surface of udder with high blood supply.

In sheep, ears were the most tick infested site (70.6%), this is in agreement with that reported by Mohammed, *et al.,* (2014) in Egypt. On the other hand, tail was the most tick infested site (77.5%) in goats, followed by ears and around eyes.In contrast, they reported from Egypt that ears were the most predilection site infested by ticks in goats. The reason of ticks in ears of sheep is not known.

From 2367 ticks (male 1591, female776) collected, three genera and five species were identified. *Hyalomma anatolicum* were found to be the most dominant tick species (74.5%) in Khartoum North, followed by *Rhipicephalus e. evertsi* (16.1%), *Rhipicephalus sangiuanus* group (9.04%), *Hyalomma rufipes* (0.2%) and less frequently *Amblyomma lepidum*(0.09) *H. anatolicum* was the most common tick species in all districts. Salih *et al*., (2004) reported that *Hyalomma anatolicum*, the exophilic tick was the most abundant species in Atbara, El Damer and Khartoum and the highest mean was recorded in Khartoum. This species is thriving in semi-desert conditions in

Northern Sudan, and is spreading southwards in the Central Sudan (Jongejan *et al*., 1987).

In cattle four species of ticks were recorded; *Hyalomma anatolicum*, *Amblyomma lepidum*, *Rhipicephalus e. evertsi*, *Rhipicephalus sanguineus* group. *H. anatolicum* was the most abundant species in cattle in the area, which agrees with previous reports from Wad Medani and Khartoum, respectively (Lazarus, 2002; Mohammed *et al*., 2004; Salih *et al*., 2004). Only two males of *A. lepidum* were found in one cattle farm in Al Silait in this study, this tick species is abundant in eastern parts of the Sudan as reported by earlier studied (Karrar *et al*., 1963; Walker *et al*., 1987). Factors such as animal movement, habitat change, drought, desertification and global climatic changes may force ticks to extend their distribution ranges beyond their known geographic regions (El Ghali and Hassan, 2012).

Likewise, four species of ticks were identified in sheep;*Hyalomma anatolicum*, *Hyalomma rufipes*, *Rhipicephalus e. evertsi*and *Rhipicephalus sanguineus* group. These species have been reported previously in Khartoum by Gad Elrab (1986). *R. sanguineus* group was the highest tick burden in sheep.*Rhipicephalus e. evertsi* was the most prevalent tick species in examined goats followed by *Rhipicephalus sanguineus* groupand *H. anatolicum.*

Regarding the sex of ticks identified in this study, the numbers of male ticks were more than female ticks (67.2 %, 32.8%). This finding is logic because the females mate only once, then detaches from the host, while male ticks remain on the host and will attempt to mate with many females before dropping off (Walker *et al.,* 2003). In addition, host grooming could easily remove partially-engorged or engorged females as compared to males (Solomon *et al.,* 1998).

Conclusions

This study revealed high prevalence of tick infestation among cattle, sheep and goat's populations in Khartoum North. *H. anatolicum* is the most common tick species infesting ruminants in the study area, which transmitting Tropical Theileriosis in livestock animals that lead to a great loss in animal production.*Rhipicephalus e. evertsi*, *Rhipicephalus sangiuanus* group, *Hyalomma rufipes* and *Amblyomma lepidum* were also reported.Animal species, age, location, herd size, housing type, tick control, method of controlling ticks, removing of manure and seasonare the risk factors associated with tick infestation prevalence in the livestock prevalence in Khartoum North.

Recommendations

According to data generated from the present survey,we recommend to map TBDs and plan of combined control strategies for ticks and TBDs inSudan.

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Appendix 1

QUESTIONAIRE

Date: ………………………………

Owner name: ……………………..................

Telephone……………………

District: ……………………………

Coordinate: N …………………………E

…………………………….

Herd size………………...

Housing type:

closed ☐ open ☐ semi closed ☐

Raising system:

one species ☐ mixed species ☐

Feeding types:

roughages ☐ concentrates ☐ mixed ☐

Animal species:

cattle ☐ sheep ☐ goats ☐

Animal breeds:

local ☐ crossbred ☐ foreign ☐

Animal sex:

male ☐ female ☐

Animal age: ………………….

Coat color:

white ☐ black ☐ brown ☐ other ☐

Tick infestation:

presence ☐ absence ☐

Predilection site:

ear ☐ udder ☐ tail ☐ knees ☐ brisket ☐ testes ☐ wither ☐

High tick infestation period in the year:

wet hot ☐ dry hot ☐ dry cold ☐ no answer ☐

Control of tick:

yes ☐ no ☐

If yes, specify the control method:

acaricides ☐ …………… interval……………

natural predator ☐ both ☐

Removing of manure:

weekly ☐ monthly ☐ other …………

Acknowledgements

First of all, thanks and praise are to Almighty Allah, The Compassionate and The Most Merciful for giving me strength and health during the period of the study.

I would like to express my deep appreciation to my supervisor **Dr. Naglaa Abd El Hakeem Abass** for her advices, guidance and continuous support.

I would like to thank **Professor Yasir Osman** for his assistance in tick identification. My thanks extended also to **Prof. Mohammed Tajeldin** for his help in data analysis.

I am very grateful to the Ministry of Agriculture, Animal Resources and Irrigation–Khartoum State, especially **Dr. Sir Alkhatim Fadlalmawla** (General Directorate of Animal Health and Epidemic Diseases) for facilitating the collection of samples during the field investigation. I also owe my great thanks to **Professor Shawgi Mohammed Hassan** for his help in tick identification.

ABSTRACT

Tick infestation has direct impact on animal health and production in many parts of the world, including sub-Saharan Africa. Tick infestation causes important economic losses, particularly in tropical and subtropical countries.

A cross-sectional study was conducted from December 2017 to April 2018 to determine the prevalence of tick infestation in cattle, sheep and goats in Khartoum North, investigate the potential risk factors associated with tick infestation in these livestock species. A total of 277 animals of different species (182 cattle, 60 sheep and 35 goats) were selected randomly and examined for tick infestation at 44 farms in Bahri and Sharg Alneel in Khartoum North (Algaili, Wadramli, Wawissi, Samrab, Shigla, Silait, Kafouri, Ailafoon and Kuku). Predesigned questionnaire was used for each examined animal to identify possible risk factors associated with tick prevalence prior to tick collection and collected ticks were further morphologically identified using taxonomic keys.

The highest prevalence of tick infestation was recorded in Bahri area 88.8% and 52.6% was in Sharg Alneel. About 68.9% (191/277) of total observed animals were found infested by ticks with the highest rate in cattle (74.2%) followed by sheep (66.7%) and goats (45.7%). Regarding the associated risk factors, tick infestation was found significant ($P < 0.004$) different among the three species of animals. Old animals (<5 years old of cattle) and (< 3years old of sheep and goats) had the highest prevalence of 87.8% compared with adults (2–5 years old of cattle) and (>6 months–3 years old of sheep and goats) 66.1% and young (> 2 years old of

cattle) and (1-6 months in sheep and goat) 56.1%. Females had slightly higher prevalence of 71.1% compared with the males 59.2%. Crossbred and foreign breed had the highest prevalence of tick infestations of 72.4% compared with local breed 62.0%. Medium herd size had the highest prevalence of tick infestation of 80.7% compared with the small herd size 67.6 % and the lowest reported in the large herd size of 20.8%. Animal kept in semi closed registered the highest prevalence of tick infestation of 95.7% compared with those kept in closed one 59.9%. The prevalence of tick infestation in farms where control of ticks was practiced was greatly less (55.1%) than farms without tick control (90%).There was significant association between tick infestation prevalence and different methods of tick control. Weekly removing of manure decreased the tick infestation prevalence (48.3%) much better than the monthly removing of manure (94.5%). The highest prevalence of tick was reported in summer (83.1%) compared with autumn (60.6%). Distribution of the tick species in different livestock revealed that, cattle were more infested by *Hyalomma. anatolicum,* sheep were more infested by *Rhipicephalus sanguineous* and goats were more infested by *Rhipicephalus e. evertsi*.

From the total count of 2367 ticks (male 1591, female776) collected, three genera and five species were identified of which the dominant tick species was *Hyalomma anatolicum*, *Rhipicephalus e. evertsi*, *Rhipicephalus Sangiuanus* group, *Hyalomma rufipes* and less frequently *Amblyomma lepidum.* Udder was the most tick infested site in cattle (54.5%), ears were the most tick infested site in sheep (70.6%) and tail was the most tick infested site in goats (77.5%).

High prevalence of tick infestation reported among examined cattle, sheep and goats population was in Khartoum North. Animal species, age, herd size, housing type, tick control, control method, removing of manure and season were considered risk factors for tick infestation prevalence. *Hyalomma anatolicum* was the most common tick species infesting ruminants in the study area.