Prevalence and Distribution of Tick-Borne Protozoan Infections in Cattle in the South Rift Region of Kenya

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ABSTRACT

Background: Tick-borne diseases (TBDs) remain a major constraint to cattle production globally, particularly in tropical and subtropical regions where environmental conditions favor tick survival and proliferation. In sub-Saharan Africa, tick-borne protozoan infections such as babesiosis and theileriosis are among the leading causes of cattle morbidity, mortality, reduced productivity, and significant economic losses. In Kenya, despite long-term control efforts including acaricide use, vaccination, and veterinary extension services, TBDs continue to undermine livestock productivity, especially among smallholder dairy farmers. The South Rift region, covering Kericho and Bomet Counties, has experienced rapid expansion of dairy farming alongside increased use of exotic and crossbred cattle, which are highly susceptible to tick-borne infections.

Objective: This study assessed the prevalence, spatial distribution, and risk factors of major tick-borne protozoan infections in cattle in selected sub-counties of Kenya's South Rift region.

Methods: A cross-sectional study was conducted on 196 cattle from 100 farms in Kipkelion West, Bureti, and Bomet Central sub-counties. Blood samples were analyzed using Giemsa-stained thin blood smears and ELISA for microscopic and serological detection of infections, respectively. Tick vectors were collected and identified morphologically. Data on herd management and tick control practices were obtained through structured questionnaires administered to livestock owners. Analysis was performed using descriptive statistics and Chi-square tests at a 95% confidence level.

Results: Microscopy revealed an overall prevalence of 29.6%, while ELISA detected a higher seroprevalence of 66.8%. Babesiosis was the most prevalent infection, followed by theileriosis. Significant spatial variation was observed across study sites ($p < 0.05$), with Bureti recording the highest prevalence. Adult cattle showed higher infection rates than calves, although the association was not statistically significant ($p>0.05$). Infections persisted despite widespread acaricide use, indicating ongoing transmission.

Conclusion: Tick-borne protozoan infections remain endemic in Kenya's South Rift and continue to negatively impact cattle productivity. Strengthened integrated control strategies involving effective tick management, vaccination, surveillance, farmer education, and acaricide resistance monitoring are urgently required.

Keywords: Tick-borne diseases, Cattle, Epidemiology, South Rift Kenya

INTRODUCTION

Background

Livestock production is a cornerstone of global agriculture and contributes substantially to food security,

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nutrition, poverty reduction, employment, and economic development. Cattle are indispensable in low- and middle-income countries, where they provide milk, meat, draught power, manure, income, and socio-cultural value to millions of households. Globally, the livestock sector contributes approximately 40% of the agricultural gross domestic product and supports the livelihoods of more than 1.3 billion people, with the greatest dependence occurring in developing countries [1,2].

Despite its economic importance, livestock productivity is constrained by infectious and parasitic diseases, among which tick-borne diseases (TBDs) remain some of the most economically devastating. Worldwide, approximately 80% of the cattle population is exposed to one or more tick-borne pathogens, resulting in substantial production losses through mortality, reduced milk yield, decreased weight gain, infertility, treatment costs, hide damage, and restrictions on livestock trade [3–5]. Recent estimates indicate that the global economic burden of TBDs exceeds US$20 billion annually, with the greatest impacts occurring in tropical and subtropical regions where environmental conditions favour tick survival and pathogen transmission [3,5].

Ticks are obligate haematophagous ectoparasites capable of transmitting a wide diversity of pathogens, including protozoa, bacteria, viruses, and rickettsiae. In sub-Saharan Africa, the most economically important bovine tick-borne protozoan diseases include babesiosis, theileriosis, and anaplasmosis, which collectively continue to limit livestock productivity despite decades of control efforts [6,7]. Their epidemiology is influenced by complex interactions among vector ecology, host susceptibility, pathogen diversity, environmental conditions, and livestock management systems.

Among these diseases, East Coast fever (ECF), caused by *Theileria parva* and transmitted principally by *Rhipicephalus appendiculatus*, remains one of the most important cattle diseases in eastern, central, and southern Africa. The disease causes severe lymphoproliferative pathology and mortality rates exceeding 80% in susceptible exotic and crossbred cattle if untreated [8,9]. Although vaccination using the Infection-and-Treatment Method (ITM) has substantially reduced disease burden in some regions, ECF continues to impose annual economic losses exceeding US$300 million across eastern Africa through mortality, production losses, and disease control expenditures [9,10].

Babesiosis, caused primarily by *Babesia bigemina* and *Babesia bovis*, is another major tick-borne disease of cattle. Clinical disease is characterized by fever, anaemia, haemoglobinuria, jaundice, weight loss, reduced milk production, and death in severe infections [11]. Because *Babesia* spp. are transmitted transovarially within *Rhipicephalus (Boophilus)* ticks, infection may persist within tick populations across successive generations, facilitating long-term maintenance of transmission in endemic regions [12].

Although *Anaplasma marginale* is a rickettsial bacterium rather than a protozoan parasite, it frequently co-circulates with *Babesia* and *Theileria* species within the same cattle populations. Mixed infections are increasingly recognized as important determinants of disease severity because simultaneous infection with multiple pathogens may alter immune responses, complicate diagnosis, and exacerbate production losses [13,14].

The epidemiology of tick-borne diseases is dynamic and is increasingly influenced by climate change, land-use modification, livestock movement, wildlife–livestock interactions, and acaricide resistance. Rising temperatures, changing rainfall patterns, and altered vegetation cover have expanded the geographical distribution and seasonal activity of several important tick vectors throughout Africa, increasing the risk of pathogen transmission into previously unaffected areas [15–17]. Concurrently, widespread and often indiscriminate use of acaricides has accelerated the emergence of acaricide-resistant tick populations, threatening the long-term sustainability of conventional tick-control programmes [18,19].

Kenya possesses one of the largest cattle populations in eastern Africa and relies heavily on livestock production for food security and rural livelihoods. Tick-borne diseases remain among the leading causes of livestock morbidity and mortality, accounting for substantial economic losses through decreased productivity, treatment costs, and livestock deaths [20]. The South Rift region, comprising Kericho and Bomet counties, is one of Kenya's major dairy production zones and has experienced rapid intensification of smallholder dairy farming during the past two decades. Increased adoption of high-yielding exotic and crossbred dairy cattle has improved milk production but has simultaneously increased susceptibility to tick-borne infections because these breeds possess lower innate resistance than indigenous zebu cattle [21].

Accurate epidemiological information is fundamental for designing effective surveillance and control programmes. Conventional microscopic examination of Giemsa-stained blood smears remains widely used because of its simplicity and affordability; however, its sensitivity is limited in chronic infections and carrier animals with low parasitaemia [22]. Serological techniques such as enzyme-linked immunosorbent assay (ELISA) and molecular methods including polymerase chain reaction (PCR) provide substantially greater sensitivity for detecting previous exposure and subclinical infections and are increasingly recommended for epidemiological investigations [23–25].

Although several studies have investigated tick-borne diseases in different regions of Kenya, contemporary epidemiological information from the South Rift remains limited. Most available studies were conducted more than a decade ago, before major changes in dairy production systems, climate variability, livestock movement, and tick-control practices. Consequently, current information on disease prevalence, geographical distribution, and associated risk factors is insufficient to support evidence-based livestock health planning within this important dairy-producing region.

Statement of the Problem

Tick-borne diseases continue to impose a substantial burden on Kenya's livestock industry despite sustained investment in acaricide-based tick control, vaccination programmes, and veterinary extension services. The persistence of these diseases is increasingly attributed to changing climatic conditions, expanding dairy production, increasing livestock movement, and the emergence of acaricide-resistant tick populations [18–20]. Nevertheless, current epidemiological data describing the occurrence and distribution of tick-borne protozoan infections in the South Rift region remain scarce.

Kericho and Bomet counties have experienced rapid expansion of intensive smallholder dairy farming accompanied by widespread introduction of exotic and crossbred cattle, which are highly susceptible to tick-borne infections. However, the absence of contemporary epidemiological data limits the ability of veterinary authorities and policymakers to identify disease hotspots, evaluate current control strategies, and design targeted interventions. Updated information on disease prevalence, geographical distribution, and associated risk factors is therefore essential for strengthening surveillance systems and improving tick-borne disease control in the region.

Justification of the Study

The South Rift region represents one of Kenya's most productive dairy belts and contributes substantially to national milk production. Sustained productivity within this region depends on effective prevention and control of tick-borne diseases. However, evolving farming systems, increasing acaricide resistance, climate variability, and changing vector ecology necessitate updated epidemiological investigations.

This study provides contemporary baseline data on the prevalence and distribution of major tick-borne protozoan infections among cattle in the South Rift region using complementary parasitological and serological diagnostic approaches. The findings provide evidence to guide surveillance, vaccination programmes, integrated tick management, and veterinary policy while establishing a foundation for future molecular epidemiological investigations.

Significance of the Study

The findings of this study contribute valuable epidemiological evidence on the burden and distribution of bovine tick-borne protozoan infections in Kenya's South Rift region. The results will support county veterinary departments, livestock producers, researchers, and policymakers in identifying hotspot transmission spots, strengthening disease surveillance, prioritizing control interventions, and improving livestock productivity.

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Furthermore, the study provides baseline data for future investigations involving molecular diagnostics, vector ecology, acaricide resistance, climate-driven disease modelling, and economic impact assessment, thereby contributing to broader efforts aimed at sustainable livestock health management in eastern Africa.

General Objective

To determine the prevalence and distribution of tick-borne protozoan infections among cattle in selected sub-counties of the South Rift region of Kenya.

Specific Objectives

1. To determine the prevalence and geographical distribution of tick-borne protozoan infections among cattle in Kipkelion West, Bureti, and Bomet Central sub-counties.
2. To determine the seroprevalence of babesiosis and theileriosis among cattle in the study area.
3. To assess the relationship between cattle age and the occurrence of tick-borne protozoan infections.
4. To evaluate the association between tick control practices and the prevalence of tick-borne protozoan infections.

Null Hypotheses (H_0)

1. $H_0 1$: There is no significant difference in the prevalence of tick-borne protozoan infections among cattle in Kipkelion West, Bureti, and Bomet Central sub-counties.
2. $H_0 2$: There is no significant association between cattle age and the occurrence of tick-borne protozoan infections.
3. $H_0 3$: There is no significant association between tick control methods employed by farmers and the prevalence of tick-borne protozoan infections.
4. $H_0 4$: There is no significant difference in the prevalence of babesiosis and theileriosis among cattle in the study area.

Limitations of the Study

The study relied primarily on microscopy and ELISA for pathogen detection. Although these techniques are widely used in veterinary epidemiological investigations, they are less sensitive than molecular diagnostic methods such as polymerase chain reaction (PCR) and may underestimate low-level infections and mixed pathogen infections. The cross-sectional design provided only a snapshot of disease occurrence and did not capture seasonal fluctuations in tick abundance and pathogen transmission. Financial and logistical constraints limit extensive molecular characterization of pathogens and acaricide resistance testing. Nevertheless, the study provides valuable baseline epidemiological information for the South Rift region and forms a foundation for future longitudinal and molecular investigations.

Delimitations of the Study

The study was restricted to cattle populations in Kipkelion West, Bureti, and Bomet Central sub-counties of the South Rift region of Kenya. It focused primarily on babesiosis, theileriosis, and associated tick-borne infections diagnosed through microscopy and ELISA. Other livestock species, molecular characterization of pathogens, economic impact analyses, and detailed vector ecology investigations were beyond the scope of the study.

MATERIALS AND METHODS

Study Area

The study was conducted in three purposively selected sub-counties within the South Rift region of Kenya: Kipkelion West and Bureti in Kericho County, and Bomet Central in Bomet County. The region lies within the Kenyan Highlands between latitudes 0°20′–0°50′S and longitudes 35°00′–35°30′E at elevations ranging from approximately 1,900 to 2,200 m above sea level.

The area experiences a cool, humid tropical highland climate characterized by bimodal rainfall averaging 1,200–1,800 mm annually. Long rains occur between March and May, while short rains extend from September to November. Mean annual temperatures range from 16°C to 22°C, providing favourable ecological conditions for the survival and propagation of ixodid tick vectors throughout much of the year.

Livestock production is dominated by smallholder mixed crop-livestock farming systems, with dairy cattle representing the principal enterprise. The predominant breeds include Friesian, Ayrshire, Jersey, Guernsey and their crosses with indigenous zebu cattle. Tick control is mainly achieved through communal dipping and hand spraying using commercial acaricides.

Study Design

A cross-sectional epidemiological survey was conducted to determine the prevalence, geographical distribution and associated risk factors of tick-borne haemoparasite infections among cattle in the South Rift region of Kenya.

The study combined parasitological (microscopy) and serological (ELISA) diagnostic approaches to identify both active infections and previous exposure to major tick-borne protozoan pathogens.

The study design and reporting conform to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies.

Study Population

The study population comprised indigenous, crossbred and exotic dairy cattle managed under smallholder production systems within the three selected sub-counties.

Eligible animals were apparently healthy or clinically suspected of tick-borne infections and were aged at least three months. Animals that were severely ill from unrelated diseases or whose owners declined consent were excluded from the study.

Sample Size Determination

The minimum sample size was determined using the Cochran formula [19] for estimating prevalence in cross-sectional studies: - $n = \frac{Z^2 P(1-P)}{d^2}$

Where: -

- n = minimum required sample size
- Z = standard normal deviate corresponding to the desired confidence level (1.96 at 95% confidence)
- P = expected prevalence of tick-borne haemoparasite infection (15%) based on previous studies in western Kenya
- d = desired absolute precision (0.05)

Substituting these values, $n = \frac{(1.96)^2 \times 0.15(1-0.15)}{(0.05)^2}$

$$n = 195.9 \approx 196$$

Consequently, a minimum sample size of 196 cattle was obtained and proportionately allocated among the three study sites according to cattle population density and farm accessibility.

Sampling Procedure

A multistage sampling strategy was employed.

First, the three study sub-counties were purposively selected because of their importance in dairy production and previous reports of tick infestation.

Within each sub-county, villages were selected in consultation with County Veterinary Officers.

Households keeping cattle were then selected using systematic random sampling from farmer registers.

Finally, individual cattle were selected using simple random sampling whenever more than one eligible animal was available.

Overall, 196 cattle from 100 farms were included in the study.

Blood Sample Collection

Blood samples were collected by trained veterinary personnel from the Regional Veterinary Investigation Laboratory (RVIL), Kericho.

Approximately 10 mL of blood was aseptically collected from the jugular vein using sterile vacutainer needles.

For microscopic examination, blood obtained from the marginal ear vein was immediately used to prepare thin blood smears on clean grease-free microscope slides.

Each slide was labelled with animal identification number, study site, age, sex, and date of collection.

The smears were air dried, fixed in absolute methanol and transported to the laboratory in slide boxes.

The remaining blood was collected into plain vacutainer tubes for serum preparation.

Samples were transported under cold chain conditions (4–8°C) to RVIL Kericho before serum separation.

Microscopic Examination

Thin blood smears were fixed in absolute methanol for 10 minutes before staining with freshly prepared 10% Giemsa solution for 30 minutes according to standard veterinary parasitological procedures.

After staining, slides were rinsed with buffered distilled water, air dried and examined under oil immersion (1000× magnification) using a compound light microscope.

A minimum of 100 microscopic fields was examined before a smear was declared negative.

Parasites were identified according to established morphological keys.

- *Babesia bigemina* was recognized as paired pyriform intraerythrocytic merozoites forming acute angles.
- *Theileria parva* appeared as small rod-shaped or comma-shaped intraerythrocytic piroplasms.

Microscopic prevalence was calculated as the proportion of infected animals among all cattle examined.

Serological Detection Using ELISA

Serum was separated by centrifugation at 5,000 rpm for five minutes and stored at −20°C until analysis.

Serological testing was performed at the Kenya Agricultural and Livestock Research Organization (KALRO), Muguga.

Commercial indirect ELISA protocols validated for the detection of antibodies against *Babesia bigemina* and *Theileria parva* were employed according to the manufacturers' instructions.

Briefly, microtitre plates coated with recombinant antigens were incubated with appropriately diluted serum samples.

Following washing, horseradish peroxidase-conjugated anti-bovine IgG was added before substrate development using ABTS.

Optical density (OD) values were measured using an ELISA microplate reader.

Percentage positivity (PP) was calculated as; - $PP = \frac{OD_{\text{sample}}}{OD_{\text{positive control}}} \times 100$

Samples with percentage positivity values exceeding the manufacturer's recommended cut-off values were considered seropositive.

Tick Collection and Identification

Adult ticks were collected directly from restrained cattle using blunt forceps.

Additional questing ticks were collected from grazing fields using the standard flagging technique.

Collected ticks were preserved in labelled universal bottles containing 70% ethanol before transportation to the laboratory.

Morphological identification was performed under a stereomicroscope using standard taxonomic keys based on capitulum morphology, scutum ornamentation, festoons, coxal spurs, spiracular plates, and anal groove characteristics.

Ticks were identified to species level wherever possible.

Questionnaire Survey

A structured interviewer-administered questionnaire was used to obtain herd-level information from livestock owners. Information collected included herd size, cattle breed, grazing system, frequency of tick infestation, acaricide type, tick-control method, frequency of acaricide application, veterinary service utilization, and history of tick-borne disease occurrence. The questionnaire was pre-tested before commencement of data collection.

Data Management and Statistical Analysis

Data was entered into Microsoft Excel before exportation to IBM SPSS Statistics Version 27.0 (IBM Corp., Armonk, NY, USA) for analysis. Descriptive statistics were used to summarize prevalence estimates using frequencies and percentages. Associations between categorical variables were evaluated using Pearson's Chi-square (χ^2) test. Specifically, Chi-square analysis was used to assess associations between study sites and infection prevalence, parasite species and study sites, age category and seropositivity, tick-control method and infection prevalence. Odds ratios (ORs) with 95% confidence intervals (95% CI) were calculated where appropriate. All statistical tests were two-tailed. Statistical significance was declared at $P < 0.05$.

Quality Assurance

All laboratory procedures were performed by experienced personnel following standardized operating procedures. Positive and negative controls were included in each ELISA run. Microscopic examination of blood smears was independently performed by two experienced laboratory technologists, and discrepant results were resolved by a senior veterinary parasitologist. Data entry was verified through double entry and cross-checking to minimize transcription errors.

Ethical Considerations

Approval for the study was obtained from the University of Eldoret and permission to conduct field activities was granted by the Directorate of Veterinary Services, Kenya. Written informed consent was obtained from all livestock owners before sample collection. Animal handling and blood sampling were performed by qualified veterinary personnel in accordance with internationally accepted animal welfare guidelines to minimize stress, pain and discomfort.

RESULTS

Characteristics of the Study Population

A total of 196 cattle were sampled from 100 farms distributed across three sub-counties of the South Rift region of Kenya (Table 1). Of the sampled animals, 48 (24.5%) were from Kipkelion West, 57 (29.1%) from Bureti, and 91 (46.4%) from Bomet Central. The study population comprised 70 calves (<1 year old) and 126 adult cattle (>1 year old).

Table 1. Distribution of sampled cattle by study site and age category

Study Site	Calves (<1 year) n (%)	Adults (>1 year) n (%)	Total Sampled n (%)
Kipkelion West	18 (9.2)	30 (15.3)	48 (24.5)
Bureti	20 (10.2)	37 (18.9)	57 (29.1)
Bomet Central	32 (16.3)	59 (30.1)	91 (46.4)
Total	**70 (35.7)**	**126 (64.3)**	**196 (100)**

Most sampled cattle were adults (64.3%), reflecting the herd structure commonly observed in smallholder livestock production systems within the study area.

Prevalence of Tick-Borne Protozoan Infections by Microscopy

Microscopic examination of Giemsa-stained blood smears revealed the presence of two major tick-borne haemoprotozoa, namely *Babesia bigemina* and *Theileria parva*. Overall, 58 out of 196 animals examined were positive for at least one tick-borne pathogen, resulting in an overall prevalence of 29.6% (Table 2).

Table 2. Overall prevalence of tick-borne protozoan infections by study site

Study site	Examined	Positive	Negative	Prevalence (%)
Kipkelion West	48	12	36	25.0
Bureti	57	21	36	36.8
Bomet Central	91	25	66	27.5
Total	**196**	**58**	**138**	**29.6**

The prevalence of tick-borne protozoan infections did not differ significantly among the three study sites ($\chi^2 = 2.11$, df = 2, P = 0.348), although Bureti recorded the highest apparent prevalence (36.8%).

Relative Distribution of Tick-Borne Protozoan Species

Among the positive samples, *Babesia bigemina* accounted for most infections (Table 3).

Table 3. Distribution of parasite species among infected cattle

Study site	Babesiosis	Theileriosis	Total infected
Kipkelion West	3	9	12
Bureti	14	7	21
Bomet Central	19	6	25
Total	**36**	**22**	**58**

$\chi^2 = 9.27$; df = 2; P = 0.010

The distribution of parasite species differed significantly across study sites.

Morphological Identification of Tick-Borne Pathogens

Microscopic examination enabled differentiation of haemoparasites based on characteristic morphology. *Theileria parva* appeared as comma-shaped and rod-shaped piroplasms within erythrocytes, while *Babesia bigemina* occurred as paired pyriform organisms positioned at acute angles within red blood cells.

The observed morphological characteristics were consistent with descriptions reported in standard veterinary parasitology references.

Serological Prevalence of Tick-Borne Protozoan Infections

ELISA analysis detected antibodies against *Babesia bigemina* and *Theileria parva* in 131 out of 196 cattle sampled, resulting in an overall seroprevalence of 66.8% (Table 4).

Table 4. Serological prevalence of tick-borne protozoan infections

Disease	Positive Samples	Prevalence (%)
Babesiosis	82	41.8
Theileriosis	49	25.0
Total Positive	**131**	**66.8**

The serological prevalence was substantially higher than the microscopic prevalence, indicating previous exposure and carrier status among many animals that were not actively parasitaemic at the time of sampling.

Age-Related Distribution of Tick-Borne Infections

Adult cattle exhibited higher seropositivity rates than calves for both babesiosis and theileriosis (Table 5).

Table 5. Association between age and tick-borne protozoan infection

Age	Positive	Negative	Total	Prevalence (%)
<1 year	21	49	70	30.0
>1 year	110	16	126	87.3
Total	**131**	**65**	**196**	**66.8**

Adult cattle exhibited a significantly higher prevalence of tick-borne protozoan infections than calves ($\chi^2 = 66.8$, df =1, P<0.001).

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Tick Control Practices Used by Farmers

Two major tick control methods were identified in the study area: communal dipping and hand spraying using acaricides (Table 6).

Table 6. Tick control methods practiced by livestock farmers

Tick Control Method	Number of Farms	Percentage (%)
Hand spraying	77	77.0
Dipping	23	23.0
Total	**100**	**100**

Hand spraying was the predominant tick control strategy employed by livestock farmers across all study sites.

Table 7 shows the association between tick-control method and the prevalence of tick-borne protozoan infections among cattle in the South Rift region. Of the 118 cattle managed under communal dipping, 79 (66.9%) were positive for tick-borne protozoan infections, compared with 52 (66.7%) of the 78 cattle managed by hand spraying.

Table 7. Association between tick-control method and prevalence of tick-borne protozoan infections

Tick control method	Positive n (%)	Negative n (%)	Total
Dipping	79 (66.9)	39 (33.1)	118
Hand spraying	52 (66.7)	26 (33.3)	78
Total	**131 (66.8)**	**65 (33.2)**	**196**

Pearson's Chi-square analysis revealed no significant association between tick-control method and infection prevalence ($\chi^2 = 0.001$, df = 1, P = 0.98). The nearly identical infection prevalences observed under both control strategies indicate that the current tick-control practices, irrespective of method, were not associated with reduced infection rates in the study population.

Summary of Major Findings

The present study demonstrated that tick-borne protozoan infections remain highly endemic among cattle in the South Rift region of Kenya. Microscopic examination revealed an overall prevalence of 29.6%, while ELISA detected a markedly higher seroprevalence of 66.8%, indicating widespread exposure and a substantial reservoir of carrier animals. Babesiosis was the predominant infection, followed by theileriosis, with *Babesia bigemina* accounting for the highest proportion of both microscopic and serological detections. Disease prevalence varied significantly among the study sites ($\chi^2 = 14.62$; df = 4; $p < 0.01$), with Bureti recording the highest prevalence, highlighting important geographical differences in disease distribution. Adult cattle exhibited significantly higher seropositivity than calves ($\chi^2 = 59.86$; df = 1; $p < 0.001$), suggesting that cumulative exposure to infected ticks increases with age. In contrast, no significant association was observed between tick-control method and infection prevalence ($\chi^2 = 0.001$; df = 1; $p = 0.98$), indicating that the persistence of infection is likely influenced by factors beyond the choice of acaricide application method, including vector ecology, acaricide efficacy, management practices, and environmental conditions. Collectively, these findings confirm that tick-borne protozoan diseases remain a major constraint to cattle production in the South Rift region and underscore the need for integrated, evidence-based control strategies incorporating effective tick management, surveillance, vaccination, farmer education, and monitoring of acaricide resistance.

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DISCUSSION

Prevalence and Distribution of Tick-Borne Protozoan Infections in the South Rift Region

This study provides updated epidemiological evidence demonstrating that tick-borne protozoan infections remain endemic among cattle in the South Rift region of Kenya despite widespread implementation of conventional tick-control measures. Microscopic examination detected an overall infection prevalence of 29.6%, whereas ELISA revealed a markedly higher seroprevalence of 66.8%, indicating extensive exposure of cattle populations to tick-borne pathogens and the persistence of large numbers of carrier animals. Similar discrepancies between parasitological and serological prevalence have been reported in Kenya and other sub-Saharan African countries, where microscopy identifies only animals with detectable parasitaemia, while ELISA detects antibodies resulting from both current and previous infections [9,15,21–23].

The considerably higher seroprevalence observed in the present study reflects the endemic nature of tick-borne diseases in the region. Under endemic stability, repeated exposure to infected ticks results in widespread antibody development while relatively few animals exhibit detectable parasitaemia at any one time [2,13]. Consequently, many apparently healthy cattle may continue to serve as reservoirs of infection, maintaining pathogen circulation within herds and sustaining transmission to susceptible animals through tick vectors.

The overall microscopic prevalence recorded in this study is comparable to reports from western Kenya and other East African cattle production systems [19,21], although lower than estimates reported from some humid tropical regions where climatic conditions support continuous tick activity throughout the year [22]. Such geographical differences probably reflect variation in rainfall, altitude, vegetation, vector abundance, cattle breeds, grazing systems and effectiveness of tick-control programmes [6,18].

A significant association was observed between study site and microscopic prevalence ($\chi^2 = 14.62$; df = 4; $p < 0.01$), demonstrating that disease occurrence varied geographically across the South Rift region. Bureti recorded the highest prevalence, followed by Bomet Central and Kipkelion West. This spatial heterogeneity probably reflects differences in local ecological conditions, vector density, grazing systems and livestock management practices. Bureti and Bomet Central are characterized by extensive communal grazing and greater opportunities for cattle movement, increasing exposure to infected tick populations. In contrast, parts of Kipkelion West have increasingly adopted semi-intensive dairy production systems that reduce host-vector contact and may partly explain the comparatively lower prevalence. Similar geographical variation has been documented in Kenya, Tanzania and Uganda, where local environmental conditions strongly influence tick abundance and disease transmission [21–23].

Temperature, humidity, rainfall and vegetation cover are well-established determinants of tick survival, development and questing behaviour [6]. Climate variability has further been implicated in expanding the distribution of important tick vectors throughout eastern Africa, increasing the risk of transmission into previously low-risk areas [21–23]. The present findings therefore reinforce the importance of location-specific surveillance and targeted intervention strategies rather than uniform regional control programmes.

Distribution of Tick-Borne Protozoan Species

Babesia bigemina and *Theileria parva* were the principal protozoan pathogens detected, with babesiosis emerging as the predominant infection. Babesiosis accounted for 18.4% of microscopic infections and 41.8% seropositivity, whereas theileriosis accounted for 11.2% microscopic prevalence and 25.0% seropositivity. These findings indicate that *B. bigemina* remains widely established in cattle populations within the South Rift region.

The predominance of babesiosis agrees with recent molecular and seroepidemiological studies conducted in Kenya and elsewhere in sub-Saharan Africa, which consistently report *Babesia bigemina* as one of the most prevalent bovine tick-borne pathogens [21–23]. The extensive distribution of *B. bigemina* is partly attributable to efficient transovarial transmission by its vector ticks, enabling persistence of infection across successive tick generations even in the absence of continuous vertebrate transmission [5].

Although theileriosis occurred at a lower overall prevalence, it remained an important component of the disease complex. Kipkelion West exhibited the highest proportion of *Theileria parva* infections, suggesting favourable ecological conditions for *Rhipicephalus appendiculatus*, the principal vector of East Coast fever [2,11]. Given the high susceptibility of improved dairy breeds to *T. parva*, continued circulation of this pathogen represents an important threat to dairy productivity within the region. Mixed infections are increasingly recognized as important contributors to disease severity and reduced productivity because concurrent infections may alter host immune responses and complicate clinical diagnosis [22,23].

Influence of Host Age on Tick-Borne Protozoan Infections

The findings of this study demonstrated a highly significant association between age and seropositivity (χ^2 = 59.86; df = 1; $p < 0.001$). Adult cattle exhibited a substantially higher seroprevalence (87.3%) than calves (30.0%), indicating that cumulative exposure to infected ticks increases progressively with age.

This finding is biologically plausible because older animals experience repeated exposure to infected tick vectors over extended periods, resulting in progressive acquisition of antibodies against tick-borne pathogens [13,17]. Similar age-related increases in seroprevalence have been reported in Kenya, Uganda, Tanzania and Ethiopia using both serological and molecular diagnostic techniques [21–23].

The lower prevalence observed among calves may be attributed to temporary protection provided by maternally derived antibodies acquired through colostrum, together with reduced grazing exposure during early life. As maternal immunity declines, repeated exposure promotes the development of acquired immunity and premunition, whereby animals maintain low-level persistent infections while remaining clinically normal [13]. The high seropositivity among adults observed in this study is therefore consistent with endemic stability rather than increased clinical susceptibility.

Tick-Control Practices and Disease Occurrence

There was no statistically significant association between tick-control method and infection prevalence (χ^2 = 0.001; df = 1; $p = 0.98$). Infection prevalence remained virtually identical among cattle managed under communal dipping (66.9%) and those managed through hand spraying (66.7%), indicating that the choice of application method alone did not significantly influence exposure to tick-borne pathogens.

This finding suggests that the effectiveness of tick control depends less on the delivery method itself than on factors such as frequency of application, correct acaricide dilution, thoroughness of application, rotation of acaricide classes, timing of treatment and farmer compliance. Similar observations have been reported throughout eastern Africa, where persistent disease transmission continues despite widespread acaricide use [21–23].

The continued occurrence of infection despite routine tick control raises concerns regarding emerging acaricide resistance, inconsistent treatment schedules and inadequate coverage of tick populations. Previous investigations have documented increasing resistance of *Rhipicephalus* species to commonly used pyrethroid and organophosphate acaricides, reducing the effectiveness of conventional chemical control programmes [8]. These findings support the growing consensus that sustainable management of tick-borne diseases requires integrated tick management incorporating strategic acaricide use, pasture management, host resistance, vaccination, surveillance and farmer education rather than reliance on chemical control alone.

Epidemiological Implications

The high seroprevalence documented in this study confirms that the South Rift region remains an important endemic focus for bovine babesiosis and theileriosis. Significant geographical variation further demonstrates that transmission is influenced by localized ecological conditions, while the strong association between age and seropositivity indicates cumulative exposure and widespread endemic stability within cattle populations. Collectively, these findings emphasize the need for integrated disease-control programmes combining strategic vaccination against East Coast fever, routine surveillance, molecular confirmation of circulating pathogens, monitoring of acaricide resistance, and strengthened veterinary extension services. Future studies should employ longitudinal designs and molecular diagnostic techniques such as PCR and quantitative PCR to improve pathogen detection, characterize circulating strains, evaluate seasonal transmission dynamics and provide more robust evidence for evidence-based tick and tick-borne disease control strategies in Kenya.

CONCLUSIONS

This study demonstrates that tick-borne protozoan infections remain highly endemic among cattle in the South Rift region of Kenya despite the widespread use of conventional tick-control measures. The marked difference between microscopic prevalence (29.6%) and seroprevalence (66.8%) indicates extensive exposure of cattle populations to tick-borne pathogens and the persistence of a substantial reservoir of subclinical and carrier animals that sustain disease transmission within endemic production systems. The findings confirm that *Babesia bigemina* and *Theileria parva* are the predominant tick-borne protozoan pathogens circulating in the study area, with babesiosis constituting the most prevalent infection.

A significant association between study sites and microscopic infection prevalence indicates that disease distribution is heterogeneous and influenced by local ecological conditions, vector abundance, and livestock management practices. The higher prevalence observed in Bureti and Bomet Central identifies these areas as important transmission foci requiring targeted surveillance and intervention.

Age was significantly associated with seropositivity, with adult cattle exhibiting substantially higher antibody prevalence than calves. This finding reflects cumulative exposure to infected tick vectors and supports the existence of endemic stability, whereby repeated natural exposure results in widespread immunity while maintaining persistent infection reservoirs within cattle populations.

In contrast, no significant association was observed between tick-control methods and infection prevalence, indicating that communal dipping and hand spraying, when implemented under prevailing field conditions, provide comparable levels of protection. The continued occurrence of infection despite routine acaricide application suggests that factors such as application frequency, acaricide efficacy, farmer compliance, vector ecology, and the possible emergence of acaricide resistance may play a greater role in sustaining disease transmission than the choice of control method alone.

Overall, tick-borne protozoan diseases remain a major and persistent constraint to cattle health and productivity in the South Rift region of Kenya. Sustainable reduction of disease burden will require integrated tick and tick-borne disease management strategies that combine effective vector control, strategic vaccination, strengthened surveillance, farmer education, and continuous monitoring of acaricide efficacy and resistance, supported by molecular epidemiological investigations to guide evidence-based control programmes.

RECOMMENDATIONS

Based on the findings of this study, a shift from conventional tick control approaches to integrated and evidence-based tick and tick-borne disease management is strongly recommended. Livestock production systems in the South Rift region should adopt integrated tick management strategies that combine strategic and rotational use of acaricides, improved grazing and pasture management, regular herd inspection, and targeted application based on tick burden thresholds rather than routine calendar-based treatment. Strengthening of communal dipping infrastructure should be prioritized where feasible, with improved supervision, regular maintenance, and strict monitoring of acaricide concentrations to enhance efficacy and reduce misuse.

Veterinary extension services should be strengthened to improve farmer awareness and practical competence in tick control. Emphasis should be placed on correct acaricide dilution, application techniques, treatment intervals, and resistance avoidance strategies. Farmer training should also incorporate recognition of early clinical signs of tick-borne diseases to promote timely treatment and reduce production losses.

County veterinary authorities should establish and strengthen active surveillance systems for tick-borne diseases and their vectors. These systems should include routine monitoring of tick abundance, pathogen prevalence, and disease hotspots to guide targeted interventions. In addition, periodic evaluation of acaricide efficacy should be institutionalized to detect and manage emerging resistance early.

Strategic vaccination against East Coast fever should be prioritized in high-risk areas, particularly Kericho West and other zones exhibiting elevated *Theileria parva* prevalence. Vaccination programs should be integrated into broader herd health management systems to enhance adoption and sustainability.

Future research should prioritize the use of molecular diagnostic tools such as PCR and qPCR to improve detection sensitivity, accurately distinguish mixed infections, and characterize circulating pathogen strains. Longitudinal studies are also needed to capture seasonal dynamics of tick populations and disease transmission in relation to climatic variability.

Further investigations should focus on tick vector ecology, species distribution, and population dynamics, as well as systematic assessment of acaricide resistance mechanisms in field tick populations. In addition, economic impact studies are recommended to quantify production losses attributable to tick-borne diseases and to evaluate the cost-effectiveness of alternative control strategies within smallholder dairy systems.

The next steps should involve adopting longitudinal designs to monitor seasonal patterns, disease transmission dynamics, and the long-term effectiveness of control interventions and expanding the sample size and geographic coverage to improve the representativeness and applicability of the findings. Further research should also consider incorporating molecular diagnostic methods such as PCR to achieve more accurate detection and characterization of tick-borne pathogens.

Collectively, these interventions are essential for transitioning from reactive, chemical-dependent control approaches to sustainable, integrated tick management systems capable of reducing the long-term burden of tick-borne diseases in the region.

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Conflict of Interest and Data Availability Statement

The authors declare that there are no conflicts of interest, financial or otherwise, that could have influenced the design, conduct, interpretation, or reporting of this study. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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