Nativa, Sinop, v. 12, n. 2, p. 320-328, 2024.
Pesquisas Agrárias e Ambientais
DOI: https://doi.org/10.31413/nativa.v12i2.17000
ISSN: 2318-7670

Over half a century of research on tick infestation in livestock: a comprehensive bibliometric analysis

Isaac Frimpong ABOAGYE *[1]

[1] Department of Animal Biology and Conservation Science, University of Ghana, Legon-ACCRA, Ghana.
*E-mail: iaboagye@ug.edu.gh

Submitted on: 01/22/2024; Accepted on: 05/13/2024; Published on: 05/24/2024.

ABSTRACT: Tick infestations and tick-borne diseases in livestock result in substantial economic losses, highlighting the importance of improved tick control strategies. This review assessed global research output on tick infestation in livestock documented in Scopus, co-authorship links with other countries, and identified research gaps based on author keywords co-occurrence analysis. Using the search term "tick infestation*" AND "livestock," 447 scientific articles from 1970 to 4 December 2023 were retrieved and used for co-authorship and co-occurrence analyses in VOSviewer. Authors affiliated with the United States of America, South Africa, the United Kingdom, and Kenya had relatively higher total link strengths (45 – 83) and, thus, co-authored more publications than those of other countries (1 – 31). The number of yearly article publications increased from three in 1970 to 28 on 4 December 2023, with a cumulative number of 447. Nonetheless, author keywords such as surveillance, acaricide resistance, distribution, tick control, vaccine, risk factors, and tick-borne diseases occurred less frequently in the articles (5 – 18) with lower link strengths (6 – 41), compared to the occurrences (33 – 71) and link strengths (45 – 128) of the most frequently encountered keywords. These findings highlight the importance of collaborative research in tick infestation in livestock to facilitate its control.
Keywords: research gaps; bibliometric maps; VOSviewer.

Cinquenta e três anos de pesquisa sobre infestação por carrapatos na pecuária: uma análise bibliométrica

RESUMO: As infestações por carraças e as doenças transmitidas por carraças no gado resultam em perdas económicas substanciais, destacando a importância de melhores estratégias de controlo de carraças. Esta revisão avaliou a produção global de pesquisas sobre infestação por carrapatos em rebanhos, documentada no Scopus, links de coautoria com outros países e identificou lacunas de pesquisa com base na análise de coocorrência de palavras-chave do autor. Usando o termo de pesquisa "tick infestation*" AND "livestock", 447 artigos científicos de 1970 a 4 de dezembro de 2023 foram recuperados e usados para análises de coautoria e coocorrência no VOSviewer. Os autores afiliados aos Estados Unidos da América, à África do Sul, ao Reino Unido e ao Quénia tinham forças de ligação totais relativamente mais elevadas (45 – 83) e, portanto, foram coautores de mais publicações do que os de outros países (1 – 31). O número de publicações anuais de artigos aumentou de três em 1970 para 28 em 4 de dezembro de 2023, com um número acumulado de 447. No entanto, palavras-chave do autor como vigilância, resistência a acaricidas, distribuição, controle de carrapatos, vacina, fatores de risco e doenças transmitidas por carrapatos doenças ocorreram com menor frequência nos artigos (5 – 18) com menor força de link (6 – 41), em comparação com as ocorrências (33 – 71) e força de link (45 – 128) das palavras-chave mais frequentemente encontradas. Estas descobertas destacam a importância da investigação colaborativa na infestação por carraças no gado para facilitar o seu controlo.
Palavras-chave: lacunas de pesquisa; mapas bibliométricos; VOSviewer.

1. INTRODUCTION

Ticks *(Subclass acari*, Order Ixodida) are obligate hematophagous ectoparasitic arthropods that are widely distributed across the world and infest humans (Springer et al., 2021; Azagi et al., 2020) and animals (CICCULLI et al., 2019; SILATSA et al., 2019). Various species of ticks are reported in different parts of the world, including the Neotropics (Estrada-Peña et al., 2020), Africa (Addo et al., 2023; Zannou et al., 2021), Asia (Ji et al., 2022; Sharifah et al., 2020) and Europe (Körner et al., 2021; Rubel et al., 2021). However, host movement (Sumner et al., 2017), such as infested migratory birds (Hasle, 2013) and livestock transportation (Barré; Uilenberg, 2010) influence their distribution. Ecological suitability is determined by several factors, including climatic variables such as temperature and humidity, host availability in time and space (estrada-peña, 2008), and absence or low density of hosts (Zannou et al., 2021), which also influence tick distribution.

Ixodid ticks use three major behavioral patterns: hunting, tick-host cohabitation, and questing to detect and attach to their host (PETNEY et al., 2011). Through blood feeding, some species of ticks serve as vectors of pathogens that cause essential diseases in their hosts. Different *Babesia* species of both human and veterinary importance have previously been

detected in 23 tick species, with *Ixodes ricinus* being the most widely reported (ONYICHE et al., 2021). *Babesia* spp. infect erythrocytes of the wild (Hussain et al., 2021) and domestic mammals such as cattle, sheep, pigs, dogs, and horses (Onyiche et al., 2021) and cause babesiosis, a parasitic tick-borne disease. This disease has considerable variation of clinical manifestations across different animal species, including abortions, decreased milk and meat production, and mortality (LI et al., 2020). Other species of tick in the genera *Rhipicephalus*, *Amblyomma*, *Haemaphysalis*, and *Hyalomma,* among others, transmit pathogens that cause anaplasmosis, heartwater and dermatophylosis, ovine and bovine theileriosis, equine theileriosis and babesiosis respectively (WALKER et al., 2003).

Tick infestations and their control are associated with extensive and inappropriate use of acaricides, resulting in resistant strains (RECK et al., 2014). The use of acaricides further raises food, environmental, and health safety concerns due to the deposition of harmful residues in milk, meat, and the environment (DE MENEGHI et al., 2016; BALBUS et al., 2013). The cost of tick infestation is enormous, accounting for billions of Dollars of losses to the livestock industry due to ill health, cost of treatment, and death of livestock (SINGH et al., 2022; CALVANO et al., 2019; GRISI et al., 2014). These challenges require research and more effective interventions for controlling tick infestation in livestock. This review assessed global research output on tick infestation in livestock documented in Scopus, co-authorship links with other countries, and identified gaps for research consideration based on author keywords co-occurrence analysis.

2. MATERIAL AND METHODS

2.1. Source of data, search strategy, and eligibility criteria

This review used scientific articles documented in the Scopus database, which is reported to index high-quality bibliometric data (BAAS et al., 2020) and a more significant amount of unique sources (WOUTERS et al., 2015). The suitability of Scopus for academic research is also based on the fact that it is one of the largest curated abstract and citation databases and has comprehensive global and regional coverage of scientific journals, conference proceedings, and books (BAAS et al., 2020; WOUTERS et al., 2015).

The search for articles on tick infestation in livestock was done within the article title, abstract, and keywords in Scopus on 4 December 2023, using the search terms "tick infestation*" and "livestock" with no limit to years. It retrieved a total of 538 documents. However, limiting the search to articles and publications in English, the query string TITLE-ABS-KEY (“tick infestation” AND “livestock”) AND (LIMIT-TO (DOCTYPE, “ar”) AND (LIMIT-TO (LANGUAGE, “English”) retrieved 461 and 447 articles, respectively. Document types excluded from the study were review, book chapter, short survey, conference paper, letter, and note. The review protocol has been registered with the OSF Registries.

2.2. Method of accessing publication output, author, and institutional information

The yearly number of article publications on tick infestation in livestock from 1970 to 4 December 2023 from the search results were tabulated and used to calculate the cumulative numbers and prepare Figure 1 using the chart tool in Microsoft Excel (version 16). Documents by author and affiliation under ‘analyze results’ on the Scopus search results page were used to access research information on the ten most prolific authors and ten most productive institutions, respectively.

2.3. Data export and construction of bibliometric maps

Information on the 447 retrieved articles from the search, comprising of citation and bibliographical information, abstract, keywords, and references, was exported in Microsoft Excel Comma Separated Values (CSV) file format compatible with VOSviewer (version 1.6.19, Centre for Science and Technology Studies, Leiden University, The Netherlands). VOSviewer is a software tool for constructing and visualizing bibliometric maps (VAN ECK; WALTMAN, 2023).

The construction of bibliometric maps was based on co-authorship and author keywords co-occurrence analyses to help identify research collaborative opportunities and gaps in tick infestation and its control in livestock. The co-authorship analysis, with country as the unit of measurement, included 39 out of the 104 author-affiliated countries, which met the minimum thresholds of five documents and zero citations per country. The constructed bibliometric map was visualized in overlay visualization mode. The citations of published documents by the authors and the total strength of co-authorship links with other countries were tabulated.

Author keywords were used as the unit of measurement in the co-occurrence analysis, which included 56 out of the 1086 keywords that met the minimum threshold of five occurrences of a keyword. The created bibliometric map was visualized in the network visualization mode. At the same time, the keywords' occurrences and the total strength of the co-occurrence links with other keywords were presented in a table.

3. RESULTS

3.1. Publication output on tick infestation in livestock

The number of yearly article publications in Scopus on tick infestation in livestock has generally been deficient (< 10) between 1970 and 2006, with a cumulative number of 50 (Figure 1). However, yearly publications on the subject increased from 2006 to 2023, with a cumulative number of articles reaching 447 as of 4 December 2023.

3.2. Leading authors and productive institutions of tick infestation research

Table 1 lists the ten most prolific authors of article publications on tick infestation in livestock, their publication statistics, their role in co-authorship, and institutions and countries of affiliation. The ten most productive institutions researching and publishing on tick infestation in livestock, their number of publications, and their respective countries are presented in Table 2.

3.3. Co-authorship links with other countries

Figure 2 is a bibliometric map of co-authorships in overlay visualization mode, with six clusters of countries (shown by the different colors) participating in tick infestation research in livestock, as well as 201 links (relationships between the affiliated countries of the authors) and 349 total link strength. Van Eck; Waltman (2023) describe co-authorship link strength as the number of

publications two researchers have co-authored. Authors affiliated with the United States of America, South Africa, the United Kingdom, and Kenya had relatively higher total link strengths (45–83), indicating more co-authored publications on the subject than those of other countries (1–31) (Table 3).

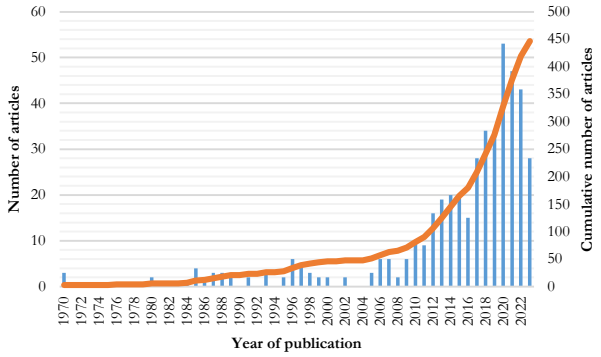

Figure 1. Annual and cumulative numbers of research articles on tick infestation in livestock indexed in Scopus from 1970 to 4 December 2023.
Figura 1. Números anuais e cumulativos de artigos de pesquisa sobre infestação por carrapatos na pecuária indexados na Scopus de 1970 a 4 de dezembro de 2023.

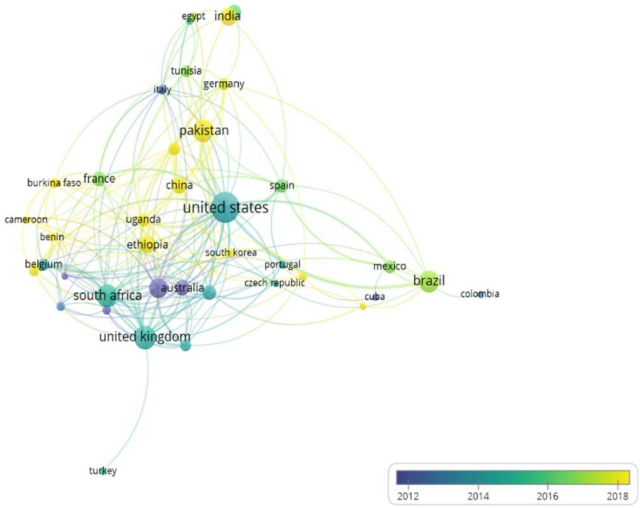

Figure 2. A screenshot of the bibliometric map created based on co-authorship (unit of analysis: affiliated countries) in overlay visualization mode.
Figura 2. Captura de tela do mapa bibliométrico elaborado a partir de coautoria (unidade de análise: países afiliados) em modo de visualização sobreposta.

Table 1. List of the ten most prolific authors in research on tick infestation in livestock.
Tabela 1. Lista dos dez autores mais prolíficos em pesquisas sobre infestação por carrapatos na pecuária.

No.	Author	Scopus author ID	Year of first publication*	TP (h-index)	TC	Current affiliation	Country
1.	Jongejan, Frans	57207606466	1980[a]	233 (56)	10910	University of Pretoria	South Africa
2.	Horak, Ivan G.	7102989086	1965[a]	308 (37)	6437	University of Pretoria	South Africa
3.	Sajid, Muhammad Sohail	56351927600	2006[b]	141 (25)	2126	Shenzhen University	China
4.	Sharma, Anil Kumar	57786093000	2004[b]	287 (38)	5427	Amity University Punjab, Mohali	India
5.	Teel, Pete D.	6701693134	1977 [a]	95 (23)	2018	Texas A&M AgriLife Research, College Station	USA
6.	Andreotti, Renato	6602478441	1992[b]	105 (23)	2304	Empresa Brasileira de Pesquisa Agropecuária- Embrapa	Brazil
7.	Madder, Maxime	55964088600	1996[a]	90 (30)	2167	Clinglobal	Mauritius
8.	Vudriko, Patrick	42262990300	2011[a]	55 (15)	721	Makerere University, Kampala	Uganda
9.	Xuan, Xuenan	7005428448	1990[a]	486 (47)	9050	Obihiro University of Agriculture and Veterinary Medicine	Japan
10.	Estrada-Peña, Agustin	7006661691	1990[a]	308 (58)	13258	Instituto Agroalimentario de Aragón (IA2), Zaragoza	Spain

TP: Total Publications; TC: Total Citation; USA: United States of America; * Role in co-authorship, superscripts; [a]: first author; [b]: co-author.

Table 2. Top ten most productive institutions researching and publishing on tick infestation in livestock.
Tabela 2. As dez instituições mais produtivas que pesquisam e publicam sobre infestação por carrapatos na pecuária.

No.	Institution	Scopus affiliation ID	Number of documents in Scopus	Years of first and recent publications	Country
1.	University of Pretoria	60021902	22	2002; 2023	South Africa
2.	University of Veterinary and Animal Sciences,	60038472	19	2008; 2023	Pakistan
3.	United States Department of Agriculture	60032280	18	1989; 2022	USA
4.	USDA Agricultural Research Service	60001989	14	2014; 2022	USA
5.	Empresa Brasileira de Pesquisa Agropecuária	60009625	14	2011; 2021	Brazil
6.	University of Agriculture, Faisalabad	60078212	14	2009; 2023	Pakistan
7.	Tehran University of Medical Sciences	60027708	13	2012; 2021	Iran
8.	International Centre of Insect Physiology and Ecology, Nairobi	60051492	12	1991; 2022	Kenya
9.	Indian Veterinary Research Institute	60005564	11	2006; 2023	India
10.	International Livestock Research Institute, Nairobi	60057834	11	1998; 2023	Kenya

USA: United States of America.

3.4. Author keywords

Figure 3 is a screenshot of a bibliometric map based on author keywords co-occurrence in network visualization mode with node sizes indicating the frequency of occurrence of keywords in published documents. Fifty-six (56) out of the 1086 keywords met the minimum threshold of five occurrences of a keyword. The most frequently encountered keywords were ticks, cattle, livestock, prevalence, and *Rhipicephalus microplus,* with occurrences and total link strengths ranging from 33 – 71 and 45 – 128, respectively (Table 4). However, keywords such as surveillance, acaricide resistance, distribution, tick control, vaccine, risk factors, and tick-borne diseases had fewer occurrences and link strengths in the 5 – 18 and 6 – 41 range, respectively.

4. DISCUSSION

4.1 Research interest and publication output

The substantial economic losses due to tick infestations and their associated tick-borne diseases (TBDs) in livestock informed this review, which assessed global research output on tick infestation in livestock and identified gaps for research consideration in the control of ticks. Authors affiliated with the United States of America, South Africa, the United Kingdom, and Kenya had relatively higher total link strengths (45–83) and, thus, co-authored more publications on tick infestation in livestock than those of other countries (1–31) [Table 3].

Although the number of yearly article publications in Scopus was consistently low (< 10) between 1970 and 2006, with a cumulative number of 50 (Figure 1), it increased cumulatively to 447 as of 4 December 2023. However, research on tick infestation in livestock tended to focus more on the author keywords: ticks, cattle, livestock, prevalence, and *Rhipicephalus microplus* based on the relatively higher frequency of their occurrences (33–71) in articles and total link strengths (45–128), which indicate the number of publications in which the keywords occur together, compared to other keywords (Table 4). Interestingly, keywords such as surveillance, acaricide resistance, distribution, tick control, vaccine, risk factors, and tick-borne diseases tended to receive less research focus as they had fewer occurrences and total link strengths in the range 5 – 18 and 6 – 41, respectively. These results suggest more livestock tick infestation research to help improve tick control.

4.2 Research collaboration and the control of ticks

The livestock industry has global significance, as it supports farmers' livelihoods and economic development in various parts of the world. The spread of ticks and TBDs, a significant burden for the industry, requires effective collaboration with individual authors, institutions, and countries actively involved in tick infestation research in livestock, such as the ten most prolific authors (Table 1) and productive institutions (Table 2) identified in this review. Such collaboration can generate new knowledge (KARRAM, 2013), build research and knowledge capacity (HALEY et al., 2022) on tick surveillance, identification, and diagnosis of TBDs, and help discover improved tick control strategies to maximize economic gains for farmers and the livestock industry. Moreover, since the spread of ticks and TBDs is facilitated by the trade and transport of livestock (BARRÉ; UILENBERG, 2010), collaboration at national and regional levels will help enforce the implementation of regulations regarding the control of tick infestation and TBDs in livestock.

Table 3. Citations of published documents and the total strength of co-authorship links with other countries
Tabela 3. Citações de documentos publicados e a força total dos vínculos de coautoria com outros países

Country	Documents	Citations	Total link strength
United States of America	77	2008	83
South Africa	41	585	49
United Kingdom	43	1062	46
Kenya	32	830	45
Uganda	13	140	31
Tanzania	17	336	29
Japan	13	283	26
Pakistan	42	892	24
Ethiopia	24	326	23
Netherlands	12	307	21
Spain	16	322	20
Belgium	12	197	19
Brazil	38	742	18
Nigeria	10	90	17
Australia	20	565	16
South Korea	7	214	16
Benin	6	75	15
Burkina Faso	8	75	15
France	17	391	15
Germany	12	282	15
China	21	276	14
Italy	9	246	14
Switzerland	6	86	12
Ghana	5	25	11
Mexico	14	284	11
Zambia	7	147	11
Cameroon	6	88	10
Tunisia	11	205	10
Zimbabwe	7	117	10
Czech Republic	5	111	9
Saudi Arabia	6	157	9
Egypt	6	153	8
Portugal	6	111	7
India	27	416	6
Sweden	5	36	6
Cuba	5	158	3
Iran	18	234	2
Colombia	5	59	1
Turkey	6	162	1

4.3 Research themes and challenges of tick control

The frequency of author keywords in published documents and link strengths, which indicate the number of publications in which the keywords occur together, give an idea about how well these keywords have been studied. Based on the fewer occurrences and link strengths of keywords such as surveillance, acaricide resistance, distribution, tick control, vaccine, risk factors, and tick-borne diseases (Table 4), the following research themes were identified for research consideration:

1. Tick surveillance and distribution
2. Tick control and acaricide resistance
3. Risk factors, tick-borne pathogens and diseases
4. Diagnosis of tick-borne diseases

Table 4. Author keywords, their occurrences and the total strength of the co-occurrence links with other keywords.
Tabela 4. Palavras-chave do autor, suas ocorrências e força total dos links de coocorrência com outras palavras-chave.

Keyword	Occurrences	Total link strength
Ticks	71	128
Cattle	55	109
Tick	40	75
Livestock	37	73
Prevalence	33	67
Rhipicephalus microplus	37	45
Babesia	13	42
Tick-borne diseases	18	41
Anaplasma	12	37
Risk factors	16	36
Pakistan	16	35
Theileria	11	34
Ehrlichia	8	33
Sheep	13	30
Ixodidae	15	28
Tick-borne pathogens	8	27
Epidemiology	12	25
Acaricide	13	24
Coxiella burnetii	9	21
Vaccine	11	20
Rhipicephalus	7	19
Boophilus	5	18
Iran	9	18
Acaricides	10	17
Goats	6	17
Ixodes ricinus	10	17
Kenya	5	17
Africa	5	16
PCR	9	16
Wildlife	8	16
Hard ticks	9	15
Hyalomma	6	15
Rickettsia	7	14
Tick control	12	14
Control	6	13
Resistance	7	13
Ruminants	6	13
Anaplasma marginale	5	12
Distribution	7	12
Q fever	5	12
Uganda	5	12
Cattle tick	18	11
Hyalomma anatolicum	7	11
Amblyomma	5	10
Seroprevalence	6	10
Amblyomma variegatum	8	9
Bovine	5	9
Ixodid ticks	7	9
Rhipicephalus appendiculatus	9	9
South Africa	6	9
Ectoparasite	5	8
Tanzania	5	8
Acaricide resistance	5	7
Surveillance	5	6
Rhipicephalus (*Boophilus*) *microplus*	5	5
Parasites	6	3

Livestock exposure to tick-infested environments or hosts (KAMRAN et al., 2021) is a significant risk factor associated with tick prevalence and burden. Through this exposure, livestock become infected with tick-borne pathogens that are transmitted to non-infected hosts through tick infestations and may increase by local climatic and ecological conditions (ALAM et al., 2013), age, gender, breed, animal species, and the lack of acaricide treatments (REHMAN et al., 2017). Host movement (SUMNER et al., 2017), such as livestock transportation (BARRÉ; UILENBERG, 2010), influence tick distribution and abundance. Veterinary-important tick species and their associated pathogens can threaten livestock survival and contribute to economic losses to the livestock industry.

Routine surveillance of these tick species and their related pathogens is essential to tracking their distributions and abundance (Centers for Disease Control and Prevention - CDC, 2022; EISEN; PADDOCK, 2021) and informing policy and control strategies. Moreover, regulation for livestock transportation that requires tick infestation assessment at different checkpoints, particularly at regional and national borders, will help reduce tick distribution and abundance.

Tick infestation and associated tick-borne diseases (TBDs) significantly burden humans, companion animals, and farm animals worldwide (SCHORDERET-WEBER et al., 2017). The extensive and inappropriate use of chemical acaricides for tick control (MUTAVI et al., 2021) and the accompanying problems of contamination of the environment and animal products with chemical residues (KUZUKIRAN et al., 2021), as well as selection for acaricide-resistant ticks (CRUZ et al., 2021), call for safer, effective, and more eco-friendly approaches for their control. This requires, among others, the search for plant-based products with acaricidal properties (BANUMATHI et al., 2017), such as *Eucalyptus globulus* essential oil (ADENUBI et al., 2021) and productive tick vaccine development.

Developing efficacious tick vaccines requires identifying several potential vulnerable targets and physiological processes that can be interrupted. Various protein molecules involved in tick-host interaction, attachment, blood digestion, water balance, haem/iron metabolism and detoxification, mating, embryogenesis, and fertility (DE LA FUENTE et al., 2016) have been identified as candidate vaccines. Although some tick mortality (IMAMURA et al., 2008; TRIMNELL et al., 2002), reduction in the number of engorged ticks (ALI et al., 2015), engorgement weight and egg laying ability (DECREM et al., 2008), impairment of blood meal uptake and digestion (TSUDA et al., 2001) have been achieved following immunization in rodent models, there are challenges. The inadequate efficacy of vaccination (PEREIRA et al., 2022; IMAMURA et al., 2008), commercial unavailability of efficacious anti-tick vaccines (MUHANGUZI et al., 2022), and the uncertainties about their effectiveness in protecting against tick infestation in natural hosts such as cattle call for further research in efficacious tick vaccine development.

4.4 Implication for tick infestation research and control

Animal husbandry is a significant source of livelihood for farmers and contributes immensely to economic development. A key challenge to the economic growth of the livestock industry is tick infestations and their associated tick-borne diseases (TBDs), which result in major financial losses to the industry. Given the generally short life cycles of ticks of veterinary importance and the risk of developing resistance to chemical acaricides extensively used for their control, an integrated approach for tick control that is effective and sensitive to the safety of animal products and the environment is appropriate. In this regard, systematic and routine surveillance for tick species of veterinary importance and their associated pathogens would be fundamental to

tracking their distribution and abundance and help in policy formulation and developing control strategies. Implementing tick-free livestock transportation regulation, searching for plant-based products with acaricidal properties (BANUMATHI et al., 2017), and developing productive tick vaccines will be critical to effectively controlling tick infestation and TBDs in livestock.

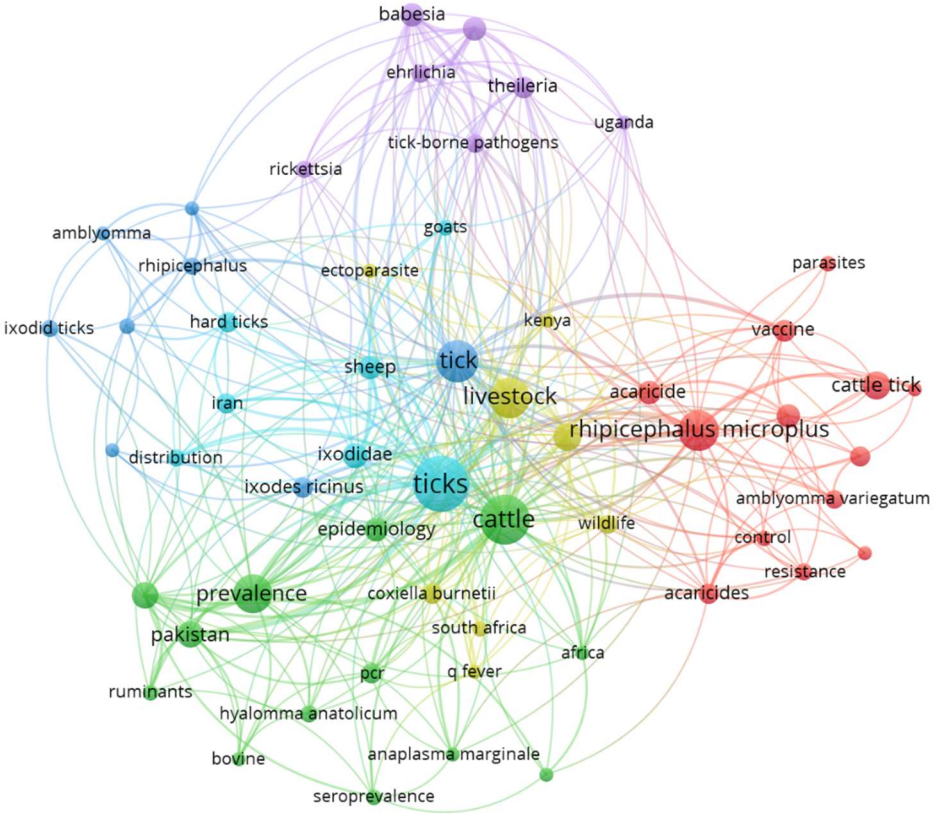

Figure 3. A screenshot of the bibliometric map created based on author keywords co-occurrence in network visualization mode. The bigger the node size for a keyword, the more frequent the keyword occurrence. The curves between nodes indicate the co-occurrence of keywords in the same publication.
Figura 3. Captura de tela do mapa bibliométrico criado com base na coocorrência de palavras-chave do autor no modo de visualização de rede. Quanto maior o tamanho do nó de uma palavra-chave, mais frequente será a ocorrência da palavra-chave. As curvas entre os nós indicam a coocorrência de palavras-chave na mesma publicação.

5. CONCLUSIONS

This review demonstrates that authors affiliated with six cluster countries participate in livestock tick infestation research. However, those affiliated with the USA, South Africa, the United Kingdom, and Kenya had relatively higher total link strengths (45 – 83), indicating more co-authored publications on the subject than those of other countries (1 – 31). Between 1970 and 2006, the number of yearly article publications in Scopus was consistently low (< 10) with a cumulative number of 50, although it increased cumulatively to 447 as of 4 December 2023. Nonetheless, author keywords such as surveillance, acaricide resistance, distribution, tick control, vaccine, risk factors, and tick-borne diseases occurred less frequently in the articles (5 – 18) with lower link strengths (6 – 41), compared to the occurrences (33 – 71) and link strengths (45 – 128) of the most frequently encountered keywords. These findings highlight the importance of collaborative research in tick infestation in livestock to facilitate its control.

6. REFERENCES

ADDO, S. O.; BENTIL, R. E.; BAAKO, B. O. A.; ADDAE, C. A.; LARBI, J. A.; BAIDOO, P. K.; WILSON, M. D.; ASOALA, V.; ODURO, D.; MATE, S.; DICLARO II, J. W. First record of *Rhipicephalus* (*Boophilus*) *microplus* in Ghana, a potential risk to livestock production. **Experimental and Applied Acarology**, v. 89, p. 475-483, 2023. https://doi.org/10.1007/s10493-023-00793-4

ADENUBI, O. T.; ABOLAJI, A. O.; SALIHU, T.; AKANDE, F. A.; LAWAL, H. Chemical composition and acaricidal activity of *Eucalyptus globulus* essential oil against the vector of tropical bovine piroplasmosis, *Rhipicephalus* (*Boophilus*) *annulatus*. **Experimental and Applied Acarology**, v. 83, p. 301-312, 2021. https://doi.org/10.1007/s10493-020-00578-z

ALAM, M. M.; KHURSHID, A.; SHARIF, S.; SHAUKAT, S.; RANA, M. S.; ANGEZ, M.; ZAIDI, S. Z. Genetic analysis and epidemiology of Crimean Congo hemorrhagic fever viruses in Baluchistan province of Pakistan. **BMC Infectious Diseases**, v. 13, n. 1, p. 201-208, 2013. http://www.biomedcentral.com/1471-2334/13/201

ALI, A.; PARIZI, L. F.; GUIZZO, M. G.; TIRLONI, L.; SEIXAS, A.; DA SILVA VAZ JR, I.; TERMIGNONI, C. Immunoprotective potential of a *Rhipicephalus* (*Boophilus*) *microplus* metalloprotease. **Veterinary**

parasitology, v. 207, n. 1-2, p. 107-114, 2015. https://doi.org/10.1016/j.vetpar.2014.11.007

AZAGI, T.; HOORNSTRA, D.; KREMER, K.; HOVIUS, J. W. R; SPRONG, H. Evaluation of disease causality of rare *Ixodes ricinus*-borne infections in Europe. **Pathogens,** v. 9, n. 2, e150, 2020. https://doi.org/10.3390/pathogens9020150

BAAS, J.; SCHOTTEN, M.; PLUME, A.; CÔTÉ, G.; KARIMI, R. Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies. **Quantitative Science Studies**, v. 1, n. 1, p. 377-386, 2020. https://doi.org/10.1162/qss_a_00019

BANUMATHI, B.; VASEEHARAN, B.; RAJASEKAR, P.; PRABHU, N. M; RAMASAMY, P.; MURUGAN, K; CANALE, A.; BENELLI, G. Exploitation of chemical, herbal and nano formulated acaricides to control the cattle tick, *Rhipicephalus* (*Boophilus*) *microplus* - a review. **Veterinary Parasitology**, v. 244, p. 102-110, 2017. https://doi.org/10.1016/j.vetpar.2017.07.021

BARRÉ, N.; UILENBERG, G. Spread of parasites transported with their hosts: case study of two species of cattle tick. **Revue Scientifique et Technique-Office International des Épizooties**, v. 29, n. 1, p. 135-160, 2010.

BALBUS, J. M.; BOXALL, A.; FENSKE, R. A.; MCKONE, T. E.; ZEISE, L. Implications of global climate change for the assessment and management of human health risks of chemicals in the natural environment. **Environmental Toxicology and Chemistry**, v. 32, n. 1, p. 62-78, 2013. https://doi.org/10.1002/ etc.2046

CALVANO, M. P. C. A.; BRUMATTI, R. C.; GARCIA, M. V.; BARROS, J. C.; ANDREOTTI, R. Economic efficiency of *Rhipicephalus microplus* control and effect on beef cattle performance in the Brazilian Cerrado. **Experimental and Applied Acarology**, v. 79, p. 459-471, 2019. https://doi.org/10.1007/s10493-019-00446-5

CDC_Centers for Disease Control and Prevention. Surveillance for *Ixodes scapularis* and pathogens found in this tick species in the United States, p. 1-37, 2022. Available on: https://www.cdc.gov/ticks/surveillance/BlackleggedTick.html

CICCULLI, V.; CAPAI, L.; QUILICHINI, Y; MASSE, S; FERNA´NDEZ-ALVAREZ, A.; MINODIER, L.; BOMPARD, P.; CHARREL, R.; FALCHI, A. Molecular investigation of tick-borne pathogens in ixodid ticks infesting domestic animals (cattle and sheep) and small rodents (black rats) of Corsica, France. **Ticks and Tick-Borne Diseases**, v. 10, n. 3, p. 606-613, 2019. https://doi.org/10.1016/j.ttbdis.2019.02.007

CRUZ, R. R.; GARCÍA, D. I. D.; SILVA, S. L.; DOMÍNGUEZ, F. R. Integrated management of the cattle tick *Rhipicephalus* (*Boophilus*) *microplus* (Acari: Ixodidae) and the acaricide resistance mitigation. Insecticides - Impact and Benefits of Its Use for Humanity. IntechOpen, 2021. DOI: https://doi.org/10.5772/intechopen.100015

DECREM, Y. ; MARILLER, M.; LAHAYE, K.; BLASIOLI, V.; BEAUFAYS, J.; BOUDJELTIA, K. Z.; VANHAEVERBEEK, M.; CÉRUTTI, M.; BROSSARD, M.; VANHAMME, L.; GODFROID, E. The impact of gene knock-down and vaccination against salivary metalloproteases on blood feeding and egg laying by *Ixodes ricinus*. **International Journal for Parasitology**, v. 38, n. 5, 549-560, 2008. https://doi.org/10.1016/j.ijpara.2007.09.003

DE LA FUENTE, J.; KOPÁČEK, P.; LEW-TABOR, A.; MARITZ-OLIVIER, C. Strategies for new and improved vaccines against ticks and tick-borne diseases. **Parasite Immunology**, v. 38, n. 12, p. 754-769, 2016. https://doi.org/10.1111/pim.12339

DE MENEGHI, D.; STACHURSKI, F.; ADAKAL, H. Experiences in tick control by acaricide in the traditional cattle sector in Zambia and Burkina Faso: Possible environmental and public health implications. **Frontiers in Public Health**, v. 4, n. 239, p. 1-11, 2016. 10.3389/fpubh.2016.00239

EISEN, R. J.; PADDOCK, C. D. Tick and tickborne pathogen surveillance as a public health tool in the United States. **Journal of Medical Entomology**, v. 58, n. 4, p. 1490-1502, 2021. https://doi.org/10.1093/jme/tjaa087

ESTRADA-PEÑA, A.; SZABÓ, M.; LABRUNA, M.; MOSQUEDA, J.; MERINO, O.; TARRAGONA, E.; VENZAL, J. M.; DE LA FUENTE, J. Towards an effective, rational and sustainable approach for the control of cattle ticks in the Neotropics. **Vaccines**, v. 8, n. 1, e9, 2020. https://doi.org/10.3390/vaccines8010009

ESTRADA-PEÑA, A. Climate, niche, ticks, and models: what they are and how we should interpret them. **Parasitology Research,** v. 103, p. 87-95, 2008. https://doi.org/10.1007/s00436-008-1056-7

GRISI, L.; LEITE, R. C.; MARTINS, J. R. D. S. ; BARROS, A. T. M. D.; ANDREOTTI, R.; CANÇADO, P. H. D.; LEÓN, A. A. P. D.; PEREIRA, J. B; VILLELA, H. S. Reassessment of the potential economic impact of cattle parasites in Brazil. **Revista Brasileira de Parasitologia Veterinária**, v. 23, p. 150-156, 2014. https://doi.org/10.1590/S1984-29612014042

HALEY, A.; ALEMU, S. K.; ZERIHUN, Z.; UUSIMÄKI, L. Internationalisation through research collaboration. **Educational Review**, p. 1-16, 2022. https://doi.org/10.1080/00131911.2022.2054958

HASLE, G. Transport of ixodid ticks and tick-borne pathogens by migratory birds. **Frontiers in Cellular and Infection Microbiology**, v. 3, e48, 2013. DOI: https://doi.org/10.3389/fcimb.2013.00048

HUSSAIN, S.; HUSSAIN, A.; AZIZ, M. U.; SONG, B.; ZEB, J.; GEORGE, D.; LI, J.; SPARAGANO, O. A review of zoonotic babesiosis as an emerging public health threat in Asia. **Pathogens**, v. 11, n. 1, e23, 2021. https://doi.org/10.3390/pathogens11010023

IMAMURA, S.; KONNAI, S.; DA SILVA VAZ, I. J.; YAMADA, S.; NAKAJIMA, C.; ITO, Y.; TAJIMA, T.; YASUDA, J.; SIMUUNZA, M.; ONUMA, M.; OHASHI, K. Effects of anti-tick cocktail vaccine against *Rhipicephalus appendiculatus*. **Japanese Journal of Veterinary Research**, v. 56, n. 2, p. 85-98, 2008. 10.14943/jjvr.56.2.85

JI, Z.; JIAN, M.; YUE, P.; CAO, W.; XU, X.; ZHANG, Y.; PAN, Y.; YANG, J.; CHEN, J.; LIU, M.; FAN, Y. Prevalence of *Borrelia burgdorferi* in Ixodidae tick around Asia: A systematic review and meta-analysis. **Pathogens**, v. 11, n. 2, e143, 2022. https://doi.org/10.3390/pathogens11020143

KAMRAN, K.; ALI, A.; VILLAGRA, C.; SIDDIQUI, S.; ALOUFFI, A. S.; IQBAL, A. A cross-sectional study of hard ticks (acari: ixodidae) on horse farms to assess the risk factors associated with tick-borne diseases. **Zoonoses and Public Health**, v. 68, n. 3, p. 247-262, 2021. https://doi.org/10.1111/zph.12809

KARRAM, G. A review of Globalization and Internationalization. In: **Higher education: theoretical, strategic and management perspectives**. MARINGE, F.; FOSKETT, N. (Eds.). London: Continuum International, 2013. p. 178-180. https://doi.org/10.1080/15700763.2013.810275

KÖRNER, S.; MAKERT, G. R.; ULBERT, S.; PFEFFER, M.; MERTENS-SCHOLZ, K. The prevalence of *Coxiella Burnetii* in hard ticks in Europe and their role in Q fever transmission revisited – A systematic review. **Frontiers in Veterinary Science**, v. 8, e655715, 2021. https://doi.org/10.3389/fvets.2021.655715

KUZUKIRAN, O.; SIMSEK, I.; YORULMAZ, T.; YURDAKOK-DIKMEN, B.; OZKAN, O.; FILAZI, A. Multiresidues of environmental contaminants in bats from Turkey. **Chemosphere**, v. 282, e131022, 2021. https://doi.org/10.1016/j.chemosphere.2021.131022

LI, L. H.; WANG, J. Z.; ZHU, D.; LI, X. S.; LU, Y.; YIN, S. Q.; LI, S. G.; ZHANG, Y.; ZHOU, X. N. Detection of novel piroplasmid species and *Babesia microti* and *Theileria orientalis* genotypes in hard ticks from Tengchong County, Southwest China. **Parasitology Research**, v. 119, p. 1259-1269, 2020. https://doi.org/10.1007/s00436-020-06622-6

MUHANGUZI, D.; NDEKEZI, C.; NKAMWESIGA, J.; KALAYOU, S.; OCHWO, S.; VUYANI, M.; KIMUDA, M. P. Anti-tick vaccines: Current advances and future prospects. In: **Vaccine design: methods and protocols**. Vol. 2. THOMAS, S (Ed.). 2022, p. 253-267. https://doi.org/10.1007/978-1-0716-1888-2_15

MUTAVI, F.; HEITKÖNIG, I.; WIELAND, B.; AARTS, N.; VAN PAASSEN, A. Tick treatment practices in the field: Access to, knowledge about, and on-farm use of acaricides in Laikipia, Kenya. **Ticks and Tick-Borne Diseases**, v. 12, n. 5, e101757, 2021. https://doi.org/10.1016/j.ttbdis.2021.101757

ONYICHE, T. E.; RĂILEANU, C.; FISCHER, S.; SILAGHI, C. Global distribution of Babesia species in questing ticks: A systematic review and meta-analysis based on published literature. **Pathogens**, v. 10, n. 2, e230, 2021. https://doi.org/10.3390/pathogens10020230

PEREIRA, D. F. S.; RIBEIRO, H. S.; GONÇALVES, A. A. M.; DA SILVA, A. V.; LAIR, D. F.; DE OLIVEIRA, D. S.; BOAS, D. F. V.; CONRADO, I. D. S. S.; LEITE, J. C.; BARATA, L. M.; GIUNCHETTI, R. C. *Rhipicephalus microplus*: An overview of vaccine antigens against the cattle tick. **Ticks and Tick-Borne Diseases**, v. 13, n. 1, e101828, 2022. https://doi.org/10.1016/j.ttbdis.2021.101828

PETNEY, T. N.; ROBBINS, R. G.; GUGLIELMONE, A. A.; APANASKEVICH, D. A.; ESTRADA-PEÑA, A.; HORAK, I. G.; SHAO, R. A Look at the World of Ticks. In: MEHLHORN, H. (Ed.) **Progress in Parasitology**, **Parasitology Research Monographs**, vol 2. Berlin, Heidelberg: Springer, 2011. p. 283-296, DOI: https://doi.org/10.1007/978-3-642-21396-0_15

REHMAN, A.; NIJHOF, A. M.; SAUTER-LOUIS, C.; SCHAUER, B.; STAUBACH, C.; CONRATHS, F. J. Distribution of ticks infesting ruminants and risk factors associated with high tick prevalence in livestock farms in the semi-arid and arid agro-ecological zones of Pakistan. **Parasites & Vectors**, v. 10, n. 1, p. 1-15, 2017. https://doi.org/10.1186/s13071-017-2138-0

RUBEL, F.; BRUGGER, K.; CHITIMIA-DOBLER, L.; DAUTEL, H.; MEYER-KAYSER, E.; KAHL, O. Atlas of ticks (Acari: Argasidae, Ixodidae) in Germany**. Experimental and Applied Acarology**, v. 84, n. 1, p. 183-214, 2021. https://doi.org/10.1007/s10493-021-00619-1

SCHORDERET-WEBER, S.; NOACK, S.; SELZER, P. M.; KAMINSKY, R. Blocking transmission of vector-borne diseases. **International Journal for Parasitology: Drugs and Drug Resistance**, v. 7, n. 1, p. 90-109, 2017. https://doi.org/10.1016/j.ijpddr.2017.01.004

SHARIFAH, N.; HEO, C. C.; EHLERS, J.; HOUSSAINI, J.; TAPPE, D. Ticks and tick-borne pathogens in animals and humans in the island nations of Southeast Asia: A review. **Acta Tropica**, v. 209, e105527, 2020. https://doi.org/10.1016/j.actatropica.2020.105527

SILATSA, B. A.; SIMO, G.; GITHAKA, N.; MWAURA, S.; KAMGA, R. M.; OUMAROU, F.; KEAMBOU, C.; BISHOP, R. P.; DJIKENG, A.; KUIATE, J.-R.; NJIOKOU, F.; PELLE, R. A comprehensive survey of the prevalence and spatial distribution of ticks infesting cattle in different agro-ecological zones of Cameroon. **Parasites & Vectors**, v. 12, p. 1-14, 2019. https://doi.org/10.1186/s13071-019-3738-7

SINGH, K.; KUMAR, S.; SHARMA, A. K.; JACOB, S. S.; RAMVERMA, M.; SINGH, N. K.; SHAKYA, M.; SANKAR, M.; GHOSH, S. Economic impact of predominant ticks and tick-borne diseases on Indian dairy production systems. **Experimental Parasitology**, v. 243, e108408, 2022. https://doi.org/10.1016/j.exppara.2022.108408

SPRINGER, A.; GLASS, A.; PROBST, J.; STRUBE, C. Tick-borne zoonoses and commonly used diagnostic methods in human and veterinary medicine. **Parasitology Research**, v. 120, n. 12, p. 4075-4090, 2021. https://doi.org/10.1007/s00436-020-07033-3

SUMNER, T.; ORTON, R. J.; GREEN, D. M.; KAO, R. R.; GUBBINS, S. Quantifying the roles of host movement and vector dispersal in the transmission of vector-borne diseases of livestock. **PLoS Computational Biology**, v. 13, n. 4, e1005470, 2017. https://doi.org/10.1371/journal.pcbi.1005470

TRIMNELL, A. R.; HAILS, R. S.; NUTTALL, P. A. Dual action ectoparasite vaccine targeting 'exposed' and 'concealed'antigens. **Vaccine**, v. 20, n. 29-30, p. 3560-3568, 2002.

TSUDA, A.; MULENGA, A.; SUGIMOTO, C.; NAKAJIMA, M.; OHASHI, K.; ONUMA, M. cDNA cloning, characterization and vaccine effect analysis of *Haemaphysalis longicornis* tick saliva proteins. **Vaccine**, v. 19, n. 30, p. 4287-4296, 2001. https://doi.org/10.1016/S0264-410X(02)00334-1

UILENBERG, G. *Babesia* - a historical overview. **Veterinary parasitology**, v. 138, n. 1-2, p. 3-10, 2006. https://doi.org/10.1016/j.vetpar.2006.01.035

VAN ECK, N. J.; WALTMAN, L. **Manual for VOSviewer version 1.6.19.** CWTS meaningful metrics. Universiteit Leiden, 2023. 54p.

WALKER, A. R.; BOUATTOUR, A.; CAMICAS J.-L.; ESTRADA-PEÑA, A.; HORAK, I. G.; LATIF, A. A.; PEGRAM, R. G.; PRESTON, P. M. **Ticks of domestic animals in Africa: a guide to identification of species**, v.74, Edinburgh: Bioscience Reports, 2003. 227p.

WOUTERS, P. ; THELWALL, M.; KOUSHA, K.; WALTMAN, L.; DE RIJCKE, S.; RUSHFORTH, A.; FRANSSEN, T.; WOUTERS, P. **The metric tide. Literature review**. Supplementary Report I to the independent review of the role of metrics in research assessment and management. HEFCE, 2015. 200p. https://doi.org/10.13140/RG.2.1.5066.3520

ZANNOU, O. M.; OUEDRAOGO, A. S.; BIGUEZOTON, A. S.; ABATIH, E.; CORAL-ALMEIDA, M.; FAROUGOU, S.; YAO, K. P.; LEMPEREUR, L.; SAEGERMAN, C. Models for Studying the Distribution of Ticks and Tick-borne diseases in animals: a systematic review and a meta-analysis with a focus on Africa. **Pathogens**, v. 10, n. 7, e893, 2021. https://doi.org/10.3390/pathogens10070893

Acknowledgments: The author appreciates the department and university he is affiliated with for the office space and Scopus access provided respectively.

Authors' contribution: The author designed the study, searched for articles, analyzed, and wrote the manuscript.

Financing: The study was self-funded by the author.

Review by institutional committee: Not applicable.

Ethics committee: Not applicable.

Data availability: The data of this research can be obtained by request from the corresponding author via e-mail.

Conflict of Interest: The author declares no conflict of interest. Supporting entities had no role in the study's design; in the collection, analysis, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results