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Review Article

Epidemiological aspects of cattle tick fever in Brazil

Aspectos epidemiológicos da tristeza parasitária bovina no Brasil

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Abstract

The present work reviews the epidemiologic situation of *Anaplasma marginale* and *Babesia* spp. infections and the occurrence of cattle tick fever outbreaks in Brazil. In areas of tick fever enzootic instability, environmental conditions interfere with the development of *Rhipicephalus (Boophilus) microplus*: chilly winter in the southern region, floods in the Pantanal, and low humidity in the Caatinga. In contrast, the climatic conditions of stable zones (Cerrado, Amazon and Atlantic Forest biomes) favor tick development. In enzootic areas, tick fever is uncommon because the animals are in frequent contact with the parasite, acquiring immunity naturally during the period of innate resistance; however, outbreaks may occur when calves become infested by considerable numbers of infected ticks during this period or in adults raised in tick-free environments that become infested for the first time when transporting to stable areas. It is necessary to better understand the disease's risk factors under stable conditions and the implications of the mechanical and other vector transmission of *A. marginale*. To prevent tick fever outbreaks in Brazil, it is important to develop and use anaplasmosis and babesiosis vaccines in cattle from enzootic unstable regions, especially when animals are moved to stable areas.

Keywords: Tick fever, enzootic instability, enzootic stability, Brazilian biomes, anaplasmosis, babesiosis.

Resumo

O presente trabalho revisa a situação epidemiológica das infecções por *Anaplasma marginale* e *Babesia* spp. e a ocorrência de surtos de Tristeza parasitária bovina (TPB) no Brasil. Em áreas de instabilidade enzoótica, as condições ambientais interferem no desenvolvimento do *Rhipicephalus (Boophilus) microplus*: o frio do inverno na região Sul; as inundações no Pantanal; e a baixa umidade na Caatinga. Por outra parte, as condições climáticas das zonas de estabilidade (os biomas Cerrado, Amazônia e Mata Atlântica) favorecem o desenvolvimento do carrapato. A TPB não é comum nas áreas estáveis, porque os animais estão em contato frequente com os parasitas, adquirindo imunidade naturalmente. Podem, porém, ocorrer surtos quando um número considerável de carrapatos infectados infesta bezerros, durante o período de resistência inata, ou quando adultos que foram criados em ambientes livres de carrapatos infestam-se, pela primeira vez, ao serem transportados para áreas estáveis. É necessário entender melhor os fatores de risco da doença em condições de estabilidade e a implicação da transmissão de *A. marginale* de forma mecânica, ou por meio de vetores diferentes do carrapato. Para prevenir surtos de TPB, no Brasil, é necessário desenvolver e usar vacinas em bovinos de regiões de instabilidade, especialmente antes de transportá-los para áreas estáveis.

Palavras-chave: Tristeza parasitária bovina, instabilidade enzoótica, estabilidade enzoótica, biomas brasileiros, anaplasmose, babesiose.

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Introduction

Cattle tick fever is a complex caused by the diseases babesiosis and anaplasmosis. The first is caused by the apicomplexa protozoans *Babesia bovis* and *Babesia bigemina*, the second is caused by the alphaproteobacteria (order: Rickettsiales) *Anaplasma marginale* (Levine, 1971; Dumler et al., 2001). Although the tick *Rhipicephalus* (*Boophilus*) *microplus* is the most important vector of *Babesia* spp. and *A. marginale* (Uilenberg, 2006), both can be transmitted by the transplacental route (Costa et al., 2016), *A. marginale* can also be transmitted mechanically by hematophagous insects, such as horseflies (Tabanidae) or stable flies (*Stomoxys calcitrans*), and iatrogenically through the use of instruments contaminated by blood of infected animals as needles, saws to dehorn, nose rings, tattoo machines, earrings, and castration instruments (Kocan et al., 2010).

Before nine months of age, calves are partially resistant to severe tick fever because of their innate protection and develop immunity when become infected. If the infestation with ticks transmitting hemoparasites is low, the inoculation rate is limited, and the animals will not acquire immunity. In contrast, if the inoculation rate is excessive in the period of innate resistance, the calves may become sick. Because in adult cattle innate resistance disappears, if they did not acquire immunity while young, infections by *A. marginale* or *Babesia* spp. will cause disease (Goff et al., 2001; Aubry & Geale, 2011).

The epidemiologic situation of tick fever in different regions can be identified by seroprevalence studies. If at least 75% of the animals in a region have antibodies for the hemoparasites, this area would be classified as stable, and the disease would be unusual. Seroprevalences lower than 12% suggest that hemoparasites do not circulate and tick fever outbreaks will not occur. If the seroprevalence is between 12% and 75%, outbreaks will occur in adult animals that were not infected by *Babesia* spp. or *A. marginale* before nine months of age and the area will be classified as unstable (Mahoney & Ross, 1972).

In Brazilian livestock, the economic impact of *R. microplus* and tick fever is high. In overall country, cattle tick causes losses estimated at 3.24 million dollars annually due to weight gain and milk production reductions (Grisi et al., 2014). In the State of Rio Grande do Sul, in the southeastern and southwestern mesoregions, the losses by deaths because of tick fever are estimated to be 1.6 million dollars annually (Almeida et al., 2006). The losses by tick fever due to treatment costs, weight loss and deaths across the entire country have not been estimated.

To determine the impact of tick fever in the country and establish control measures, it is necessary to understand the current situation of the tick fever in the country and establish control measures. The objective of this paper is to review Brazil's epidemiologic situation regarding *A. marginale* and *Babesia* spp. and the occurrence of outbreaks of tick fever, taking note of the features specific to each region and biome.

Epidemiologic Situation and Occurrence of Tick Fever Outbreaks in the Different Regions of Brazil

North region

The Amazon biome is present in most of the northern region of Brazil. The Cerrado (savannah) biome is found only in a portion of the State of Tocantins (Figure 1). The climate of the Amazon biome is equatorial: throughout the year, the rainfall and temperatures are high (Nimer, 1989). In this region, the conditions are ideal for the development of *R. microplus*; however, seasonal variations and the number of annual generations are still unknown. In Amazonia, because of the constant presence of the tick, the epidemiological condition of tick fever apparently is of enzootic stability; in the State of Pará, the seroprevalences of *A. marginale* and *Babesia* spp. were 75.18% (506/673) and 97.34% (661/679), respectively (Silva et al., 2014).

The climate of the Cerrado biome is tropical: the dry season occurs between March and September, and the wet season between October and February (Nimer, 1989). The climatic conditions of the Cerrado in the northern region of Brazil favor tick development; consequently, may be stability for tick fever. In the State of Tocantins, in Nellore and Tabapuã breeds, the seroprevalences of *A. marginale* were 89.9% (455/506) (Trindade et al., 2011); of *B. bovis,* 91.7% (464/506); and of *B. bigemina,* 90.5% (458/506) (Trindade et al., 2010).

Northeast region

Four biomes cover the northeastern region of Brazil: Caatinga, Atlantic Forest, Cerrado and Amazon (Figure 1). The Caatinga biome comprises most of the Northeast, reaching into all the states, except Maranhão. The Cerrado occupies portions of Maranhão, Piauí and Bahia. The transition area between the Caatinga and the Atlantic Forest is

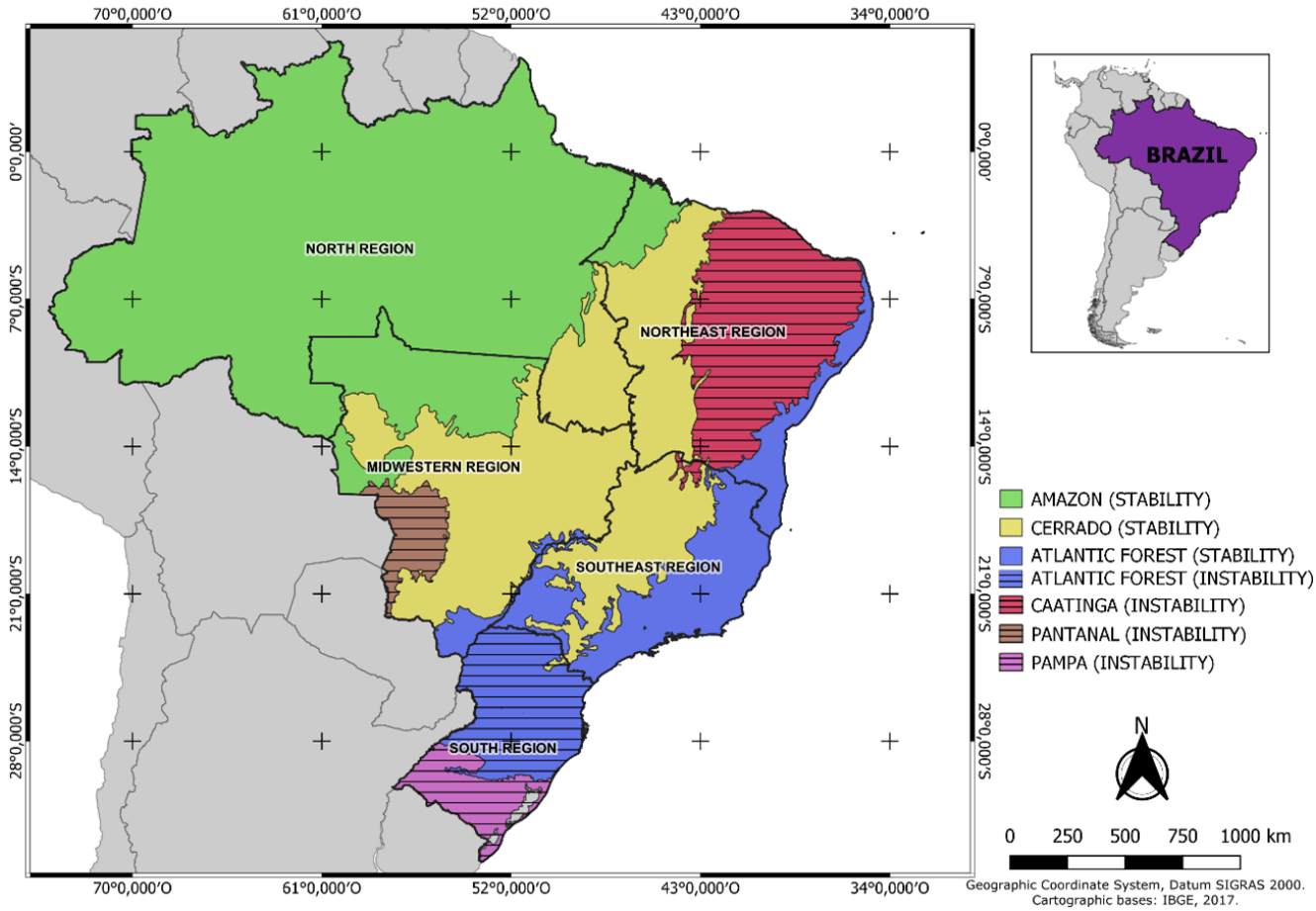

Figure 1. Cattle tick fever enzootic unstable zones in Brazil. The horizontally striped areas (Pantanal, Caatinga and Pampa biomes) are of instability as well as to the south of the Atlantic Forest (blue striped). The non-striped, blue part of the Atlantic Forest is a zone of stability.

known as Agreste and stretches across the States of Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, and Bahia in the same way as the Atlantic Forest.

The Caatinga biome is exclusive to Brazil, almost entirely in the Northeast region, its climate is semiarid. The dry season is intense and prolonged, and the rains, which occur in summer and autumn, are irregular (Nimer, 1989). In the Caatinga, ticks do not develop well because the low humidity makes the free-living stages unviable (Barros et al., 2017), except when introduced from stable areas during the rainy season or in some regions that are slightly wetter (Costa et al., 2011). In the Caatinga biome, cattle have low prevalence of antibodies for *Babesia* spp. and *A. marginale* because of the reduced tick infestation. In Paraíba, in the Sertão Paraibano and Borborema mesoregions, the observed seroprevalences of *A. marginale, B. bovis* and *B. bigemina* were 17.72% (81/457), 24.94% (114/457) and 9.4% (43/457), respectively (Costa et al., 2013). In the semiarid of Pernambuco, the *A. marginale, B. bovis* and *B. bigemina* seroprevalences were 39.8% (343/861), 42.6% (367/861) and 37.1% (320/861), respectively (Santos et al., 2017). In northern Bahia, seroprevalence of 66.62% (565/848) for *B. bovis* and 55,54% (471/848) for *B. bigemina* were observed (Barros et al., 2005). These values suggest that in the Caatinga the epidemiological situation of tick fever is unstable, thus outbreaks may occur. In the Veterinary Hospital of the Campina Grande Federal University, Patos Municipality, Paraíba, 1.26% (14/1113) of the bovine diagnostics performed between 2000 and 2007 were tick fever: *A. marginale* causing 35.71% (5/14) of the outbreaks, *Babesia* spp. 14.28% (2/14) and both 50% (7/14). Most of the outbreaks occurred in the rainy season, with increase in relative humidity, ticks were introduced from other regions and infested cattle with low immunity (Costa et al., 2009). At the same hospital, between 2007 and 2009, 24 outbreaks of tick fever were diagnosed: 75% (18/24) were caused by *A. marginale*, 8.3% (2/24) by *B. bigemina,* and 8.3% (2/24) by *B. bovis*. The remaining 8.3% (2/24) was occasioned by mixed infections. The mean morbidities and mortalities of all the outbreaks were 11.6% and 4.15%, respectively. In most of the outbreaks,

R. microplus, present in wet regions such as riverbanks or mountain ranges over 400 m, was the most important hemoparasite vector, except for one occasion in which the disease was transmitted by horseflies (Costa et al., 2011). In both reports, the affected animals were mostly crossbreeding adults.

In the Litoral Piauiense microregion of the State of Piauí, in the border area between the Caatinga and Cerrado, climate is tropical with temperatures varying between 23 and 33.6 °C and a mean precipitation of 1200 mm. These environmental conditions favor tick development; however, the incorrect use of acaricides causes variations in the seroprevalence between farms of this microregion. Enzootic instability for *B. bovis* and *B. bigemina* is observed in this region, with seroprevalences of 68.8% (139/202) and 52.5% (106/202), respectively; however, stability is observed for *A. marginale* with a seroprevalence of 89.1% (180/202) (Souza et al., 2013); in one of the herds used in this study, a tick fever outbreak occurred in 3-month-old calves at the beginning of the rainy season, with a morbidity of 13.3% (Souza et al., 2018). In the State of Piauí, in general, tick fever occurs because of high tick infestations at the end of the rainy season; both calves and adults can become sick, however, clinical signs are more intense in adults (Francisco Souza, Pernambuco Federal Rural University. UFRPE, personal communication, 2022).

In the Atlantic Forest biome of the northeastern region, the climate is tropical humid: it is hot and rainy, raining principally between April and September (Nimer, 1989). This environment favours the development of the tick throughout the year, setting up conditions for enzootic stability. In southern Bahia it was observed seroprevalences of 97.58% (121/124) and 100% (124/124) for *B. bigemina* and *B. bovis*, respectively (Araújo et al., 1997).

The climate of the northeastern Agreste ranges from humid tropical to semiarid, this allows *R. microplus* to develop throughout the year; however, the tick decreases in the dry season, but does not entirely disappear (Farias, 2007). Because Agreste is the intersection between two biomes, one with enzootic stability (Atlantic Forest) and the other with instability (Caatinga), the tick fever epidemiologic situation is variable: while in Bananeiras Municipality, Paraíban Agreste, seroprevalences of 5.76% (3/52), 13.46% (7/52) and 21.15% (11/52) for *A. marginale, B. bigemina* and *B. bovis*, respectively, indicate enzootic instability (Costa et al., 2013), in the Agreste region of Bahia, seroprevalences of 97% (361/372) and 98.65% (367/372) for *B. bovis* and *B. bigemina*¸ respectively, indicate stability (Araújo et al., 1997).

The Amazon biome in the northeastern region apparently is epidemiologically stable for babesiosis. In the São Luis Island, Maranhão State, was observed a seroprevalence of 97.9% (275/281) for both *B. bovis* and *B. bigemina* in crossbreeding dairy cattle (Costa et al., 2015).

Southeast region

Southeastern Brazil is covered by the Atlantic Forest and Cerrado biomes (Figure 1). The first is present in all the states, but the second is just present in Minas Gerais and São Paulo. The climatic conditions of both biomes are appropriate for *R. microplus* development throughout the year; however, the tick's life cycle is faster in the rainy season. Commonly, in one year, the tick develops for four generations and a fifth generation may occur (Cruz et al., 2020).

Tick fever is stable in the Cerrado biome of the Southeast region. *A. marginale* seroprevalence was 97.68% (845/865) in four mesoregions of Minas Gerais: Triangulo Mineiro, Alto Paranaíba, Sul de Minas and Zona Metalúrgica (Ribeiro, 1978). In the municipality of Uberlandia, Triángulo Mineiro mesoregion, the *B. bigemina* seroprevalence was 97.33% (146/150) (Cunha et al., 2002). In the Bauru mesoregion, State of São Paulo, seroprevalences were 91.63% (449/490) for *B. bovis* in Holstein and Nellore cattle, and 81.8% (200/245) for *B. bigemina* just in Holstein cattle (D'Andrea et al., 2006).

The epidemiologic condition for tick fever in the Atlantic Forest biome is also stable. In the Lavras microregion, Minas Gerais, the seroprevalences in dairy cattle for *A. marginale* and *B. bovis* were 93.47% (315/337) and 87.83% (296/337), respectively (Carvalho et al., 2012). In Rio de Janeiro, the Norte Fluminense and Médio Paraíba mesoregions were stable for *B. bovis* (Souza et al., 2000a; Soares et al., 2000), *A. marginale* (Souza et al., 2000b, 2001) and *B. bigemina* (Souza et al., 2000c). In São Paulo, in the Vale do Paraíba mesoregion, the *B. bovis* and *B. bigemina* seroprevalences were 88% (103/117) and 94% (110/117), respectively (Barci et al., 1994), while in the Presidente Prudente mesoregion, the *B. bovis* seroprevalence was 86.67% (582/671) in Holstein and Nellore cattle; for *B. bigemina* it was 92.55% (293/317) just in Holstein cattle (D'Andrea et al., 2006).

In the Southeast region, tick fever outbreaks occur sporadically. In Viçosa, Minas Gerais, 7- to 9-month-old Holstein calves suffered cerebral babesiosis, 100% of the sick animals died (Patarroyo et al., 1982). In São Paulo,

an anaplasmosis outbreak occurred in adult Holstein cattle that had recently been brought from Uruguay; 4.95% (50/1010) of the animals got sick, but none died (Machado et al., 2015).

Midwestern region

The Midwestern region is covered by the Amazon, Cerrado and Pantanal biomes (Figure 1). The Cerrado is present in all states; the Pantanal, in a part of Mato Grosso and Mato Grosso do Sul; and the Amazon, just in the north of Mato Grosso.

In the State of Goiás, seroprevalences were 98.9% (178/180) and 93.3% (168/180) for *B. bovis* and *B. bigemina*, respectively (Santos et al., 2001), showing babesiosis stability in the Cerrado biome. However, the disease may occur sporadically as in Mambaí, Goiás, where an anaplasmosis outbreak occurred in a group of confined animals that were carried to a paddock with an abundance of ticks. Animals of all ages and of European breeds and crosses were affected and the mortality was 2.5% (Machado et al., 2015). In Campo Grande, Mato Grosso do Sul, three 13- to 108-day-old crossbreed calves died due to babesiosis caused by *B. bovis*. The outbreak occurred between November and December and was due to animal infestation with high quantity of ticks during the period of innate resistance (Kessler et al., 1983).

The climate in the Pantanal biome is tropical with the rainy season taking place between December and June, and the dry season between June and November (Nimer, 1989). The tick peak occurs just at the end of the dry season (Cançado, 2008) because the parasite's eggs are affected by floods during the rainy season (Pupin et al., 2019). In the Pantanal, the epidemiologic situation of tick fever varies because, throughout the year, the *R. microplus* presence is irregular. While the bordering area of the Cerrado and Pantanal biomes was classified as stable to babesiosis because of the seroprevalence of 83.9% (1145/1365) found for *B. bovis* (Madruga et al., 2000) and of 94.3% (1289/1367) for *B. bigemina* (Madruga et al., 2001), the Pantanais mesoregion in the State of Mato Grosso do Sul was classified as unstable, with seroprevalences of 72.25% (289/400), 61.25% (245/400) and 51.25% (205/400) for *A. marginale, B. bovis* and *B. bigemina,* respectively (Ramos et al., 2020). In the Pantanal, tick fever occurs in some farms with low and high areas when cattle are transported from the former to the latter. Outbreaks also occur when animals from the Pantanal are transported to the Cerrado (Lemos et al., 2022). The Laboratory of Veterinary Pathology of the UFMS diagnosed babesiosis in 0.35% (19/5298) of the cases attended between 1995 and 2017: 78.94% (15/19) of the outbreaks were caused by *B. bovis*; 5.26% (1/19) by coinfection of *B. bovis* and *B. bigemina*; and in 15.78% (3/19) of cases *Babesia* specie was not determined. In outbreaks of babesiosis by *B. bovis,* morbidity and mortality were 14.53% and 10.25%, respectively. Tick fever occurred throughout the year, and bovines of all ages were affected. *Bos indicus* were more frequently affected because in this region it is the predominant type of cattle (Pupin et al., 2019). In this study, it is not differentiated between the outbreaks that occurred in the Pantanal biome and those in the Cerrado.

South region

The southern region of Brazil is covered by the Pampa biome, located just in the south of Rio Grande do Sul, and the Atlantic Forest biome (Figure 1). This region has a subtropical climate and well-defined seasons (Nimer, 1989). In winter, the temperature decreases, and frosts occur, so most *R. microplus* larvae become unviable and almost disappear from pastures (Furlong et al., 2003). The first tick generation, that develops in the spring from the eggs and/or larvae that survive the winter, is small and inconspicuous; the second generation occurs in the summer and is more prevalent; and the third generation occurs in autumn, corresponding to the peak of infestation (Farias, 2007).

Tick fever epidemiologic conditions in most parts of the State of Paraná is unstable. In Umuarama Municipality, the seroprevalence was 64.22% (149/232) for *B. bovis* (Osaki et al., 2002); despite the *A. marginale* seroprevalence of 76% (172/226), was also considered unstable because the antibody titers were low (Yoshihara et al., 2003). In dairy cattle, in the Centro-sul region, the *A. marginale* seroprevalence was 58.74% (223/130) (Marana et al., 2009), and in the Southeast region, it was 24.4% (84/344) (Sott et al., 2016).

In the State of Santa Catarina, tick fever is an important disease. In the Oeste Catarinense mesoregion, confinement dairy is the predominant production system. In this region, the Veterinary Pathology Laboratory of the Catarinense Federal Institute (IFC), Concordia campus, diagnosed tick fever in 6.9% (112/1623) of the necropsies performed between 2013 and 2020; 45,53% (51/112) of the outbreaks were caused by *A. marginale* and 49.04% 54,46% (61/112) by *Babesia* spp. (Perosa et al., 2022). The disease occurs mainly in summer and autumn in dairy adult cattle (Mendes et al., 2016) when animals are moved from confinement onto tick-infested pastures (Ricardo

Mendes, IFC Concordia campus, personal communication, 2022). A different scenario is seen in northern Santa Catarina, where babesiosis in beef cattle is stable (Souza et al., 2002). In this region the tick fever is the most prevalent disease in cattle, affecting recently weaned calves and sometimes adults who go through stressful situations, such as parturition; *Bos taurus* breeds and their crosses are the most affected; animals are constantly infested by ticks, and tick fever occurs throughout the year (Elizabeth Schwegler, IFC Araquari campus, personal communication, 2022).

The State of Rio Grande do Sul apparently is unstable for babesiosis: in the Sudeste Rio-Grandense mesoregion, the *B. bovis* and *B. bigemina* seroprevalences were 15.3% (58/379) and 37.73% (143/379), respectively (Correia, 2006); and in the Sudoeste Rio-Grandense mesoregion, some farms were unstable for *B. bovis* due to bovine and ovine rotative grazing (Martins et al., 1994). These low seroprevalences may be due to fluctuating tick conditions throughout the year. In the Centro Oriental and Centro Occidental mesoregions, the Veterinary Pathology Department of the Santa María Federal University diagnosed tick fever in 5.33% (225/4220) of the diagnoses performed between 1964 and 2008 where it was the third most frequent disease (Lucena et al., 2010). At the same laboratory, 1.86% (20/1071) of the cases attended between 1999 and 2003 were diagnosed as cerebral babesiosis with the outbreaks occurring mostly in summer and the affected animals were of European breeds and older than nine months (Rodrigues et al., 2005). In the Sudeste and Sudoeste mesoregions, the Regional Diagnostic Laboratory at the Faculty of Veterinary Medicine of the Pelotas Federal University (UFPel) diagnosed tick fever in 55.12% (328/595) of the bovines attended between 1978 and 2014. *B. bovis* occasioned 45% (135/328) of the outbreaks; *A. marginale,* 34% (101/328); and *B. bigemina,* 2.7% (8/328). A total of 4.7% (14/328) were mixed infections. The disease was more frequent in summer, and the mean morbidity and mortality were 3% and 1.3%, respectively (Oliveira et al., 2017). In the tick fever outbreaks diagnosed between 1978 and 2005 at the UFPel, most of the animals were between one and three years old and were of European breeds or crosses (Almeida et al., 2006).

In the State of Rio Grande do Sul, a tick fever predisposing factor is animal transport during favorable tick periods. Between April and May, a group of Devon adult cattle were carried from a tick-free farm in the Nordeste Rio-Grandense mesoregion to the Metropolitana de Porto Alegre mesoregion where the animals were infested by ticks and suffered cerebral babesiosis; the outbreak resulted in 50.9% mortality (Antoniassi et al., 2009). In November, a group of tick-infested bovines were transported from the Rio Grande do Sul center to Santa Vitória do Palmar Municipality. As Santa Vitória do Palmar is the only municipality of Brazil considered tick-free, the local animals became infested with the parasite and suffered cerebral babesiosis. The outbreak occurred between January and March, and the morbidity and lethality rates were 10.18% and 100%, respectively (Schild et al., 2008).

In southern Brazil, although tick fever occurs mainly in animals older than nine months, it has also been diagnosed in younger calves. In the Sudoeste Rio-Grandense mesoregion, 40 Hereford heifers calved between March and May and 50% of their calves suffered babesiosis due to *B. bovis*. The animals became sick because colostrum management was inadequate and they were exposed to high tick infestation; the lethality was 100% (Oliveira et al., 2018).

Final Considerations

In Brazil, it is difficult to establish a general concept of the disease epidemiology due to the complexity of the large range of scenarios that exist in each biome and the lack of studies. In this review, a general classification that could help to predict the behavior of the disease in each region was realized. The enzootic stability zones are the Cerrado in the Midwest and South-east regions, the Atlantic Forest in the Northeast and Southeast regions, and the Amazon in the northern region; these areas represent nearly 82% of Brazil. The enzootic instability zones are the Caatinga in the Northeast region, the Pantanal in the Midwest region, and the southern region; almost the 18% of the Brazilian territory (Figure 1). Ferreira et al. (2022), based in prevalence data, classified the North and Southeast regions as stable zones, the Southern region as free area and the Northeast as unstable region. In the present work, based on information from different sources, we advance in the characterization of regions and biomes as unstable or stable based on the principles of Mahoney & Ross (1972). However, it is necessary to continue carrying out serological studies and description of outbreaks to better characterize the epidemiology of tick fever in the different regions and biomes of Brazil.

Throughout the year, in unstable areas, temperature and/or humidity are highly variable. In the southern region, while the temperatures approach 0 °C in winter, in summer, they can rise to 40 °C. In the Caatinga biome the dry period is prolonged, and the relative humidity can decrease as much as 50% (Embrapa, 2021). In the Pantanal

biome there are deep regions that stay flooded almost all year. These climatic variations influence tick presence and, consequently, the transmission of the tick fever etiologic agents. In the southern region, in winter, the tick does not spread due to the cold, and the quantity is insufficient to maintain tick fever immunity; in this region, ticks develop three generations, less than in the rest of the country: the final generation occurs in autumn, cause higher infestations and consequently more tick fever outbreaks. In the Caatinga biome, the number of *R. microplus* generations (usually less than three per year) depend on the humidity changes: in extended rainy seasons the number of generations produced can be three or more; however, when the dry season is prolonged, because of the low humidity, the egg hatching rate is low, and the larvae does not survive. The tick can subsist in wetter regions (elevated zones or riversides) or during rainy years (Barros et al., 2017). Important predisposing factors for tick fever in the Caatinga include introducing cattle infested by ticks from enzootic zones during the rainy season or transportation of adult animals to zones where the tick subsists. In the Pantanal biome, ticks cannot survive flooding in low-lying areas; tick fever will occur if animals are carried from there to elevated areas where the tick is present. In unstable regions, because cattle have little exposure to ticks and do not get infected with *Babesia* spp. and/or *A. marginale* before nine months of age, they do not acquire immunity; if these animals get infected as adults, they will develop tick fever.

In enzootic stable areas, constantly elevated temperature and humidity conditions favor tick development, the parasite is present throughout the year and may generate up to five generations (Cruz et al., 2020). Because of this, bovine under nine months of age become infected and naturally immunized against *A. marginale* and *Babesia* spp. without getting sick; therefore, when becoming adult, the probability of being affected by tick fever will be lower (Madruga et al., 1987). However, adults can become sick if they have weak immunity to hemoparasites and become infested by ticks: when they are mobilized from tick-free zones to enzootic areas; when they are raised in confined systems and are transported to pasture; or when they are carried to an area where their immunity is not compatible with the local hemoparasite variants. Calves may become sick if they experience a high tick infestation during the period of innate resistance.

There are no differences in susceptibility to anaplasmosis between *Bos taurus* and *Bos indicus* species (Wilson et al., 1980); however, babesiosis is more intense in *Bos taurus* (Bock et al., 2004). Additionally, *Bos taurus* animals are more susceptible to tick infestation (D'Andrea et al., 2006) and, consequently, have a higher risk of developing tick fever. Because of this, in stable areas, farmers must keep in mind that introducing purebred *Bos taurus* and crossbreeding with *Bos indicus* to increase milk or meat production will result in higher tick infestations in their animals and, consequently, a higher risk of tick fever outbreaks.

Seroprevalence studies in Brazil have made it possible to differentiate between tick fever stable and unstable zones; however, knowledge about outbreak occurrence is poor. In stable zones, sporadic outbreaks relate to animal transport from unstable or free areas, high tick infestation in calves, incorrect colostrum management, confined production systems, introduction of *Bos taurus* genetic, and recurrent application of injections have been reported. Nevertheless, it is necessary to explore other tick fever predisposing factors in the Amazon, Pantanal and Atlantic Forest biomes, to more accurately estimate the epidemiology and the impact of the disease in Brazil. It is also important to investigate the relevance of the transmission by hematophagous insects and the iatrogenic transmission in anaplasmosis outbreaks, which have been little studied.

In Brazil, *Anaplasma centrale* outer membrane protein based-vaccines and attenuated strains of *Babesia* spp. were developed and marketed (Kessler et al., 1987; Arteche, 1992), however, their use has not been adopted, and currently there are no vaccines available for sale; this may be due to a lack of knowledge by producers and veterinarians, difficulties in biological management and conservation and/or excessive costs (Miraballes et al., 2018). In neighboring countries as Argentina, the vaccine is routinely marketed (INTA, 2022). It is important to develop strategies to standardize adult animal vaccination from unstable or free zones, especially before being transported to tick-endemic areas.

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Ethics declaration

Because in this study were used information of public studies, this study did not require ethical approval.

Conflict of interest

The authors declare that they have no competing interests.

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