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ORIGINAL ARTICLE

Distribution, seroprevalence and risk factors for bovine brucellosis in Brazil: Official data, systematic review and meta-analysis

Isis Daniele dos Santos Rocha[a], Inácio José Clementino[b], Débora Luise Canuto de Sousa[a], Clebert José Alves[a], Carolina de Sousa Américo Batista Santos[a], Sérgio Santos de Azevedo[a,*]

[a] *Post-Graduate Program of Science and Animal Health, Academic Unit of Veterinary Medicine, Federal University of Campina Grande, Patos, Paraíba State, Brazil*
[b] *Department of Veterinary Medicine, Federal University of Paraíba, Areia, PB, Brazil*

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Abstract Bovine brucellosis is an endemic disease in Brazil, and evidence-based assessments of the available literature on its seroprevalence and risk factors are limited. The aim of this study was to systematically review and summarize studies related to seroprevalence and risk factors of bovine brucellosis in the entire Brazil, in addition to comparing published data with the most recent official reports. Articles available in scientific databases and published between October 2006 and October 2021 were evaluated. Forty-five publications were included in the meta-analysis on the seroprevalence of brucellosis and 29 publications in the review on risk factors. The largest number of publications was found for the State of Mato Grosso do Sul (n = 4), and the highest and lowest seroprevalences were observed in Acre (11%; 95% CI: 8.0–14.0%) and in the Federal District (0.4%; 95% CI: 0.2–0.7%). The main risk factors were the purchase of animals for breeding, vaccination, the number of heifers (female ≥2 years), the presence of calving paddocks and the occurrence of abortions. The need for new official studies has been suggested to determine the true prevalence of bovine brucellosis in Brazil, supported by the National Program for the Control and Eradication of Animal Brucellosis and Tuberculosis.

* Corresponding author.
E-mail address: sergio.santos@professor.ufcg.edu.br (S.S. de Azevedo).

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PALABRAS CLAVE
Brucella abortus;
Notificación obligatoria;
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Ganado;
Seroprevalencia;
Factores de riesgo

Distribución, seroprevalencia y factores de riesgo de brucelosis bovina en Brasil: datos oficiales, revisión sistemática y metaanálisis

Resumen La brucelosis bovina es una enfermedad endémica en Brasil y existen pocos datos sobre su seroprevalencia y factores de riesgo basados en la evidencia. Los objetivos de este estudio fueron revisar y resumir sistemáticamente los resultados sobre seroprevalencia y factores de riesgo de la brucelosis bovina en todo Brasil reportados en la bibliografía, además de comparar los datos publicados con los de los informes oficiales más recientes. Se evaluaron los artículos disponibles en las bases de datos científicas publicados entre octubre de 2006 y octubre de 2021. Se incluyeron 45 publicaciones en el metaanálisis sobre la seroprevalencia de brucelosis y 29 publicaciones en la revisión de los factores de riesgo. El mayor número de publicaciones informan datos para el estado de Mato Grosso do Sul (n = 4) y las seroprevalencias más altas y más bajas se observaron en Acre (11%; IC 95%: 8,0-14,0%) y en el Distrito Federal (0,4%; IC 95%: 0,2-0,7%), respectivamente. Los principales factores de riesgo fueron la compra de animales para reproducción, la vacunación, el número de vaquillas (hembras ≥2 años) y la presencia de potreros de parto y de abortos. Se indica la necesidad de nuevos estudios oficiales para determinar la verdadera prevalencia de la brucelosis bovina en Brasil, apoyados por el Programa Nacional de Control y Erradicación de la Brucelosis y Tuberculosis Animal.

Introduction

Bovine brucellosis is a zoonotic bacterial disease that mainly affects the reproductive organs, reduces animal welfare and causes global economic implications, representing an obstacle to the development of livestock activity[42]. *Brucella abortus* is the most prevalent etiologic agent of bovine brucellosis in Brazil[2] and can be transmitted to humans especially by the consumption of unpasteurized milk and dairy products and raw or undercooked meat produced in endemic areas, or by handling animals, aborted fetuses and infected placenta[26]. In humans, the disease causes febrile syndrome and complications such as orchitis, endocarditis or arthritis[4].

Control and prevention measures of bovine brucellosis spread and mitigation of its impact on the economy and public health are supported by regular surveillance and trend assessment, which make it possible to predict and control re-emergence or outbreaks in areas with continued prevalence[26]. In this scenario, the Brazilian National Program for the Control and Eradication of Animal Brucellosis and Tuberculosis (https://www.gov.br/agricultura/pt-br/assuntos/sanidade-animal-e-vegetal/saude-animal/programas-de-saude-animal/pncebt), implemented by the Ministry of Agriculture, Livestock and Supply (MAPA), establishes the mandatory notification of brucellosis as one of the control measures, in addition to the vaccination of females aged 3–8 months with B19 and aged ≥8 months with RB51 vaccines, excluding males and pregnant females, as well as the inspection of transport and slaughter of seropositive animals.

Based on the data available in the Animal Health Information System, all Brazilian states have had cases of infected animals and herds every year, or have had them at some point in the last four years (considering available data), indicating a wide distribution of the disease in the country[7]. In addition, it is important to mention that underreporting has been identified as responsible for the lower seroprevalence of the disease in some Brazilian states. Therefore, research on the seroprevalence of bovine brucellosis is essential to establish the true picture of the disease in Brazil and support control measures.

The purchase of breeding stock, vaccination, the occurrence of abortions, veterinary assistance and the presence of flooded pasture areas are considered risk factors for bovine brucellosis because they can influence the occurrence and distribution of the disease[10,42]. These risk factors may differ among different Brazilian states, and are also likely to be dynamic over the years, making it difficult to establish standards. In general, the information on risk factors for bovine brucellosis in Brazil is still very dispersed in the literature and there is no clear profile of the main factors in the country and for its states.

The objective of this study was to systematically review and summarize studies related to the seroprevalence and risk factors for bovine brucellosis in Brazil, in addition to comparing published data with the most recent official notification data.

Materials and methods

Systematic review procedure

The protocol used to carry out this systematic review was predefined based on the PRISMA guidelines[32], including: (a) a literature search to identify potential articles of relevance, (b) assessment of the relevance of the articles, (c) quality assessment, and (d) data extraction. The number of articles that met the pre-established criteria at each stage are summarized in Figure 1.

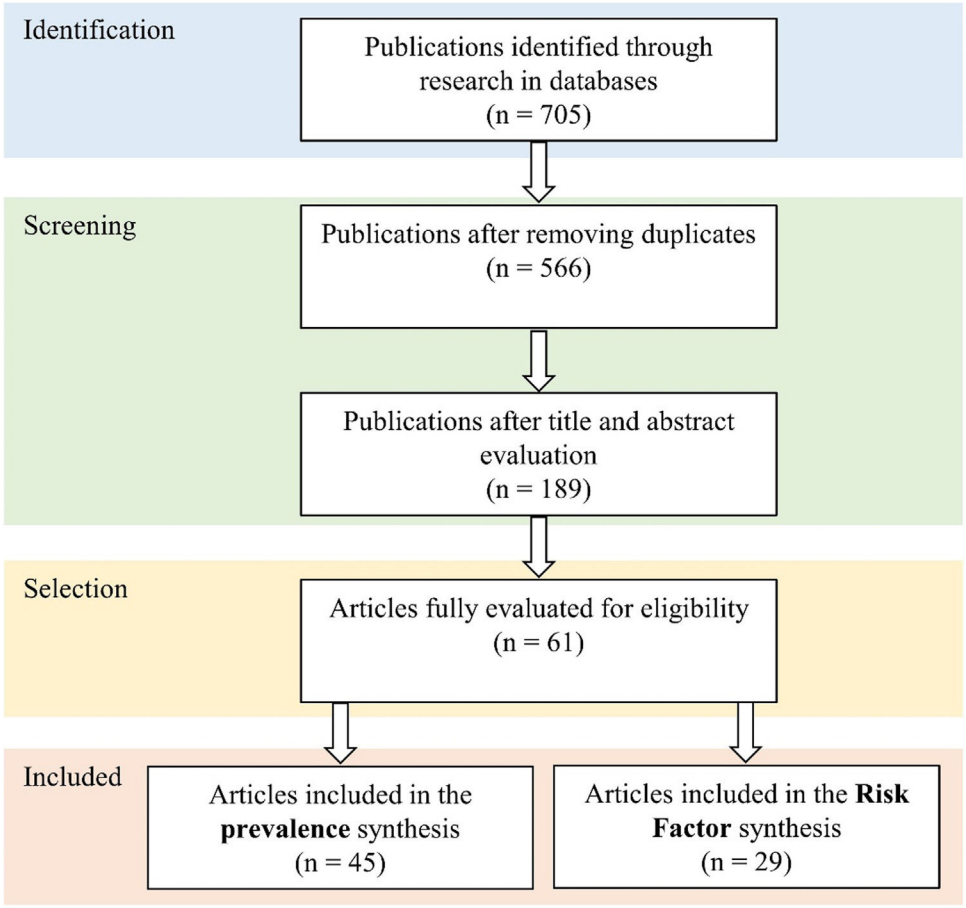

Figure 1 Article selection flowchart showing the number of articles in each phase of the systematic review.

Publication search strategy

The search for published articles on the seroprevalence and risk factors for bovine brucellosis (*Brucella abortus*) in Brazil was conducted from September 15 to October 25, 2021. The following databases were used to search for publications: SciELO, Google scholar, PubMed and Science Direct. The search terms included five keywords: ''bovine brucellosis'', ''*Brucella abortus*'', ''Brazil'', ''prevalence'' and ''risk factors''. These words were combined to construct the different search terms:

a. Bovine brucellosis or *Brucella abortus* + Brazil.
b. Prevalence + bovine brucellosis or *Brucella abortus* + Brazil.
c. Risk factors + bovine brucellosis or *Brucella abortus* + Brazil.

During the searches, the keyword combinations were expanded (such as: prevalence + bovine brucellosis + risk factors + Brazil) to capture more articles, but the five initially defined keywords were restricted to refine the number of resulting articles. The searches were limited to articles published in English and Portuguese, in the last 15 years. References cited in retrieved articles were also evaluated to maximize article retrieval.

Inclusion and exclusion criteria

In the preliminary screening, all duplicate publications and publications that did not meet the inclusion criteria were eliminated. For this purpose, a reading of the title and content of the abstract of each article was performed. The following criteria were used:

a. The article reported original data on bovine brucellosis in Brazil;
b. The article provided information on the prevalence and/or risk factors for bovine brucellosis in Brazil;
c. The article provided information on the serological tests for bovine brucellosis diagnosis in Brazil [Rose Bengal Test (RBT) as screening, and 2-Mercaptoethanol and/or complement fixation tests as confirmatory methods] according to MAPA.

Studies that did not meet the predetermined criteria were excluded. Theses, dissertations, review articles and abstracts in conference proceedings were also excluded. For articles whose relevance could not be determined by reading the abstract alone, full texts were evaluated.

Data collection and processing

Data collection was divided into two stages: (1) data extraction on the prevalence of bovine brucellosis and (2) selection of data on risk factors. The format for extracting prevalence data was prepared based on the geographic location (state) of the survey, sample, number of positive samples, prevalence and respective 95% confidence intervals (95% CI), period of the survey, first author and year of publication.

The number of positive samples complies with Normative Instruction SDA No. 10, March 03, 2017, of the Ministry of Agriculture, Livestock and Food Supply – MAPA, by which serological tests for the diagnosis of brucellosis are performed on individually identified animals, in accordance with the following criteria: I – females aged ≥24 months vaccinated with B19; II – females aged ≥8 months vaccinated with RB51 or not vaccinated; III – males aged ≥8 months intended for reproduction; or other categories may be tested at the discretion of the licensed veterinarian. The Rose Bengal Test (RBT) is used as a routine test (screening), and positive animals should be submitted to a confirmatory test within thirty days. The 2-Mercaptoethanol test is used as a confirmatory test in animals reactive to the RBT. The complement fixation test is also used as a confirmatory method for testing animals that are reactive to RBT or that present inconclusive results to the 2-Mercaptoethanol test. Results are considered to be inconclusive if the 2-Mercaptoethanol test is negative, and the standard tube agglutination test (STT) shows antibody titers of at least 50 for non-vaccinated animals with B19 and 100 for vaccinated animals. Therefore, the animal was deemed positive if it reacted to serological tests.

Data on risk factors were extracted based on the geographic location (state), risk factors with significant effect ($p < 0.05$), period of the survey, first author and year of publication. Therefore, the risk factors that did not show a significant effect were not included in this research. In each sentence that described the risk factor, connectives were eliminated (e.g., that, in, in, etc.) and words with the same meaning were combined, when possible and necessary to present the same structure in the different studies (e.g., ''veterinary care'', ''having veterinary assistance'' or ''veterinary assistance'' = ''veterinary care'').

Official notification data on bovine brucellosis in Brazil

To obtain a more recent (for the years 2017–2019) characterization of the distribution of bovine brucellosis cases in Brazil, the most recent available data were collected from the Animal Health Information System of the MAPA.

Statistical analysis

Statistical analysis was performed on R environment software, version 3.0.0, RStudio interface. A meta-analysis was performed for the seroprevalence data, based on a random effect model. The forest plot was used to present the variations between studies, the seroprevalence estimates and their respective 95% CI for all included studies, along with the size of the combined effect. Likewise, subgroup analyses for the primary outcome (seroprevalence of brucellosis in different states) were performed by state. Cochran's Q test and inverse variance index (I^2) were calculated to evaluate the heterogeneity of the results. The tau test (τ^2) was used to assess the variance of effect size estimates in the study population. The presence of publication bias was visualized using the funnel plot. A ''word cloud'' was generated with the words related to risk factors for bovine brucellosis using the *wordcloud* function, based on the information collected from 29 articles.

Results

Results of the seroprevalence of bovine brucellosis

After an initial literature screening of 705 publications, 139 were removed as duplicates and 566 articles remained for further analysis (Fig. 1). In the second stage of the screening process, 377 publications were removed because they were theses, dissertations, review articles, abstracts in conference proceedings, did not address the central theme, described the seroprevalence of brucellosis in buffaloes (or animals other than cattle). A total of 61 articles were evaluated for eligibility, and 45 articles, published between October 2006 and October 2021, were included in the study for the meta-analysis of bovine brucellosis seroprevalence.

Table 1 shows the articles for each Brazilian state regarding the sample size, number of positive animals, seroprevalence of brucellosis and 95% confidence interval, year of the survey and references. The largest number of articles was found for Mato Grosso do Sul (n = 4), followed by the states of Maranhão, Paraíba, Santa Catarina, São Paulo and Tocantins (three articles per state). In turn, only one study was registered for the states of Sergipe, Roraima, Pernambuco, Rio Grande do Norte, Rio de Janeiro, Goiás, Amazon, Bahia and Acre and, therefore, there is a very limited number of publications, making it impossible to accurately characterize the seroprevalence of brucellosis in these States. In addition, no published articles in this regard were found for the states of Amapá, Ceará and Piauí.

Publication bias assessment

The result of the effect estimates in relation to their standard error indicated that there was no evidence of publication bias in the studies reporting the seroprevalence of bovine brucellosis in Brazil (t test = 0.25, $p = 0.8071$) (Fig. 2). The distribution of studies was slightly symmetrical, centered on the central dotted line of the funnel plot, despite the predominant trend of results pointing to low seroprevalence (predominantly negative results for brucellosis), especially in two studies[37,40], where the number of positive samples was only 1 and 2, respectively. Therefore, the result indicates that the studies satisfied the sampling for both seronegative and seropositive animals for bovine brucellosis.

Table 1 Summary of the surveys reporting the seroprevalence of bovine brucellosis in Brazil.

State	Number of animals	Number of positive animals*	Prevalence (%)	95% CI (%)	Year	Reference
Acre	527	56	10.6	–	NI	44
Alagoas	400	11	2.75	–	2014	41
Alagoas	398	11	2.75	–	NI	19
Amazônas	109	7	6.42	–	2016	20
Bahia	10803	81	0.66	[0.41–0.93]	2004	2
Distrito Federal	2019	7	0.16	[0.04–0.28]	2003	23
Espírito Santo	5067	83	3.8	[0.9–10.10]	2011–2014	3
Espírito Santo	5351	88	3.53	[1.93–6.37]	2002–2003	4
Goiás	10738	240	3.01	[2.69–3.33]	2002	39
Maranhão	6779	112	2.25	[1.70–3.60]	2007–2009	7
Maranhão	525	26	4.95	–	2013	12
Maranhão	1265	15	1.2	–	2015–2016	46
Mato Grosso	12435	464	5.1	[3.50–7.20]	2014	2
Mato Grosso	13684	1395	10.2	[7.40–13.1]	2002–2003	33
Mato Grosso do Sul	9466	727	7.7	–	1998	14
Mato Grosso do Sul	10025	700	7	[5.60–8.70]	2009	28
Mato Grosso do Sul	378	1	0.26	[0.05–1.48]	2012–2013	37
Mato Grosso do Sul	724	16	2.21	–	2016–2017	38
Minas Gerais	20643	226	1.09	[0.78–1.41]	2002	22
Minas Gerais	18990	113	0.81	[0.05–1.10]	2011	35
Pará	7724	792	10.25	–	2008–2012	31
Pará	385761	11640	3.01	–	NI	13
Paraíba	3489	43	2	[1.10–3.90]	2012–2013	15
Paraíba	55691	199	0.36	–	2008–2009	8
Paraíba	771	15	3.6	–	2011	36
Paraná	14850	153	1.73	[1.10–2.36]	2001–2002	16
Paraná	1227	33	2.6	–	2010–2011	25
Pernambuco	3901	52	1.4	[0.70–2.70]	2008–2009	1
Rio de Janeiro	8239	248	4.08	[2.83–5.33]	2003–2004	27
Rio Grande do Norte	1531	95	6.2	–	2007–2008	21
Rio Grande do Sul	16072	111	1.02	[0.60–1.43]	2004	29
Rio Grande do Sul	6872	81	0.98	[0.57–1.57]	2013	43
Rondônia	9083	144	1.9	[1.40–2.50]	2014	24
Rondônia	9703	560	6.22	[4.88–7.56]	2004	50
Roraima	9087	369	4.1	–	2007–2009	47
Santa Catarina	8630	16	1.21	[0.09–4.97]	2012	5
Santa Catarina	686086	7586	1.11	[1.08–1.13]	2013–2018	6
Santa Catarina	7801	2	0.06	[0.00–0.17]	2001	40
São Paulo	8761	187	3.81	[0.72–6.90]	2001	18
São Paulo	12920	227	2.4	[1.80–3.10]	2011	17
São Paulo	813	26	3.2	–	2007	30
Sergipe	4640	134	3.36	[2.28–4.44]	2002–2003	45
Tocantins	20908	688	4.43	[3.57–5.29]	2002–2003	34
Tocantins	4005	28	2.21	[1.05–4.01]	2014–2015	48
Tocantins	845	142	16.8	[14.3–19.4]	2007	49

NI: not identified; CI: confidence interval.

* Animal deemed positive if reactive to serological tests [Rose Bengal Test (screening) and 2-Mercaptoethanol/complement fixation tests (confirmatory)] according to Normative Instruction SDA No. 10 (MAPA, 2017).

Meta-analysis

The forest plot derived from the meta-analysis on the seroprevalence of bovine brucellosis in Brazil is shown in Figure 3. The meta-analysis indicated a high level of variability among studies ($\tau^2 = 1.3184$; $I^2 = 99.7\%$, test $Q = 377.8$, df = 14 and $p < 0.001$). Individual study prevalence estimates ranged from 0% to 17%, with the combined random overall

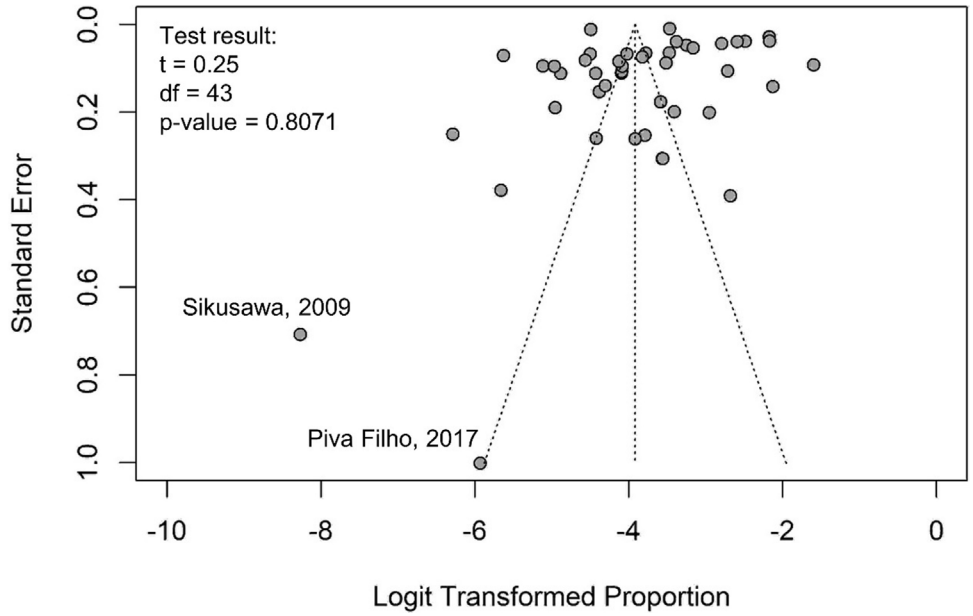

Figure 2 Forest plot for bovine brucellosis seroprevalence data in Brazil extracted from the main available publications.

seroprevalence of 2% (95% CI: 1%, 3%). The total sample size (number of animals evaluated) ranged from 109[22] to 686 086[6].

Subgroup meta-analysis

A subgroup meta-analysis was performed for the Brazilian states and year of the survey (Supplementary Material). Regardless of the year of data collection, the highest prevalence was observed in Acre 11% (95% CI: 8–14%) followed by the states of Mato Grosso and Mato Grosso do Sul, with 7.1% (95% CI: 6.8–7.4%) and 7% (95% CI: 6.7–7.4%), respectively, while the lowest prevalence was observed in the Federal District (0.4%; 95% CI: 0.2–0.7%) and Paraíba (0.4%; 95% CI: 0.4–0.5%). Data collection in the available research was mainly concentrated in two time periods, between 2011 and 2015 (15 articles with data from this period) and between 2001 and 2005 (14 articles). Another period of data collection with a considerable number of publications was 2006–2010 (nine articles). It should be mentioned that only three articles included data collected between 2016 and 2021. These results revealed that there is a significant lack of research on the prevalence of bovine brucellosis in Brazil in the last five years.

Distribution of official notified cases

Figure 4 shows the number of cases of bovine brucellosis in Brazil according to the Animal Health Information System, for all Brazilian states in the years of 2017–2019. Bovine brucellosis cases were reported in all Brazilian states, except in Alagoas, where there were no notifications in these three years. The highest number of cases was registered in Santa Catarina (1524, 1657, 3866 cases in 2017, 2018 and 2019, respectively) and Paraná (925, 692 and 639 cases in 2017, 2018 and 2019, respectively). The policy of reporting cases of bovine brucellosis is based on serological tests performed by veterinarians qualified and trained for this purpose. In addition, these cases are reported to the Official Veterinary Service of each state.

Main risk factors for bovine brucellosis in Brazil

The search and selection of articles on the risk factors and seroprevalence of brucellosis were conducted simultaneously, until the last stage of the review (Fig. 1). Then, 61 articles were fully evaluated to determine their eligibility for risk factors, but 29 articles were included in the analysis of the main risk factors for bovine brucellosis in Brazil. Editing and matching was performed on the texts to identify certain concepts, such as the most frequently occurring word or phrase or their similarity. The final result allowed to identify 210 structures, similar or not, that characterized 47 risk factors with a significant effect ($p < 0.05$) on the epidemiology of brucellosis in Brazil.

The highest frequency of occurrence was observed for the term ''purchase of animals for breeding'' (Fig. 5), being recorded in 20 articles (Table 1). Other terms with high frequency were ''vaccination'' (n = 15), ''number of heifers/females ≥2 years'' (n = 15), ''calving paddock'' (n = 14) and ''occurrence of abortions'' (n = 13). In addition, ''presence of flooded areas'' (n = 11), ''herd size'' (n = 10) and ''presence of equines'' (n = 9) are noteworthy.

Discussion

Brazil has one of the largest cattle herds in the world, standing out as the second largest meat producer. Therefore, cattle breeding is one of the main segments of agribusiness in Brazil. However, bovine brucellosis represents a threat to livestock activity in the country because it causes reproductive losses such as abortions, which can impact the economy

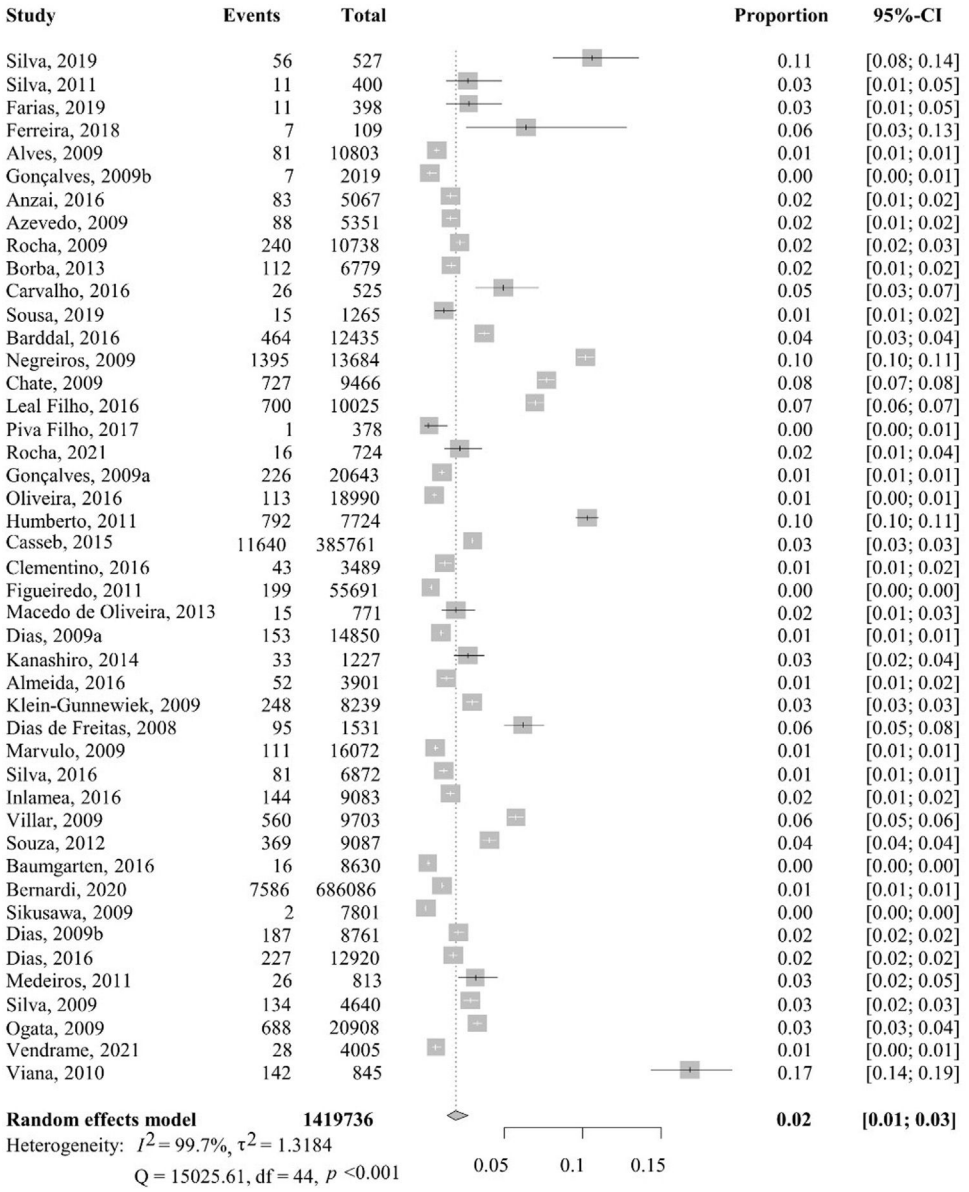

Figure 3 Funnel plot describing the publication bias of studies reporting the prevalence of bovine brucellosis in Brazil.

of this sector[10,42]. In this scenario, research studies on the seroprevalence of bovine brucellosis are essential to identify epidemiological information of the disease in endemic regions. The absence of epidemiological information makes it difficult to assess trends, plan control measures and make decisions by official authorities[11,42]. In this research, we did not find any published article on the seroprevalence of bovine brucellosis in the states of Amapá, Ceará and Piauí in the last 15 years. In addition, in the other states, the occurrence of only one or two investigations predominated, revealing a scarcity of information. This may hide the current epidemiological situation of the disease in Brazil. One of the factors that may contribute to this scenario is the underreporting of the disease to the Official Veterinary Service. In MAPA's Animal Health Information System, it is possible to observe the number of registered cases of *B. abortus* in Brazil since 1999. However, it was not until 2012 that the presentation of case distribution across the country by state began. In Alagoas, for example, only 37 cases have been registered so far (2012–2016) by the Official Veterinary Service. As for the state of Amapá, this number totals 73 cases (2013–2019).

Mandatory notification of brucellosis in Brazil is established by the National Program for the Control and Eradication of Animal Brucellosis and Tuberculosis (PNCEBT). Through this program, some official studies were conducted on the seroprevalence of brucellosis in Brazil, including a set of publications in 2009[2,4,14,16,22,27,34,39,40,45,50] and 2016[3,6,10,15,17,24,35,43]. No other official nationwide study has been conducted to determine the seroprevalence of bovine brucellosis. It is also worth mentioning that these few official studies did not cover all the Brazilian states. On the other hand, official notification data indicate that bovine brucellosis is present in all the Brazilian states, despite the

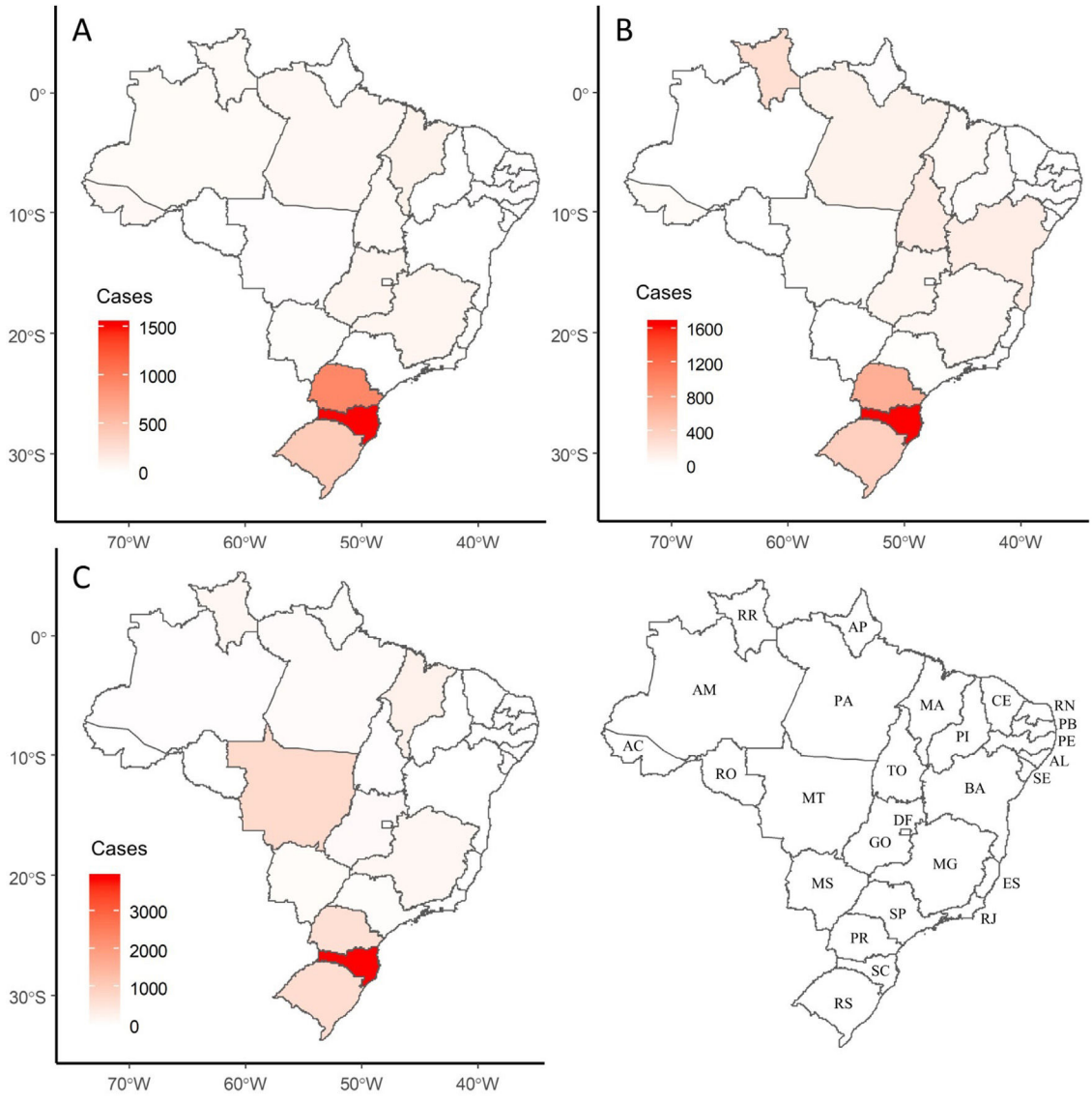

Figure 4 Distribution of the number of bovine brucellosis cases notified to the Official Veterinary Service (MAPA, 2021) in the years 2017 (A), 2018 (B) and 2019 (C) in the different Federation Units (RS: Rio Grande do Sul; SC: Santa Catarina; PR: Paraná; SP: São Paulo; MS: Mato Grosso do Sul; RJ: Rio de Janeiro; ES: Espírito Santo; MG: Minas Gerais; DF: Distrito Federal; GO: Goiás; MT: Mato Grosso; RO: Rondônia; AC: Acre; AM: Amazonas; RR: Roraima; AP: Amapá; PA: Pará; MA: Maranhão; TO: Tocantins; BA: Bahia; PI: Piauí; CE: Ceará; RN: Rio Grande do Norte; PB: Paraíba; PE: Pernambuco; AL: Alagoas; SE: Sergipe).

fact that there were no notifications for the State of Alagoas in the last three years (Fig. 4). Considering the importance of brucellosis and the economic impact that it can cause to cattle production, studies addressing the real situation of bovine brucellosis in the states for a better implementation of measures with regard to control and eradication are essential.

Surveys on bovine brucellosis are even more important in endemic regions and when there is underreporting of the disease to the Official Veterinary Service, because the shortage of official notifications is one of the main limitations of the national and international systems for the control and prevention of infection[9,11]. These surveys are based on the PNCEBT regulations and aimed to determine the prevalence of foci and positive animals, as well as to identify risk factors[9]. In this sense, the Official Veterinary Services are responsible for conducting field work. Farms are randomly selected and blood samples from a pre-established number of bovine females aged 24 months or older are collected for further analysis. The underreporting of bovine brucellosis may be related to a scarcity/lack of information, financial risk concern, as positive animals must be removed from the herd, and other factors that influence the decision-making of farmers and veterinarians about the notification process[9]. Positive and inconclusive results must be notified by licensed veterinarians[6]. In addition, cattle infected with *B. abortus* do not always develop clinical signs of the disease and the occurrence of infected asymptomatic and/or seronegative animals contribute to the underreporting of cases. Another fact that may have contributed to the low prevalence of

Figure 5 Most frequently used words extracted from 29 articles published between 2009 and 2021. The longer the words, the more frequent they are.

brucellosis in the country is the shortage of private sector veterinarians to work in the program under the supervision of the Official Veterinary Service. According to the Situational Diagnosis of the PNCEBT/MAPA[8], until 2018, there was a shortage of these professionals in the states of Amazonas, Acre, Amapá and Roraima.

The purchase of animals for breeding was identified as the main risk factor for bovine brucellosis in Brazil, taking into consideration the surveys available from October 2006 to October 2021. In this scenario, it is strongly recommended that the commercialization of farm animals be part of the control measures to be adopted by the Official Veterinary Service, and that the official animal health agency implement measures to guarantee the commercialization of healthy animals[10]. For this purpose, the issuance of the Animal Transit Guide (ATG) is conditioned to non-reactive (negative) animals and the vaccination of bovine females must be proven. In addition, strong health education programs to the farmers should be promoted in order to provide further information on control of this risk factor.

The result of 'vaccination' as a risk factor may seem contradictory at first considering the immunizing characteristic of vaccines such as B19 and RB51. However, this association could be attributed to several factors. First, the absence of a systematic vaccination policy during the time of the studies might have led to inconsistent vaccination practices. Second, veterinarians typically recommend vaccination after confirming disease suspicion on the farms, which might result in delayed or incomplete vaccination coverage[29,39]. In addition, the overall management practices on different farms could also contribute to the observed discrepancies and highlight the complexity of the vaccination scenario and its potential impact on the prevalence of bovine brucellosis in the studied population. It is important to point out that Brazilian studies have shown that farms where vaccination was used as a preventive measure would be less likely to have infected animals than those that do not adopt the sanitary standard, reinforcing the fact that the vaccines sold in Brazil (B19 and RB51) induce protection, and the idea that the PNCEBT has been effective[2,4,23].

The history of the presence of ''calving paddocks'' in the farms, as well as the ''occurrence of abortions'' are consequences of the presence of the disease and not a cause. The use of calving paddocks is a measure adopted to avoid

contact between susceptible animals and aborted fetuses, placental remains and vaginal secretions, which can contaminate pastures and water sources[12,34]. However, the lack of knowledge about the proper destination of abortive products poses an imminent risk to farms[44].

The variable ''flooded areas'' was associated with herds infected with *B. abortus*[1,2,7]. The survival of *Brucella* spp. in the environment is increased by the presence of humidity and, the greater the survival in the environment, the greater the chance of the agent infecting a new susceptible animal. The survival time of *Brucella* spp. on wet soil is 66 days, while in mud it can vary from eight days to eight months. Thus, flooded areas and flooded pastures can facilitate the spread of the disease[1,2,5,24].

The association of foci with the ''presence of horses'' on the farms was observed, but it is difficult to interpret. However, this is probably due to cattle and horses being raised in the same place, since horses are used to manage the herd. In addition, it is quite common to have intense movement of horses to other farms. Harnesses, spurs, ropes, among other items, when contaminated, can constitute a risk factor, since the agent can spread through fomites[3].

The results of this meta-analysis indicate the need for new official studies to determine the true prevalence of bovine brucellosis in Brazil, supported by the National Program for the Control and Eradication of Animal Brucellosis and Tuberculosis. The studies must adequately characterize the epidemiological situation of bovine brucellosis in all Brazilian states, compare survey data with Animal Health Information System data to identify possible flaws in the mandatory reporting system; and, correlate the seroprevalence data with possible risk factors for the disease to identify probable new patterns of the disease, also considering the different geographic and socioeconomic regions of the country.

The systematic review and meta-analysis described here included 45 publications on the seroprevalence of bovine brucellosis in Brazil. The largest number of publications was found for the State of Mato Grosso do Sul (n = 4), while for Amapá, Ceará and Piauí no articles were found. The highest and lowest seroprevalence were observed in Acre (11%; 95% CI: 8.0–14.0) and in the Federal District (0.4%; 95% CI: 0.2–0.7), respectively. There is a great scarcity of data from recent surveys (last 5 years) on the bovine brucellosis panorama in Brazil. However, the cases reported to the National Animal Health Information System reveal that the disease is endemic in all Brazilian states. Thus, it is necessary that new research be developed to adequately characterize the epidemiological situation of bovine brucellosis in Brazil, with updated seroprevalence data and risk factors.

Informed consent

Informed consent was obtained from all subjects involved in the study.

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Authors' contributions

Isis Daniele dos Santos Rocha: Conceptualization, Data curation, Investigation, Methodology, and Writing – original draft. Inácio José Clementino: Investigation and Methodology. Débora Luise Canuto de Sousa: Investigation and Methodology. Clebert José Alves: Investigation and Methodology. Carolina de Sousa Américo Batista Santos: Data curation, Investigation, and Methodology. Sérgio Santos de Azevedo: Conceptualization, Data curation, Investigation, Methodology, and Writing – review & editing.

Conflicts of interest

The authors declare no conflicts of interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ram.2023.08.002.

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