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REGULAR ARTICLES

Epidemiology of bovine cysticercosis and associated economic losses in the state of Rio Grande do Sul, Brazil

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Abstract

Bovine cysticercosis (BCC) is the most frequently detected zoonosis in Brazilian slaughterhouses and is considered a problem for public health and beef production chain, requiring epidemiological studies focusing on evaluating its prevalence, spatial distribution, and economic losses in order to improve and adopt specific strategies for BCC control. Thus, this study focused to establish BCC prevalence and spatial distribution in the state of Rio Grande do Sul, Brazil, and estimate the economic losses for cattle farmers suppliers of one exporter slaughterhouse. A set of 70,591 bovine carcasses were *postmortem* inspected from 2019 to 2020, which came from 134 municipalities located in eight distinct regions in the state of Rio Grande do Sul. The prevalence found was 3.44% (C.I. 95% 3.30–3.57%), and animals infected with unviable cysticerci were more frequently detected (70.56%) than those carrying viable ones (29.44%). The most frequent destination of carcasses and viscera was non-export (65.48%), followed by freezing/salting (25.41%), heat treatment (8.74%), and rendering (0.37%), resulting in a total economic burden of at least US$ 167,868.53 for cattle farmers. Some regions had higher risk for BCC occurrence, such as Porto Alegre, Caxias do Sul, Santa Maria, Ijuí, and Passo Fundo (OR > 1, $p < 0.05$), respectively. These results highlight the need of adopting prophylactic measures, mainly in specific areas, in order to control BCC and reduce the economic losses for beef production chain.

Keywords Epidemiology · GIS · Meat inspection · Parasitology · *Taenia saginata* · Zoonosis

Introduction

Taenia saginata is the etiological agent of two distinct diseases—taeniosis and bovine cysticercosis (BCC). Taeniosis occurs through ingestion of larval stages (viable cysticerci) in raw or undercooked beef by human beings, the definitive hosts according to the parasite's life cycle, due to the production of eggs in the small intestine and subsequent elimination in feces, contaminating the environment. On the other hand, BCC occurs due to ingestion of pastures and water contaminated with *T. saginata* eggs by bovines. In this cycle, cattle are the intermediate host and harbor the larval stage in several anatomic sites (Murrel et al. 2005) but mainly in the tongue, heart, esophagus, liver, and masticatory muscles (masseter and pterygoids) (Brazil 2017).

BCC is considered the most frequent zoonosis detected by sanitary inspection in Brazilian slaughterhouses, during *postmortem* examination, resulting in economic impact for farmers due to condemnation or thermal treatments of carcasses (Rossi et al. 2015). According to Guimarães-Peixoto et al. (2012), one Brazilian state (Paraná) lost US$ 31,915,700 due to BCC occurrence in the period from 2004 to 2008. The infection in Brazilian cattle herds is related to several risk factors, such as farms located near sugarcane, coffee, and orange crops (Rossi et al. 2014); the access to uncontrolled water sources; the presence of fisherman near the farms (Rossi et al. 2015); flooded pastures (Maia et al. 2017); densely human populated areas (Rossi et al. 2016); high rainfall index (Pereira et al. 2017); and areas with improper sewage systems (Alves et al. 2017).

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The meat inspection performed in slaughterhouses aims to detect infected carcasses and viscera and give a proper conditional treatment (salt or thermal) or to condemnation (Brazil 2017). These practices are critical in order to prevent human taeniosis and to identify areas with high BCC incidence with the consequent need of prophylactic measures use. Brazil is a very large country, with distinct social, economic conditions and sanitary practices adoption during animal production, resulting in a wide variation on BCC spatial distribution. This variation occurs in geographical regions, within different states and municipalities of Brazil (Rossi et al. 2020).

Previous studies using Brazilian slaughterhouses data were able to detect important differences in BCC spatial distribution in the states of Mato Grosso do Sul (Pereira et al. 2017), Mato Grosso (Rossi et al. 2016), Paraná (Guimarães-Peixoto et al. 2012; Souza et al. 2007), Goiás (Aquino et al. 2017), Espírito Santo (Cipriano et al. 2015), Paraíba (Maia et al. 2017), and Rondônia (Alves et al. 2017). However, as far as we know, there are no studies performed in the state of Rio Grande do Sul focusing on establishing BCC prevalence, spatial distribution, and economic impact for farmers. This state is located in the Southern Region and presents one of highest BCC prevalence in Brazil (Rossi et al. 2020).

Thus, this study aimed to establish the prevalence and spatial distribution of BCC in municipalities and regions of the state of Rio Grande do Sul, Brazil, and estimate the economic impact for cattle farms suppliers of a single slaughterhouse in this state.

Material and methods

Data of BCC (viable, unviable, and total) cases in 70,591 bovine carcasses inspected between March 2019 and April 2020 in one exporter slaughterhouse, under the Federal Inspection Service (SIF) supervision, located at the state of Rio Grande do Sul, Brazil, was obtained. The animals included in this study were both males and females originating from 134 municipalities of eight distinct geographic regions (Porto Alegre, Pelotas, Santa Maria, Uruguaiana, Ijuí, Passo Fundo, Caxias do Sul, and Santa Cruz do Sul-Lajeado) within the state (Fig. 1) (IBGE 2017).

The *postmortem* inspection and the carcass destination criteria applied in cases of BCC detection were performed according to Brazilian beef inspection laws (Brazil 1971, 2017). Briefly, the *postmortem* inspection for BCC detection is performed through visualization, palpation, and incisions on several sites of the carcasses and viscera, including the head (incisions in masseter and pterygoid muscles), tongue (palpation and a unique longitudinal incision), liver (visual inspection including bile ducts), heart (multiple incisions with atria and ventricles exposed), diaphragm (palpation and incisions), and esophagus (palpation and incisions). If BCC is detected in any of the inspection lines, the carcasses and viscera are deviated to the Final Inspection Department (DIF) where the esophagus and liver are visually revised and other incisions are performed in the head, tongue, heart, diaphragm, and carcass muscles (Brazil 1971, 2017).

The infected carcasses and viscera destination vary according to BCC intensity. The Brazilian law states that carcasses with a single unviable cysticercus must have it removed and beef can only be sold in the internal market. On the other hand, carcasses with a single viable cysticercus must be submitted to a thermal treatment (freezing at − 10 °C for at least 10 days) or salt treatment (21 days in specific conditions). Carcasses are only condemned for human consumption if there is an intense infection, which is characterized by the presence of at least eight cysticerci distributed as follows: at least two cysticerci in at least two preferential sites (masseter and pterygoid muscles, tongue, heart, diaphragm, esophagus, and liver), totalizing four cysticerci, and at least four more cysticerci in forequarter and hindquarters cuts (chuck, brisket, shank, round, and sirloin). The carcasses presenting more than one cysticercus but less than intense infections must be heat-treated (76.6 °C for at least 30 min or canning) (Brazil 2017).

These criteria were used for the calculation of economic losses for beef farmers considering the percentage of destinations and the monetary discount applied by the studied slaughterhouse. For this purpose, the average carcass value was considered US$487.71, the discount when carcasses were destinated to freezing or salt treatment as a 20% reduction on price (-US$ 97.54 per animal) and 100% (-US$ 487.71 per animal) when destinated to heat treatment or rendering. Those carcasses with only one unviable cysticercus did not cause reduction on the monetary values for cattle farmers, and consequently no losses were considered in the calculus.

The prevalence 95% confidence interval was performed according to Wilson's method (Thrusfield and Crhistley 2018). The calculation was performed using "binom" package in Software R® (R CORE TEAM 2018). The association between BCC and the administrative regions was calculated using the one with the lowest prevalence as the control (OR = 1), and the others were compared with it (Thrusfield and Crhistley 2018). The OR calculations were performed using Epi Info v.7.2.2.6. (CDC, Atlanta, USA), and significance was obtained through corrected chi-square or Fisher's exact test ($p < 0.05$). Maps were created using software Terraview® v.4.2.2.

Results

Out of 70,591 bovines that were slaughtered and inspected during the studied period, 2425 were infected with BCC, establishing a prevalence of 3.44% (C.I. 95% 3.30–3.57%). Animals infected with unviable cysticercus were more

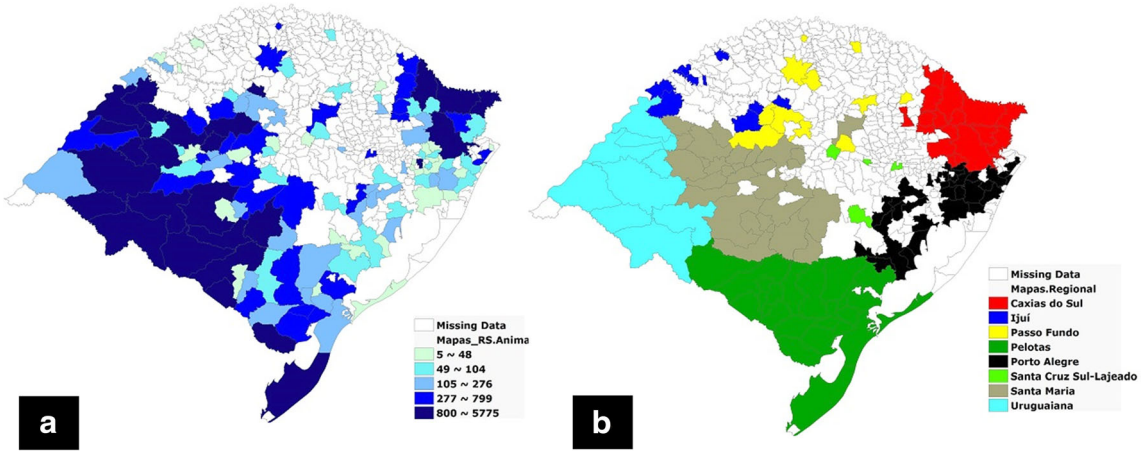

Fig. 1 (**a**) Spatial distribution according to the original municipality of slaughtered bovines in the period from May 2019 to April 2020 in one slaughterhouse located in the state of Rio Grande do Sul, Brazil. (**b**) Distribution of the 134 municipalities according to their geographical regions (IBGE 2017)

frequently detected (70.56%) than carrying viable ones (29.44%). Bovines infected with single unviable cysticerci were the most frequent, and consequently, the internal market was the most frequent destination (65.48%), followed by freezing/salting (25.41%), heat treatment (8.74%), and rendering (0.37%) (Fig. 2). The group of farms that supplies this slaughterhouse had an estimated economic loss of approximately US$ 167,868.53 (Table 1). Those carcasses presenting mild infections which were destined to heat treatment were the most important source of economic losses (U$ 103,394.50), followed by freezing/salting (U$ 60,084.64) and rendering (U$ 4389.39) (Table 1).

The maps generated showed a variation on BCC prevalence within the regions of the state of Rio Grande do Sul (Table 2 and Fig. 3). Porto Alegre was the region that had the highest BCC prevalence (5.72%, CI 95% 5.10–6.41), while Santa Cruz Sul-Lajeado had the lowest one (1.74, CI 95% 0.97–3.08) (Table 2). In addition, Table 2 shows that the regions Porto Alegre, Caxias do Sul, Santa Maria, Ijuí, and Passo Fundo presented a significantly higher risk (OR > 1; $p < 0.05$) of animal BCC infection than Santa Cruz do Lajeado (OR = 1).

The cysticercosis infected bovines originated from 116 municipalities, with prevalence ranging from 1.24 to 29.03% (Fig. 3). On the other hand, BCC was not detected in only 18 municipalities (Electronic File 1). BCC prevalence in the ten municipalities which destined the largest number of animals for slaughter [Dom Pedrito (5775 bovines), Lavras do Sul (4212), Bom Jesus (3349), São José dos Ausentes (3134), Alegrete (3106), Santiago (2551), Vacaria (2358), Macambará (2055), São Francisco de Paula (1980), Tupanciretã (1886), São Francisco de Assis (1601) and São Borja (1564)] ranged from 1.51 to 5% (Fig. 3; Eletronic File 1). In addition, the ten municipalities with highest BCC prevalence detected were Guabiju (29.03%), Dois Irmãos (18.75%), Canela (18.8%), Jaguari (16.67%), São Pedro do Sul (13.77%), Novo Hamburgo (13.04%), Igrejinha (12.50%), Restinga Seca (12.31%), Tuparendi (12.0%), and Campestre da Serra (11.54%).

Table 1 Economic losses for a group of farms due a set of 2425 animals infected with BCC and the monetary discount applied by one Brazilian slaughterhouse located in the state of Rio Grande do Sul

Average carcass value = U$ 487.71				
	Discount (%)	Discount value per infected carcass (US$)	Number of carcasses	Total discounted value (US$)
One unviable	0	0	1588	0
Freezing or salt treatment	20	97.54	616	60,084.64
Heat treatment	100	487.71	212	103,394.50
Rendering	100	487.71	9	4389.39
Total	–	–	2425	167,868.53

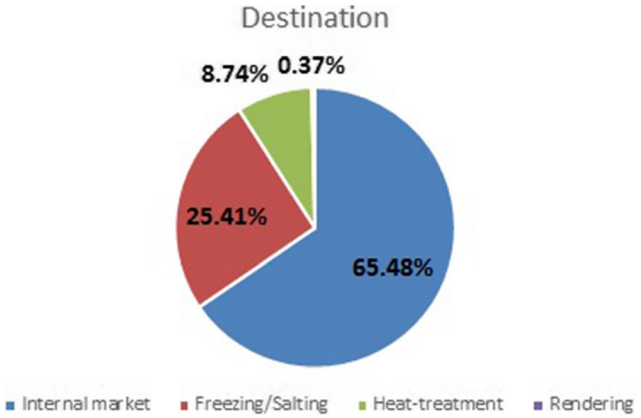

Fig. 2 Destination of carcasses and viscera infected with BCC according to infection intensity in one Brazilian slaughterhouse located in the state of Rio Grande do Sul, from March 2019 to April 2020

Discussion

BCC is globally widespread, and its prevalence varies among the continents, such as in Europe (0.0 to 30.0%) (Laranjo-González et al. 2016), Africa (0.02 to 26.3%) (Dermauw et al. 2018), Asia (< 0.001 to 25%) (Torgerson et al. 2019), and the Americas (0.1 to 19%) (Braae et al. 2018). The prevalence established in the state of Rio Grande do Sul is placed between the intervals described in these continents. In the Americas, Brazil was the country where the majority of BCC studies performed provide information about its distribution within distinct regions (Braae et al. 2018).

Rossi et al. (2017) performed a retrospective study regarding BCC prevalence in 19 Brazilian states from 2010 to 2015 and found a national prevalence of 0.62%, with values ranging from 0 to 2.01%. The highest prevalence was observed in the states of São Paulo (1.77%), Santa Catarina (1.96%), Paraná (2.01%), and Rio Grande do Sul (1.62%). The prevalence found in our study is higher than the value previously reported, highlighting that efficient control measures were not successfully adopted until this moment. Afterwards, Rossi et al. (2020) performed a systematic review and meta-analyses and considered the highest prevalence in the South (3.4%), followed by Southeast (2.7%), Northeast (1.5%), Central-Western (0.9%), and North (0%). The prevalence established in this study was the same than the value reported for the South Region, where the state of Rio Grande do Sul is located.

In another study performed by Teixeira et al. (2015) from 2009 to 2013 in one slaughterhouse located in the municipality of Pelotas, in the state of Rio Grande do Sul, the BCC prevalence found was 2.5%. This lower value obtained could be explained due to differences on sample size (only 15,408 animals included), origin diversity (fewer municipalities), and potential difference in BCC detection methodology during beef inspection since this study was conducted in a small slaughterhouse. The region of Pelotas had an identical prevalence (Table 2) compared with the value reported by these authors, highlighting that the difference on BCC prevalence can be attributed to regional factors within this state.

The regions of Santa Maria, Uruguaiana, and Pelotas are important cattle producers (Rio Grande do Sul 2018a), being responsible for a large amount of slaughtered animals (Table 2). These regions had the lowest human population density in the state, while the regions of Porto Alegre and Caxias do Sul are the most densely populated ones (Rio Grande do Sul 2018b) and coincidentally those with the highest BCC prevalence (5.72% and 4.56%, respectively). In areas with high human population density, taeniosis occurrence is more frequent, and environmental contamination is more prominent, resulting in increased BCC occurrence in cattle (Rossi et al. 2016; Pereira et al. 2017).

The state of Rio Grande do Sul is one of the Brazilian states with high availability of superficial water, and rainfalls are evenly distributed over the whole year, allowing aquiculture and rice production (Rio Grande do Sul 2018c; IBGE 2018).

Table 2 Number of animals inspected, BCC cases, BCC controls, prevalence (with 95% confidence interval), OR (with 95% confidence interval), and *p* value (using corrected chi-square or Fisher's exact test) in the eight regions located in the state of Rio Grande do Sul, Brazil, from March 2019 to April 2020

Regions	Animals (*n*)	Cases (*n*)	Controls (*n*)	Prevalence (%)	CI 95%	OR	CI 95% OR	*p*
Porto Alegre	4829	276	4553	5.72	5.10–6.41	3.43	1.87–6.30	0
Caxias do Sul	13,644	622	13,022	4.56	4.22–4.92	2.70	1.48–4.93	0.0011
Santa Maria	18,660	686	17,974	3.68	3.42–3.96	2.16	1.18–3.94	0.0138
Ijuí	3122	111	3011	3.56	2.96–4.26	2.08	1.12–3.90	0.0258
Passo Fundo	3694	120	3574	3.25	2.72–3.87	1.90	1.02–3.54	0.0436
Pelotas	14,453	367	14,086	2.54	2.30–2.81	1.47	0.80–2.70	0.2572
Uruguaiana	11,556	232	11,324	2.01	1.77–2.28	1.16	0.63–2.13	0.7437
Santa Cruz Sul-Lajeado	633	11	622	1.74	0.97–3.08	**1**	–	–
Total	70,591	2425	68,166	3.44	3.30–3.57	–	–	–

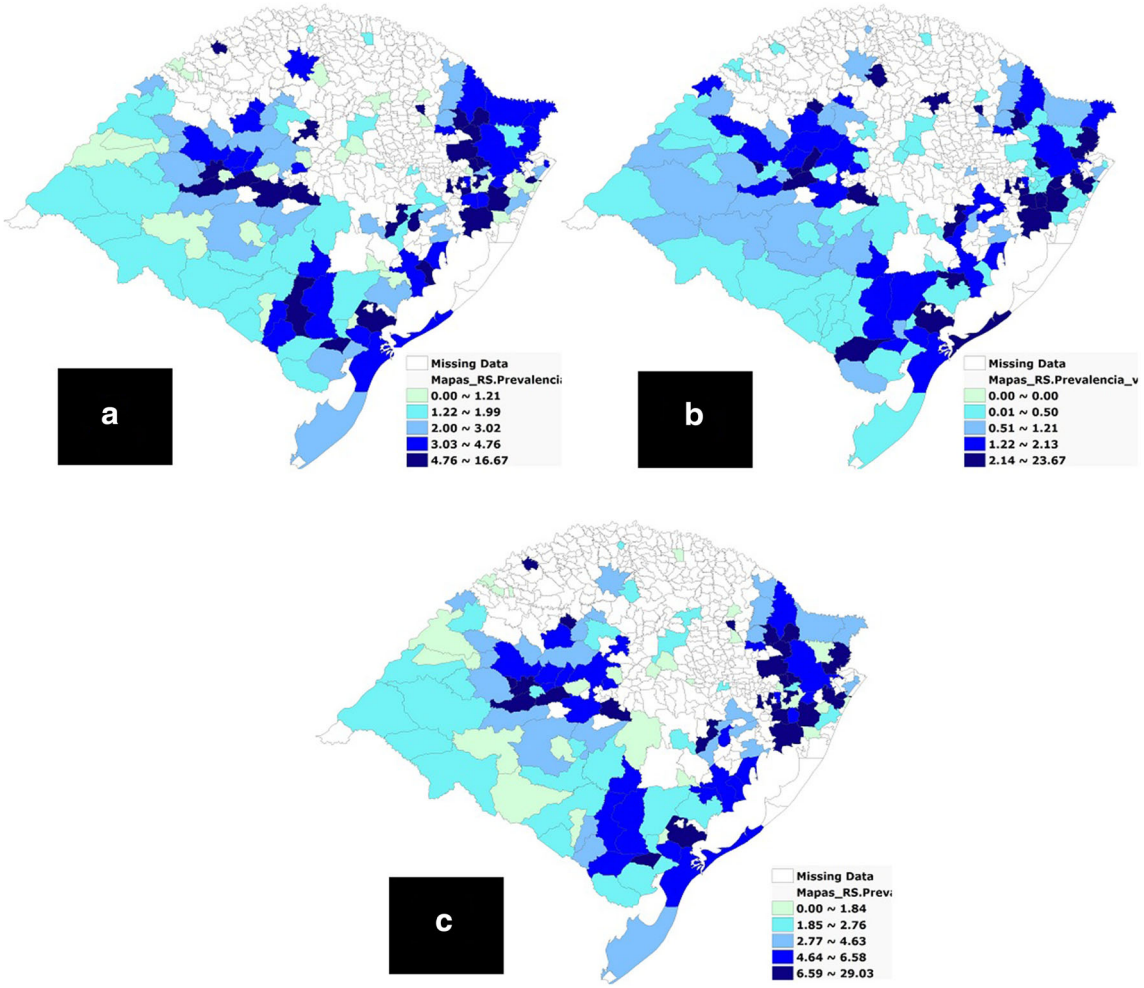

Fig. 3 Maps demonstrating BCC prevalence in the 134 municipalities located in the state of Rio Grande do Sul, from March 2019 to April 2020. (**a**) Viable BCC prevalence; (**b**) unviable BCC prevalence; and (**c**) total BCC prevalence (viable and unviable)

The Human Development Index (HDI) in this state is considered high (0.746); however, there are differences in population income, health, and education across municipalities and regions (IBGE 2010). The infection in animals probably occurs due over flooding of rivers on pastures, contaminating it with *T. saginata* eggs (Cabaret et al. 2002). Water contamination can be originated from untreated sewage discharges into rivers or estuaries and from the presence of infected humans, such as fishermen in rivers near cattle's farms (Rossi et al. 2015) or rural temporary workers (Rossi et al. 2014). There are other risk factors described in literature which probably contribute to BCC spread in this state, such as extensive cattle production, proximity to wastewater treatment stations, high rainfall index, occurrence of illegal slaughter without sanitary inspection (allowing taeniosis and consequently environmental contamination), and use of land for recreational activities (Magalhães et al. 2017; Pereira et al. 2017).

The detection of carcasses infected with a single unviable cysticerci is common in Brazil (Rossi et al. 2015), as also shown in this study; however, mild or heavy infections result in significant economic losses for cattle farmers (Table 1). Even though carcasses infected with single unviable cysticerci do not pose an economic loss for farmers, the beef is not suitable for exportation, which results in an economic loss for the slaughterhouse. In this study, the economic losses due BCC was at least U$ 167,868.53 for the cattle farmers responsible for the 70,591 animals sampled. Hypothetically, considering the total number of bovines slaughtered from the state of Rio Grande do Sul during 2019 (749,641 animals), the percentage of carcass destination found in this study, and the monetary discount applied by the slaughterhouse, cattle farmers lost at least U$ 1,763,549.64 during the studied period. This value is very likely to be higher when the conditional treatments (heating, freezing, or salting) and non-export are considered. BCC economic impact has been reported in other Brazilian states, such as in Paraná, where 29,708,550 kg of condemned beef resulted in losses of about U$ 31, 915.700, without considering the impact of non-export of carcasses (Guimarães-Peixoto et al. 2012). Even with an apparently high economic loss pointed out in this study, which could be

greatly reduced through the adoption of prophylactic measures, the beef production chain in the state neglects this disease as well as its associated economic losses.

Some prophylactic measures such as constructing septic tanks, where basic sanitation is not possible, associated to health education are cheap and critical in order to control BCC (Nickele and Busato 2016). Education could be done in schools or farms, including control strategies such as the importance of cook beef properly and anthelmintic treatment of definitive hosts (Faustina et al. 2011; Nickele and Busato 2016). There are informative material created in other continents such as in Europe that can be easily adapted to Brazil (COST Action TD1302) (http://www.cystinet.org). Others important strategies for disease control would be BCC case notification in order, so health agencies could take action on problematic farms in order to reduce animal's infection, tougher fiscalization to prevent illegal slaughters (Nickele and Busato 2016), and encouraging the adoption of Good Agricultural Practices in farms (Rossi et al. 2015).

In conclusion, the prevalence of BCC in the state of Rio Grande do Sul was 3.44% (CI 95% 3.30–3.57%) with some regions presenting a higher risk for its occurrence and resulting in an economic burden of at least US$ 167,868.53 for farms that supplied just one slaughterhouse during 1 year. Our data highlights the need of adopting prophylactic strategies, mainly in densely populated areas, in order to promote Brazilian beef production chain and reduce its BCC associated losses.

Data availability Raw data is available in Electronic File 1.

Compliance with ethical standards

Conflict of interest The authors declare that they no conflict of interest.

Ethics approval The manuscript does not contain clinical studies or patient data.

Consent to participate The manuscript does not contain clinical studies or patient data.

Consent for publication The manuscript does not contain clinical studies or patient data.

Code availability Not applicable.

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