

## BOVINE CYSTICERCOSIS AND MUNICIPAL SANITATION: A GEOSPATIAL RISK FACTOR ANALYSIS FOR THE BEEF SUPPLY CHAIN IN SOUTHERN BRAZIL

CISTICERCOSE BOVINA E SANEMANTO: FATORES DE RISCO E ANÁLISE GEOESPACIAL DE PREVALÊNCIA NA CADEIA PRODUTIVA DA CARNE BOVINA NO SUL DO BRASIL

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**ABSTRACT:** Bovine cysticercosis (BCC) is a significant parasitic zoonosis detected during *post-mortem* sanitary inspection, impacting both public health and the competitiveness of the beef supply chain. In this study, the prevalence, geospatial distribution, and risk factors associated with BCC in Parana, Southern Brazil were analyzed. Official records from the State Inspection Service (SIE) covering 1,019,339 slaughtered cattle were integrated with socioeconomic and sanitary indicators provided by the Brazilian Institute of Geography and Statistics (IBGE) for the 2018-2020 period. A prevalence of 0.14% (1,461/1,019,339) was observed. A dataset of 18,665 animals from affected batches (at least one case of cysticercosis was confirmed) was utilized for demographic and environmental correlations. Geospatial analysis identified high-prevalence clusters in the Central North and Southern regions. Municipalities such as Paçandu (1.00%), Ourizona (0.75%), and Floraí (0.75%) in the Central North, along with Enéas Marques (0.66%) and Planalto (0.50%) in the South, presented the highest rates. A positive correlation ( $\rho=0.19$ ,  $p=0.0057$ ) was found between municipal BCC prevalence and the reliance on individual sewage solutions (septic tanks/rudimentary pits). Furthermore, host gender and lesion viability were linked, with females showing higher rates of calcified lesions, likely due to longer exposure periods. These findings underscore the role of sanitation infrastructure as a primary driver for BCC and highlight the need for integrating geospatial data into risk-based food control strategies to safeguard the beef market and public health.

**Keywords:** Food safety. *Taenia saginata*. *Post-mortem* inspection. Geospatial analysis. Sewage management.

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**RESUMO:** A cisticercose bovina configura-se como uma zoonose parasitária de grande relevância, rotineiramente detectada na inspeção sanitária *post-mortem* nos frigoríficos. Seu impacto vai além da saúde pública, afetando diretamente a cadeia produtiva da carne. Este estudo analisou a prevalência, a distribuição geoespacial e os fatores de risco da cisticercose bovina no estado do Paraná. Para isso, integraram-se registros oficiais do Serviço de Inspeção Estadual (SIE), referentes ao abate de mais de 1 milhão de bovinos entre 2018 e 2020, além de indicadores socioeconômicos e sanitários do IBGE. Os resultados revelaram uma prevalência de 0,14%, sendo que a análise de 18.665 animais oriundos de lotes afetados permitiu estabelecer correlações demográficas e ambientais precisas. Geograficamente, identificou-se a formação de aglomerados de alta prevalência nas regiões Centro-Norte (em municípios como Paiçandu, Ourizona e Florai) e Sul (notadamente em Enéas Marques e Planalto). Um achado crucial foi a correlação positiva ( $\rho=0,19$ ;  $p=0,0057$ ) entre a ocorrência da doença e a aplicação de soluções individuais de esgoto, como fossas sépticas e rudimentares. Notou-se, ainda, que o sexo do hospedeiro influencia o estado das lesões: fêmeas apresentaram maior índice de calcificação, o que sugere um tempo de exposição prolongado ao parasita. Os dados reafirmam que a precariedade do saneamento é um dos principais fatores de risco da cisticercose bovina, evidenciando ainda que o uso de dados oficiais para a produção de análises geoespaciais é indispensável para estratégias de controle sanitário mais eficazes e para a segurança do mercado de alimentos.

**Palavras-chave:** Segurança alimentar. *Taenia saginata*. Inspeção *post-mortem*. Análise geoespacial. Saneamento.

## 1. BACKGROUND

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The global demand for animal protein has steadily increased over the years. In Brazil, a leading global beef supplier, the livestock sector is essential to the economy. The state of Parana, located in the Southern region, plays a significant role in this context, maintaining a herd of approximately 8 million heads and slaughtering over 1.8 million animals annually (SEAB, 2025). In recent years, the state has expanded its international reach, especially after achieving the status of a Foot-and-Mouth Disease-free zone without vaccination (SEAB, 2025).

To ensure sanitary quality and prevent the spread of foodborne diseases and zoonoses, strict hygiene measures and inspection protocols must be applied throughout the food chain (FAO, 2019). In slaughterhouses, *ante-* and *post-mortem* inspections are critical for monitoring and controlling pathological agents. Among these, bovine cysticercosis (BCC) is one of the most frequently diagnosed parasitic zoonoses in Brazilian slaughterhouses, causing significant economic losses due to carcass condemnation and downgrading (Rossi et al., 2017).

BCC is caused by the larval stage (*Cysticercus bovis*) of the human tapeworm *Taenia saginata*. Humans, the definitive hosts, become infected by consuming raw or undercooked beef containing viable cysticerci, while cattle, the intermediate hosts, acquire the infection accidentally by ingesting water or pasture contaminated with human feces containing eggs (Eichenberger et al., 2020).

Although BCC has a worldwide distribution, the highest prevalence rates are associated with developing countries characterized by inadequate sanitary conditions and intensive livestock-agriculture interfaces. Retrospective analysis of slaughterhouse records provides valuable data for epidemiological surveillance, allowing for the identification of spatiotemporal trends and risk factors. Accordingly, the aim of this study was to determine the prevalence, describe the geospatial distribution, and statistically evaluate sanitary risk factors associated with BCC in cattle slaughtered under state inspection in Parana.

## 2. METHODS

### 2.1. STUDY AREA AND DATA COLLECTION

The study was conducted in the state of Parana, Southern Brazil. A retrospective study was performed using the official sanitary inspection database provided by the Parana Agribusiness Defense Agency (ADAPAR). The data included *post-mortem* examination records from cattle slaughtered under the State Inspection Service (SIE) over a two-year period (March 2018 to February 2020).

Data were stratified for different analytical purposes. The global state prevalence was calculated based on the total universe of animals inspected by the SIE during the period ( $n=1,019,339$ ). For the geospatial distribution, demographic profile, and statistical risk assessment, a specific subset was established comprising all animals belonging to slaughter batches (lots) in which at least one case of cysticercosis was confirmed. This subset totaled 18,741 animals, for which traceability to the municipality of origin was verified.

### 2.2. SANITARY AND GEOSPATIAL DATA

Socioeconomic and sanitary data were obtained from the Brazilian Institute of Geography and Statistics (IBGE). The primary variables analyzed included the percentage of households per municipality served by sewage collection and treatment systems, compared

to those relying on individual solutions (such as septic tanks or rudimentary pits) or lacking any treatment.

### 2.3. STATISTICAL ANALYSIS

Data processing and statistical analysis were performed using R software (versions 3.6.3 for geospatial analysis and 4.5.2 for statistical analysis). Descriptive statistics were used to calculate prevalence and characterize the gender distribution of cases. The geospatial distribution of prevalence was mapped using the *geobr* and *ggplot2* packages, whereas statistical figures were generated using the *ggpubr* package.

To evaluate the influence of host gender on the viability of *cysticercosis* lesions with high certainty, the analysis was restricted to batches with 100% gender purity ( $n = 1,091$ ), categorized as exclusively male or exclusively female. Lesions were classified as viable or calcified, based on official sanitary inspection records. The association between gender and cyst viability was assessed using the Chi-square test ( $\chi^2$ ), with  $p < 0.05$  considered statistically significant.

To evaluate the association between sanitary conditions and BCC prevalence, a non-parametric Spearman rank correlation test was performed. The municipal-level prevalence was correlated with the percentage of households utilizing individual sewage disposal solutions. A  $p < 0.05$  was considered statistically significant.

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## 3. RESULTS

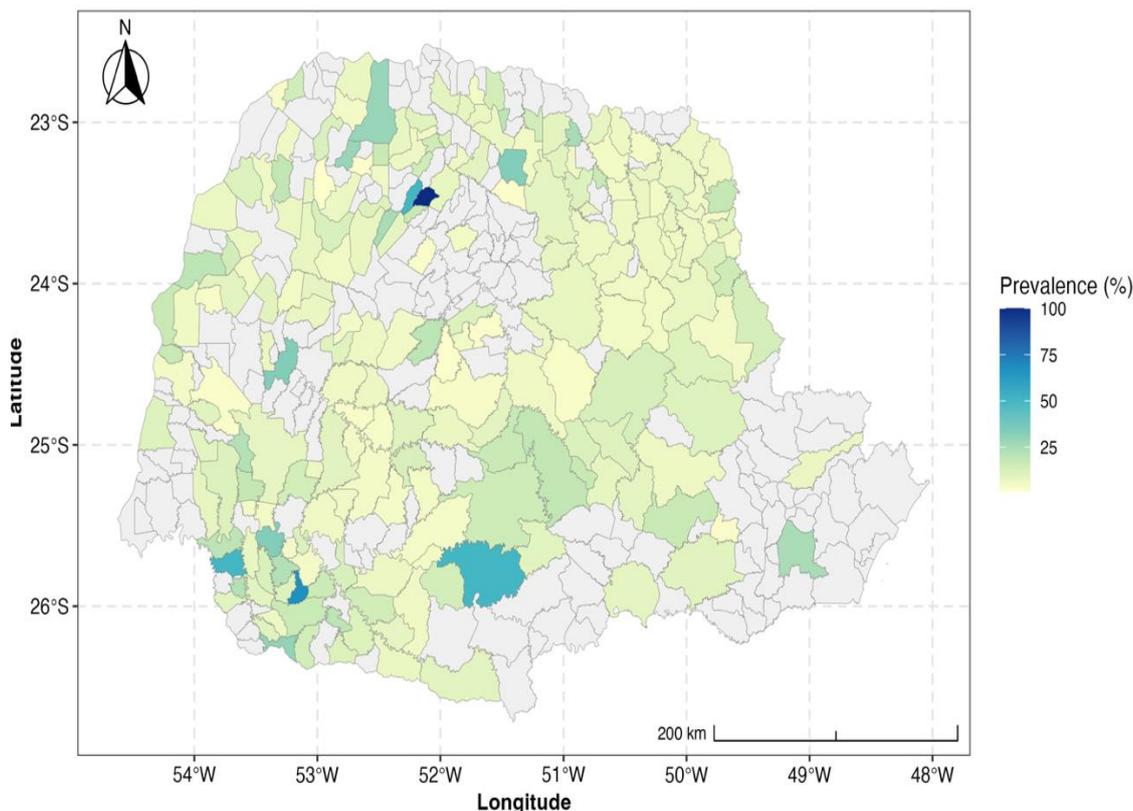
### 3.1. PREVALENCE AND GEOSPATIAL DISTRIBUTION

During the study period, 1,019,339 cattle were inspected by the SIE in Parana. A total of 1,461 animals were diagnosed with bovine *cysticercosis*, resulting in an overall state prevalence of 0.14%.

The geospatial analysis was based on the traceable subset of animals from affected batches. The distribution of prevalence is shown in (Fig.1). The highest prevalence clusters were observed in the Central North and Southern regions. Municipalities such as Paiçandu (1.00%), Ourizona (0.75%), and Floraí (0.75%) in the Central North, and Enéas Marques (0.66%) and Planalto (0.50%) in the South, presented the highest rates.

### Geospatial Distribution of Cysticercosis Prevalence

State of Paraná



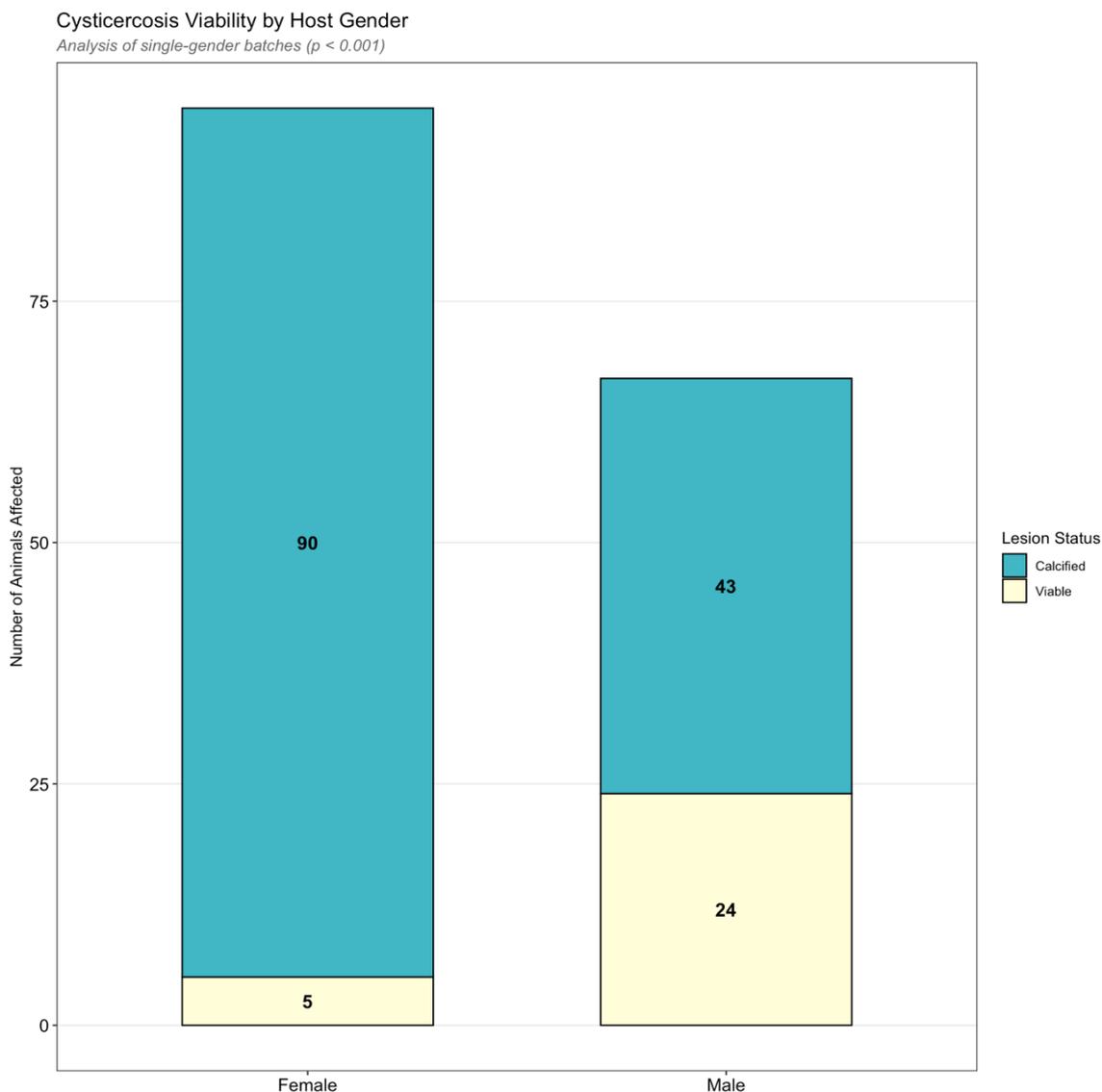
**Fig.1.** Geospatial distribution of BCC in Parana from cattle slaughtered under State Inspection Service over a two-year period.

### 3.2. DEMOGRAPHICS

Regarding the demographic profile of the animals in affected batches, females accounted for most cases, while males represented a smaller proportion (**Fig.2**). A significant association was observed between host sex and the viability of *cysticercosis* lesions in single gender batches ( $\chi^2$ ,  $p < 0.001$ ). Although females accounted for a higher absolute number of cases, the proportion of viable lesions was significantly higher in males compared to females (**Fig.3**).



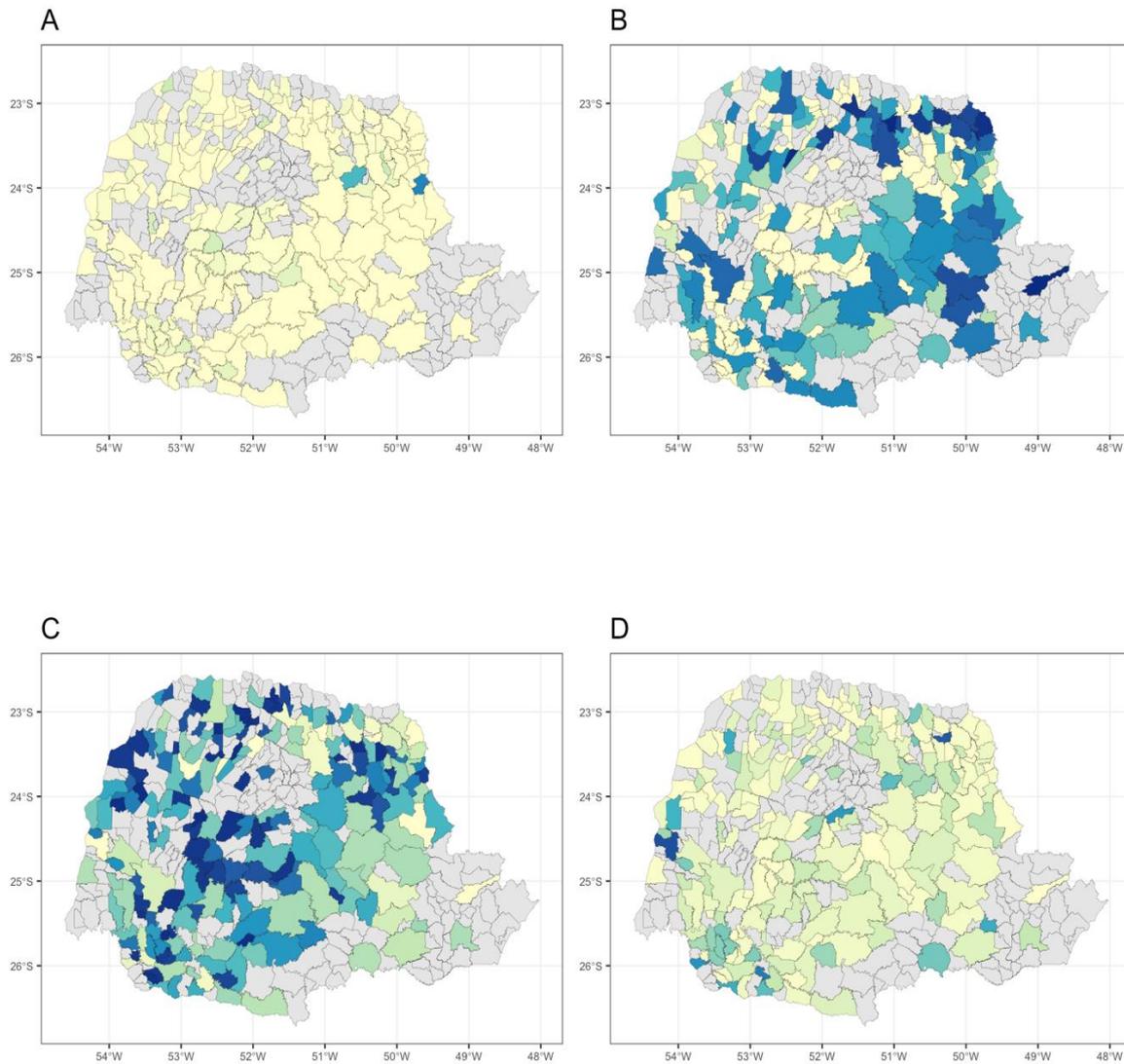
**Fig.2.** Distribution by gender within the *cysticercosis*-positive batches (N=18,665). The chart illustrates the total population of animals present in the affected lots, comprising females and males. This represents the overall study universe from which the cases were identified.



**Fig.3.** Viability of *cysticercosis* lesions according to host sex in single-gender batches ( $n=1,091$ ). The chart displays the frequency of viable (yellow) and calcified (blue green) lesions, highlighting the higher proportion of viable cysts in males (35.8%) compared to females (5.3%). An association was observed between host sex and lesion status ( $\chi^2$ ,  $p < 0.001$ ), supporting the hypothesis of longer exposure times and higher calcification rates in females.

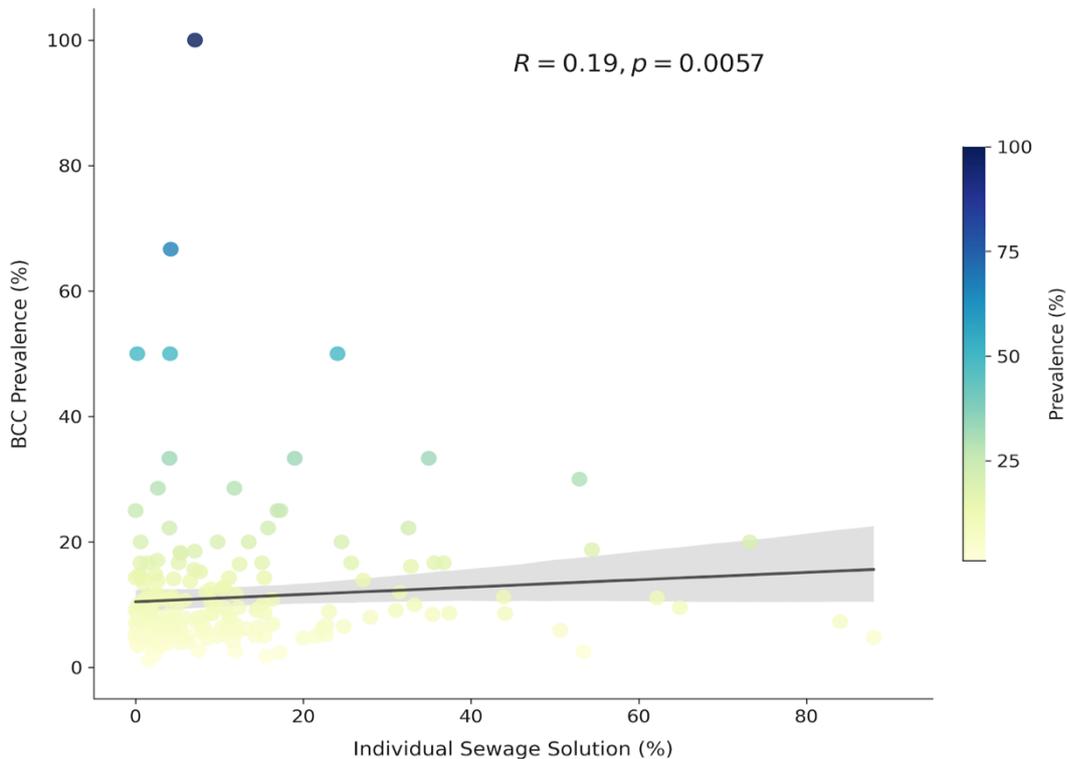
### 3.3 ANALYSIS OF SANITARY RISK FACTORS

The relationship between municipal sanitary infrastructure and *BCC* prevalence was evaluated statistically. (Fig.4). illustrates the distribution of sewage disposal methods. The statistical analysis revealed a positive correlation (Spearman's  $\rho=0.19$ ,  $p=0.0057$ ) between the use of individual sewage solutions (e.g., septic tanks, rudimentary pits) and the prevalence of bovine *cysticercosis* within affected batches (Fig.5).



**Fig.4.** Spatial distribution of sanitary infrastructure in Parana state. The maps illustrate the percentage of households per municipality categorized by sewage disposal methods: (A) collected but untreated sewage; (B) collected and treated sewage; (C) neither collected nor treated sewage; (D) individual solutions (e.g., septic tanks and/or rudimentary pits). The color gradient represents the percentage density, ranging from yellow (0%) to deep blue (100%), while light grey areas indicate municipalities that were not mentioned.

**Correlation: Individual Sewage Solutions vs. Prevalence**  
 Analysis by Municipality (Spearman's Rank)



**Fig.5.** Correlation between bovine *cysticercosis* (BCC) prevalence and the percentage of households using individual sewage solutions (septic tanks and rudimentary pits) by municipality. Statistical analysis was performed using Spearman's rank correlation coefficient ( $\rho=0.19$ ;  $p=0.0057$ ). Each point represents a municipality, correlating its sanitary infrastructure profile with the prevalence observed in the analyzed batches.

#### 4. DISCUSSION

The overall prevalence of 0.14% found in this study, based on routine meat inspection, aligns with recent reports in Southern Brazil and is lower compared to older studies in the same region (Guimarães-Peixoto et al., 2012). While it is recognized that complementary diagnostic methods, such as serology, often reveal higher prevalence rates by detecting circulating antigens or antibodies (Jansen et al., 2017), the results of the present study reflect the reality of official sanitary surveillance. Therefore, while the total number of cases may be higher in specific diagnostic settings, the use of official inspection data remains an essential and reliable tool for identifying spatial clusters and evaluating the impact of public health and environmental factors on a regional scale.

The statistical association between higher BCC prevalence and municipalities reliant on individual sewage solutions represents a significant finding in this study. In many Brazilian

rural areas, these decentralized systems (often consisting of rudimentary pits) provide insufficient containment, leading to the leaching of untreated effluent into the soil and groundwater. The improper disposal of human waste under these conditions enables the environmental persistence of *T. saginata* eggs, effectively closing the transmission cycle. This contamination of pastures and water bodies serves as a direct pathway for cattle infection, reinforcing the critical link between deficient sanitary infrastructure and the maintenance of the parasite's life cycle in the region."

The demographic analysis revealed a higher frequency of bovine *cysticercosis* in females (58.5%). This finding corroborates epidemiological patterns described in recent large-scale studies in Brazil (Dias et al., 2025) and internationally, such as in Egypt, where the prevalence in females was significantly higher than in males (Bayoumi et al., 2023).

A significant finding of this studcon was the higher proportion of viable cysts in males (35.8%) compared to females (5.3%). From a food safety perspective, this disparity is critical, as viable *cysticerci* represent the immediate infective stage for humans (Laranjo-González et al., 2017). Since males in the Brazilian production system are typically slaughtered at a younger age to ensure meat tenderness and market efficiency, they often reach the slaughterhouse before the host's immune system can promote the calcification of the larvae (Rossi et al., 2015). Consequently, although females show a higher overall prevalence due to cumulative exposure, young males act as more efficient vehicles for the transmission of *T. saginata* to consumers. This underscores the need for enhanced vigilance during the inspection of younger cattle, as the presence of viable lesions poses a direct challenge to zoonosis control (OIE, 2020).

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In the Brazilian livestock system, females sent to slaughter are predominantly culled cows (originating from breeding or dairy herds) of advanced age compared to males, which are typically finished for beef at a younger age. The longer lifespan of these females implies a cumulative exposure time to environmental contamination, significantly increasing the probability of ingesting *T. saginata* eggs compared to younger steers, as previously demonstrated by Rossi et al. (2016) and Alberti et al. (2018).

## 5. CONCLUSION

This study confirms that bovine *cysticercosis* remains endemic in Parana's cattle herds, characterized by distinct geospatial clusters at the municipal level. Statistical evidence

identifies the deficiency in public sewage infrastructure, specifically the high reliance on decentralized, individual disposal solutions as a significant determinant for the disease's persistence in the region. In this scenario, sanitary inspection in slaughterhouses stands as an indispensable epidemiological surveillance tool, serving as the primary mechanism for identifying disease hotspots and ensuring food safety. Furthermore, the higher risk associated with older animals (females) highlights the importance of host exposure duration within the epidemiological chain. Consequently, effective control requires a "One Health" approach, integrating the rigor of official inspection with strategic investments in public sanitation infrastructure. Furthermore, utilizing geospatial data to target health education in high-prevalence clusters is essential to break the transmission cycle, ensuring both public health safety and the economic sustainability of the beef supply chain in international markets.

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