

# Retrospective study of brucellosis and bovine tuberculosis occurrence in São João do Itaperiú, Santa Catarina, Brazil (2013–2022)

## Estudo retrospectivo da ocorrência de brucelose e tuberculose bovina em São João do Itaperiú, Santa Catarina, Brasil (2013–2022)

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### Highlights

Movement of cattle without prior testing risk of brucellosis and bovine tuberculosis.  
Untested cattle showed a higher risk of brucellosis and bovine tuberculosis.  
Persistent outbreaks of brucellosis and bovine tuberculosis were observed over time.  
Cattle were used for reproduction without mandatory sanitary testing.  
Need to strengthen animal health inspection and surveillance measures.

### Abstract

Brucellosis and bovine tuberculosis are zoonoses of significant sanitary and economic relevance, making their control a priority within animal health and epidemiological surveillance frameworks. This study aimed to analyze the influence of inter- and intra-municipal cattle transit on the occurrence of these diseases in the municipality of São João do Itaperiú, Santa Catarina, Brazil, between 2013 and 2022. The research was based on official data extracted from the Santa Catarina Agricultural Defense Management System (SIGEN+) and the Brazilian System for Veterinary Surveillance and Emergencies (SISBRAVET), including records of animal movement, diagnostic tests, slaughter, and notifications of positive cases. A total of 1,026 cattle had a length of stay exceeding the average age at slaughter, suggesting their use for reproduction. Of these, 834 had not undergone mandatory sanitary examinations. Among the 157 cattle that tested positive, 135 were diagnosed with brucellosis and 22 with tuberculosis; of these, 131 (83.4%) had entered the municipality without prior testing. Animals without prior testing had a 17.83-fold higher risk of testing positive for brucellosis than previously tested animals. For tuberculosis, animals intended for fattening also showed an increased risk, with an approximately

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2.57-fold higher likelihood of testing positive. An incongruity was found between the purpose declared in the Animal Transit Guide (GTA) and the actual use of the animals, revealing regulatory gaps and failures in enforcement. It is recommended that the criteria for issuing GTAs be reassessed, including the requirement for diagnostic testing of uncastrated males and improved monitoring of animals' residence time on properties. The results reinforce the importance of integrated sanitary policies focused on prevention, traceability, and sanitary education to mitigate the risk of zoonotic disease transmission.

**Key words:** Animal health surveillance. Animal transit. Zoonoses.

## Resumo

A brucelose e a tuberculose bovina são zoonoses de elevada relevância sanitária e econômica, cujo controle é prioridade no âmbito da defesa sanitária e epidemiológica agropecuária. Este estudo teve como objetivo analisar a influência do trânsito inter e intramunicipal de bovinos na ocorrência dessas enfermidades, no município de São João do Itaperiú, SC, Brasil, entre 2013 e 2022. A pesquisa baseou-se em dados oficiais extraídos do Sistema de Gestão da Defesa Agropecuária Catarinense (SIGEN+) e Sistema Brasileiro de Vigilância e Emergência Veterinária (SISBRAVET), considerando registros de movimentação animal, exames diagnósticos, abates e notificações de casos positivos. Foram identificados 1.026 bovinos com permanência superior à média de idade ao abate, sugerindo destinação à reprodução, dos quais 834 não apresentaram exames sanitários obrigatórios. Dentre os 157 animais diagnosticados como positivos, 135 para brucelose e 22 para tuberculose, 131 (83,4%) haviam ingressado no município sem exames prévios. O risco de positividade para Brucelose no grupo de animais não submetidos a testes prévios foi 17,83 vezes maior em comparação com o grupo submetido a testes prévios. Para a Tuberculose, observou-se também um risco superior no grupo de animais destinados à engorda, com os animais apresentando um risco aproximadamente 2,57 vezes maior de positividade. Constatou-se incongruência entre a finalidade declarada nas Guias de Trânsito Animal (GTA) e a real utilização dos animais, revelando lacunas normativas e falhas de fiscalização. Recomenda-se a reavaliação dos critérios para emissão de GTAs, com inclusão de exigência diagnóstica para machos não castrados e rastreamento da permanência dos animais nas propriedades. Os resultados reforçam a importância de políticas sanitárias integradas, com foco em prevenção, rastreabilidade e educação sanitária, para mitigar os riscos de disseminação dessas zoonoses.

**Palavras-chave:** Trânsito animal. Vigilância sanitária. Zoonoses.

## Introduction

Brucellosis and bovine tuberculosis are among the most prevalent and geographically wide-spread zoonoses, representing not only a public health challenge but also a significant obstacle to live-stock productivity. These diseases cause substantial economic losses to

cattle farmers, mainly due to reduced production and compromised trade in animal products (Khurana et al., 2021; Borham et al., 2022). Brucellosis remains enzootic in approximately two-thirds of developing countries, indicating the persistence of the pathogen in cattle populations (Cárdenas et al., 2019). In developing countries, zoonotic

transmission also contributes to human tuberculosis cases (Smaniotto et al., 2019). The movement of animals between herds and regions is considered one of the main risk factors for disease spread (Vanderwaal et al., 2016). Based on these and other considerations, the Brazilian Ministry of Agriculture, Livestock and Supply (MAPA) established the National Program for the Control and Eradication of Brucellosis and Animal Tuberculosis (PNCEBT) in 2001. The program aims to control and eradicate these diseases through guidelines encompassing prophylaxis, surveillance, and sanitary measures (Todeschini et al., 2018). This initiative aims not only to reduce disease incidence but also to strengthen the competitiveness of national livestock in domestic and international markets (Ribeiro et al., 2020). In 2020, 66,819 new cases of human tuberculosis were registered in Brazil, although the origin of infection, human or zoonotic, cannot always be precisely determined (Abujamra et al., 2023). Smaniotto et al. (2019) highlighted the relevance of animal health monitoring in disease control strategies. In the context of human health, Bernardi et al. (2022) reported the endemicity of brucellosis in the western region of Santa Catarina, emphasizing the epidemiological relevance of this zoonosis in areas of intense agricultural activity. In the state of Santa Catarina, cattle are individually identified by six months of age through the Individual Identification and Traceability System for Cattle and Buffaloes of Santa Catarina (SRBOV-SC), as established by Portaria nº 60 (2016), issued by the State Secretariat of Agriculture and Livestock. This measure aims to ensure both sanitary and zootechnical traceability of herds, thereby contributing

to disease prevention and control. This information is monitored and managed through the Santa Catarina Agricultural Defense Management System (SIGEN+), an official digital platform that consolidates Animal Health Defense data in the state. This strategic tool enables real-time monitoring of sanitary movements and events, thereby strengthening epidemiological surveillance and decision-making in animal health. Since 2013, the municipality of São João do Itaperiú in the northeastern region of the state of Santa Catarina, Brazil, has recorded four outbreaks of brucellosis and three of bovine tuberculosis. The affected properties were subjected to the sanitary measures required by the PNCEBT, including temporary interdiction and complementary examinations conducted by a veterinarian authorized by MAPA, in accordance with the intervals defined by Instrução Normativa Nº 10 (2017) and Portaria nº 17 (2012) and Portaria nº 32 (2020). These measures aim to ensure the eradication of pathogenic agents in affected herds and prevent the spread of zoonoses, in accordance with PNCEBT guidelines. Considering the occurrence of brucellosis and tuberculosis outbreaks in the municipality of São João do Itaperiú, and given that prior health examinations, particularly for animals intended for reproduction, may reduce the risk of introducing and disseminating these pathogens in local herds, this study was designed to analyze inter- and intra-municipal cattle transit and its possible influence on the occurrence of these zoonoses. To date, the exact number of animals moved for reproductive purposes without the required examinations remains unknown, limiting effective monitoring and sanitary control.

Therefore, this study sought to improve the understanding of epidemiological factors associated with the occurrence of bovine brucellosis and tuberculosis at the municipal level, providing support for the refinement of animal health surveillance strategies.

The most likely hypothesis for the origin of the recorded outbreaks is the introduction of infected animals into herds, although this causal relationship has not been formally investigated to date. In this context, the study aimed to analyze the influence of inter- and intra-municipal cattle transit, considering the presence or absence of legally required sanitary examinations, on the occurrence of outbreaks of bovine brucellosis and tuberculosis in the municipality of São João do Itaperiú, Santa Catarina, Brazil, between 2013 and 2022.

## Materials and Methods

The study was conducted in the municipality of São João do Itaperiú, located in the north-eastern region of the state of Santa Catarina, Brazil, at 26°37'04" south latitude and 48°46'05" west longitude, with an altitude of 13 m. With a territorial area of 151.42 km<sup>2</sup>, the municipality had a cattle herd of 6,373 animals distributed across 324 rural properties as of September 28, 2022, according to data from the SIGEN+. São João do Itaperiú was selected for this study due to its history of bovine brucellosis and tuberculosis outbreaks. The initial time frame for data extraction was 2013, corresponding to the implementation of the SIGEN+ database, from which official reports on cattle transit and slaughter in the municipality were obtained. Due to

variation in slaughter age, the average slaughter age was calculated to establish a comparative parameter for analyzing the duration of animal stay in the municipality. For this purpose, data on cattle slaughtered in establishments under sanitary inspection in São João do Itaperiú were collected for the period from 2013 to 2022. This average age was used as a criterion to identify cattle that entered the municipality with an Animal Transit Guide (GTA) intended for fattening, but remained longer than expected for this purpose and were classified as animals having potential reproductive use. Notably, cattle intended for reproduction must mandatorily present negative test results for brucellosis and tuberculosis at the time of the GTA issuance, in accordance with current sanitary regulations. For the analysis, initiated in December 2022, cattle that entered the municipality in or before 2018 were considered; thus, these animals were ≥47 months old at the time of evaluation. This age threshold was adopted based on the assumption that such animals, by exceeding the established average slaughter age, would likely be retained on farms for reproductive purposes. An investigation was conducted from December 2022 to April 2023 to identify cattle that were expected to have been slaughtered but remained on farms since 2018 or earlier, suggesting potential reproductive use. In parallel, SIGEN+ data were used to evaluate records of cattle entering the municipality of São João do Itaperiú for the declared purpose of reproduction over the period from 2013 to 2022. In this analysis, only animals that entered with valid negative test results for brucellosis and tuberculosis, as required by current sanitary legislation, were considered.

These data enabled a comparison between animals that complied with mandatory testing requirements and those potentially used for reproduction without mandatory sanitary requirements.

The survey of positive cases of bovine brucellosis and tuberculosis covered the period from 2013 to 2022 and was based on initial investigation forms "FORM-IN" and supplementary forms "FORM-COM," as well as the Brazilian System for Veterinary Surveillance and Emergencies, which are official instruments and systems used by MAPA to record disease occurrences. Additionally, SI-GEN+ records were used to trace the individual history of animals based on their identification data, enabling the determination of the percentage of cattle that tested positive for brucellosis or tuberculosis without having undergone diagnostic testing at the property of origin prior to transit. These data helped identify potential gaps in animal health surveillance procedures and assess possible associations between animal movement and disease introduction into local herds. With the consolidation of records, the prevalence of bovine brucellosis and tuberculosis was estimated according to the declared purpose of animal movement in the GTA. In parallel, relative risk (RR) was calculated by comparing scenarios with and without prior diagnostic testing, enabling a direct comparison between these conditions. The study design was observational, retrospective, and analytical, following a historical cohort approach, appropriate for the use of secondary data and for evaluating the association between irregular cattle transit for reproduction and the occurrence of bovine brucellosis and tuberculosis in the municipality. The prevalence of animals

positive for brucellosis or tuberculosis was calculated by dividing the number of positive cattle by the total number of cattle moved within each GTA purpose category. RR was estimated as the ratio of disease prevalence in the Fattening group (considered the exposed or higher-risk group) to that in the Reproduction group (considered the unexposed or lower-risk group). The respective 95% confidence intervals (95% CI) were estimated using Wilson's method for proportions, which is particularly appropriate for low event frequencies. To assess whether the observed prevalence in each group differed significantly from zero, the exact binomial test was applied. Additionally, prevalence between animals moved without prior testing (fattening) and those moved with negative test results (breeding) was compared using the chi-square test of independence and Fisher's exact test, with the latter applied due to the low number of positive cases in the breeding group. The significance level was set at 5% ( $\alpha = 0.05$ ).

## Results and Discussion

The average age of cattle slaughtered in the municipality of São João do Itaperiú, Santa Catarina, Brazil, was 31 months, with a range of up to 257 months between the youngest and oldest animals. Based on data extracted from the SIGEN+ system, 1,026 cattle were identified between December 2022 and April 2023 that remained in municipal herds beyond the average slaughter age. These animals were classified as probable breeders and, as such, were subject to specific sanitary requirements, including mandatory diagnostic testing for brucellosis and tuberculosis. During the period from

2013 to 2022, seven outbreaks of bovine brucellosis and tuberculosis were recorded in the municipality of São João do Itaperiú, indicating the persistence of these zoonoses despite ongoing control measures. Among these outbreaks, four were identified through active surveillance in slaughterhouses, including two cases of tuberculosis and two of brucellosis, highlighting the value of this approach as a complementary tool for early disease detection. The remaining three outbreaks were identified through other mechanisms: one through mandatory sanitary testing required for bank financing; another following the observation of clinical signs suggestive of the disease; and one tuberculosis case during the investigation of an epidemiological link with a previously identified outbreak. These findings reinforce the relevance of multiple surveillance strategies, including both passive and active approaches, and highlight the need to improve sanitary control and traceability systems, particularly regarding animal movement and the consistent requirement for diagnostic testing prior to transit. Analysis of animals that tested positive for brucellosis or tuberculosis from 2013 to 2022 revealed that most cases occurred in females older than 36 months (Tables 1, 2, and 3). This finding aligns with the epidemiological profile of these diseases, particularly brucellosis, which affects adult females more frequently due to increased susceptibility associated with reproductive function. Of the 157 positive animals identified across the seven outbreaks

in the municipality, 131 had entered the affected properties without prior mandatory testing for brucellosis and tuberculosis, representing approximately 83.4% of cases. Only three positive animals entered with properly documented negative test results, whereas 23 were born on the properties where they were subsequently diagnosed. In six of the seven outbreaks, cattle had entered without sanitary examinations, highlighting deficiencies in animal transit control as a key risk factor for the introduction and spread of these diseases. In only one outbreak, related to brucellosis, all positive animals were born on the property, suggesting the possibility of vertical or horizontal transmission within the herd. In the investigation of cattle presumed to be used for reproduction without mandatory health examinations, 834 animals were identified across 84 properties in the municipality of São João do Itaperiú. Of these, 115 cattle were randomly inspected on-site between January and June 2023, covering 25 properties. The inspections showed that 86 animals (74.78%) were being used for reproduction. Disease prevalence analysis indicated a 15.83% positivity rate among animals not previously tested. In contrast, among animals subjected to the required examinations, the prevalence was 0.89%. The overall prevalence, considering both groups, was 11.52% (Table 4). For tuberculosis, prevalence was 2.28% in animals without prior testing and 0.89% in those previously tested, resulting in an overall prevalence of 1.88% across fattening and breeding groups.

**Table 1****Brucellosis and bovine tuberculosis cases according to sex. São João do Itaperiú, Santa Catarina, Brazil (2013–2022)**

Disease	Female	Male	Total
Brucellosis	134	1	135
Bovine tuberculosis	17	5	22
Total	151	6	157

**Table 2****Reported cases of brucellosis and bovine tuberculosis in São João do Itaperiú, Santa Catarina, Brazil, from 2013 to 2022**

Disease	<25 months	25-36 months	>36 months	Total
Brucellosis	46	21	68	135
Bovine tuberculosis	3	2	17	22
TOTAL	49	23	85	157

**Table 3****Distribution of brucellosis and bovine tuberculosis outbreaks according to year of diagnosis and pre-transit examination status in São João do Itaperiú, Santa Catarina, Brazil, from 2013 to 2022**

Year	Disease	Positive	With prior exams	No prior exams
2013	Brucellosis	11	5 (45.45%)	6 (54.56%)
2015	Brucellosis	111	2 (1.80%)	109 (98.20%)
2016	Brucellosis	7	0 (0%)	7 (100%)
2017	Bovine tuberculosis	7	5 (71.42%)	2 (28.58%)
2019	Brucellosis	3	2 (66.66%)	1 (33.33%)
2020	Bovine tuberculosis	14	9 (64.29%)	5 (35.71%)
2021	Brucellosis	1	1 (100%)	0 (0%)
2021	Bovine tuberculosis	1	0 (0%)	1 (100%)
2022	Brucellosis	2	2 (100%)	0 (0%)

**Table 4**

**Prevalence and relative risk of cattle testing for brucellosis and bovine tuberculosis according to pre-transit testing status in São João do Itaperiú, Santa Catarina, Brazil, until 2018**

Purpose in GTA	Prevalence (n)	Total (N)	Prevalence (%)	CI (95%)	RR	p
Brucellosis						
Fattening (without prior testing)	132	834	15.83	13.51 a 18.46		
Reproduction (with previous testing)	3	338	0.89	0.18 a 2.60		
Total (Brucellosis)	135	1172	11.52	9.69 a 13.35	17.83	<0.0001
Bovine tuberculosis						
Fattening (without prior testing)	19	834	2.28	1.27 a 3.29		
Reproduction (with previous tests)	3	338	0.89	0.18 a 2.60		
Total (Bovine tuberculosis)	22	1172	1.88	1.10 a 2.65	2.57	0.123
Total	157	1172	13.40	11.45 a 15.35		

GTA: Animal Transit Guide.

CI: Confidence Interval.

RR: Relative Risk.

Comparative analysis of infection risk revealed a marked disparity in the health status of animals assigned to different purposes in the GTA. The risk of brucellosis positivity in the group of animals destined for fattening (not subjected to prior testing) was 17.83 times higher (RR  $\approx$  17.83; 95% CI [5.72; 55.62]);  $p < 0.0001$ ) compared to the breeding group (subjected to prior testing). This discrepancy highlights the effectiveness of current sanitary measures for breeding herds and, conversely, indicates that cattle destined for fattening constitute a substantial high-risk reservoir for brucellosis. For tuberculosis, although a higher risk was observed in the fattening group (RR  $\approx$  2.57), the CI included unity (95% CI [0.76; 8.61]), indicating that the difference in prevalence did not reach statistical significance at the 95% level ( $p > 0.05$ ). This finding may be attributed to the lower overall prevalence of

tuberculosis in the municipality or to a limited sample size. However, its epidemiological relevance persists because 83.4% of the total animals that tested positive for both zoonoses entered the municipality without prior testing. Considering that between 2013 and 2022, only three of the 157 cattle that tested positive for brucellosis or tuberculosis had undergone mandatory health examinations prior to entering the municipality of São João do Itaperiú, it can be inferred that the remaining 131 either entered already infected or became infected after arrival. The remaining 23 positive cattle were born on the affected properties and may have been infected postnatally. The 131 introduced animals should have undergone prior testing, as required by State Decree No. 2,919 of June 1, 1998, regulated by Lei nº 10.366 (1997), which mandates testing for animals intended for reproduction. Non-

compliance with this regulation represents a critical failure in sanitary control and highlights the risks associated with irregular animal movement. Reinforcing the hypothesis of disease introduction through infected cattle, it is noteworthy that none of the properties classified as outbreak sites had production systems focused on fattening or finishing cattle, indicating that the animals were maintained for extended periods for reproductive purposes. Furthermore, the only outbreak without a history of cattle entry likely resulted from contact with animals on a neighboring property with confirmed positive cases, suggesting the possibility of local (contiguous) spread.

It can be inferred from the analyzed data that cattle acquired for fattening, as declared in the GTA, but remaining in municipal herds for more than 47 months were, in practice, used for reproduction. This discrepancy between declared purpose and actual use indicates a regulatory gap that compromises the effectiveness of sanitary control mechanisms. Even when the initial purpose is fattening, the need for specific regulations addressing this functional transition becomes evident, particularly when the duration of stay on farms is used as a criterion for reclassifying animal purpose. Such regulations could include systematic tracking of animals' residence time, including successive movements between properties, as well as mandatory sanitary examinations for uncastrated males, regardless of the purpose declared in the GTA. These measures would strengthen traceability and epidemiological surveillance, contributing significantly to the prevention of diseases such as brucellosis and bovine tuberculosis. In Santa Catarina, sanitary control of bovine brucellosis and

tuberculosis is conducted in state-inspected slaughterhouses through serological sampling of female cattle for brucellosis and analysis of lesion-derived material for tuberculosis diagnosis. Most outbreaks in the state have been identified through this active surveillance approach. However, preventive measures are considerably more cost-effective than laboratory diagnosis and subsequent sanitation interventions for both public authorities and rural producers. In addition to financial savings, prevention contributes to public health protection by reducing the incidence of human cases. Brucellosis, for example, is a chronic and debilitating disease (Souza et al., 2023). Tuberculosis also imposes a significant sanitary and socioeconomic burden, particularly due to treatment-related adverse effects and the potential for community transmission. The risk of human infection is even higher when slaughter occurs in facilities without sanitary inspection. In 2017, for example, 20.74% of cattle slaughter in Brazil was estimated to occur clandestinely (Costa et al., 2023), highlighting the need to strengthen public policies focused on animal health surveillance, traceability, and sanitary education for both producers and consumers. Brazil recorded a total of 66,819 new cases of tuberculosis in humans in 2020 (Abujamra et al., 2023). However, the exact origin of these infections remains uncertain, and the transmission route cannot be determined, whether through contact with infected animals, human-to-human spread, or the consumption of raw milk and untreated dairy products. Despite this limitation, 10% to 20% of human tuberculosis cases in underdeveloped countries may have a zoonotic origin (Smaniotto et al., 2019). This estimate highlights the importance

of integrating animal health surveillance into human tuberculosis control strategies, particularly in regions with a high prevalence of bovine tuberculosis and in contexts involving occupational exposure or the consumption of animal products without adequate sanitary control.

Ribeiro et al. (2020) conducted a spatial distribution study of bovine brucellosis from 2014 to 2018 to evaluate the effectiveness of actions under the PNCEBT. They identified 567 infected herds and 7,405 positive cattle in Santa Catarina during the analyzed period. Although the regression analysis did not indicate a significant decreasing trend in prevalence over the years ( $p \leq 0.05$ ), these results should be interpreted with caution. The high notification rate observed in the state does not necessarily reflect a higher actual incidence of the disease; instead, it may be associated with enhanced active surveillance and greater sensitivity of the detection system, characteristic of regions progressing toward more rigorous control and eradication phases. Therefore, these figures should not be directly compared with data from states where brucellosis remains largely underreported. Furthermore, there is no contradiction between the findings of Ribeiro et al. (2020) and previous epidemiological surveys, such as those by Sikusawa et al. (2009) and Baumgarten et al. (2016), because the latter used stratified probabilistic sampling methodologies to estimate population-level prevalence, whereas the more recent study analyzed notification data (Franc et al., 2018; Franco et al., 2007). Together, these results reinforce the need for continuous improvement of animal health surveillance systems and the sustained implementation of preventive

strategies in the state. To emphasize the importance of controlling zoonoses such as brucellosis and tuberculosis, it is essential to analyze temporal trends in human cases. This approach enables the evaluation of the effectiveness of control strategies and supports the development of more targeted, evidence-based public policies. An example is Portugal, where Santos et al. (2024) analyzed reported human brucellosis cases. The results indicated that the disease has not yet been eradicated, reinforcing the need for continuous and well-structured surveillance systems. The Portuguese experience demonstrates that even in countries with established public health systems, effective control of these zoonoses depends on sustained epidemiological monitoring. Bourdette and Sano (2023) identified 903 confirmed human cases of brucellosis in Brazil from 2014 to 2018, out of 3,612 reported suspected cases. The authors highlight that, due to the nonspecific clinical presentation of the disease, substantial underdiagnosis is likely, as low clinical suspicion can hinder laboratory confirmation. In light of the findings of this study, a work plan will be proposed in partnership with the Municipal Health Department of São João do Itaperiú, focusing on the temporal analysis of human cases and their correlation with infection data in cattle herds, aiming to strengthen prevention and control strategies for these zoonoses in the local population. It can also be inferred that the delayed resolution of bovine brucellosis and tuberculosis outbreaks in the municipality may be associated with a shortage of trained professionals for diagnostic testing, which compromises the timeliness of sanitary interventions and favors the persistence of infection within herds.

## Conclusions

This study revealed a strong association between the entry of cattle not tested for brucellosis and tuberculosis and the occurrence of outbreaks in the municipality, highlighting critical failures in the sanitary control of animal transit. The predominance of positive animals associated with irregular movements reinforces the need to improve surveillance and strengthen traceability measures. It is recommended that regulations governing cattle movement be revised, inspection procedures strengthened, and sanitary education initiatives expanded. These measures are essential to improve the control of bovine brucellosis and tuberculosis and to reduce their impacts on animal health, livestock production, and public health.

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