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The prevalence and spatial epidemiology of cysticercosis in slaughtered cattle from Brazil

A prevalência e epidemiologia espacial da cisticercose em bovinos abatidos no Brasil

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Abstract

Bovine cysticercosis is a disease that is endemic in several countries with an important zoonotic potential but with an increasing public health concern. The meat inspection at slaughterhouses is fundamental to establish the prevalence and prevention of zoonotic diseases, such as cysticercosis. However, in Brazil, there is no study investigating the dynamics of cysticercosis in slaughtered cattle from the entire country. Thus, the aim was to use Geographic Information System (GIS) as a tool to analyze the prevalence of bovine cysticercosis in slaughtered cattle, by using the data from slaughterhouses inspected by the Federal Inspection Service of the Ministry of Agriculture, Livestock and Supply (SIF/MAPA), during January/2007 to April/2010. Data from slaughtered cattle was used to generate a bovine cysticercosis database for all states and municipalities of Brazil, in order to analyze and create epidemiological maps using the GIS software. During the period analyzed, 75.983.590 cattle were slaughtered and the prevalence of bovine cysticercosis in Brazil was 1.05%, with the Southeast region presenting the majority of cases. The highest amount of bovine cysticercosis cases occurred in the state of São Paulo (400,834) followed by Mato Grosso do Sul (151,735), and Paraná (94,046), while there was no observation of occurrence in nine states. The data provided by slaughterhouses inspected by The SIF/MAPA can be used as an informative source for animal and public health agencies for the prevention of the taeniasis/cysticercosis complex. This study elucidates the importance of meat inspection associated with epidemiological maps, targeting the disease control in livestock and the active surveillance for potential zoonotic human infection. Data from this study suggest bovine cysticercosis is endemic in several Brazilian states, and the risk of infection is directly related with the principal areas of commercial cattle rearing, irrespective of the demographics of the human population.

Key words: *Taenia saginata*, cysticercosis, spatial epidemiology, bovine

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Resumo

Cisticercose bovina é uma doença endêmica em vários países com um importante potencial zoonótico e uma crescente importância na saúde pública. A inspecção da carne nos matadouros é fundamental para estabelecer a prevalência e prevenção de doenças zoonóticas, tais como a cisticercose. No entanto, no Brasil, não há estudo que tenha investigado a dinâmica da cisticercose em bovinos abatidos em todo o país. Assim, o presente estudo teve como objetivo usar Sistema de Informação Geográfica (GIS) como uma ferramenta para analisar a prevalência de cisticercose bovina em bovinos, usando os dados de matadouros inspecionados pelo Serviço de Inspeção Federal do Ministério da Agricultura, Pecuária e Abastecimento (SIF/MAPA), no período de janeiro de 2007 a abril de 2010. As informações de bovinos abatidos foram usadas para gerar um banco de dados sobre cisticercose bovina para todos os estados e municípios do Brasil, a fim de analisar e criar mapas epidemiológicos usando o software GIS. Durante o período analisado, 75.983.590 bovinos foram abatidos e a prevalência de cisticercose bovina no Brasil foi de 1,05%, com a região Sudeste apresentando a maioria dos casos. A maior quantidade de casos cisticercose bovina ocorreram no estado de São Paulo (400.834), seguido por Mato Grosso do Sul (151.735) e Paraná (94.046), enquanto não houve observação de ocorrência em nove estados. Os dados fornecidos por matadouros inspecionados pelo SIF/MAPA podem ser usados como uma fonte informativa para animais e agências de saúde pública para a prevenção do complexo teníase/cisticercose. Este estudo elucida a importância da inspecção da carne associado aos mapas epidemiológicos, visando o controle da doença nos rebanhos bovinos e a vigilância ativa para infecção zoonótica potencial para humano. Os dados deste estudo sugerem que a cisticercose bovina é endêmica em vários estados brasileiros, e o risco de infecção está diretamente relacionado com as principais áreas de criação de bovinos, independentemente da demografia da população humana.

Palavras-chave: *Taenia saginata*, cysticercose, epidemiologia espacial, bovinos

Introduction

Bovine cysticercosis is a disease caused by the larval stage of *Taenia saginata*, formerly known as the taeniasis/cysticercosis complex, and humans have been characterized as the definitive host. This parasite causes severe animal and human health impacts, constituting a major problem in various regions of the world, being important in Latin American, African, and the Mediterranean countries as a result of socioeconomic, environmental, and personnel conditions (ALMEIDA; SANTOS, 2002). It is estimated that 77 million people are infected with cysticercosis worldwide (REGASSA et al., 2009). The disease has been reported in 15 Latin American countries, including Brazil, and it is estimated that 400 thousand people are infected in South America (BERN et al., 1999). However, the prevalence of this disease in humans is highly variable within a country and between countries, and can be directly related to the differences of hygienic conditions, quality of meat inspection, and culinary habits (ALLEPUZ et al., 2009). Recently, the World Health Organization (WHO) included cysticercosis as part of the Neglected Zoonosis subgroup for its 2008–2015 strategic plans for the control of neglected tropical diseases (WHO, 2007).

This disease causes considerable livestock-associated financial losses and represents a significant food safety problem. Humans become infected by eating raw or undercooked meat containing the viable cysticerci. The tapeworm develops within the small intestine and becomes sexually mature in about three months, producing gravid proglottids, which are mobile and either migrate from the anus of the infected host spontaneously or are shed in feces (DORNY; PRAET, 2007). Transmission to animals occurs by the ingestion of food or water contaminated with the feces of infected humans (GEYSEN et al., 2007). Bovine cysticercosis is asymptomatic after development in infected animals. However, it produces irreversibly effects to the beef-cattle industry, when the disease is diagnosed at slaughterhouses by visual inspection of specific

sectioned tissues. This results in considerable economic losses, due to the total condemnation of infected carcasses and organs, or the depreciation of the meat value, since its destination is salting, canning, or freezing (SAÚDE ANIMAL NOTÍCIAS, 2006).

The prevalence data of bovine cysticercosis is highly variable worldwide, ranging from 0.007% to 6.8% in Europe, with a wide variation between countries. In Ethiopia, the prevalence in slaughtered cattle ranged from 24.3% to 46.5% (JOBIRE et al., 1996). In Brazil, the available prevalence data is restricted to some geographical regions of the country, and has been reported as ranging from 0.69% in the State of Mato Grosso, Midwestern Brazil (SCHEIN et al., 2004), to 27% in the State of Paraná, Southern Brazil (SOUZA et al., 2007). Thus, prevalence studies of bovine cysticercosis are scarce, and there is no recent mapping of the disease in Brazil.

The Geographic Information Systems technology (GIS) provides a useful tool to establish the relationships of disease data between environmental features at known infected sites and produce epidemiological maps of disease risk (MALONE et al., 1998; FUENTES, 2006). Environmental and remote sensing data might be incorporated within a GIS system and be used for the routine health management programs, including bovine cysticercosis. Due to the significant importance associated with livestock production and public health, the knowledge of the frequency of this zoonotic disease throughout Brazil, as well as the origin of slaughtered animals, is of paramount importance.

Consequently, the aim of this study was to employ GIS technology as a tool to determine the prevalence of bovine cysticercosis during 2007 to 2010, based on data obtained from slaughterhouses that are under the Brazilian Federal Inspection Service. This represents a starting point for the adoption of control measures and prophylaxis of infection.

Materials and Methods

Data from slaughtered cattle from all 27 Brazilian states, totalizing 5,514 municipalities, during January/2007 to April/2010 were obtained from the Federal Inspection Service (SIF) of the Ministry of Agriculture, Livestock, and Supply (SIF/ MAPA) database.

In Brazil, the compulsory notification of the occurrence of bovine cysticercosis in slaughtered cattle is achieved by classifying the disease as live or calcified cysticercosis; this being a routine gross inspection done by veterinarians employed by the SIF. These veterinarians visually examine sectioned areas of the masseter muscles, tongue, diaphragm, and the heart for possible cysts at slaughterhouses in Brazil. All data (such as, the number of animal slaughtered, presence or absence of disease, and the State of origin of the affected animal) of slaughtered cattle is registered daily within the SIF database by the Official Veterinarian. Data obtained during the evaluation of cattle submitted for inspection at slaughterhouses registered with the SIF/MAPA was used to determine the infection rates of bovine cysticercosis.

The data was assembled using Microsoft Excel® v2007 and included the geographical coordinates (latitude and longitude), the number of slaughtered cattle and total number of infected cattle per year from each municipality. The data was then analyzed by using the ArcGIS® software (ArcGIS®9, version 9.3, ESRI, Redlands, CA, USA), to georeference the coordinates of each municipality to GIS map layers on environmental features in Brazil. The prevalence of slaughtered cattle positive for cysticercosis per year (2007-2010) was the attribute selected in the software to generate the epidemiological maps.

Results

During January/2007 to April/2010, 75,983.590 cattle were slaughtered in Brazil, with the overall prevalence of bovine cysticercosis of 1.05%

(796,941 cases). The number of slaughtered cattle and the positive cases of cysticercosis observed in these animals in Brazilian states are summarized in Table 1. The highest prevalence during this period was observed in the State of São Paulo (3.34%), followed by Mato Grosso do Sul (1.34%) and Paraná (2.91%) (Table 1). The lowest prevalence (0.001%) of cysticercosis occurred in the States of Acre, Alagoas, Amazonas, and Pará. Further, the Federal Inspection Service did not diagnose the occurrence of this disease in nine Brazilian states (Pernambuco, Federal District, Amapa, Piaui, Ceará, Rio Grande do Norte, Amapa, and Maranhão) during this period of evaluation. Additionally, the largest amount (17.5%) of slaughtered cattle originated from the State of Mato Grosso, while cattle infected from the state of São Paulo contributed to 50% of the total prevalence.

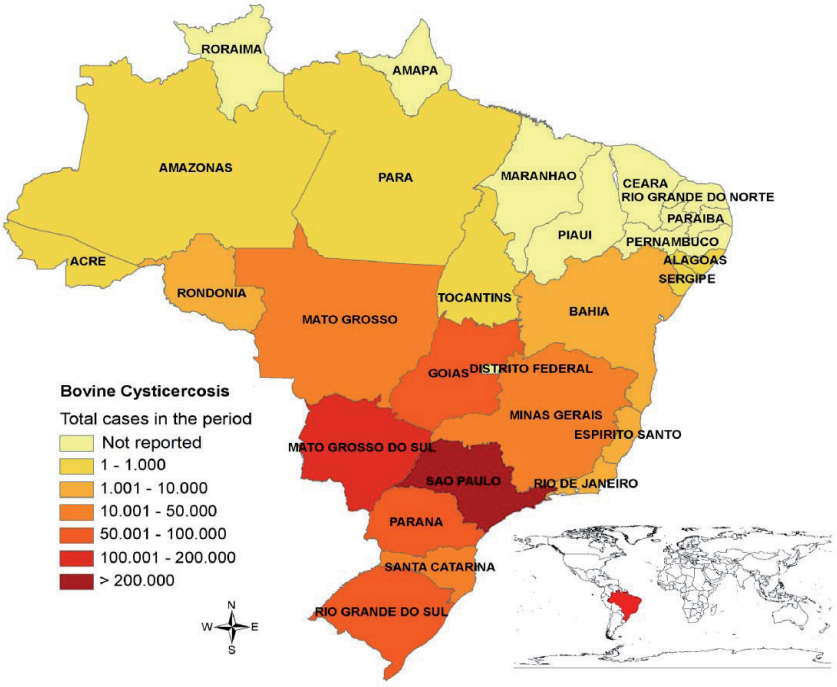
The epidemiological distribution of the prevalence of bovine cysticercosis in Brazil obtained by using the GIS is illustrated in Figures 1 (by states) and 2 (by municipalities). The prevalence of bovine cysticercosis was markedly elevated in the Midwest, Southeast, and Southern regions of Brazil, with the states of São Paulo, Mato Grosso do Sul, and Paraná having the vast majority of cases (Figure 1). Additionally, the GIS generated data clearly illustrated a higher rate of infection in cities that are below latitude 10º 00' 00'' S (Figure 2).

Table 1. The distribution and prevalence of cysticercosis by States* in slaughtered cattle from Brazil.

States	2007	2008	2009	April/2010	Total (%)[a]
Acre	0 /294,572	0 /274,711	2 /283,343	11 /88,569	13 /941,195 (0.001)
Amazonas	10/75,243	10/71,677	4/80,753	0/33,376	24 /261,049 (0,01)
Pará	20/1,915,278	21/1,590,895	14/1,654,956	4/699.460	59 /5,860,589 (0,001)
Rondônia	1,570/1,980,893	1,398/1,641,190	1,207/1,734,381	245/882,708	4,420 /6,239,172 (0,07)
Tocantins	282/1,037,760	254/812,087	242/777,971	89/397,361	867 /3,025,179 (0,02)
Alagoas	3/59,377	5/47,480	0/1,951	0/0	8 /108,808 (0,01)
Bahia	250/412,792	2,015/367,369	1,031/325,751	250/125,786	3,546 /1,231,696 (0,28)
Sergipe	40/45,140	79/40,151	78/40,817	9/17,599	206 /143,707 (0,14)
Goiás	23,322/2,711,378	20,975/2,649,508	18,728/2,314,979	4,243/922,719	67,268 /8,598,584 (0,78)
Mato Grosso	6,467/4,488,484	4,431/3,664,409	4,457/3,738,954	1,094/1,809,102	16,449 /13,700,949 (0,12)
Mato Grosso do Sul	49,877/3,513,366	43,262/2,996,704	46,402/3,056,222	12,194/1,357,107	151,735 /10,923,399(1,34)
Espírito Santo	2,120/225,310	2,293/229,486	1,446/171,483	391/57,565	6,250 /683,844 (0,91)
Minas Gerais	12,444/1,901,929	16,261/2,130,197	12,673/2,029,128	3,346/735,944	44,724 /6,797,198 (0,65)
Rio de Janeiro	330/27,032	484/47,117	317/21,097	72/10,432	1,203 /105,678 (1,13)
São Paulo	135,525/4,022,536	110,229/3,461,752	83,399/3,184,555	71,681/1,332,922	400,834 /12,001,765 (3,34)
Paraná	31,042/1,095,811	29,477/977,426	27,335/803,329	6,192/345,904	94,046 /3,222,470 (2,91)
Santa Catarina	3,577/104,375	3,241/100,073	3,351/97,810	651/39,028	10,820 /341,286 (3,17)
Rio Grande do Sul	24,850/677,056	21,544/705,305	23,685/735,953	7,789/378,168	77,868 /2,496,482 (3,12)
Total	291,729/23,905,090	255,979/20,947,970	224,271/20,955,623	108,261/8,445,721	796,941 /75,983.590 (1,05)

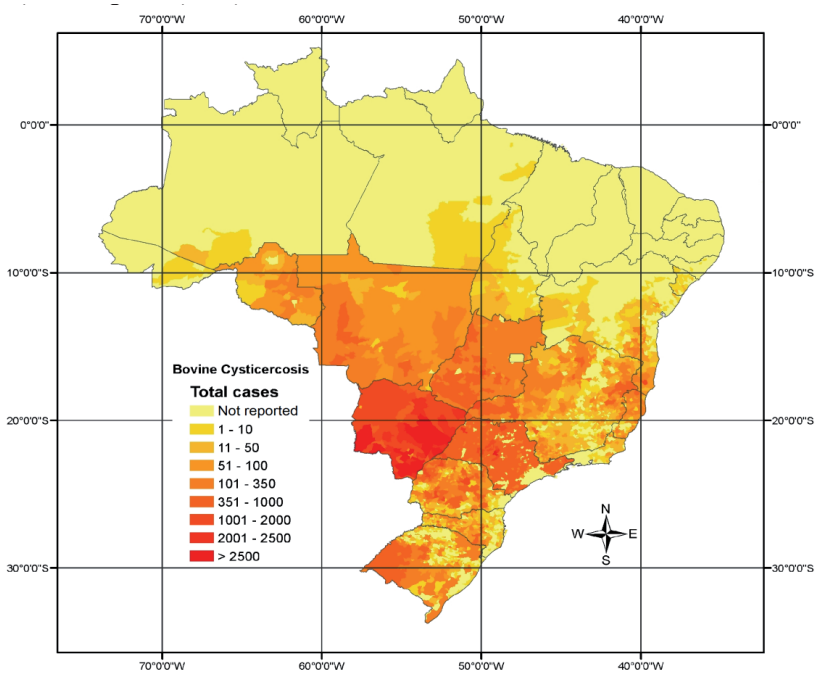
*The States in which there is no report of disease by the Federal Inspection Service are not included.
[a] The prevalence of cysticercosis is given in brackets.
Source: Elaboration of the authors.

Figure 1. The epidemiological map demonstrating the prevalence of bovine cysticercosis in slaughtered cattle originated from Brazilian States during January/2007 to April/2010.



Source: Elaboration of the authors.

Figure 2. The epidemiological map demonstrating the prevalence of bovine cysticercosis in slaughtered cattle originated from Brazilian municipalities during January/2007 to April/2010. Grids lines refers to latitude (South) and longitude (West).



Source: Elaboration of the authors.

Discussion

During this study, the prevalence of bovine cysticercosis in cattle slaughtered in Brazil during the 2007–2010 was 1.05%. Similar results were obtained in other Central and South American countries (Chile, Colombia, El Salvador, Mexico and Nicaragua), where a prevalence of 0.27% was described (SCHENONE; LETONJA, 1974). Alternatively, bovine cysticercosis has been considered as eradicated in Peru, Haiti, and Honduras (GRACEY; COLLINS; HUEY, 1999). Analyses of data obtained from the Federal Inspection Service (SIF) during 1971 to 1982, demonstrated that the prevalence of bovine cysticercosis in Brazil was 2.25% (VIANA, 1995), was increased to approximately 2.65% in 1989 (OPAS, 1994), and 5% of cattle were infected with cysticerci in 1993 (SANTOS, 1993). In Brazil, within the slaughterhouses that are inspected by the SIF (mandated by federal law), there is continuous evaluation of carcasses and organs for possible infection, with the primary objective to prevent the occurrence of the taeniasis/cysticercosis complex in humans. This system facilitates the adequate disposal of carcasses and offal of cattle infected with cysticercosis, and serves as a source of geographical statistical data, which is primordial for health surveillance. Consequently, slaughterhouses can be used as potential data sources for animal and public health surveillance studies, by recording evidence of endemicity, as well as indicators of possible regional epidemics or seasonal trends. Other studies have highlighted the importance of identifying the origin of infected herds and tracing of these animals, since it might lead to the identification of high risk areas where the occurrence of taeniasis and cysticercosis would certainly be interrelated (SANTOS, 1993; PARKINSON, 1972; FUKUDA et al., 2003). Although this correlation was not the aim of this study, recent epidemiological data have suggested that some indigenous Brazilian communities (ARAGÃO et al., 2010), and rural villages (GOMES et al., 2002; PRESTES-CARNEIRO et al., 2006).

In Brazil beef cattle rearing is primarily done by using the extensive production system where animals have free access to low-land pastures, which might be in direct contact with contaminated streams and rivers. This productive system might facilitate the widespread occurrence of bovine cysticercosis in some areas of the study, irrespective of the agro-ecological and socio-cultural differences. In addition, problems associated with poor health, inadequate infrastructure, low public health awareness and inadequate sewage are the main factors associated with the elevated prevalence of cysticercosis in developing countries (BUDKE; WHITE; GARCIA, 2009). Politically, Brazil is divided into five regions: north, south, northeast, mid-west, and southeast. The results illustrated in figure 1 show that the prevalence of bovine cysticercosis was markedly higher in the Midwest, Southeast, and Southern regions of Brazil, with the states of São Paulo, Mato Grosso do Sul, and Paraná having the vast majority of cases. Further, a comparatively larger infection rate was observed below latitude 10º 00’ 00’’ S (Figure 2); this geographical region represents the most economically developed areas in Brazil, where the Southern and Southeastern municipalities are located. These geographical areas also have the highest distribution indices and technology associated with cattle production, including the majority of beef cattle that is raised for exportation. Additionally, a comparatively higher infection rate below latitude 10º 00’ 00’’ S, might be the manifestation of reduced population density in areas above this latitude due to the lower concentration of commercial cattle breeding and/or of the reduced human-animal contact. Paradoxically, the northeastern region of Brazil, which is located above this latitude, is endemic for various infectious diseases due to deficient socio-economic conditions which facilitate the transmission and maintenance of the taeniasis/cysticercosis complex (GOMES et al., 2002), but reports of bovine cysticercosis within this region were not found within normal literature databases and were not identified by the SIF. However, porcine cysticercosis due to *Taenia solium*

has been identified in human populations from this region (GOMES et al., 2002; SATO et al., 2006). Therefore the possibility of bovine cysticercosis occurring in this region cannot be totally ignored. It is important to note that during this study, the areas designated as "not reported", is based exclusively on data obtained from the SIF, without considering the results of State and Municipal inspection services, which are independent law-enforced regulatory institutions. Therefore, cases of bovine cysticercosis could have been reported in these areas by the State or Municipal authorities, so the possibility of occurrence cannot be totally excluded.

During this study, the prevalence of bovine cysticercosis in the state of São Paulo was 3.3%, which represented 50% of the overall national prevalence. However, a study that analyzed the occurrence of bovine cysticercosis in this state by using data retracted from the SIF database during 1996–2000 revealed a prevalence of 8.7% (MARQUES et al., 2008). These studies clearly demonstrated a marked reduction of bovine cysticercosis within this state, and might reflect the increasing hands-off technology that is used in commercial beef cattle rearing. Interestingly, the largest number of cattle slaughtered in Brazil originated from the state of Mato Grosso (17.5 %), wherein a relatively low prevalence of bovine cysticercosis (0.12%) was demonstrated. This state is located in the Midwest region of Brazil, which is characterized by having a reduced demographic concentration of human population in small towns relative to the amount of cattle that is being raised. Alternatively, the state of São Paulo has the largest population but an increasing human contact with commercial beef cattle production, which might explain the comparative elevated prevalence of cysticercosis (IBGE, 2007).

This study demonstrated a reduction (23%) in the number of cases of bovine cysticercosis from 2007 to 2009. This decreased prevalence might represent an actual reduction of infection or a manifestation of inconsistency during the visual inspection of carcasses at slaughterhouses, resulting in false-negative results. It must be highlighted that standardized meat inspection methods, used by veterinarians of the SIF, are restricted to superficial sections at preferential sites of cysticerci and easily accessible muscles, and might not necessarily provide reliable data, thereby contribute to underestimated prevalence of the disease (PEREIRA; SCHWANZ; BARBOSA, 2006). However, it is important to mention that there was a corresponding decrease (12%) in the number of slaughtered cattle during this period, which might have also contributed to the decrease in the number of cases of cysticercosis. Additionally, when ELISA is used as diagnostic tool in epidemiological surveys, the prevalence of bovine cysticercosis might increase 10 fold relative to the visual method of inspection of carcasses (DORNY et al., 2000). Consequently, data obtained by using only visual inspection of carcasses is limited and might result in false-negatives, so the use of other diagnostic techniques that are more sensitive/specific in combination with visual inspection is recommended for active surveillance studies.

Human cysticercosis has multiple impacts on the host, since infection affects the health, social and family life, and productivity (CARABIN et al., 2005), of infected persons. Therefore, the disease might be a constraint to the improvement of the life and livelihood of small-holding farming communities, which can be at risk of infection, as has been demonstrated in some remote villages of Brazil (GOMES et al., 2002; PRESTES-CARNEIRO et al., 2006). Efforts to comprehensively assess the global burden of cysticercosis are currently ongoing, where the health and agricultural impacts of the disease are given equal consideration (IBGE, 2007; PEREIRA; SCHWANZ; BARBOSA, 2006; DORNY et al., 2000; CARABIN et al., 2005). Initial results of a global burden assessment indicate a serious impact of cysticercosis on the public health and agricultural systems of endemic countries (BUDKE; WHITE; GARCIA, 2009). However, a full assessment of

the burden of disease has been hampered by the lack of adequate epidemiological data, which could be overcome by the establishment of specialized centers of diseases control (CARABIN et al., 2004). As was done in cattle during this study, the use of spatial information to evaluate the prevalence of cysticercosis is a novel approach that attempts to detect the most potentially active sites for the transmission of cysticercosis in an endemic area. This type of analysis has contributed to epidemiological studies of other diseases (i.e., rabies, bovine tuberculosis, and schistosomiasis) (CARABIN et al., 2006). Data from this study suggest that the risk of cysticercosis infection is widely dispersed throughout many regions of the Brazilian territory, but is correlated with the principal areas of commercial cattle rearing, irrespective of the demographics of the human population.

The WHO estimates that 50 million individuals are infected with the taeniasis/cysticercosis complex and 50 thousand people die annually (WHO, 2007). Although there are drugs considered effective against the so-called neglected tropical diseases (PRAET et al., 2009), the choice of an efficient antiparasitic drug for cysticercosis is still guided by collateral factors, such as drug availability and costs (WILLINGHAM et al., 2010), but the actual solution lies in the implementation of adequate measures to prevent the taeniasis/cysticercosis complex (HAY; LENNON, 1999). Additionally, preventive chemotherapy not only runs the risk of having to be continued indefinitely, but can also induce drug resistance without the long-term protection a vaccine can offer as complementary intervention (UTZINGER et al., 2010). One of the main obstacles to control and eliminate infections of *Taenia saginata* is the absence of reliable epidemiological data of taeniasis and cysticercosis, which could be surpassed by the implementation of adequate surveillance systems for these diseases (CARABIN et al., 2004). Targeting the success in controlling human cysticercosis, requires the integrated adoption of several measures such as improving sanitary conditions, public health education, better systems of bovine production and increased efficiency during meat inspection, (GARCIA, 2008; MINISTÉRIO DA SAÚDE, 1996). This is especially important for sanitary and public education, which are directly responsible for the infection of animals and the consequent increase in prevalence (IBGE, 2007). In general terms, the federal inspection system has been effective, since it has reliably and constantly detects cases of cysticercosis after slaughter. In addition, the use of GIS technology for the routine monitoring of disease outbreaks in a continental country, such as Brazil, where there are no efficient epidemiological barriers, might result in better control strategies. Taeniasis and cysticercosis do not result in sudden large scale international outbreaks, and consequently do not constitute an appropriate subject for international notification. Therefore, it would be more appropriate for local authorities to establish a national program of surveillance and reporting of taeniosis and cysticercosis as part of a routine system (MINISTÉRIO DA SAÚDE, 1996).

Conclusion

Bovine cysticercosis is endemic in several Brazilian states, with a significant prevalence, within the Midwest, Southeast and South regions, where the highest rates in slaughtered cattle have been identified by the Federal Inspection Service. This study elucidates the importance of meat inspection associated with epidemiological maps, targeting the disease control of livestock and active surveillance for potential zoonotic human infection.

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