Analysis of bovine cysticercosis in the state of Goiás, Brazil and economical losses for beef farms

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SUMMARY

This study aimed to assess the prevalence and spatial distribution of bovine cysticercosis in the state of Goiás, Brazil; to verify its association with epidemiological variables, and to establish the economical losses for beef farms. A set of 23 255 979 bovines from 246 municipalities were slaughtered from 2007 through 2014. The prevalence of bovine cysticercosis was 0·53% [95% confidence interval (95% CI) 0·5295–0·5354]. The Central mesoregion showed a higher risk [odds ratio (OR) = 4·44; 95% CI 4·2936–4·5895] for detecting infected animals with cysticerci compared with those raised at North and Northeast mesoregion (OR = 1·02 and OR = 1·02). The microregion of Goiânia had a higher risk for bovine cysticercosis occurrence (OR = 11·05, 95% CI 10·6933–11·4099) compared with the microregion of São Miguel do Araguaia (OR = 1). None of the epidemiological variables evaluated in this study was significantly associated ($P > 0·05$) with bovine cysticercosis prevalence.

In conclusion, the prevalence of bovine cysticercosis in the state of Goiás, Brazil, was 0·53% and some mesoregions and microregions presented a higher risk for its occurrence. The economical losses due to its occurrence during the period ranged from US$9 260 728·57 to 11 313 816·67. These results highlighted the needs of adopting prophylactic measures and the development of political strategies in specific regions in order to control this zoonose and reduce the economical losses for beef production chain and the costs for public health.

Key words: epidemiology, geographic information system (GIS), spatial distribution, taeniasis-cysticercosis, zoonose.

INTRODUCTION

The *Taenia saginata*-cysticercosis is a disease caused by one parasite that requires two hosts during its life cycle. Human beings and bovines are considered as definitive and intermediate hosts, respectively. The cattle infections occur through the ingestion of *T. saginata* eggs (Lopes *et al*. 2014).

Bovine cysticercosis is the most common disease detected during inspection of cattle's carcasses and viscera in Brazil. The prevalence values are probably underestimated because the ongoing model of sanitary inspection has a low sensitivity due to the possible presence of cysticerci in muscles and viscera, which are not routinely inspected (Lopes *et al*. 2011.). However, meat inspection is required in order to avoid its transmission to human beings and to provide information for health institutions regarding its occurrence in farms, municipalities and regions (Onyango-Abuje *et al*. 1996; Minozzo *et al*. 2002; Fukuda, 2003; Giovannini *et al*. 2014).

The states of Goiás, Mato Grosso, Mato Grosso do Sul, São Paulo, Minas Gerais, Pará and Rondônia raised 72% of bovines, which were slaughtered in Brazil, contributing to keep the country in the second position in the raking of world's beef producers and allowing export of beef to 143 countries. Additional values of 1·9 and 4·4% in beef production and export in Brazil is estimated from 2014 through 2024 (BRASIL, 2014).

There is a need of developing and adopting sanitary control programmes during cattle raising in Brazil in order to reduce the risk of *T. saginata*-cysticercosis transmission worldwide considering the raising tendency of Brazilian beef export. According to Brazil (1952), carcasses considered as

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infected need to be heat-treated using freezing in order to inactivate the parasite.

To neglect this disease causes trade barriers and estoppels to Brazilian beef in global market and also economical losses to beef production chain (Rossi *et al*. 2015).

The prevalence of bovine cysticercosis in Brazil is 1·05% and differences on its value is reported among several states. In Goiás, the reported prevalence is 0·78% (Dutra *et al*. 2012).

In order to contribute to the knowledge about bovine cysticercosis epidemiology in this state, this study aimed to assess the prevalence and spatial distribution of bovine cysticercosis in the state of Goiás, Brazil; to verify its association with epidemiological variables, and to establish the economical losses for beef farms.

MATERIALS AND METHODS

A retrospective study regarding bovine cysticercosis occurrence was performed through accessing the database from Brazilian Ministry of Agriculture, Livestock and Food Supply (MAPA http://www.agricultura.gov.br/assuntos/inspecao/produtos-animal/sif/servico-de-inspecao-federal-sif), which contains data provided by the Federal Inspection Service (SIF). A set of 23 255 979 bovines from 246 municipalities in the state of Goiás, Brazil, including both genders and age ranging from 18 to 60 months were inspected through the years 2007–2014.

The animals were slaughtered according to the standardized technology, and the carcasses and viscera were inspected according to Brazilian legislation (Brazil, 1952). SIF adopts *post-mortem* inspection for bovine cysticercosis through incisions in muscles (masseteres, pterygoids, tongue and heart), palpation and visual examination of head, viscera and carcasses external surfaces according to the Regulation of Sanitary and Industrial Inspection of Animal's Products Origin (RIISPOA) (Brazil, 1952). The cysticerci were classified as viable and unviable according to their characteristics (translucent or opaque, respectively).

The obtained data were grouped per year (from 2007 to 2014), mesoregions and microregions from this state (Figures 1AB). This study included five mesoregions (Central, East, North, Northeast and South) and 18 microregions (Anápolis, Anicuns, Aragarças, Catalão, Ceres, Chapada dos Veadeiros, Entorno do Distrito Federal, Goiânia, Iporá, Meia Ponte, Pires do Rio, Porangatu, Quirinópolis, Rio Vermelho, São Miguel do Araguaia, Sudoeste de Goiás, Vale do Rio dos Bois and Vão do Paranã) according to the classification from Brazilian Institute of Geography and Statistics (IBGE, 2016, http://cidades.ibge.gov.br/xtras/uf.php?lang=&coduf=52&search=goias).

The prevalence and the 95% confidence interval (95% CI) were calculated through the Wilson's method (Thrusfield, 2010). The relation among bovine cysticercosis in municipalities, mesoregions and microregions was calculated using that one with the lower prevalence [considered as odds ratio (OR) = 1] and the others were compared with it. Z test was used to evaluate significance ($P < 0{\cdot}05$) (Thrusfield, 2010).

Data regarding the human population density (inhab per km^2), Human Development Index (IDH), poverty incidence index, cattle population size, area of temporary tillage (ha), grassland area (ha), sugarcane area (ha), farmer condition (seated without definitive title) and numbers of houses without sanitary room were obtained from IBGE website (http://cidades.ibge.gov.br/xtras/uf.php?lang=&coduf=52&search=goias). The classification of tourism practices was also obtained through from the state of Goiás Government website (www.goiasturismo.go.gov.br).

The association among bovine cysticercosis prevalence in municipalities (dichotomized using the median value – zero and one for the values below

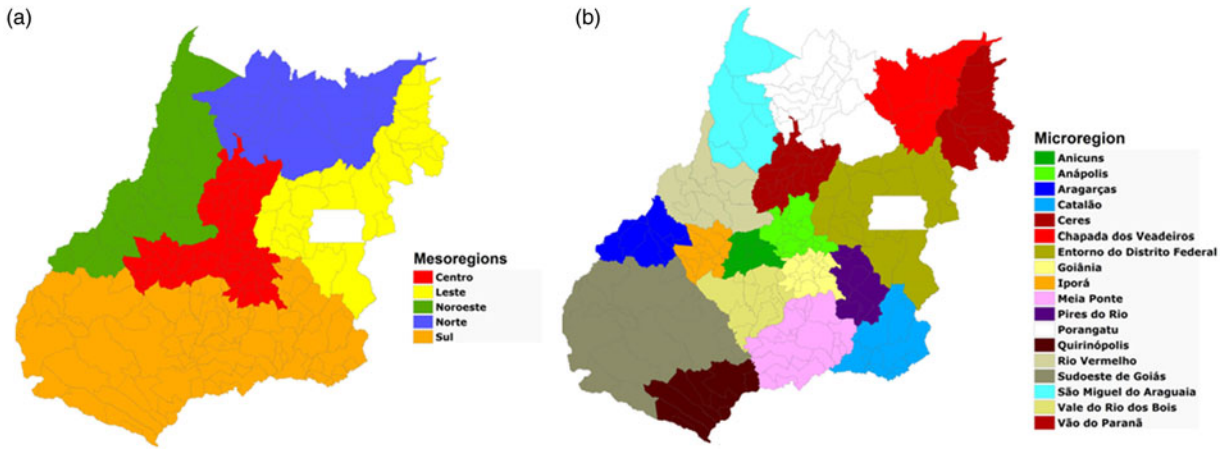

Fig. 1. Mesoregions (a) and microregions (b) in the state of Goiás, Brazil.

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and above, respectively) with epidemiological factors, such as human population density (inhab/km^2), forage area (ha), sugar cane area (ha), producer's condition (settled with or without permanent title), houses without sanitary room and touristic practices.

A simple binary logistic regression analysis was applied to all variables mentioned above, and those with $P \leq 0{\cdot}20$ were selected.

Then, a multivariate binary logistic regression analysis was performed using the significant variables in the univariate analysis ($P \leq 0{\cdot}20$). The strength of the association between dependent and independent variables was estimated by OR, which was obtained from logistic regression estimations ($P \leq 0{\cdot}05$).

The economic losses were estimated based on bovine cysticercosis prevalence and the penalties applied to farms suppliers of infected cattle using the scheme adopted by slaughterhouses in this state. Carcasses with intense cysticercosis infections, i.e. more than one cysticercus in an area of about 22 cm^2, must be rendered and consequently the producer is not paid. Mild-to-moderate infections require freezing or canning and the producer receives 30–50% of the value, for unviable or viable cysticercosis, respectively. The carcasses' weight were considered as 225 kg and their value was gathered from Center of Advanced Studies and Applied Economy – ESALQ/USP (CEPEA) from December from 2017 to 2014. The dollar conversion rate used was |US$1·00 = R$3·15 (reais).

Statistical analyses were performed using software Epi Info, v. 7.1.5.2 (https://www.cdc.gov/epiinfo/index.html). Maps were created using the Terraview® software (http://www.dpi.inpe.br/terraview/index.php_) through quantile method (divided in four categories).

RESULTS

A set of 123 728 bovines were considered as infected with cysticerci from the 23 255 979 animals slaughtered (prevalence = 0·53; 95% CI 0·5295–0·5354) through the years 2007–2014 in the state of Goiás, Brazil. Among the cysticerci detected, 52 351 and 71 377 were considered as viable and unviable, respectively. The areas considered with high-bovine cysticercosis prevalence (viable and unviable) are located in the centre of the state of Goiás (Figs. 2A and B).

The Central mesoregion was considered as the one with the highest prevalence ($P = 1{\cdot}01\%$; 95% CI 4·2936–4·5895) during this period, while South (0·62%), North (0·23%) and Northeast (0·23%) regions showed low-prevalence values (Figs. 2A and B and Table 1).

A significant statistical difference ($P \leq 0{\cdot}05$ on risk for bovine cysticercosis occurrence through the years was observed at 2008 (OR = 1·31; CI 1·2650–1·3664), 2013 (OR = 1·07; CI 1·0271–1·1170) and 2014 (OR = 1·34; CI 1·2884–1·3958). However, the areas considered as with higher prevalence were not modified (Fig. 3 and Table 2).

None of the variables, such as human population density (inhab per km^2), IDH, poverty incidence index, cattle population size, area of temporary tillage (ha), grassland area (ha), sugarcane area (ha), farmer condition (seated without definitive title), numbers of residences without sanitary room and municipalities categorized as touristic, were significantly associated ($P > 0{\cdot}05$) with bovine cysticercosis prevalence in municipalities.

This study performed a simulation of the economic losses during the study period using the prevalence value in this state (0·53%), carcasses weight (225 kg) and carcasses prices (Table 3). The economical losses for beef farmers located in the

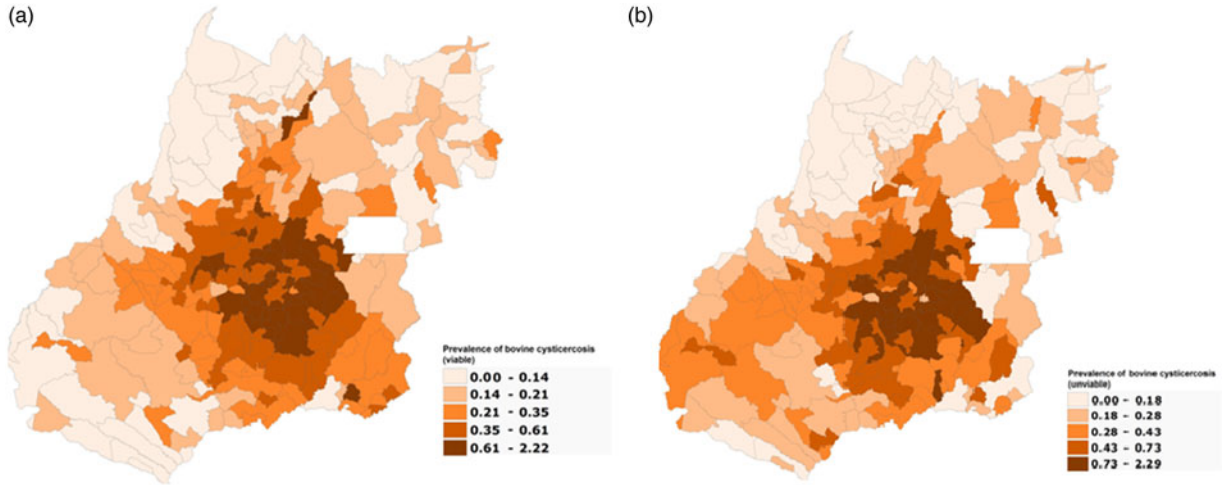

Fig. 2. Spatial distribution of bovine cysticercosis prevalence in the state of Goiás, Brazil, through the years 2007–2014. (a) viable cysticerci; (b) unviable cysticerci.

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Table 1. Analysis of association between the mesoregions of the state of Goiás, referring to the prevalence of bovine cysticercosis diagnosed between 2007 and 2014

Mesoregions	Animals slaughtered	Cysticercosis positive	Prevalence (%)	95% CI	OR	95% CI	*Z* test	Significance level
Norte	1 652 806	3799	0·23	0·23–0·27	1·00			
Nordeste	6 687 520	15 652	0·23	0·20–0·27	1·02	0·9828–1·0551	1·00	0·3166
Leste	1 862 932	7979	0·43	0·33–0·52	1·87	1·7962–1·9408	31·63	0·0000
Sul	9 098 574	56 269	0·62	0·57–0·67	2·70	2·6137–2·7915	59·20	0·0000
Centro	3 954 147	40 029	1·01	0·91–0·111	4·44	4·2936–4·5895	87·66	0·0000
Total	23 255 979	123 728	0·53	0·5295–0·5354				

Mesoregions with OR >1 and CI 95% >1 had higher risk for bovine cysticercosis occurrence.

Table 2. Analysis of association between the microregions of the state of Goiás, referring to the prevalence of bovine cysticercosis diagnosed between 2007 and 2014

Microregions	Animals slaughtered	Cysticercosis positive	Prevalence (%)	95% CI	OR	95% CI	*Z* test	Significance level
São Miguel do Araguaia	3 338 585	4995	0·15	0·1455–0·1538	1·00			
Porangatu	1 435 146	3091	0·22	0·2078–0·2230	1·44	1·3773–1·5067	15·93	<0·0001
Vão do Paranã	729 676	2075	0·28	0·2722–0·2966	1·90	1·8082–2·0034	24·61	<0·0001
Rio Vermelho	2 514 939	7474	0·30	0·2905–0·3039	1·99	1·9192–2·0619	37·59	<0·0001
Chapada dos Veadeiros	217 660	708	0·33	0·3014–0·3492	2·18	2·0129–2·3566	19·35	<0·0001
Quirinópolis	1 976 941	7429	0·38	0·3673–0·3843	2·52	2·4286–2·6094	50·39	<0·0001
Aragarças	833 996	3183	0·38	0·3684–0·3949	2·56	2·4455–2·6733	41·33	<0·0001
Catalão	636 586	2631	0·41	0·3975–0·4291	2·77	2·6418–2·9039	42·22	<0·0001
Sudoeste de Goiás	3 404 756	14 153	0·42	0·4088–0·4225	2·79	2·6973–2·8772	62·18	<0·0001
Entorno do DF	1 133 256	5904	0·52	0·5077–0·5342	3·50	3·3657–3·6296	64·99	<0·0001
Ceres	630 048	3481	0·55	0·5342–0·5708	3·71	3·5504–3·8721	59·24	<0·0001
Iporá	558 620	4051	0·73	0·7029–0·7474	4·88	4·6767–5·0819	74·75	<0·0001
Anicuns	1 257 871	9449	0·75	0·7361–0·7663	5·05	4·8807–5·2278	92·42	<0·0001
Meia Ponte	1 414 724	11 285	0·80	0·7830–0·8123	5·37	5·1903–5·5485	98·69	<0·0001
Vale do Rio dos Bois	1 226 186	14 897	1·21	1·1955–1·2343	8·21	7·9484–8·4757	128·48	<0·0001
Pires do Rio	439 381	5874	1·34	1·3029–1·3708	9·04	8·7071–9·3919	114·01	<0·0001
Anápolis	656 021	9183	1·40	1·3714–1·4282	9·47	9·1528–9·8079	127·52	<0·0001
Goiânia	851 587	13 865	1·63	1.6013–1·6550	11·05	10·6933–11·4099	145·16	<0·0001
Total	23 255 979	123 728	0·53	0·5295–0·5354				

Microregions with OR >1 and CI 95% >1 had higher risk for bovine cysticercosis occurrence.

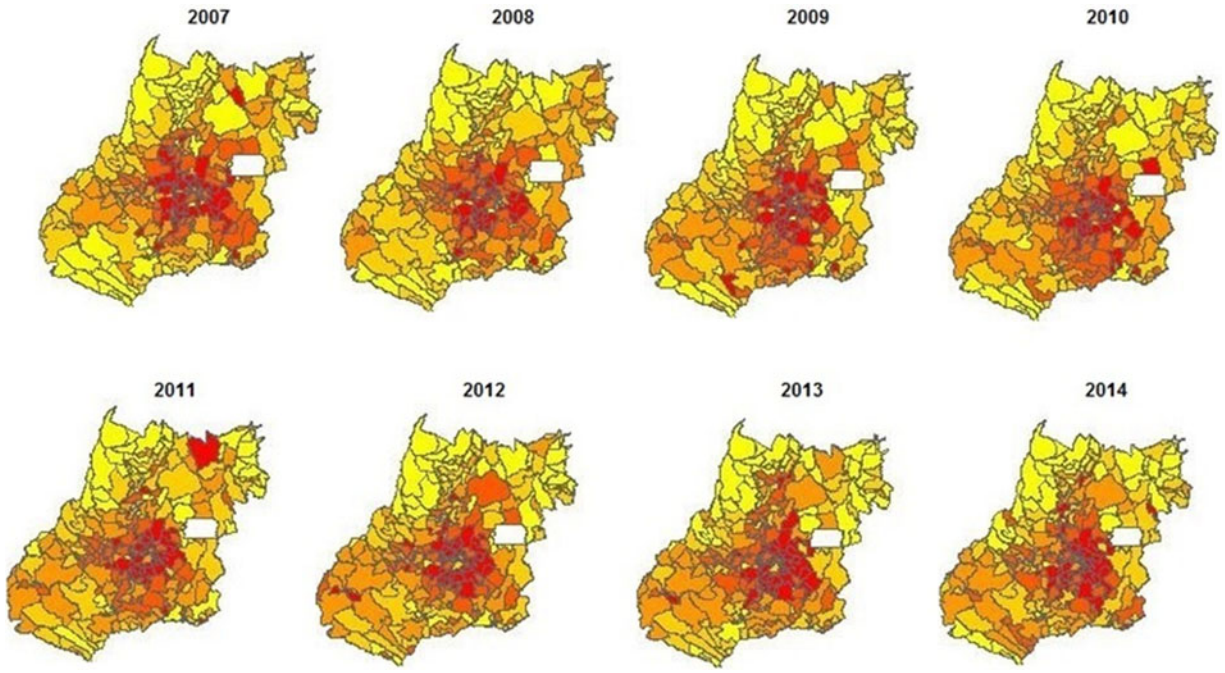

Fig. 3. Spatial distribution of bovine cysticercosis prevalence in municipalities in the state of Goiás, Brazil, through the years 2007–2014.

state of Goiás ranged from US$9 260 728·57 to US $11 313 816·67 due to the presence of unviable and viable cysticercosis, respectively, without considering the economical losses that occur due to beef rendering (100% of discount on paid value).

DISCUSSION

No significant association ($P > 0{\cdot}05$) was found in this study between bovine cysticercosis prevalence in municipalities and epidemiological variables, such as human population density per km^2, HDI, poverty incidence index, cattle population size, area of temporary tillage (ha), grassland area (ha), sugarcane area (ha), farmer condition (seated without definitive title), numbers of residences without sanitary room and municipalities categorized as touristic. The absence of statistical correlation probably occurred due the low variability of values of bovine cysticercosis prevalence in municipalities located in the state of Goiás (ranged from 0·15 to 0·50%) (Table 3) or a homogeneity of the other variable values.

The prevalence value assessed in this study (0·53%; 95% CI 0·5295–0·5354) was higher than that reported by Santos and Moreira (2010) in the state of Minas Gerais, Brazil (0·37%). This difference probably occurred due to differences on data obtaining. These authors used viable cysticerci counting to establish prevalence value, while in our study, the prevalence was 0·23% using the same criteria.

This value (0·53%) was lower than others obtained in several studies (using the same criteria), as those performed by Dutra *et al*. (2012); Silva *et al*. (2012) and Rossi *et al*. (2015). These authors established values of bovine cysticercosis prevalence of 0·78, 3·23 and 0·71%, respectively. It is important to emphasize that these results refers to data obtained in the same state, but these differences are difficult to explain due to differences on the criteria used in other studies, such as sample size and the period.

The prevalence value assessed in this study (0·53%) is lower than the value reported in Brazil (1·05%) (Dutra *et al*. 2012), and in the states of Paraná (2·2%) (Guimarães-Peixoto *et al*. 2012) and São Paulo (4·8%) (Ferreira *et al*. 2014). In the other hand, the prevalence is similar to the value reported in the state of Mato Grosso (0·08%) (Rossi *et al*. 2016), which is located in the same Brazilian region (West-Centre). A possible explanation for this difference of bovine cysticercosis prevalence among the states of Paraná/São Paulo and Mato Grosso/Goiás is the differences on human population density (pop. per km^2). The values in the states of Paraná and São Paulo are 52·4 and 166·2, while it is 3·3 and 17·6 in Mato Grosso and Goiás, respectively. The differences on population size of definitive and intermediate hosts influence *T. saginata* life cycle and bovine cysticercosis prevalence (Rossi *et al*. 2016).

A similarity can be observed comparing the prevalence assessed in this study with those reported in other countries, such as Iran (0·25%) (Khaniki *et al*. 2010), Chile (0·58%) (Faustina *et al*. 2012) and European countries (<1%) (Laranjo-González *et al*. 2016).

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Table 3. Losses (simulation discount of 30–50% off) generated to the rural producers in the state of Goiás by the occurrence of cysticercosis (calcified and alive), from 2007 to 2014

	Simulation of losses caused by cysticercosis											
	Alive cases						Calcified cases					
	No. of cases	Total weight in @[a]	Value of @ (R$)[b]	Value of @ (US$)[c]	30% off (R$)	30% off (US$)	No of cases	Total weight in @[a]	Value of @ (R$)[b]	Value of @ (US$)[c]	50% off (R$)	50% off (US$)
2007	7·479	112·185@	73	23·17	3 004 461·00	953 797·14	9·146	137·190@	73	23·17	4 094 752·50	1 299 921·43
2008	6·064	90·960@	78	24·76	2 977 884·00	945 360·00	8·484	127·260@	78	24·76	3 547 440·00	1 126 171·43
2009	7·088	106·320@	71	22·54	3 367 210·50	1·068 955·71	10·539	158·085@	71	22·54	3 774 360·00	1 198 209·52
2010	6·876	103·140@	92	29·21	4 549 860·00	145 987·30	10·99	164·850@	92	29·21	4 744 440·00	1 506 171·43
2011	6·97	104·550@	92	29·21	3 642 372·00	1 156 308·57	8·798	131·970@	92	29·21	4 809 300·00	1 526 761·90
2012	6·087	91·305@	88	27·94	2 888 028·00	916 834·29	7·293	109·395@	88	27·94	4 017 420·00	1 275 371·43
2013	6·281	94·215@	106	33·65	4 106 016·00	1 303 497·14	8·608	129·120@	106	33·65	4 993 395·00	1 585 204·76
2014	5·506	82·590@	137	43·49	4 635 463·50	1 471 557·71	7·519	112·785@	137	43·49	5 657 415·00	1 796 004·76
Total	52·351	785·265@	–	–	29 171 295·00	9 260 728·57	71·377	1·070·655@	–	–	35 638 522·50	11 313 816·67

[a] Mean body weight of each animal estimated at 15 arrobas (@); total weigh in @ = N. cases * 15@.
[b] Market value for the month of December of the corresponding year – CEPEA, Center for Advanced Studies in Applied Economics – ESALQ/USP http://www.cepea.esalq.usp.br.
[c] Exchange rate: US$1·00 = R$3·15.

The no-detection of bovine cysticercosis in animals slaughtered from two municipalities does not mean a real absence of this disease at these areas due to the low sensitivity of the ongoing model of meat inspection and the practice of slaughter without inspection (illegal), which remains occurring in this state (Lopes *et al*. 2011).

Another important result is the similarity observed in the municipalities in the state of Goiás regarding the prevalence of animals infected with viable and unviable cysticercosis. There is an ideology that the risk for *T. saginata*-cysticercosis occurrence need to be assessed using data of viable cysticerci detection due to animal's movement in several farms during their raising, not allowing to establish in which farm the infection occurred. However, it is important to mention that the areas with higher prevalence of viable and unviable cysticercosis were very similar for evaluation in municipalities (Figs. 2A and B).

Ferreira *et al*. (2014) stated that bovine cysticercosis is not only related to bovine population size but also is closely related to the presence of human beings. The comparison among bovine cysticercosis prevalence (viable and unviable) with cattle distribution in this state is shown in Figs. 4A and B. Besides that, in this study, similarity or tendency between prevalence of bovine cysticercosis and high human population is observed in their spatial distribution as shown in Figs. 4A and C.

Besides the low value of bovine cysticercosis prevalence in the state of Goiás compared with other Brazilian states, this disease causes important economical losses for beef farms and cattle slaughterhouses. Thus, sanitary programmes aiming its control need to be adopted in Brazil. These programmes need to include prophylactic measures useful to control the risk factors reported in Brazil, such as the access to contaminated water or raising of animals in high-populated areas (Ferreira *et al*. 2014; Rossi *et al*. 2015; Rossi *et al*. 2016).

The economical losses due to bovine cysticercosis occurrence in this Brazilian state through 8 years ranged from US$9 260 728·57 to US$11 313 816·67 without considering the economical losses due to rendering of infected carcasses. Furthermore, according to the data published in Annual Report 2015, the Brazilian beef production chain in Brazil generated R$380 billion during 2013 and sale of cattle to slaughter generated R$62·7 billion (BRAZIL, 2014). Comparing these values with the economical losses during 2013 (R$12 million) due to the occurrence of only one disease (bovine cysticercosis) in one low-prevalent Brazilian state (Goiás), allow us to infer that the economical losses are really important for Brazilian beef production chain considering the high prevalence of this disease in other Brazilian states.

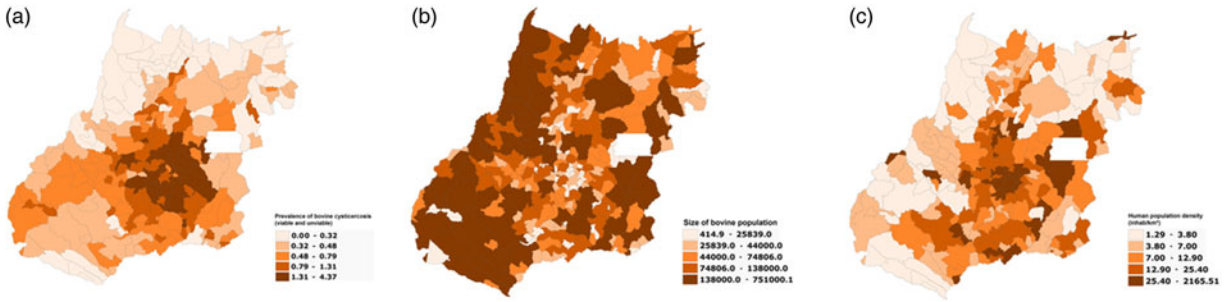

Fig. 4. Spatial distribution of bovine cysticercosis prevalence (a), cattle population size (b) and human population density (c) in municipalities in the state of Goiás, Brazil, through the years 2007–2014.

Concluding remarks

Bovine cysticercosis prevalence in the state of Goiás, Brazil, was 0·53% (95% CI 0·5295–0·5354) from 2007 to 2014. The mesoregions (Central and South) and the microregions Goiânia, Anápolis, Pires do Rio and Vale do Rio dos Bois showed a higher risk for bovine cysticercosis detection. The economical losses ranged from US$9 260 728·57 to 11 313 816·67 due to occurrence of unviable and viable cysticercosis, respectively. These results highlight the importance of meat inspection to improve the knowledge about high-occurrence areas that requires interventions in order to reduce the economical losses for beef production chain.

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