Topic of General Interest

Economic losses due to bovine brucellosis in Brazil[1]

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ABSTRACT.- Santos R.L., Martins T.M., Borges A.M. & Paixão T.A. 2013. **Economic losses due to bovine brucellosis in Brazil.** *Pesquisa Veterinária Brasileira 33(6):759-764.* Departamento de Clínica e Cirurgia Veterinárias, Escola de Veterinária, Universidade Federal de Minas Gerais, Avenida Antônio Carlos 6627, Pampulha, Belo Horizonte, MG 31270-901, Brazil. E-mail: rsantos@vet.ufmg.br

Brucellosis is an important zoonosis of worldwide distribution. Reliable epidemiologic brucellosis data covering approximately 90% of the cattle population in Brazil have been recently published. Therefore, considering the scarcity of information regarding the economic impact of bovine brucellosis in Brazil, the goal of this study was to estimate economic impact of brucellosis on the Brazilian cattle industry. Several parameters including abortion and perinatal mortality rates, temporary infertility, replacement costs, mortality, veterinary costs, milk and meat losses were considered in the model. Bovine brucellosis in Brazil results in an estimated loss of R$ 420,12 or R$ 226,47 for each individual dairy or beef infected female above 24 months of age, respectively. The total estimated losses in Brazil attributed to bovine brucellosis were estimated to be approximately R$ 892 million (equivalent to about 448 million American dollars). Every 1% increase or decrease in prevalence is expected to increase or decrease the economic burden of brucellosis in approximately 155 million Reais.

INDEX TERMS: *Brucella abortus*, brucellosis, cattle, economic losses.

RESUMO.- [**Perdas econômicas devidas à brucelose bovina no Brasil.**] A brucelose é uma zoonose de importância mundial. Recentes dados epidemiológicos dessa doença foram obtidos por meio de estudos que abrangeram em torno de 90% do rebanho bovino do Brasil. Observa-se escassez de informações sobre o impacto econômico causado pela brucelose bovina, portanto, o objetivo do presente estudo foi estimar as perdas econômicas na pecuária brasileira. Gastos relacionados com as ocorrências de abortos, natimortos, subfertilidade, descartes involuntários, mortalidade, intervenções veterinárias, diminuição da produção de leite e de carne, foram considerados nos cálculos. As perdas devidas à brucelose bovina no Brasil foram estimadas em R$ 420,12 ou R$ 226,47 para cada fêmea infectada acima de 24 meses de idade em rebanhos de leite ou corte, respectivamente. O prejuízo total estimado foi de, aproximadamente, R$ 892 milhões (equivalentes a $ 448 milhões de dólares americanos). A cada 1% de variação na prevalência, estima-se a variação de 155 milhões de reais no custo da brucelose bovina no Brasil.

TERMOS DE INDEXAÇÃO: *Brucella abortus*, brucelose, bovino, perdas econômicas.

INTRODUCTION

Brucellosis is an important zoonosis of worldwide distribution. Clinical manifestations of brucellosis are determined by the combination of pathogen and host species since *Brucella* spp. have distinct host preferences (Xavier et al. 2009a, Poester et al. 2013). Most of *Brucella* species are capable of infecting humans, with *B. melitensis* having the highest zoonotic potential (Young 1995) followed by *B. suis* and *B. abortus*. In cattle, brucellosis is mostly caused by *B. abortus* infection (Poester et al. 2013), and it is characterized by abortions during the last trimester of gestation, perinatal mortality, and infertility, whereas bulls can develop orchitis (Carvalho Neta et al. 2010, Poester et al. 2013). Importantly high bacterial loads are present in aborted fetuses and fetal membranes (Xavier et al. 2009b), favoring

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transmission within the herd. In addition, *B. abortus* infection is associated with interstitial, often subclinical, mastitis that is associated with shedding of the organism in the milk (Xavier et al. 2009b), which poses a health hazard for human consumption of unpasteurized dairy products.

The Brazilian National Program for Control and Eradication of Brucellosis and Tuberculosis has recently provided detailed epidemiological data covering most of the cattle population in the country (Poester et al. 2009), including the states of Bahia (Alves et al. 2009), the Federal District (Gonçalves et al. 2009a), Espírito Santo (Azevedo et al. 2009), Goiás (Rocha et al. 2009), Minas Gerais (Gonçalves et al. 2009b), Mato Grosso do Sul (Chate et al. 2009), Mato Grosso (Negreiros et al. 2009), Paraná (Dias et al. 2009b), Rio de Janeiro (Klein-Gunnewiek et al. 2009), Rondônia (Villar et al. 2009), Rio Grande do Sul (Marvulo et al. 2009), Santa Catarina (Sikusawa et al. 2009), Sergipe (Silva et al. 2009), São Paulo (Dias et al. 2009a) e Tocantins (Ogata et al. 2009). In addition, recent epidemiological data from the State of Pará has been included in the present study (Minervino et al. 2011). Together these studies provide epidemiological data covering approximately 90% of the cattle population in Brazil.

Considering the scarcity of information regarding the economic impact of bovine brucellosis in Brazil, with only outdated information available (Brasil 1971), the goal of this study was to estimate economic impact of brucellosis on the Brazilian cattle industry.

MATERIALS AND METHODS

Data sources

Epidemiological data were mostly from prevalence studies from the Brazilian National Program for the Control and Eradication of Brucellosis and Tuberculosis (Poester et al. 2009), with the exception of the State of Pará (Minervino et al. 2011). Data regarding population and categories of cattle in all Brazilian States were obtained from the Instituto Brasileiro de Geografia e Estatística (IBGE 2011). Data regarding Gross Domestic Product (GDP) were obtained from the Centro de Estudos Avançados em Economia Aplicada (CEPEA/ESALQ 2013) and IBGE (2012). Tables 1 and 2 summarize the raw data employed in this study.

Parameters for calculating economic losses

For the purpose of this study, serologically positive cattle were considered infected. Reproductive and productive parameters were based on previously published indicators (Bernués et al. 1997) with minor adaptations as follows: (i) 15% incidence of abortions in infected heifers and cows; (ii) an average of 2 months of temporary infertility for each infected cow and heifer, considering that 20% of cows that aborts become sterile, which has been included in the calculation of replacement costs; (iii) an incidence rate of perinatal mortality of 10% for calves born from infected cows or heifers; (iv) 15% loss of the total milk yield of infected cows; (v) 5% loss in meat production by infected cows; (vi) 1% mortality risk for infected cows that aborted (i.e. 0.15% of infected cows and heifers); (vii) increase in the rate of replacement corresponding to 15% of the infected cows and heifers (the cost was calculated based on the difference of the value received by a slaughtered cow under sanitary conditions and the cost of a replacement cow); and (viii) replacement costs of infected bulls, considering roughly half of the seroprevalence of heifers and cows (as

Table 1. Prevalence of bovine brucellosis per State in Brazil

State	Farm prevalence (%)*	Seropositive prevalence (%)*	Reference
Acre	NA	NA	-
Alagoas	NA	NA	-
Amapá	NA	NA	-
Amazonas	NA	NA	-
Bahia	4.20	0.66	Alves et al. (2009)
Ceará	NA	NA	-
Distrito Federal	2.52	0.16	Gonçalves et al. (2009a)
Espírito Santo	9.00	3.53	Azevedo et al. (2009)
Goiás	17.54	3.01	Rocha et al. (2009)
Maranhão	NA	NA	-
Mato Grosso	41.20	10.20	Negreiros et al. (2009)
Mato Grosso do Sul	41.50	7.93	Chate et al. (2009)
Minas Gerais	6.04	1.09	Gonçalves et al. (2009b)
Pará	ND	10.92	Minervino et al. (2011)
Paraíba	NA	NA	-
Paraná	4.02	1.73	Dias et al, (2009a)
Pernambuco	NA	NA	-
Piauí	NA	NA	-
Rio de Janeiro	15.42	4.08	Klein-Gunnewiek et al. (2009)
Rio Grande do Norte	NA	NA	-
Rio Grande do Sul	2.06	1.02	Marvulo et al. (2009)
Rondônia	35.18	6.22	Villar et al. (2009)
Roraima	NA	NA	-
Santa Catarina	0.32	0.06	Sikusawa et al. (2009)
São Paulo	9.70	3.81	Dias et al. (2009b)
Sergipe	12.60	3.36	Silva et al. (2009)
Tocantins	21.22	4.43	Ogata et al. (2009)

* NA = not available, ND = not determined.

Table 2. Cattle population in Brazil per State and selected categories

State	Cattle population*	Milking cows	Heifers and cows ≥24 months of age (%)**		
			All herds	Beef cattle	Dairy cattle
Acre	2,549,497	71,376	26.82	24.62	1.81
Alagoas	1,268,304	154,893	15.54	8.84	6.01
Amapá	127,499	11,295	43.30	37.97	2.51
Amazonas	1,439,597	126,623	22.77	18.92	2.27
Bahia	10,667,903	2,104,008	19.89	13.93	5.10
Ceará	2,611,712	549,897	12.03	3.67	7.88
Distrito Federal	98,000	19,500	25.40	16.21	8.74
Espírito Santo	2,223,262	408,545	23.49	10.40	12.79
Goiás	21,744,650	2,615,611	30.75	21.09	8.69
Maranhão	7,264,106	591,945	24.59	19.27	3.09
Mato Grosso	29,265,718	633,782	32.25	28.61	2.58
Mato Grosso do Sul	21,553,851	530,463	31.44	29.74	1.22
Minas Gerais	23,907,915	5,631,067	24.52	11.41	12.78
Pará	18,262,547	795,268	30.13	23.24	4.43
Paraíba	1,354,268	259,283	12.14	6.10	5.39
Paraná	9,461,856	1,588,638	20.59	16.33	3.91
Pernambuco	2,502,156	619,919	11.15	4.62	5.77
Piauí	1,688,024	156,232	16.64	13.10	2.17
Rio de Janeiro	2,178,896	427,278	24.02	11.64	12.10
Rio Grande do Norte	1,047,797	262,489	15.03	6.74	7.53
Rio Grande do Sul	14,478,312	1,530,014	25.73	24.15	1.11
Rondônia	12,182,259	989,643	30.09	19.27	10.50
Roraima	651,511	22,707	29.50	17.83	1.95
Santa Catarina	4,039,217	1,021,605	12.83	9.92	2.72
São Paulo	11,024,796	1,452,770	23.77	17.71	5.54
Sergipe	1,178,771	226,927	14.99	9.34	4.80
Tocantins	8,025,400	425,443	33.00	25.79	3.40
Total	212,797,824	23,227,221	26.62	20.18	5.48

* Estimated cattle population for 2011. ** Proportions based on the census of 2006.

observed in the study by Minervino et al. 2011), an average bull/cow ratio of 1/25, and same approach for calculating replacement costs as calculated for females (item vi). Costs associated with veterinary assistance were calculated based on a previous study performed under field conditions in Brazil (Lucas 2006). Importantly, since this study is aimed to estimate losses, but not total cost of bovine brucellosis, in spite of its social importance, costs associated with human health were not considered as well as the costs of the Brazilian National Program for Control and Eradication of Brucellosis and Tuberculosis.

Except when stated otherwise, all estimated costs for dairy cattle were based on values previously reported by Lucas (2006), whereas estimated costs for beef cattle were based on Jorge Jr et al. (2006). Reference values were updated based on current market values of milk and meat for dairy and beef cattle, respectively, which were based on values reported by the Centro de Estudos Avançados em Economia Aplicada (CEPEA/ESALQ 2013) for the month of January 2013. Estimated costs of each parameter are detailed in Table 3.

Table 3. Current estimated costs for each productive parameter for dairy or beef cattle

Parameter	Dairy cattle		Beef cattle	
	Milk (liters)	Reais (R$)	@ steer	Reais (R$)
Cost of abortion or perinatal mortality (unit)	366.44	323,53	1.54	150,50
Cost of temporary infertility (per seropositive cow)	4.01	3,54	0.18	17,59
Cost of Replacement of cows (unit)	815.43	719,94	6.18	603,97
Cost of Replacement of bulls (unit)*	1,223.14	1.079,91	9.27	905,95
Mortality of seropositive cattle (unit)	2,753.64	2.431,18	11.32	1.106,30
Veterinary costs (per seropositive cow)	5.54	4,89	0.043	4,20
Milk production loss (per seropositive cow)	223.85	197,57	-	-
Meat production loss (per seropositive beef cow)	-	-	0.58	56,68

* Due highly variable market values, the cost for replacing bulls was estimated as 150% of the cost of replacement of cows. Sources: modified from Lucas (2006); Jorge Jr et al. (2006); Centro de Estudos Avançados em Economia Aplicada (CEPEA, USP/ESALQ <http://cepea.esalq.usp.br>); and IBGE (2011).

Model

Economic losses were calculated for dairy (ELDC) and beef cattle (ELBC) for each Brazilian State for which comprehensive epidemiological data was available (Poester et al. 2009), according to the following formula:

$$ELDC = Ab_d + Pm_d + Ti_d + Rc_d + Rb_d + Mt_d + Vc_d + M$$

Where:
Ab_d is the cost of abortion in dairy cattle (Ab_d = number of dairy females with age above 24 months X prevalence X 0.15 X 323.53);
Pm_d is the cost of perinatal mortality in dairy cattle (Pm_d = number of dairy females with age above 24 months X prevalence X 0.10 X 323.53);
Ti_d is the cost of temporary infertility in dairy cattle (Ti_d = number of dairy females with age above 24 months X prevalence X 3.54);
Rc_d is the cost of replacement of dairy cows (Rc_d = number of dairy females with age above 24 months X prevalence X 0.15 X 719.94);
Rb_d is the cost of replacement of bulls (Rb_d = number of dairy females with age above 24 months X 1/2 prevalence X 1/25 X 1079.91);
Mt_d is the cost due to mortality of seropositive dairy cows (Mt_d = number of dairy females with age above 24 months X prevalence X 0.15 X 0.01 X 2431.18);
Vc_d is the veterinary costs (Vc_d = number of dairy females with age above 24 months X prevalence X 4.89);
M is milk production loss (M = State annual milk production [according to IBGE, 2011] X prevalence X 0.15 X 0.8829).

$$ELBC = Ab_b + Pm_b + Ti_b + Rc_b + Rb_b + Mt_b + Vc_b + Me$$

Where:
Ab_b is the cost of abortion in beef cattle (Ab_b = number of beef females with age above 24 months X prevalence X 0.15 X 150.5);
Pm_b is the cost of perinatal mortality in beef cattle (Pm_b = number of beef females with age above 24 months X prevalence X 0.10 X 150.5);
Ti_b is the cost of temporary infertility in beef cattle (Ti_b = number of beef females with age above 24 months X prevalence X 17.59);
Rc_b is the cost of replacement of beef cows (Rc_b = number of beef females with age above 24 months X prevalence X 0.15 X 603.97);
Rb_b is the cost of replacement of bulls (Rb_b = number of beef females with age above 24 months X 1/2 prevalence X 1/25 X 905.95);
Mt_d is the cost due to mortality of seropositive beef cows (Mt_d = number of beef females with age above 24 months X prevalence X 0.15 X 0.01 X 1106.30);
Vc_d is the veterinary costs (Vc_d = number of beef females with age above 24 months X prevalence X 4.20);
Me is meat production loss (Me = number of beef females with age above 24 months X prevalence X 56.68).

Linear regression analysis was performed using the GraphPad Instat software version 3.10.

RESULTS

Each infected cow represent an estimate loss of R$ 420,12 or R$ 226,47 in case of dairy or beef cattle, respectively. Total estimated losses in Brazil were estimated to be approxi-

Table 4. Estimated economic losses in dairy and beef cattle in Brazilian states with comprehensive epidemiological data available*

State	Dairy cattle	Beef cattle	Total
Bahia	1.868.296,94	2.321.192,53	4.189.489,48
Distrito Federal	9.463,17	5.859,48	15.322,65
Espírito Santo	4.373.472,08	1.872.869,21	6.246.341,29
Goiás	26.953.925,30	32.282.555,22	59.236.480,52
Mato Grosso	27.784.600,37	199.964.995,36	227.749.595,73
Mato Grosso do Sul	10.228.498,61	116.873.082,42	127.101.581,03
Minas Gerais	20.152.144,28	6.826.750,96	26.978.895,24
Pará	29.961.048,03	114.314.497,85	144.275.545,87
Paraná	10.200.340,57	6.158.942,21	16.359.282,78
Rio de Janeiro	5.122.400,89	2.371.200,97	7.493.601,86
Rio Grande do Sul	5.614.626,90	8.226.209,53	13.840.836,44
Rondônia	23.718.015,07	33.425.186,43	57.143.201,49
Santa Catarina	216.062,40	55.274,52	271.336,91
São Paulo	13.375.114,77	17.227.857,21	30.602.971,98
Sergipe	1.855.085,13	888.414,13	2.743.499,26
Tocantins	4.610.792,96	23.473.875,24	28.084.668,20
Total	186.043.887,48	566.288.763,25	752.332.650,73
Estimated losses in the remaining States**	42.436.663,87	97.947.198,40	140.383.862,27
Estimated total losses in Brazil***	228.480.551,35	664.235.961,65	892.716.513,00

* Values are expressed in Reais (R$), with one American dollar corresponding to R$ 1,99 (exchange rate of January 31st, 2013). ** Pondered average prevalence was applied to cattle population of the remaining states (Acre, Alagoas, Amapá, Amazonas, Ceará, Maranhão, Paraíba, Pernambuco, Piauí, Rio Grande do Norte, and Roraima) considering the proportion of dairy and beef cattle in these states. *** Values adjusted to the remaining States (that do not have comprehensive epidemiological data available) that collectively have 10.57% of the Brazilian cattle population.

mately R$ 892 million (about US$ 448 million), which corresponds to 0.3201% of the 2011 Brazilian GDP referring to animal production or 0.0215% of the 2011 National GDP. Economic losses per state and activity (i.e. dairy or beef cattle) are detailed in Table 4. Total losses and the percentage of loss of the agribusiness GDP per state are illustrated in Figures 1 and 2, respectively. The impact of different components of cost varied among states, which was strongly influenced by both the prevalence of bovine brucellosis and the ratio between dairy and beef cattle (Fig.3).

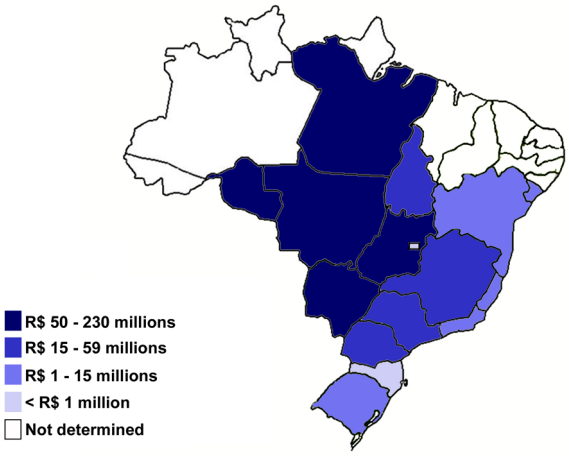

Fig.1. Total estimated economic losses due to bovine brucellosis per state in Brazil.

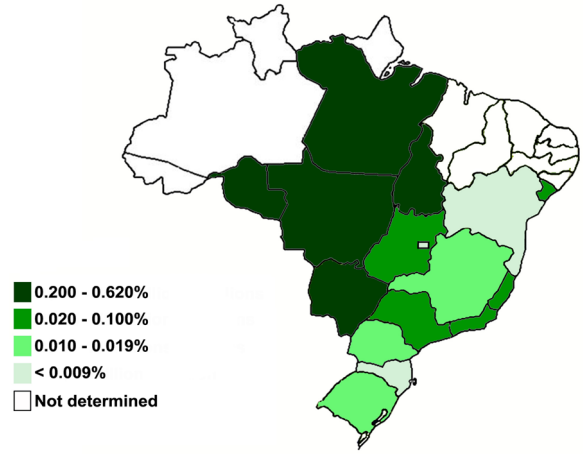

Fig.2. Percentage of losses of the agribusiness Gross Domestic Product (GDP) due to bovine brucellosis per state in Brazil.

Considering the total cattle population in each of the states where epidemiological data were available, a linear regression analysis to predict economic losses as a function of prevalence, resulted in the following best fitted model: [Losses per head (R$) = 0.1864 + 0.7281 x Prevalence (%)]; which has a slope that is statistically significantly different from zero (P<0.0001). This analysis indicates that a one percent increase in prevalence results in roughly an additional loss of R$ 0.73 (seventy three cents of Reais or 0.37 cents of American dollars) per head of cattle in Brazil (Fig.4), which considering the estimated current cattle population in Brazil (Table 2), would result in an additional loss of R$ 154,938,095.65 for each 1% increase in prevalence, and obviously proportional economic gain associated with decrease in the prevalence.

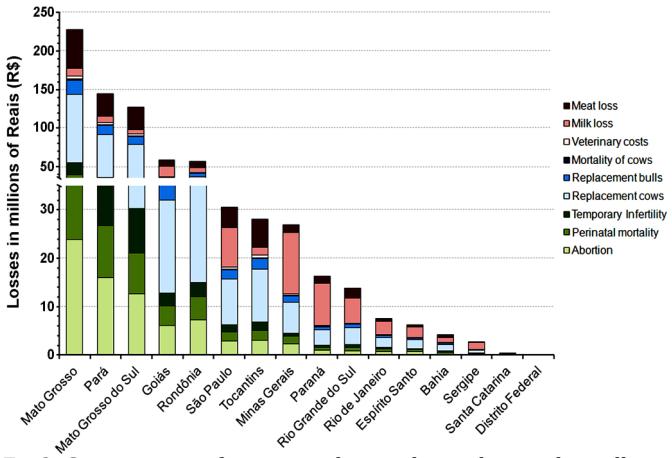

Fig.3. Composition of economic losses due to bovine brucellosis in Brazilian states with available comprehensive epidemiological data (X axis). Different components of economic losses, including abortion, perinatal mortality, temporary infertility, replacement of cows, replacement of bulls, mortality of cows, veterinary costs, milk loss, and meat loss, are indicated.

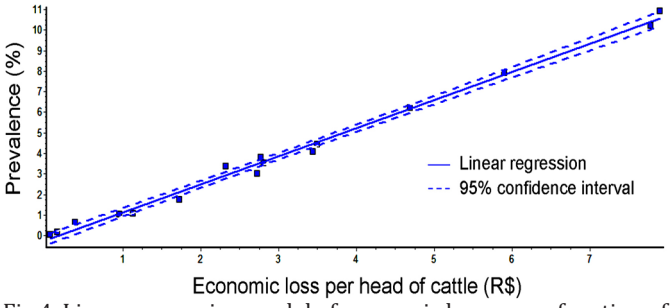

Fig.4. Linear regression model of economic losses as a function of prevalence of bovine brucellosis in Brazil. Solid line indicate the linear regression and the dotted line indicates 95% confidence interval. Data points refer to each one of 16 states for which comprehensive epidemiological data was available. The slope is significantly different from zero (P<0.0001).

DISCUSSION

This study provided a thorough assessment of economic losses associated with brucellosis in Brazil, indicating a heavy economic burden on the national livestock industry, which is a major component of the national GDP. This study is extremely important since previous studies are restricted to the farm level (Lucas 2006) or are completely outdated (Brasil 1971). These data are highly relevant for establishing public policies for control and eradication programs. Brazil has a National Program for Control and Eradication of Brucellosis and Tuberculosis that among other things has recently provided reliable epidemiological data (Poester et al. 2009) that generated the basic data for this study that resulted in a precise estimate of the economic burden imposed by bovine brucellosis in Brazil. An accurate estimate of economic losses due to bovine brucellosis is strategic for planning destination of financial resources for

control programs. Importantly, these losses compromise over 0.3% of the Brazilian GDP fraction generated by animal production, which is highly significant considering that Brazil currently has the largest commercial bovine heard in the world, and the country is a leading beef exporter. Additional parameters for dimensioning the economic impact of bovine brucellosis in Brazil is the fact the total losses of about 892.7 million Reais is roughly equivalent to a little more than one billion liters of milk or more than 500 thousand fattened steers for slaughter.

A comprehensive model was developed in this study, which was based on reliable epidemiological data (Alves et al. 2009, Gonçalves et al. 2009a, 2009b, Azevedo et al. 2009, Rocha et al. 2009, Chate et al. 2009, Negreiros et al. 2009, Dias et al. 2009a, 2009b, Klein-Gunnewiek et al. 2009, Villar et al. 2009, Marvulo et al. 2009, Sikusawa et al. 2009, Silva et al. 2009, Ogata et al. 2009, Minervino et al. 2011), on sound clinical parameters (Bernués et al. 1997), and on scientifically determined economic variables appropriate for dairy (Lucas 2006) or beef cattle (Jorge Jr et al. 2006). This model has an intermediate level of stringency. As previously discussed by Bernués et al. (1997), clinical parameters used in this study (i.e. abortion and perinatal mortality rates, temporary infertility, replacement costs, mortality, veterinary costs, milk and meat losses) are quite conservative when compared to the range previously reported in the literature. The option for electing conservative clinical parameters prevented an overestimation of the actual economic loss.

Losses were strongly influenced by prevalence and production system (i.e. dairy vs. beef cattle). For instance, comparing the states of Minas Gerais and Tocantins, in spite of having strikingly different epidemiological situations, the first with a relatively low prevalence (1.09%) and the second with a high prevalence (4.43%), they have similar levels of economic losses (26.9 vs. 28.0 million Reais, respectively). Interestingly, composition of losses is predominantly due to milk loss in the case of Minas Gerais, while replacement costs are the major component in the case of Tocantins (Fig.2). These differences reflect the fact that Minas Gerais has 5.6 million milking cows that generates approximately 8.7 billion of litters of milk annually (IBGE 2011), whereas Tocantins has only 0.4 million milking cows, producing 0.2 billion of litters of milk annually. Importantly, although the most important clinical manifestation of bovine brucellosis is abortion and perinatal mortality (Carvalho Neta et al. 2010, Xavier et al. 2009b), losses associated with abortion and perinatal mortality do not correspond to a major fraction of the losses in any of the states studied (Fig.3).

Although we elected to develop a highly comprehensive model for this analysis, the model does not cover all variables that could ultimately be strongly influenced by prevalence of bovine brucellosis. For instance, only the cost of vaccination represents additional several million Reais since in 2011 approximately 11.8 million cattle have been vaccinated in Brazil (OIE 2012). Furthermore, possible human infections due to bovine brucellosis have not been precisely assessed in Brazil, where there are scarce reports of human infections, although it has been clearly identified a significant human health issue among risk occupational groups in Brazil (Ramos et al. 2008) since the country is free of *Brucella melitensis*, which reduces the risk of human brucellosis (Poester et al. 2002). Although underreported, human brucellosis in Brazil certainly represents an additional economic burden due to medial costs, although and most importantly, human infections have a major social impact due to decreased productivity and quality of life, and occasionally incapacitation or death.

CONCLUSION

Bovine brucellosis in Brazil results in heavy economic losses to the livestock industry with significant impact on both dairy and beef cattle. These data clearly indicate that appropriate control programs may have an extremely favorable cost/benefit relationship since any decrease in prevalence has a direct effect on the economic burden imposed by the disease. Future studies should address the public health implications of brucellosis.

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