#### **REGULAR ARTICLES**

# *Neospora caninum* causes severe economic losses in cattle in the humid pampa region of Argentina

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Abstract This work estimates the economic losses due to Neospora abortions in the humid pampa region of Argentina. The total dairy and beef cattle population at risk of abortion is 1,771,326 and 9,726,684 head, respectively. In dairy cattle, there was an 8 % risk of experiencing abortion due to a variety of causes, but 16.5 % of them were due to Neospora caninum. The economic losses were estimated at US\$1,865 (range, 1,400–2,331) per abortion, which equates to a total loss of US\$43,607,430 (range, 15,622,600-194,412,390) for the dairy industry at the humid pampa region of Argentina. In beef cattle, the overall risk of abortion was estimated to be 4.5 % for all pregnancies, whereas 6.7 % are specifically due to N. caninum, with an economic loss of US\$440 (range, 150-730) per abortion. This amounts to an annual loss to the beef industry of US \$12,903,440 (range, 1,130,700-42,070,630) in the same area. The results of this study show that Neospora infections and thus abortions cause severe economic impacts in the dairy and beef industries in the humid pampa region of Argentina, which is one the most important areas of cattle production in the world.

**Keywords** *Neospora caninum* · Cattle · Economic losses · Argentina

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#### Introduction

Neosporosis, an abortigenic disease of cattle caused by the protozoan Neospora caninum, is one of the most important causes of reproductive failure worldwide. In Argentina, the disease was first identified by detection of specific antibodies in aborted cows (Venturini et al. 1995). Its presence was later confirmed by immunohistochemistry in aborted bovine fetuses belonging to a dairy farm where an outbreak of abortions was recorded (Campero et al. 1998). Transplacental transmission of N. caninum was demonstrated because specific antibodies were found in 20.2 % of 104 bovine fetuses from slaughterhouses (Venturini et al. 1999). A cross-sectional study carried out on 5,594 dairy and beef heifers and cows showed that animals with a history of abortion were 85 % more likely to be positive to N. caninum than animals without a record of abortion. Also, dairy cattle had increased odds ratio of being N. caninum positive. Replacement dairy heifers were 76 % more likely to be N. caninum positive than beef cows (Moore et al. 2009). Moreover, records of abortions due to N. caninum in beef cattle are also available in the central region on the country named humid pampa (Moore et al. 2003).

The cattle industry has socioeconomic importance in Argentina. The country has 48 million head of cattle being 3.3 million dairy and 44.9 million beef cattle (Ministerio de Agricultura, Ganadería y Pesca de la Nación (MAGyP) 2010). There were 10,100 dairy farms producing 11,600 million L of fluid milk in 2010 (MAGyP 2010). The Argentinean population consumes 43 L and 33 kg of fluid milk and dairy products, respectively, per capita per year. Total exported products reach 307,133 metric tonnes giving an income of US\$756 million. Regarding the beef industry, 40 % of 224,448 producers have less than 100 head of cattle, and 1.3 % have over 2,000 head. The average consumption of beef meat per capita was 60 kg between 2001 and 2010, and US\$1,652,731,000 were earned from exporting

661,378 metric tonnes in 2010 (MAGyP 2010). Ninety-one percent and 45 % of the Argentinean dairy and beef cattle population, respectively, are located in the humid pampa (MAGyP 2010).

Australia and New Zealand (Ellis 1997; Reichel and Ellis 2006), Canada (Chi et al. 2002), Switzerland (Häsler et al. 2006a, b), the Netherlands (Bartels et al. 2006), and USA (Barr et al. 1998; Larson et al. 2004) have all estimated costs associated to *Neospora* infections in cattle; however, the economic impact of bovine neosporosis has been scarcely reported in South America. The aim of this study is to estimate the economic losses due to *Neospora*-related abortions in cattle in the humid pampa of Argentina.

### Materials and methods

## Area and cattle population

The humid pampa, the main agricultural and cattle area of Argentina with approximately 500,000 km<sup>2</sup>, embraces the provinces of Buenos Aires, east of La Pampa, south of Santa Fe, southeast of Córdoba and south of Entre Ríos. The total cattle population was 25,386,846 head on 97,866 farms in 2010 (National Agri-Food Health and Quality Service 2010).

Within the humid pampa, there are ten important dairy areas called: (1) North Abasto, (2) South Abasto, (3) West of Buenos Aires, (4) Mar y Sierras, (5) Centre of La Pampa, (6) Villa María, (7) South of Córdoba, (8) Central of Santa Fe, (9) South of Santa Fe, and (10) south of Entre Ríos (Fig. 1). Ninety-one percent of the total dairy cattle population is in these areas (National Agri-Food Health and Quality Service



**Fig. 1** Dairy areas: *1* North Abasto, *2* South Abasto, *3* West of Buenos Aires, *4* Mar y Sierras, *5* La Pampa, *6* Villa María, *7* South of Córdoba, *8* Central of Santa Fe, *9* South of Santa Fe, *10* South of Entre Ríos and the main beef cattle-raising region: *A* Salado river basin

2010). The number of dairy herds, average size (number of cows plus heifers), and the total dairy cattle at risk, based on their pregnancy status according to the National Agri-Food Health and Quality Service (2010), are shown in Table 1.

Within the humid pampa is the main beef cattle-raising region of the country, which is named the Salado river basin (Fig. 1). With an approximate area of 7 million ha, this basin constitutes the most important agricultural activity with five million cattle (cows, heifers, steers, calves and bulls) managed under pastoral systems (National Agri-Food Health and Quality Service 2010). The remaining female beef cattle are out of this basin but spread all over the humid pampa. The number of beef herds, average size (number of cows plus heifers) and the total beef cattle at risk based in the pregnancy rate according to the National Agri-Food Health and Quality Service (2010) are shown in Table 1.

Economic losses: rationale for the estimation

Current values were provided by five private veterinarians (telephone survey) and market prices published at two national newspapers during 2010. Costs involved fetal loss (including hormonal treatment for oestrus synchronization, artificial insemination for the breeding and professional assistance), laboratory diagnosis, reduced milk yield associated to abortion (the loss of total milk yield was assumed), the replacement of the aborted culled cow by a pregnant heifer and the returns for selling the culled cow for dairy and beef systems (Table 2). To estimate a range of the costs, two options were included: (1) the aborted cow is not sold, and the replacement heifer is not bought, and (2) the replacement heifer is bought, but there are returns by selling the aborted (Table 2).

For dairy cattle, the annual abortion rate was estimated to be 8 %, ranging from 5 to 12.9 % according to different sources (MAGyP 2010; Morrell 2010; National Agri-Food Health and Quality Service 2010). For beef cattle, the annual abortion rate was estimated to be 4.5 %, ranging from 2.5 to 7.5 % and varying at farm level and the source (Maresca et al. 2007; MAGyP 2010). Either for dairy or beef cattle, the mentioned variability in annual abortion rates did not show any increasing or decreasing trend over time (Maresca et al. 2007; MAGyP 2010; Morrell 2010; National Agri-Food Health and Quality Service 2010). For the estimation, the

 
 Table 1 Dairy and beef cattle at risk of experiencing a Neosporarelated abortion in the humid pampa

Cattle	Herds (n)	Average of cows+ heifers (n)	Pregnancy rate (%)	Cattle at risk ( <i>n</i> )
Dairy	9,754	227	80	1,771,326
Beef	88,112	133	83	9,726,684

Table 2	Estimated	direct and	indirect co	osts of N.	caninum	abortions i	n beef	and dairy	cows in the	humid pampa
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	Dairy (US\$)		Beef (US\$) <sup>a</sup>		
	Option "A"	Option "B"	Option "A"	Option "B"	
Fetal loss	250	250	150	150	
Professional assistance	Not done	50	Not done	50	
Laboratory diagnosis		140		140	
Pregnant heifer replacement	Not replaced	1,441	Not replaced	950	
Loss of milk yield associated with/due to abortion	1,150 <sup>b</sup>	Milk yield from the heifer	_	_	
Proceeds from selling cow in good body condition	Not sold	450	Not sold	560	
Total US\$	1,400	2,331	150	730	
Mean		1,865		440	

<sup>a</sup> There were no data related to the costs associated with the time lost in the production of beef calves due to delays in replacing culled affected animals with new pregnant heifers

<sup>b</sup> Mean of losses associated with the loss of milk yield due to abortion in heifer or cow (17.1 L×US\$0.22×305 days—milk yield)

median of these values were considered (Table 3). Cost estimates were calculated through the lowest to the highest estimate of total and specific *N. caninum* abortion risk.

The risk of abortion due to N. caninum was calculated using records belonging to the Veterinary Diagnostic Laboratories at INTA Balcarce from 1994 to August 2007 (Campero et al. 2003; Moore et al. 2008; Morrell 2010). According to these records, there were not any significant temporal variations in the proportions of causative agents involved in the abortions (Morrell 2010). The presence of histological lesions compatible with Neospora infections and further identification of the parasite by immunohistochemistry were the criteria for the final diagnosis as was previously mentioned by Campero et al. (2003). The median was calculated from the following proportions for dairy and beef aborted fetuses, respectively: 16.5 % of 115 and 3.1 % of 226 specimens (Campero et al. 2003), 12.6 % of 175 and 7.9 % of 442 specimens (Moore et al. 2008) and 36.5 % of 33 and 6.7 % of 97 specimens (Morrell 2010).

## Results

The total dairy and beef cattle population at risk of abortion in the humid pampa was 1,771,326 and 9,726,684 head, respectively. The economic loss per abortion for dairy and beef cattle, respectively, was estimated to amount to US \$1,865 (range, 1,400–2,331) and US\$440 (range, 150–730) (Table 2).

In dairy cattle, it was estimated that there was an 8 % (range, 5–12.9 %) risk of suffering abortion from all causes, but 16.5 % (range, 12.6–36.5 %) of these were due to *N. caninum*. The economic losses were estimated at US\$1,865 (range, 1,400–2,331) per abortion, which equals to a total loss of US\$43,607,430 (range, 15,622,600–194,412,390) for the dairy industry in the humid pampa.

Similarly, with over nine million beef cattle in the humid pampa at risk, with an overall risk of abortion of 4.5 % (range, 2.5–7.5 %) for all pregnancies, and 6.7 % (range, 3.1–7.9 %) of this due to *N. caninum* and an estimated economic loss of US\$440 (range, 150–730) per abortion, this equates to an annual loss for the beef industry of US \$12,903,440 (range, 1,130,700–42,070,630). Economic loss estimation for dairy and beef cattle in the humid pampa is shown in Table 3.

Finally, considering the average number of females and the pregnancy rate at dairy and beef farm level (Table 1), the medians in percentages for the total abortion risk and for *Neospora*-related abortion and the estimated cost per abortion (Table 3), a range of economic losses at dairy and beef farm levels, are estimated (Table 4). On individual dairy farms, estimated losses due to *N caninum* abortions ranged

Table 3 Estimated economic losses due to N. caninum-related abortions in dairy and beef cattle in the humid pampa of Argentina

Cattle	Cattle at risk ( <i>n</i> )	Median total abortion risk (%) (range)	Median abortion risk by <i>N. caninum</i> (%) (range)	Median number of abortions due to <i>N</i> . <i>caninum</i> ( <i>n</i> ) (range)	Mean cost per abortion (US\$) (range)	Estimated economic losses (US\$) (range)
Dairy	1,771,326	8 (5.0–12.9)	16.5 (12.6–36.5)	23,382 (11,159–83,403)	1,865 (1,400–2,331)	43,607,430 (15,622,600–194,412,390)
Beef	9,726,684	4.5 (2.5–7.5)	6.7 (3.1–7.9)	29,326 (7,538–57,631)	440 (150–730)	12,903,440 (1,130,700–42,070,630)

 Table 4
 Estimated economic losses due to N. caninum abortions per dairy and beef farm in the humid pampa of Argentina

	Female cattle per farm	Female cattle at risk	Lowest cost estimate (US\$)	Median cost estimate (US\$)	High cost estimate (US\$)
Dairy	227	182	1,592.50	4,480.48	19,975.43
Beef	133	110	12.79	145.93	475.78

from a low of US\$1,592.50 to a high estimate of US \$19,975.43, with a median value of US\$4,480.48. For the average-sized individual beef farms, estimated losses reached a median of US\$145.93 (range from US\$12.79 to US\$475.78).

### Discussion

This paper estimates the severe economic impact of Neosporarelated abortions in the beef and dairy cattle industries in the humid pampa of Argentina, which is one the most important area of cattle production in the world. In other countries with large cattle industries, economic losses due to neosporosis have previously been reported (Reichel 2000; Barr et al. 1998; Chi et al. 2002; Häsler et al. 2006a, b; Bartels et al. 2009). In Argentina, 9 and 55 % of the dairy and beef cattle, respectively, are located outside of the humid pampa (MAGyP 2010). If this rationale for the estimation of economic losses due to N. caninum is extrapolated to the whole country, Neospora-related abortions may cause a hypothetically economic lose of over US \$50 million in both dairy and beef cattle. Unfortunately, there are no data from diagnoses of bovine abortions from the subtropical or southern regions of Argentina to assist with this extrapolation. Furthermore, there are differences in values such as loss in the milk yield due to abortion, lack of values to replace a heifer or salvage value for culling a cow.

Over 50,000 dairy and beef calves could be lost by neosporosis every year in the humid pampa. By controlling neosporosis in cattle, there may be an increased production of fluid milk and dairy products, and beef meat. That offer will be easily taken by the Argentinean population since the consumption of fluid milk and dairy products is going up since the last decade (MAGyP 2010). Between 2001 and 2010, the consumption of beef meat has been stable within the Argentinean population (MAGyP 2010), but any increased production could be exported with profits for the country.

The high economic losses for the dairy industry compared with the beef industry are associated with the high value of milk production versus beef production. However, not only the prevalence of infection but also the proportions of *Neospora*-related bovine abortions (Campero et al. 2003; Moore et al. 2002, 2008, 2009) had an important impact in this assessment. Horizontal transmission causing Neospora-related abortions could be more frequent in dairy cattle because they are more intensively reared than beef cattle (Moore et al. 2009). Genetic predisposition to suffer deleterious effects from neosporosis has been suggested in Spain where pure dairy breeds are more likely to have Neospora-related abortions than beef breeds (Santolaria et al. 2011). However, similar genetic studies have not been performed in Argentina yet. On the other hand, more intensive management is carried out among beef farmers because extensive growing of crops has limited the area for beef cattle. Management practices like supplementation, higher stocking rate, earlier age of mating or concentration of females at calving may increase the postnatal transmission of Neospora infections in Argentinean beef cattle. The lower economic losses for the beef industry compared with the dairy industry may be due to a miscalculation in the estimation performed in this study. There was an incomplete representation of all of the costs that producers could incur from abortions. For instance: (1) increased labour and management costs incurred in the culling and replacement of affected animals and (2) time lost in the production of beef calves due to delays in replacing culled affected animals with new pregnant heifers.

At the individual farm level, losses on beef farms appear generally low, not exceeding US\$500 per annum even at the upper range of the estimates. This may make it difficult to communicate the estimated losses of *N. caninum* abortions to individual farmers. On the average-sized dairy farms in the humid pampa, estimated losses due to *N. caninum* abortions, even for low estimates of abortion risk and specific *Neospora* abortion contribution, exceed US\$1,500 and may reach as high as almost US\$20,000 if high estimates are assumed. The median estimates for losses at the dairy farm level (of US \$4,480.00) should easily be able to be communicated to farmers and raise their interest in control measures (Reichel et al. 2013).

Hygienic measures or culling infected animals has been proposed to control the disease (Dubey et al. 2007). Despite their low efficacy, inactivated vaccines should be used because they will still have preventive effects under epizootic Neospora-related abortions (Romero et al. 2004; Bartels et al. 2006; Weston et al. 2011). In the New Zealand and Australian dairy situation, a control strategy of "no intervention" has been reported as the optimal economic choice up to a within-herd prevalence of 18 or 21 % over a 1- or 5-year horizon, respectively (Reichel and Ellis 2006). However, if herds with low prevalence of infection experience postnatal exposure, epizootic abortions may occur (McAllister et al. 2000). Each country needs to state clearly what strategy private veterinarians should follow. The use of inactivated vaccine must be revaluated because it could provide some economic benefits by using it in farms where postnatal transmission is frequent (Moré et al. 2009; Moore et al. 2009). Others may use a live vaccine under governmental controlled

conditions. The animal health national organisations must evaluate local risk factors for limiting the severe economic losses from neosporosis in cattle.

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**Conflict of interest** None of the authors of this paper have a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of this article.

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