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REGULAR ARTICLES

Estimating the total economic costs of *Neospora caninum* infections in dairy cows in Turkey

Pınar Ayvazoğlu Demir[1] · Funda Eşki[2] · Armağan E. Ütük[3]

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Abstract

The aim of this study was to estimate the total cost of *Neospora caninum* infection in cows in Turkey. According to present literature, the mean seroprevalence of infection was estimated as 14.7%. The seropositivity rate of *N. caninum* in aborted cows was found to be 18%. The financial costs were estimated in US$ at 2019 prices. The total cost of *N. caninum* infection was estimated at US$710 (438–1043) per a dairy cow and the annual economic costs were estimated at US$40.5 (24.6–60.3) million for Turkey. In this study, the distribution of economic costs caused by neosporosis per cow was determined to be 67.3% for abortion, 16.8% prolonged calving interval, 4.6% milk loss, 3.5% additional artificial insemination, and 7.7% veterinary and diagnostic costs, respectively. All studies that have been conducted so far on Neosporosis are focused on the prevalence and the diagnosis of the disease in Turkey. In this study, we firstly determined the economic costs due to *N. caninum* infections and try to attract attention on the economic impacts of the disease. As a result, awareness among breeders regarding the epidemiology, control, and eradication of neosporosis should be raised through training activities; coordination between the relevant institutions and organizations should be ensured; emergency action plans should be prepared; and further spread of the disease should be prevented.

Keywords *Neospora caninum* · Economic costs · Dairy cow · Turkey

Introduction

Neospora caninum, one of the most important infectious abortifacient protozoer agents in cows, causes big economic losses in beef and dairy industry worldwide (Khan et al. 2019). In addition to abortion, economic impact of disease is increased due to fetal death, resorption, mummification, stillbirth, decrease in milk yield, infertility, premature culling and slaughtering, and veterinary costs (Hall et al. 2005; Dubey et al. 2007; Reichel et al. 2013; Eşki and Ütük 2018).

Abortion is the primary problem caused by *N. caninum* at cattle farms. Particularly, the economic costs are directly associated with the value of aborted fetuses. Additional inseminations, potential milk losses, professional help, and replacement of culled animals are among the other direct costs associated with *N. caninum* (Dubey 2003; Haddad et al. 2005).

Although there are few data on the exact losses expressed in USD, some estimates report the annual losses as 546.3 million dollars in dairy and 114.4 million dollars in beef industry in the USA (Reichel et al. 2013).

To the best of our knowledge, there is no study on the direct and indirect economic losses due to the *N. caninum* infections in Turkey. The aim of this study was to determine the estimated economic losses of neosporosis in dairy industries in Turkey, to highlight this aspect of the disease, and to emphasize its importance once again.

Materials and methods

In estimating economic costs due to neosporosis in Turkey, the data related to the number of animals under risk and the prevalence of *N. caninum* according to regions were used (Table 1).

✉ Funda Eşki
fndeski@hotmail.com

[1] Faculty of Veterinary Medicine, Department of Livestock Economics and Management, Kafkas University, 36100 Kars, Turkey

[2] Faculty of Ceyhan Veterinary Medicine, Department of Obstetrics and Gynecology, Cukurova University, 01330 Adana, Turkey

[3] Faculty of Ceyhan Veterinary Medicine, Department of Parasitology, Cukurova University, 01330 Adana, Turkey

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The overall prevalence of *N. caninum* in Turkey was specified based on the current literature by using the PubMed, WOS (Web of Science), and Google scholar browsers, and the list of literature is presented in Table 1. The mean seroprevalence of the *N. caninum* and the seropositivity rate of *N. caninum* in aborted cows were calculated from the results of reported studies conducted in different regions of Turkey.

In this study, the loss of fetus due to abortion and the possible costs incurred after abortion were calculated. Therefore, the direct economic costs due to *N. caninum* were estimated as lost from aborted fetus, loss of milk production (Thurmond and Hietala 1997; Barling et al. 2000), prolonged calving intervals (measured in days) (Bartels et al. 2006), additional inseminations costs (Hall et al. 2005; Dubey et al., 2017), and veterinary and diagnostic test costs. However, other losses such as professional help and replacement of culled animals during in *N. caninum* infection have not been estimated. Economic costs were estimated over a 1-year period. The total annual economic costs were estimated at the country level and per a dairy cow. Calculation methods for the estimated economic costs are presented in Table 2. SPSS 16 package program and 2019 current dollar rates were used.

In this study, the total cost (C) of *N. caninum* was calculated by using the below mentioned formula (adapted from Bartels et al. (2006), Reichel et al. (2013), and Demir et al. (2019)):

$$\sum = X_1 + X_2 + X_3 + X_4 + X_5$$

The details of the production and financial data used in the estimation of the economic costs due to *N. caninum* and their references were presented in Table 3.

The secondary data collected from international literature was used in order to evaluate the economic losses caused by the infection in a sound manner. Additionally, in this study, the average values obtained from the interviews conducted with five veterinarians (through Delphi survey) were also used in the estimation of the economic costs.

N. caninum-induced abortion are the most common in the 5th to 7th months of pregnancy (Dubey et al. 2006) and aborted cows are expected to miss one lactation. Therefore, the abortion costs are calculated by deducting the slaughtered cow value (US$147) from the dairy cow value (cows in lactation) (US$1957) (Reichel et al. 2013).

According to the data published by the Turkish Statistical Agency, the annual average milk production in Turkey is 3.100 kg/head. Based on this, the average milk loss associated with the infection was calculated as approximately 107 kg (min 92; max 122) within one lactation period in Turkey.

In the Delphi survey, it was reported that the average cost of artificial insemination was $10.4 per cow and the additional insemination cost was calculated to be $25 per cow.

No vaccination is applied against *N. caninum* in Turkey, and thus, the vaccination costs were not calculated.

Results

In cattle, mean seroprevalence of *N. caninum* was reported earlier as 14.70% (1.672/11.373) and ranging from 0 to 67% with respect to the different regions, and the seropositivity of *N. caninum* was determined based on earlier reports as 18% (862/4782) (min 0; max 53%) in aborted cows. The economic analyses were made based on the production and financial parameters shown in Table 2. The estimated economic cost per cow and the total cost for Turkey were presented in Table 4.

When we examine Table 4, the total estimated annual economic costs were determined as US$710 per cow and its impact on Turkish economy was US$40.5 (24.6–60.3) million. The distribution of estimated economic costs is presented in Fig. 1.

Discussion

To date, the majority of studies on *N. caninum* in cattle have focused on the prevalence of the disease, but revealing the economic losses caused by the disease with the numbers will contribute to a better understanding of the disease's importance and raising awareness on the subject.

The prevalence of neosporosis varies considerably between continents, countries, and regions (Dubey et al. 2007). In this study, the seropositivity of the agent was reported earlier as 14.7% (1.672/11.373) in dairy and 18% (862/4782) in aborted cattle in Turkey. According to these results, we could see that the mean seroprevalence of *N. caninum* (14.7%) in Turkey is lower than the mean seroprevalence of the world (20–22.9%) (Ribeiro et al., 2019), but close to the Asian (14.8%) and African (16.1%) countries (Eşki and Ütük 2018). To the best of our knowledge, there is no study on the economic impacts of neosporosis in Turkey.

In *Neospora* infections, the economic costs are directly associated with the value of abortion, fetal death, and stillbirths. Reduction of milk yield, expenses for veterinary and laboratory diagnosis, prolonged calving intervals, and additional inseminations are the causes of other direct losses, and these parameters increase the total cost in the long periods during the disease (Dubey 2003; Haddad et al. 2005; Reichel et al. 2013; Eşki and Ütük 2018). In this study, the direct losses were taken into account and our results were in parallel with the results of Haddad et al. (2005) and Dubey et al. (2007). However, the production differences due to different races, different flock management practices and feeding systems, and possible infection-related losses were not considered in calculating the economic costs.

Although it is a controversial concept, the milk production is generally adversely affected in dairy cows due to neosporosis (Liu et al. 2020), and in seropositive cows, the

Table 1 Literature about *Neospora caninum* in Turkey

Province	Test	No. tested	No. positive	% Positive	Abortion No. tested	Abortion No. positive	% Abortion rate	Reference
Burdur	cELISA	400	21	5.25%	49	8	16%	Adanir et al. (2015)
Burdur	cELISA	91	20	21.98%			NA	Öcal et al. (2014)
Adana	cELISA	225	24	10.67%			NA	Eski and Ütük. (2018)
Adana	cELISA	16	4	25.00%	16	4	25%	Erol et al. (2019)
Sakarya	cELISA	92	10	10.87%			NA	Öncel and Biyikoğlu, 2003
Tekirdağ	ELISA	124	7	5.65%			NA	Bıyıkoğlu et al. (2003)
Kırklareli	ELISA	150	15	10.00%			NA	Bıyıkoğlu et al. (2003)
Kırklareli	cELISA	25	4	16.00%	25	4	16%	Erol et al. (2019)
Bursa	cELISA	104	20	19.23%	52	12	23.10%	Eşki et al. (2016)
Bursa	cELISA	33	3	9.09%	33	3	9.09%	Erol et al. (2019)
Istanbul	cELISA	8	0	0.00%	8	0	0.00%	Erol et al. (2019)
Sakarya	cELISA	4	0	0.00%	4	0	0.00%	Erol et al. (2019)
Tekirdağ	cELISA	20	8	40.00%	20	8	40.00%	Erol et al. (2019)
Afyonkarahisar	cELISA	485	102	21.03%	62	32	51.60%	Çelik et al. (2013)
Denizli	cELISA	3	0	0.00%	3	0	0.00%	Erol et al. (2019)
Izmir	cELISA	13	3	23.08%	13	3	23.08%	Erol et al. (2019)
Manisa	cELISA	10	1	10.00%	10	1	10.00%	Erol et al. (2019)
Muğla	cELISA	100	32	32.00%	100	32	32.00%	Erol et al. (2019)
Kayseri	cELISA	186	13	6.99%	9	3	33.30%	İça et al. (2006)
Ankara	ELISA	453	46	10.15%			NA	Vural et al. (2006)
Ankara	cELISA	14	1	7.14%	14	1	7.14%	Erol et al. (2019)
Eskişehir	ELISA	387	21	5.43%	387	21	5.43%	Vural et al. (2006)
Çankırı	ELISA	418	29	6.94%	418	29	6.94%	Vural et al. (2006)
Kırıkkale	ELISA	434	142	32.72%	434	142	32.72%	Vural et al. (2006)
Kırşehir	ELISA	409	80	19.56%	409	80	19.56%	Vural et al. (2006)
Yozgat	ELISA	369	75	20.33%	369	75	20.33%	Vural et al. (2006)
Nevşehir	ELISA	392	20	5.10%	392	20	5.10%	Vural et al. (2006)
Kayseri	ELISA	425	46	10.82%	425	46	10.82%	Vural et al. (2006)
Aksaray	ELISA	261	91	34.87%			NA	Öcal et al. (2014)
Aksaray	cELISA	307	162	52.77%	307	162	52.77%	Erol et al. (2019)
Niğde	cELISA	264	70	26.52%			NA	Karatepe and Karatepe (2016)
Kırşehir	cELISA	116	21	18.10%	18	6	33.30%	Yıldız et al. (2017)
Kırşehir	cELISA	4	0	0.00%	4	0	NA	Erol et al. (2019)
Çankırı	cELISA	11	1	9.09%	11	1	9.09%	Erol et al. (2019)
Eskişehir	cELISA	8	3	37.50%			NA	Erol et al. (2019)
Kırıkkale	cELISA	147	23	15.65%	147	23	15.65%	Erol et al. (2019)
Kırıkkale	cELISA	75	50	66.67%			NA	Öcal et al. (2014)
Bingöl	cELISA	149	7	4.70%	32	1	3.12%	Aktaş et al. (2005)
Elazığ	cELISA	120	18	15.00%			NA	Aktaş et al. (2005)
Malatya	cELISA	100	4	4.00%			NA	Aktaş et al. (2005)
Muş	cELISA	144	7	4.86%			NA	Aktaş et al. (2005)
Kars	ELISA	301	6	1.99%	73	6	8.20%	Akca et al. (2005)
Kars	cELISA	1.100	79	7.18%			NA	Mor and Akca (2012)

Table 1 (continued)

Province	Test	No. tested	No. positive	% Positive	Abortion No. tested	Abortion No. positive	% Abortion rate	Reference
Kars	cELISA	304	17	5.59%	304	17	5.59%	Mor et al. (2011)
Elazığ	cELISA	183	15	8.20%			NA	Simsek et al. (2008)
Van	cELISA	450	22	4.89%			NA	Alan et al. (2011)
Erzurum	cELISA	385	41	10.65%	47	10	21.27%	Balkaya et al. (2012)
Erzurum	cELISA	3	0	0.00%	3	0	0.00%	Erol et al. (2019)
Erzincan	cELISA	11	0	0.00%	11	0	0.00%	Erol et al. (2019)
Malatya	cELISA	6	1	16.67%	6	1	16.67%	Erol et al. (2019)
Şanlıurfa	cELISA	305	23	7.54%			NA	Sevgili et al. (2005)
Siirt	cELISA	2	0	0.00%	2	0	0.00%	Erol et al. (2019)
Şanlıurfa	cELISA	201	67	33.33%	201	67	33.30%	Erol et al. (2019)
Samsun	cELISA	224	51	22.77%			NA	Kaya et al. (2011)
Bartin	cELISA	2	0	0.00%	2	0	0.00%	Erol et al. (2019)
Çorum	cELISA	5	2	40.00%	5	2	40.00%	Erol et al. (2019)
Kastamonu	cELISA	23	2	8.70%	23	2	8.70%	Erol et al. (2019)
Samsun	cELISA	10	2	20.00%	10	2	20.00%	Erol et al. (2019)
farm vet	cELISA	134	47	35.07%	90	22	24.44%	Pişkin and Ütük (2009)
Kırıkkale. İzmir. Tokat	cELISA	557	60	10.77%	234	16	6.83%	Yildiz et al. (2009)
Turkey	cELISA	71	33	46.48%			NA	Kul et al. (2009)
Total		11.373	1672	14.7%	4782	862	18.0%	

predicted milk losses were mentioned as 3–4% (Hernandez et al. 2001). If the milk yield loss was associated with abortion, this rate was expressed as 28% per cow (Bartels et al. 2006). Using this data, the average milk losses were estimated as 107 kg/cow in one lactation period in Turkey. In another study (Thurmond and Hietala, 1997), the average milk loss was estimated as 384 kg/cow, which is higher than our estimate (107 kg/cow). This difference may be associated with the low average milk production per a dairy cow in Turkey.

Today, there is no treatment and control method available and effective against neosporosis (Goodswen et al. 2013). In New Zealand and Costa Rico, vaccination was tried for the control of the disease; however, this was later abandoned due to its low effect and increased risk of embryonic death (Khan et al. 2019). On the other hand, the majority of the studies conducted in Turkey are directed towards determining the prevalence of the disease in cattle, not for the purposes of protection and control.

No vaccination is applied against *N. caninum* in Turkey, and thus, the vaccination costs were not calculated. However, it is determined that aborted cows are treated against secondary infections and additional diagnostic tests are conducted

Table 2 Economic cost calculation method of *N. caninum* in Turkey

Effect (E)	Calculation methods
Cost of abortion (x_1)	Population size (N) × Infection rate (IR) × (value of Dairy cow in Lactation period (LD) − Slaughtered cow value (SC))
Loss of milk production (x_2)	Population size (N) × Infection rate (IR) × Loss of milk yield per cow (LM) × Price of milk (PM)
Prolonged calving interval (x_3)	Population size (N) × Infection rate (IR) × Prolonged calving intervals days per cow (EC) × Cost per day (CD)
Extra insemination (x_4)	Population size (N) × Infection rate (IR) × Extra inseminations per cow (EI) × Cost of extra inseminations (CI)
Costs of veterinary service and diagnostic test (x_5)	[Treated cattle per year (TC) × Cost per treatment (CT)] + [Treated cattle per year (T) × Cost per test (C)]

Table 3 Description of input variables used in the estimation of the economic costs due to *N. caninum* in Turkey

Variable	Value	References
1. Production parameters		
-Total number of dairy cattle	9,682,621	TUİK (2019)
-Daily milk production (kg/cow/day)	10 kg	Calculation of TUİK (2019)
-Reduction in milk yield	3.5 (3–4)%	Hernandez et al. (2001)
-Mean pregnancy rate in Turkey	75%	Gündal Çörekçi et al. (1996); Soydan and Kuran, 2002
-Total number of pregnant (cow or heifer)	7.261.966	Calculation of TUİK (2019)
-Mean abortion rate in Turkey (%)	4.7 (0.43–8-.90)	Gülümser (2011)
-Mean N. caninum prevalence (%)	18.0 (0.0–53-.0)	Calculated
-Mean calving interval in Turkey (day)	420 (400–4-50)	Expert opinion
-Prolonged calving intervals (day)	72.0 (3–105)	Bartels et al. (2006)
-Extra inseminations	2.4 (1.8–3.-9)	Muñoz-Zanzi et al. (2004); Hall et al. (2005); Dubey (2017)
2. Financial parameters		
-Price of milk (US$/kg)	0.30	USK (2019)
-Cost of abortion (per cow)	478 (348–6-96)	Calculation of TUİK (2019)
-Cost of prolonged calving intervals (US$/day)	1.66	Bartels et al. (2006)
-Cost of inseminations (US$/head)	10.4 (8.7–17-.4)	Expert opinion
-Veterinary services (US$/head)	48 (35–61)	Expert opinion
-Diagnostic test (US$/head)	7	Republic of Turkey Ministry of Agriculture and Forestry, Veterinary Control Central Research Institute

5.75 TL = 1 US$ in 2019 year

Table 4 The total cost of *N. caninum* per infected cow in Turkey

Effect	Estimation cost per cow (US$)	Mean Estimation cost in Turkey (US$)	Minimum Estimation cost in Turkey (US$)	Maximum Estimation cost in Turkey (US$)
Cost of abortion (x_1)	478.3 (347.8–696.0)	29.382.545	21.369.124	42.759.616
Loss of milk production (x_2)	32.5 (27.9–37.2)	1.996.010	1.710.865	2.281.154
Prolonged calving intervals (x_3)	119.5 (4.98–174.3)	7.342.858	305.952	10.708.335
Extra insemination (x_4)	25.0 (15.7–67.8)	1.538.577	961.611	4.169.063
Veterinary services and diagnostic test (x_5)	55 (42–68)	337.899	255.361	417.766
Total cost	710 (438–1043)	40.597.889	24.602.913	60.335.934

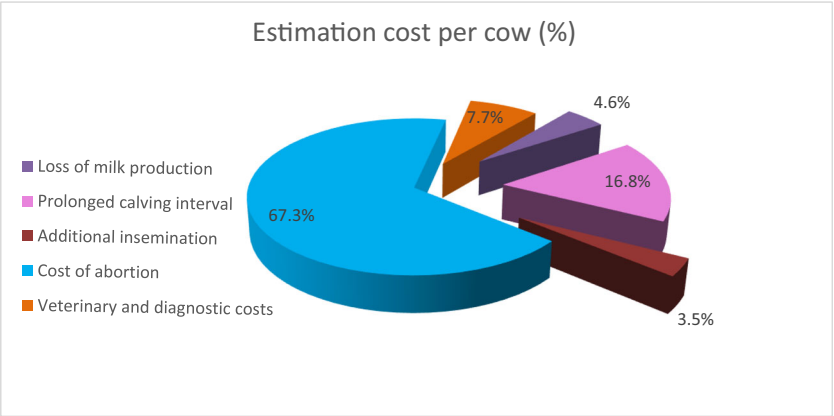


Fig. 1 The distribution of estimated economic costs due to neosporosis

based on the demands of breeders (expert opinion). In this study, economic costs were estimated at US$48/head for veterinary services and US$7/head for diagnostic tests.

In most of the studies, it was stated that *N. caninum* had a negative effect on reproductive performance (Moore et al. 2003; Haddad et al. 2005; Eşki and Ütük 2018). In seropositive cows, the number of inseminations until conception is more, and the calving intervals are longer than the seronegative cows (Hall et al. 2005; Kamga-Waladjo et al., 2010; Vanleeuwen et al. 2010). Average number of inseminations until conception are 3.7 to 3.9 in seropositive cows, while this number is 2.1 to 2.4 in seronegative ones (Hall et al. 2005; Kamga-Waladjo et al. 2010; Canatan et al. 2014). In this study, the number of inseminations until conception was accepted as 2.4 for the calculation of economic costs due to infertility. In Turkey, the average calving interval is 420 days; however, in neosporosis, this period is affected and prolongs to 520 days. This means that the normal service period extends from 45–60 days to 72 days (3–105) after abortion (Bartels et al., 2006). In another study, prolonged calving interval was estimated as 595 due to neosporosis (lactation period, 305; dry period, 290) days in cattle (Liu et al. 2020).

The total cost of neosporosis differs by countries, regions, flock size, and associated risk factors (age, parity, breed, definite hosts, grazing, climatic season, biosecurity) (Dubey et al. 2007; Dubey et al., 2017). *Neospora caninum* prevalence is divided into three groups as low (8%; 4–14), medium (15%; 12–18), and high (24%; 20–28) (Ribeiro et al., 2019). Although there are no many resources on the economics of neosporosis, the annual total economic cost is about US$1092.1 in the USA (South and North America) and US$68.7 in Europe that have higher prevalence of neosporosis (Reichel et al. 2013; Ribeiro et al., 2019). In dairy industry, estimated annual losses were US$38.5 million in Argentina and US$35.7 million in New Zealand, which have low *N. caninum* prevalence (Reichel et al. 2013). In this study, the annual estimated total cost of neosporosis was estimated at US$40.5 million. Our result was similar to Argentina (US$38.5 million) and New Zealand (US$35.7 million), which have similar seroprevalences to Turkey.

In dairy cattle, there was 16.5% risk of experiencing abortion due to *N. caninum*. The economic costs were estimated at US$1.415 per abortion for the dairy industry in Argentina (Moore et al. 2015). In this study, the seropositivity of the *N. caninum* was reported earlier as 18% in aborted dairy cattle in Turkey. The estimated cost of *N. caninum*-induced abortion was estimated at US$710 per cow. This value was nearly equal to the Netherlands (US$700), and lower than Canada (US$1300), England (US$1800), and the USA (US$12.200) (Reichel et al. 2013). We consider that the differences in the total cost of the disease may be associated with methodological methods used in different studies (Hernandez et al. 2001; Hall et al. 2005; Bartels et al. 2006; Reichel et al. 2013; Liu et al. 2020). In light of the collected data, neosporosis causes severe economic impacts on the dairy industry in Turkey.

Conclusion

To date, all studies on neosporosis focus on the prevalence and the diagnosis of the disease in Turkey. In this study, we firstly determined the economic costs due to *N. caninum* infections and try to attract attention on the economic impacts of the disease. As a result, awareness among breeders of the epidemiology, control, and eradication of neosporosis should be raised through training activities; coordination between the relevant institutions and organizations should be ensured; emergency action plans should be prepared; and further spread of the disease should be prevented.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article has not been published previously and is not under consideration for publication elsewhere. The publication of this article is approved by all authors and explicitly by the responsible authorities where the work was carried out.

Statement of informed consent This article will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright holder.

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