SEROPREVALENCE AND RISK FACTORS ASSOCIATED WITH NEOSPORA CANINUM IN DAIRY CATTLE OF WESTERN DAIRY POCKET AREA IN CHITWAN DISTRICT OF NEPAL

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ABSTRACT
Dairy industry is growing in Nepal and western dairy pocket area is the main milk producing area in Chitwan district. This study was carried out to determine the seroprevalence and risk factors associated with *N. caninum* in western dairy pocket area in Chitwan district of Nepal. A cross-sectional study was conducted from April 2014 to July 2014 among the small holder dairy farms, and out of 2188 animals from different sampling villages, 186 (8.5%) animals were randomly selected. Individual blood samples (5-10 ml) were collected and screened for *N. caninum* antibodies by ELISA test kit. The study showed that apparent overall prevalence of *N. caninum* to be 4.84% and true prevalence, 4.07%. The prevalence varied from a low of 0% to a high of 13.16% in various VDCs. The prevalence rates among Holstein-Friesian cross and Jersey cross Cattle were 6.94% and 3.51% respectively. The seroprevalence of *N. caninum* was found to be 16.13% and 2.5% in animals with and without history of abortion respectively, showed statistically significant different (p value <0.05). Similarly, prevalence were 13.64% and 3.66% in animals with and without presence of dog respectively and 8.5%, 3.39% and 0% in the animals of age group of 3-5 years, 1-3 years and above 5 years respectively, showed statistically non-significant association (p value <0.05). This study shows that *N. caninum* is associated with abortion in dairy cattle of Chitwan region. The study may contribute the base line data of *N. caninum* in Nepal for future preventive strategy for stake-holders and government.

Key words: Dairy cattle, Neospora caninum, Seroprevalence, Nepal

INTRODUCTION
*Neospora caninum* is an intracellular apicomplexan protozoan parasite, one of the major causes of abortion, neonatal morbidity and mortality in cattle, sheep, goats and horses (Dubey et al., 2007). It is one of the most important causes of abortion in dairy cattle in many countries of the world (Dubey and Lindsay, 1996; Paré et al., 1996; Anderson et al., 2000; Trees and Williams, 2005; Dubey, 2003). It was first reported in dog in Norway (Bjerkas et al., 1984) and in cattle in Mexico in 1987 (Trees and Williams, 2005; Sevgili and Altas, 2005). The sexual stage of life cycle of *N. caninum* occurs in dog; act as the definite host, whereas asexual stage of life cycle occurs in cattle, sheep, goats and horses; acts as the intermediate hosts of the parasite (Gondim et al., 2002). Transmission of *N. caninum* occurs through vertically from infected pregnant dams to her offspring or horizontally between infected cows to cows or infected cows to dogs (Barber and Trees, 1998; Bergeron et al., 2000; Davison et al., 2001; Akca et al., 2005; Bartels et al., 2005). Experimental infection of *N. caninum* also occurs in pregnant cattle and abortion occurs on the basis of time of inoculation (Williams et al., 2000), infection in early gestation results in fetal death (Macalodowie et al., 2004), whereas in mid-gestation results in fetal infection and fetal survival (Maley et al., 2003). The most common route of transmission of *N. caninum* infection in cattle is vertical (placental) transmission and occurs through infected dam to her offspring during successive pregnancies (Antony and Williamson, 2001; Fröslling et al., 2005). Neosporosis in dairy cattle has been reported in various countries of the world as in Senegal (Kamga et al., 2010), Egypt (Ibrahim et al., 2009), Sudan (Ibrahim et al., 2012), Algeria (Ghalmi et al., 2012), Pakistan (Nazir et al., 2013), Italy (Otranto et al., 2003), Iran (Nematollahi et al., 2011), Paraguay (Osawa et al., 2002), France (Ould et al., 1999), Japan (Koiwai et al., 2006) and China (Xu et al., 2012) but not reported from Nepal so far. The aim of current study was to estimate, for the first time, the seroprevalence and risk factors associated with *N. caninum* in dairy cattle of the western dairy pocket area in Chitwan district of Nepal which helps to prevent or control neosporosis in dairy cattle.

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MATERIALS AND METHODS

Study area
A cross-sectional study was conducted from April 2014 to July 2014 among the smallholder dairy farms of the western dairy pocket area in Chitwan district of Nepal. The geographic locations of the five sampling sites of the western dairy pocket area in Chitwan district of Nepal are consisting of the following villages: Divyanagar, Gunjanagar, Sharadanagar, Mangalpur and Gitanagar.

Sampling
Five villages were randomly selected from a sampling frame of total villages of western dairy pocket in Chitwan district of Nepal. Out of 2188 animals in these villages, 186 (8.5%) animals were randomly selected from various farms of the villages. Individual blood samples (5-10 ml) were collected by venipuncture from the jugular vein of dairy cattle using dry vacutainer tubes and labeled according to animal age, breed, herd holder and location. The samples were forwarded to the National Avian Disease Diagnostic Laboratory, Bharatpur, Chitwan (for antibody testing). After centrifugation at 1000 revolutions/minute for 20 minutes, sera were removed and stored at -20°C until testing.

Serological examination
Antibodies to *N. caninum* were screened in dairy cattle sera using commercially available IDEXX Neospora X2 Ab test kit (IDEXX Laboratories, Inc., Westbrook, Maine, USA) according to the manufacturer’s instructions. The S/P (sample to positive) ratio was used to determine the seropositivity of *N. caninum* in dairy cattle where S is the difference between the optical density of the sample and optical density of the negative sample and P is the difference between the optical density of the positive control and the optical density of the negative control. The reading was made using ELISA reader having filter with optical density of 650 nm. The tested samples were interpreted as seropositive for *N. caninum* when S/P ratio was greater than or equal to 0.5.

Epidemiological data
Epidemiological data were collected through semi-structured questionnaires from the farmers or farm owners of the selected areas in order to obtain information about the risk factors such as: Farm location, cattle age, Cattle breed, presence of dog in the farm, abortion history of cattle and infertility problems in cattle.

Statistical analysis
The data were analysed by using the softwares Win Episcope 2.0, WinPepi (version 4.0) and Epi Info 2002 (Anderson et al., 2000). The assessment of Chi square and Fischer’s exact tests at 95% confidence interval were used to compare selected risk factors: villages, ages, breeds, Dogs and history of Abortion. The true prevalence of the *N. caninum* was calculated at 95% confidence interval using computer software ‘True Prevalence program of the Survey Toolbox’ considering apparent prevalence, sample size, sensitivity and specificity of the ELISA test kit. The sensitivity and specificity of the ELISA test kit for *N. caninum* are 100% and 99.2% respectively.

RESULTS AND DISCUSSION
The overall seroprevalence of *N. caninum* in dairy cattle of western dairy pocket area in Chitwan district of Nepal was found to be 4.84%. Out of 186 samples, 9 samples were found to be positive by IDEXX Neospora X2 ELISA Test Kit. The Apparent Prevalence was found to be 4.84% and True prevalence was found to be 4.07% (CI 95%: 2.524-5.621). The data of all the risk factors and their association with seroprevalence included in the study were represented in Table 1.

Among the five VDCs, highest number of positive samples (five) were found in Gitanagar (13.16%) followed by two positive samples in Mangalpur (5.41%). Sharadanagar (2.70%) and Divyanagar(2.70%) showed one positive sample in each and no positive samples were found in Gunjanagar (0%). The result obtained was subjected for Chi-squared test to test significance of variation. The result showed that seroprevalence of *N. caninum* antibody in various locations was statistically non significant (p > 0.05).
There were 7 (8.33%) positive samples for age group 3-5 years, 2 (3.39%) for age group 1-3 years and no positive sample for age group above 5 years (0%). The result obtained was subjected to Chi-squared test to test. The result showed that seroprevalence of N. caninum antibody in various age groups was statistically non significant (p > 0.05). Odd ratio for 1-3 years and 3-5 years was 0.386 and for above 5 years and 3-5 years was 0. It indicates that animals of age group 3-5 years are at more risk to disease than age groups 1-3 years.

The breed wise seroprevalence breed were found to be 4 (3.51%) and 5 (6.94%) for Jersey Cross and Holstein Friesian respectively. The result obtained was subjected to Fisher’s Exact test. The result showed that seroprevalence of N. caninum antibody in various breed was statistically non significant (p > 0.05). Odd ratio for Jersey Cross and Holstein Friesian was 1.311. It indicates that animals of Jersey Cross breed are at more risk than Holstein Friesian breed.

Out of 9 positive samples, 5(16.13%) were associated with history of abortion. Similarly, 4(7.55%) positive samples were associated with history of infertility (repeat breeding and anoestrus) and 3(13.64%) were associated with history of presence of dog. Number of samples with history of neonatal death were found to be zero. The result obtained was subjected to Fisher’s Exact test. The result showed statistically significant (p<0.05) association of history of abortion with seroprevalence of N. caninum. Other risk factors as infertility and presence of dog were statistically non significant (p > 0.05). Odd ratio for animals with history of abortion and non-abortion was 7.26, for infertile and fertile animals were 2.09 and for presence and absence of dogs were 4.16. It indicates animals with history of abortion are at about 7.26 times more risk than those without abortion. Similarly, the animals with history of presence of dog in the farm are at 4.16 times more risk than without dogs in the farm. Conversely, infertile animals are at 2.09 times less risk than fertile animals.

Table 1. Risk Factors wise distribution of Neospora caninum in the cattle sera

| Location         | Total Samples | Positive Sample | Apparent Prevalence (%) | True Prevalence (%) | Confidence Interval (CI) (95%) | Odd Ratio (95% CI) | Chi-squared P Value | Fisher’s Exact Test P value |
|------------------|---------------|-----------------|-------------------------|---------------------|-------------------------------|--------------------|----------------------|--------------------------|
| Mangalpur        | 37            | 2               | 5.41                    | 4.65                | 0.988-8.306                   | 0.080              |
| Gunjanagar       | 37            | 0               | 0.00                    | N/A                 | N/A                           |                    |
| Divyanagar       | 37            | 1               | 2.70                    | 1.92                | 0.000-4.537                   |                    |
| Sharadanagar     | 37            | 1               | 2.70                    | 1.92                | 0.000-4.357                   |                    |
| Gitanagar        | 38            | 5               | 13.16                   | 12.46               | 7.064-17.856                  |                    |
| Age              |               |                 |                         |                     |                               |                    |
| 1-3 years        | 59            | 2               | 3.39                    | 2.61                | 0.293-4.929                   | 0.386** (0.077-1.928) | 0.401               |
| >5 years         | 43            | 0               | N/A                     | N/A                 | N/A                           | 0.080              |
| Age              |               |                 |                         |                     |                               |                    |
| Breed            |               |                 |                         |                     |                               |                    |
| Jersey Cross     | 114           | 4               | 3.51                    | 2.73                | 0.000-5.493                   | 2.052* (0.322-5.329) | 0.470               |
| Holstein Friesian| 72            | 5               | 6.94                    | 6.19                | 3.243-9.136                   |                    |
| Others           |               |                 |                         |                     |                               |                    |
| Abortion         | 31            | 5               | 16.13                   | 15.45               | 8.954-21.954                  | 7.26* (1.828-28.831) | 0.015               |
| Infertility      | 53            | 4               | 2.58                    | 1.79                | 0.541-3.047                   | 2.09* (0.538-8.104) | 0.465               |
| Presence of dog  | 133           | 5               | 3.76                    | 2.98                | 1.361-4.607                   | 4.158** (0.960-18.001) | 0.151               |
| Absence of dog   | 22            | 3               | 13.64                   | 12.94               | 5.744-20.143                  |                    |
| Presence of dog  | 164           | 6               | 3.66                    | 2.88                | 1.440-4.326                   |                    |

The present study is the first report on the seroprevalence of N. caninum in dairy cattle of western dairy pocket area in Chitwan district of Nepal. Neosporosis has been reported in many countries (Kim et al., 2002; Kim et al., 1998; Gondim et al., 2004) with different prevalence rates since the disease was recognized in 1988. The seroprevalence of antibody to N. caninum in this study is 4.84%, in dairy cattle of western dairy pocket area in Chitwan district of Nepal.
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Chitwan, is lower than that reported for cattle in Brazil (14.09%) (Gondim et al., 2004), Romania (34.6%) (Gvavrea et al., 2011), Pakistan (43%) (Nazir et al., 2013), Jordan (35%) (Talafha and Al-Majali, 2013), China (15.07%) (Xu et al., 2012), India (12.61%) (Sengupta et al., 2012), Iran (10.5%) (Nematollahi et al., 2011), Sudan (10.7%) (Ibrahim et al., 2012) but resembles that reported in Australia (3.2%) (Nasir et al., 2012), Korea (4.1%) (Kim et al., 2002), Czech Republic (5.83%) (Vaclavek et al., 2003), France (5.6%) (Ould et al., 1999) and Japan (5.7%) (Koiwai et al., 2006). This difference in seroprevalence may be due to the type of test used, their cut-off points, change in geographic area, variation in sample size and other associated risk factors.

The seroprevalence of N. caninum in aborted cattle was 16.13% which is higher than that of non-aborted cattle and the prevalence of N. caninum in samples with history of abortion is higher than samples without history of abortion (Voural et al., 2006). Our study showed similar results. Although the presence of antibodies to N. caninum in dairy cattle only indicates the exposure to the parasite, the probability of abortion in seropositive cattle is 7.26 times higher than in seronegative cattle. The results of this study showed that there was a significant relationship with abortion (p<0.005). The highest risk of abortion due to neosporosis was in the 3-5 years old of cattle however relationship between neosporosis and abortion is a speculative. Jensen et al. (1999) reported that seroprevalence increases with age. Razmi et al. (2006) reported the highest risk of abortion due to neosporosis in dairy cattle of 1-2 years of age. In contrast, Hajikolaei et al. (2008) and Sadrebazzaz et al. (2004), observed no significant difference between age and seropositivity to neosporosis. The presence of farm dog increases the seropositivity of N. caninum in the dairy cattle although it is non-significant but shows higher risk of N. caninum to dairy cattle. Bartels et al. (1999), Mainar et al. (1999) and Otranto et al. (2003) also reported that presence of farm dog increases the seropositivity to N. caninum to the cattle. The seropositivity of N. caninum in this study is higher in Holstein Friesian cross breed than Jersey cross breed and is non-significant. Sadrebazzaz et al. (2004) also observed non-significant relation between the breeds of cattle to the seropositivity of N. caninum. The percentage of seropositivity of N. caninum is higher in cattle with infertility problems than the cattle with normal fertility and observed non-significant relation to the N. caninum.

In conclusion, the present study shows that N. caninum is present in Chitwan district of Nepal and 4.84% dairy cattle are positive for N. caninum by ELISA test kit on selected sampling sera. The exposure to N. caninum was more frequently associated with history of abortions, infertility and presence of dogs respectively. This result suggests that N. caninum might be one of the major causes of abortion in dairy cattle in this region. As this is the first study of N. caninum in Nepal and it has been done only for Chitwan district with limited risk factors, it may contribute the baseline data of N. caninum in Nepal which will help for future preventive strategy for stakeholders and government authority to investigate further.

REFERENCES
1. Anderson ML, Andrianarivo AG and Conrad PA (2000). Neosporosis in cattle. Animal Reproduction Science 60-61: 417-31.
2. Akca A, Gokce HI, Guy CS, McGarry JW and Williams DJ (2005). Prevalence of antibodies to Neospora caninum in local and imported cattle breeds in the Kars province of Turkey. Research in Veterinary Science 78: 123-126.
3. Antony A and Williamson NB (2001). Recent advances in understanding the epidemiology of Neospora caninum in cattle. The New Zealand Veterinary Journal 49: 42-47.
4. Barber JS and Trees AJ (1998). Naturally occurring vertical transmission of Neospora caninum in dogs. International Journal for Parasitology 28: 57-64.
5. Bergeron N, Fecteau G, Pare J, Martineau R and Villeneuve A (2000). Vertical and horizontal transmission of Neospora caninum in dairy herds in Quebec. Canadian Veterinary Journal 41: 464-467.
6. Bartels CJ, Wouda W and Schukken YH (1999). Risk factors for Neospora caninum-associated abortion storms in dairy herds in The Netherlands (1995-1997). Theriogenology 52: 247-257.
7. Bartels CJ, van Maanen C, van der Meulen AM, Dijkstra T and Wouda W (2005). Evaluation of three enzyme-linked immunosorbent assays for detection of antibodies to Neospora caninum in bulk milk. Veterinary Parasitology 131: 235-246.
8. Bjerkas I, Mohn SF and Presthus J (1984). Unidentified cyst-forming sporozoan causingencephalomyelitis and myositis in dogs. Zeitschrift für Parasitenkunde 70: 271-274.
9. Dubey JP, Schares G, and Ortega-Mora LM (2007). Epidemiology and control of Neosporosis and Neospora caninum. Clinical Microbiology Reviews 20: 323-367.
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10. Dubey JP and Lindsay DS (1996). A review of *Neospora caninum* and neosporosis. *Veterinary Parasitology* 67: 1-59.
11. Dubey JP (1984). Review of *Neospora caninum* and neosporosis in animals. *The Korean Journal of Parasitology* 41: 1-16.
12. Davison HC, Guy CS, McGarry JW, Guy F, Williams DJ, Kelly DF and Trees AJ (2001). Experimental studies on the transmission of *Neospora caninum* between cattle. *Research in Veterinary Science* 70: 163-168.
13. Frösslung J, Uggla A and Björkman C (2005). Prevalence and transmission of *Neospora caninum* within infected Swedish dairy herds. *Veterinary Parasitology* 128: 209-218.
14. Gondim LFP, Gao L and McAllister MM (2002). Improved production of *Neospora caninum* oocysts, cyclical oral transmission between dogs and cattle, and in vitro isolation from oocysts. *Journal of Parasitology* 88: 1159-1163.
15. Gondim LFP, McAllister MM, Pitt WC, and Zemlicka DE (2004). Coyotes (*Canis latrans*) are definitive hosts of *Neospora caninum*. *International Journal for Parasitology* 34: 159-161.
16. Gavrea RR, Iovu A, Losson B and Cozma V (2011). Seroprevalence of *Neospora caninum* in dairy cattle from north-west and centre of Romania. *Parasitology* 18: 349-51.
17. Ghalimi F, China B, Ghalimi A, Hammitouche D and Losson B (2012). Study of the risk factors associated with *Neospora caninum* seroprevalence in Algerian cattle populations. *Research in Veterinary Science* 93: 655-661.
18. Hajikolaei MR, Hamidinejat H and Goraninejad S (2008). Serological study of *Neospora caninum* infection in cattle from Ahvaz, Iran. *International Journal of Veterinary Parasitology* 2: 63-66.
19. Ibrahim AME, EiFalah AM and El Hussein ARM: (2012). First report of *Neospora caninum* infection in cattle in Sudan. *Tropical Animal Health and Production* 44: 769-772.
20. Ibrahim HM, Huang PL, Salem TA, Talaat RM, Nasr, MI, Xuan X and Nishikawa Y (2009). Short report: seropositivity with gestation number and pregnancy outcome in Danish dairy herds. *Preventive Veterinary Medicine* 40: 151-163.
21. Jensen AM, Bjorkman C, Kjeldsen AM, Wedderopp A, Willadsen C, Uggla A and Lind P (1999). Association of *Neospora caninum* seropositivity with gestation number and pregnancy outcome in Danish dairy herds. *Veterinary Parasitology* 80: 263-267.
22. Kamga-Waladjo AR, Gbati OB, Kone P, Lapo RA, Chatagnon G, Serge NB, Panguij LJ, Hassane PED, Akakpo JA and Tainturier D (2010). Seroprevalence of *Neospora caninum* antibodies and its consequences for reproductive parameters in dairy cows from Dakar-Senegal, West Africa. *Tropical Animal Health and Production* 42: 953-959.
23. Kotwai M, Hamaoka T, Haritani M, Shimizu S, Zeniya Y, Eto M, Yokoyama R, Tsutsui T, Kimura K, and Yamane I (2006). Nationwide seroprevalence of *Neospora caninum* among dairy cattle in Japan. *Veterinary Parasitology* 135: 175-179.
24. Kim JH, Lee JK, Lee BC, Park BK, Yoo HS, Hwang WS, Shin NR, Kang MS, Jean YH, Yoon HJ, Kang SK, and Kim DY (2002). Diagnostic survey of bovine abortion in Korea: with special emphasis on *Neospora caninum*. *The Journal of Veterinary Medical Science* 64: 1123-1127.
25. Macaldowie C, Maley SW, Wright S, Bartley P, Esteban-Redondo I, Buxton D and Innes EA (2004). Placental pathology associated with fetal death in cattle inoculated with *Neospora caninum* by two different routes in early pregnancy. *Journal of Comparative Pathology* 131: 142-156.
26. Maley SW, Buxton D, Rae AG, Wright SE, Schock A, Bartley PM, Esteban-Redondo I, Swales C, Hamilton CM, Sales J and Innes EA (2003). The pathogenesis of neosporosis in pregnant cattle: inoculation at mid-gestation. *Journal of Comparative Pathology* 129: 186-195.
27. Mainar-Jaime RC, Thurmond MC, Berzalherranz B and Hietala SK (1999). Seroprevalence of *Neospora caninum* and abortion in dairy cows in northern Spain. *Veterinary Record* 145: 72-75.
28. Nazir A, Maqbool A, Khan MS, Sajid A and Lindsay DS (2013). Effects of age and breed on the prevalence of *Neospora caninum* in commercial dairy cattle from Pakistan. *Journal of Parasitology* 99: 368-70.
29. Nematollahi A, Jaafari R and Moghadam GH (2011). Seroprevalence of *Neospora caninum* infection in Dairy Cattle in Tabriz, Northwest Iran. *Iranian Journal of Parasitology* 6: 95-98.
30. Nasir A, Lanyon SR, Schaeres G, Anderson ML and Reichel MP (2012). Sero-prevalence of *Neospora caninum* and Besnoitia besnoiti in South Australian beef and dairy cattle. *Veterinary Parasitology* 186: 480-5.
31. Osaka T, Wasfling J, Acosta L, Ortellado C, Ibarra J and Innes E (2002). Seroprevalence of *Neospora caninum* infection in dairy and beef cattle in Paraguay. *Veterinary Parasitology* 110: 17-23.
32. Ould-Amrouche A, Klein F, Osdoit C, Mohammed HO, Touratier A, Sanaa M and Mialot JP (1999). Estimation of *Neospora caninum* seroprevalence in dairy cattle from Normandy, France. *Veterinary Research* 30: 531-538.
33. Otranto D, Llazari A, Testini G, Traversa D, Frangipane di Regalbono A, Badan M and Capelli G (2003). Seroprevalence and associated risk factors of neosporosis in beef and dairy cattle in Italy. *Veterinary Parasitology* 118: 7-18.

34. Paré J, Thurmond MC and Hietala SK (1996). Congenital *Neospora caninum* infection in dairy cattle and associated calf hood mortality. *Canadian Journal of Veterinary Research* 60: 133-139.

35. Perez E, Gonzales O, Dolz G, Moraks JA, Bair B and Conrad PA (1998). First report of bovine neosporosis in dairy cattle in Costa Rica. *Veterinary Record* 142: 520-521.

36. Razmi GR, Mohammadi GR, Garrosi T, Farzaneh N, Fallah AH and Maleki M (2006). Seroepidemiology of *Neospora caninum* infection in dairy cattle herds in Mashhad area, Iran. *Veterinary Parasitology* 135: 187-189.

37. Sengupta PP, Balumahendiran M, Raghavendra AG, Honnappa TG, Gajendragad MR and Prabhudas K (2012). Prevalence of *Neospora caninum* antibodies in dairy cattle and water buffaloes and associated abortions in the plateau of Southern Peninsular India. *Tropical Animal Health and Production* 45: 205-10.

38. Sevgili M and Altas MG (2005). Seroprevalence of *Neospora caninum* in cattle in the province of Sanliurfa, Turkey. *Journal of Veterinary Animal Science* 29: 127-130.

39. Sadrebazzaz A, Haddadzadeh H, Esmailnia K, Habibi G, Vojgani M and Hashemifesharaki R (2004). Serological prevalence of *Neospora caninum* in healthy and aborted dairy cattle in Mashhad, Iran. *Veterinary Parasitology* 124: 201-204.

40. Talafha AQ and Al-Majali AM (2013). Prevalence and risk factors associated with *Neospora caninum* infection in dairy herds in Jordan. *Tropical Animal Health and Production* 45: 479-85.

41. Trees AJ and Williams DJ (2005). Endogenous and exogenous transplacental infection in *Neospora caninum* and *Toxoplasma gondii*. *Trends in Parasitology* 21: 558-561.

42. Vaclavek P, Koudela B, Modry D and Sedlak K (2003). Seroprevalence of *Neospora caninum* in aborting dairy cattle in the Czech Republic. *Veterinary Parasitology* 115: 239-245.

43. Voural G, Aksoy E, Bozkir M, Kucukayan U and Erturk A (2006). Seroprevalence of *Neospora caninum* in dairy cattle herds in central Anatolia, Turkey. *Veterinarski Archiv* 76: 343-349.

44. Williams DJL, Guy CS, McGarry JM, Guy F, Tasker L, Smith RF, MacEachern K, Cripps PJ, Kelly DF and Trees AJ (2000). *Neospora caninum*-associated abortion in cattle: the time of experimentally induced parasitaemia during gestation determines foetal survival. *Parasitology* 121: 347-358.

45. Xu MJ, Liu QY, Fu JH, Nisbet AJ, Shi DS, He XH, Pan Y, Zhou DH, Song HQ and Zhu XQ (2012). Seroprevalence of *Toxoplasma gondii* and *Neospora caninum* infection in dairy cows in subtropical southern China. *Parasitology* 139: 1425-8.