*Parasitology*

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# The global seroprevalence of *Toxoplasma gondii* infection in bovines: a systematic review and meta-analysis

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**Review**

**Cite this article:** Shariatzadeh SA *et al* (2021). The global seroprevalence of *Toxoplasma gondii* infection in bovines: a systematic review and meta-analysis. *Parasitology* **148**, 1417–1433. https://doi.org/10.1017/S0031182021001116

Received: 18 February 2021
Revised: 4 June 2021
Accepted: 7 June 2021
First published online: 30 June 2021

**Key words:**
Bovine; meta-analysis; seroprevalence; toxoplasmosis; zoonosis

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## Abstract

Bovines, especially cattle, are considered as one of the main sources of *Toxoplasma gondii* infection for humans. A more comprehensive understanding of the occurrence of *T. gondii* is needed to provide a global perspective on the prevalence of *T. gondii* in bovines. Here, we present the results of the first systematic review and meta-analysis on the global *T. gondii* seroprevalence in bovines. Six databases (PubMed, ScienceDirect, Web of Science, Scopus, ProQuest and Google Scholar) were comprehensively searched for relevant studies published between 1 January 1967 and 30 May 2019. Among 7691 publications searched, 178 studies (from 50 countries) with 193 datasets were included in the meta-analysis. The global pooled and weighted seroprevalence of *T. gondii* among bovines was 17.91% [95% confidence interval (CI): 15.32–20.6]. Weighted prevalence based on the host was as follows: cattle 16.94% (95% CI: 14.25–19.81), buffalo 22.26% (95% CI: 16.8–29), yak 23% (95% CI: 14–33) and bison 8.1% (95% CI: 3.9–13.7). Continued monitoring on the status of *T. gondii* seroprevalence in bovines is essential. Study on the prevalence of *T. gondii* in the products of bovines such as milk, meat, etc., which are considered as the source of transmission of infection to humans, is recommended.

## Introduction

*Toxoplasma gondii* is the only obligatory intracellular protozoan infecting almost all warm-blooded animals. Approximately one-third of the world's population is estimated to be infected with this parasite (Guo *et al.,* 2015). *Toxoplasma gondii* infection in the general population can remain asymptomatic, but could be fatal in the immunocompromised patients. Pregnant women are a very important group, because this parasite may lead to miscarriage or neurological disorders in the fetus (Dong *et al.,* 2018*b*). The route of transmission of *T. gondii* to humans could be vertical or horizontal *via* the consumption of resistant oocysts from the environment or uncooked meat of infected animals (Belluco *et al.,* 2018). Approximately, 60% of toxoplasmosis occurs horizontally, which varies from country to country. Intermediate hosts, such as livestock animals play an important role as reservoirs of infection for humans. Studies in six major European cities, estimated that, 30–63% of the infections in pregnant women are meat-borne (Cook *et al.,* 2000). Direct microscopic observations, polymerase chain reaction (PCR), bioassay and antibody detection by serological techniques are common methods of diagnosing *T. gondii*. But, in epidemiological studies, serological methods are preferred for the diagnosis of *T. gondii* infection in animals. It is because other methods are not suitable for the analysis of a large sample size (Montoya, 2002; Ferra *et al.,* 2015).

However, bovines do not appear to be a suitable host for *T. gondii*, but cattle are considered as one of the sources of *T. gondii* infection for humans (Hoffmann *et al.,* 2017). In fact, the meat and milk contaminated with *T. gondii* are the risk factor for *T. gondii* infection (Dubey and Thulliez, 1993; Hill and Dubey, 2013; Kalita and Sarmah, 2015). Further research is needed to determine the prevalence of *T. gondii* infection in bovines worldwide and the associated factors to help control it in these animals. Since *T. gondii* is a common important pathogen in humans and livestock, a more comprehensive understanding of the occurrence of *T. gondii* in the animal is essential. Although numerous valuable studies have been performed on the seroprevalence of *T. gondii* worldwide, to our knowledge, no global meta-analyses have been performed based on the systematic review of the literature. Therefore, the present systematic review and meta-analysis has been accomplished to draw a global perspective on the



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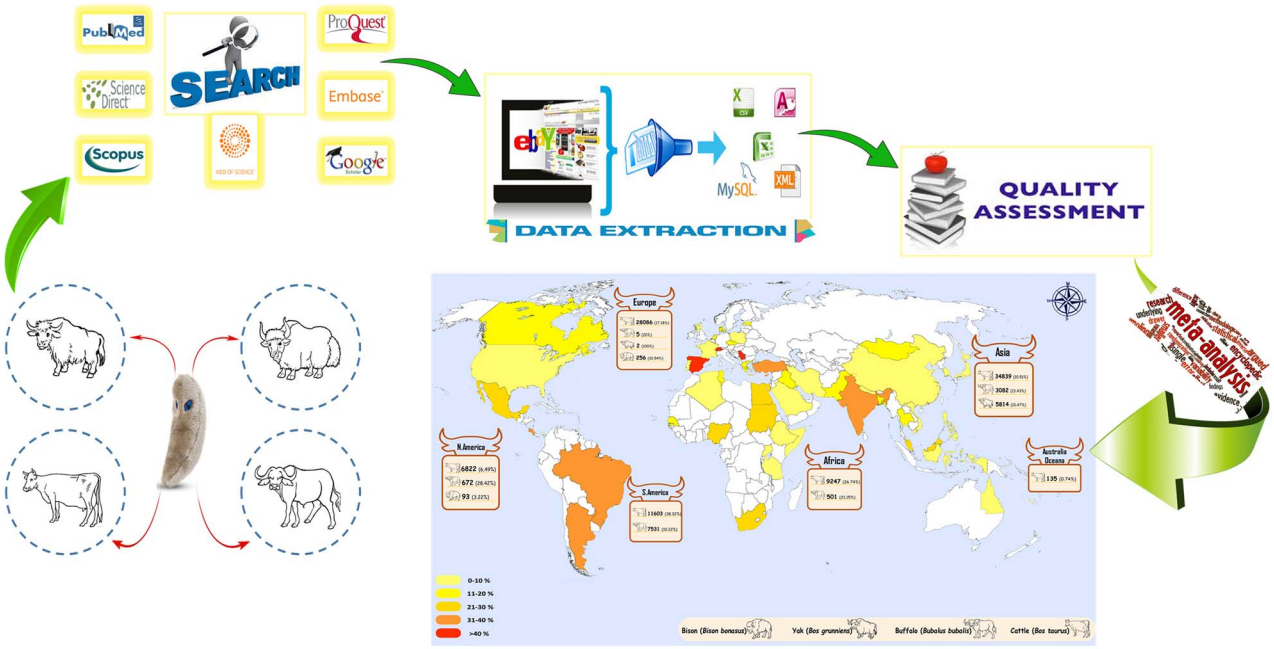


**Fig. 1.** Graphical summary of this study on global seroprevalence of bovine *Toxoplasma* infection.

seroprevalence of *T. gondii* in bovines to better understand the global seroprevalence and importance of the bovine *T. gondii* infection.

## Methods

### Design and protocol registration

The present systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA) as described previously (Shamseer *et al.*, 2015). The details of the study protocol are available on the website of the International Prospective Register of Systematic Reviews with the identifier Central Registration Depository of CRD42019107442 (Daryani *et al.*, 2018).

### Search strategy

Seroprevalence of *T. gondii* in bovines including cattle (*Bos taurus*), buffalo (*Bubalus bubalis*), yak (*Bos grunniens*) and bison (*Bison bonasus*) were of interest in this global review. To begin, we searched scientific databases for all the articles on the prevalence of bovine *T. gondii* infection published up to 30 May 2019. These keywords used alone or in combination were as follows: '*Toxoplasma gondii*', '*T. gondii*', 'toxoplasmosis', 'seroprevalence', 'prevalence', 'serological test', 'bovine', 'cattle', 'heifer', 'calf', 'buffalo', 'yak' and 'bison'. The searching process of articles was carried out using English language databases including 'Web of Science', 'Scopus', 'PubMed', 'Science Direct', 'ProQuest' and 'Google Scholar'. The systematic search of articles was conducted from 20 April to 30 May 2019 by two researchers independently (SAS and ASP).

### Inclusion and exclusion criteria

Abstracts and full texts were assessed independently by the two researchers using a piloted form. The final decisions about the inclusion or exclusion of studies were made separately. Disagreements were resolved through arbitration by another author. Following the removal of duplicate entries, articles were evaluated according to the following criteria: (1) cross-sectional studies about the prevalence of *T. gondii* infection in bovines, (2) studies conducted only on cattle, buffalo, yak and bison and (3) studies where *T. gondii* infection in bovines was diagnosed by detecting immunoglobulin G (IgG) and/or IgM antibodies against *T. gondii*. The exclusion criteria comprised of: (1) case-control studies, review articles, dissertations, letters and animal models, (2) studies provided unclear data, (3) articles that were not available in the English language, (4) studies conducted on human and other animals and (5) conference abstracts.

### Data extraction and the study quality assessment

All necessary information on the studies was recorded using Microsoft Excel software. The following data were collected for each study: the first author's name, publication year, country, continent, location, sample size, number of positives and negatives cases, bovine species, gender and age of each animal and type of serological method.

The Joanna Briggs Critical Evaluation Checklist was implemented to assess the quality of included records (Munn *et al.*, 2014). This checklist contains ten questions with four options designated as yes, no, unclear and not-applicable, regarding study quality. The papers with total scores of <5, 6 and 7–10 were considered to be of low, moderate and high quality, respectively. Our decisions to include or exclude the articles were influenced by the score of quality assessment and the articles with a quality score <5 were deleted.

### Data synthesis and statistical analysis

In this study, the pooled rate seroprevalence of *T. gondii* with a 95% confidence interval (CI) was calculated using the random-effects model using StatsDirect software, version 2.8.0 (http://statsdirect.com). Heterogeneity among included studies was examined by Cochran's $Q$ and $I^2$ statistics test. $I^2$ values of 50% or more were considered heterogeneous. A forest plot in the random effects model was used to calculate the pooled seroprevalence of *T. gondii* in bovines. To determine the source of heterogeneity, subgroup analyses were carried out. In a subgroup

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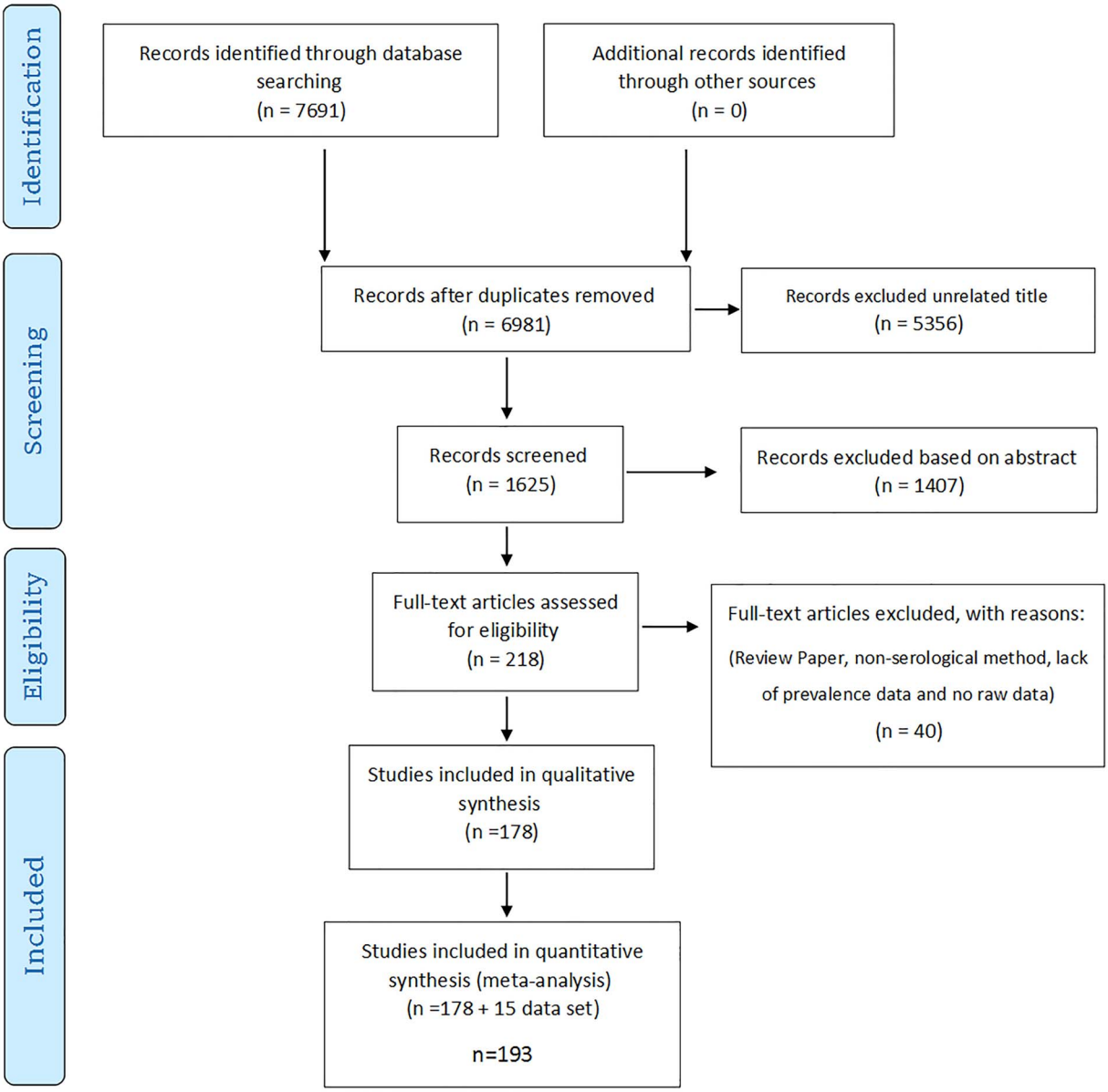


**Fig. 2.** Flow chart of the study selection process showing inclusion and exclusion of studies identified.

analysis, the seroprevalence of *T. gondii* was estimated based on year, gender, the continent of origin, type of animal, type of diagnostic method and sample size. Publication bias was evaluated graphically and statistically by applying Egger's and Begg's tests. In all statistical analyses, $P$ value <0.05 was considered significant.

## Results

A graphical summary of this study on global seroprevalence of bovine *Toxoplasma* infection is shown in Fig. 1. Our preliminary search of seven databases yielded 7691 articles but 710 were excluded from the study due to duplication. After a primary screening of the titles of the articles based on keywords, 5356 studies were extracted. In the next step, by screening the abstracts of the articles and based on the inclusion/exclusion criteria, 1407 of them were excluded. After reading the full text of the articles, 40 other papers were excluded. Finally, 178 (overall, 108 688 bovines, including 90 732 cattle, 11 791 buffaloes, 5816 yaks and 349 bison) of these articles (total data: 193) were entered into the meta-analysis with respect to the inclusion/exclusion criteria (Fig 2). The publication date of the studied articles was from 1967 to 2019.

Overall, there were 25 studies (28 349 bovines) in Europe, 84 studies (43 735 bovines) in Asia, 31 studies (9748 bovines) in Africa, 36 studies (26 721 bovines) in America and 2 studies (135 bovines) in Australia/Oceania. Among the included articles in this systematic review, enzyme-linked immunosorbent assay (ELISA) was the most common diagnostic method (53 studies), followed by modified agglutination test (MAT) in 24 studies, indirect immunofluorescence antibody test (IFAT) in 41 studies, direct agglutination test (DAT) in seven studies, latex agglutination test (LAT) in 30 studies, Sabin–Feldman dye test (SFDT) in 8 studies, indirect haemagglutination (IHA) in 25 studies, 2-mercaptoethanol (2ME) in one study, complement fixation test (CFT) in one study, Lateral flow chromatographic immunoassay (LFCIA) in one study, Indirect agglutination test (IAT) in one study and Micro precipitation in agar gel (MPA) in one study.

The main characteristics of the included studies are given in Table 1. In the studies, seroprevalence of *T. gondii* among bovines varied (from 0 to 100%) and a heterogeneity in the papers was observed (Cochran $Q = 28\,162.82$; $I^2 = 99.3\%$; $df = 192$;

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**Table 1.** Baseline characteristics of the included studies in this systematic review and meta-analysis based on years

| No. | Author (Ref) | Hosts | Country | Diagnostic methods | Total individuals (*n*) | Seroprevalence *n* (%) | Quality score |
|---|---|---|---|---|---|---|---|
| 1 | Work (1967) | Cattle | Denmark | SFDT | 211 | 24 (11.4) | 6 |
| 2 | Maronpot and Botros (1972) | Cattle-buffalo | Egypt | IFAT | 418 | 111 (6.5) | 5 |
| 3 | Chhabra and Mahajan (1978) | Cattle | India | IHA | 219 | 52 (23.7) | 5 |
| 4 | Costa *et al.* (1978) | Cattle | Brazil | IFAT | 204 | 66 (32.3) | 5 |
| 5 | Riemann *et al.* (1978) | Cattle | United States | IHA | 33 | 67 (18.1) | 5 |
| 6 | Tizard *et al.* (1978) | Cattle | Canada | SFDT | 1759 | 309 (7.5) | 7 |
| 7 | Aganga *et al.* (1981) | Cattle | Nigeria | IHA | 200 | 6 (3) | 5 |
| 8 | | | | IFAT | 200 | 6 (3) | |
| 9 | Makinde and Ezeh (1981) | Cattle | Nigeria | IHA | 638 | 416 (5.2) | 6 |
| 10 | McColm *et al.* (1981) | Cattle | Scotland | SFDT | 250 | 7 (2.8) | 6 |
| 11 | van Knapen *et al.* (1982) | Cattle | Netherlands | ELISA | 180 | 8 (6.6) | 5 |
| 12 | Chhabra *et al.* (1985) | Cattle-buffalo | India | IHA | 351 | 64 (18.2) | 6 |
| 13 | Dubey (1985) | Cattle-bison | United States | MAT | 2632 | 84 (3.1) | 8 |
| 14 | Zain Eldin *et al.* (1985) | Cattle | Sudan | IHA | 175 | 70 (40) | 5 |
| 15 | Bekele and Kasali (1989) | Cattle | Ethiopia | IHA | 785 | 55 (7) | 7 |
| 16 | Norton *et al.* (1989) | Cattle | Queensland | IHA | 105 | 0 (0) | 5 |
| 17 | Rajamanickam *et al.* (1990) | Cattle | Malaysia | IHA | 132 | 0 (0) | 5 |
| 18 | Moreno *et al.* (1991) | Cattle | Spain | IFAT | 304 | 122 (0.1) | 5 |
| 19 | | | | 2ME | 304 | 125 (1.1) | |
| 20 | Hejlicek and Literak (1992) | Cattle | Czech | SFDT | 218 | 49 (22.4) | 5 |
| 21 | | | | CFT | 176 | 6 (3.4) | |
| 22 | | | | MPA | 209 | 1 (0.5) | |
| 23 | Garcia-Vazquez *et al.* (1993) | Cattle | Mexico | ELISA | 397 | 47 (11.8) | 7 |
| 24 | Hoghooghirad and Afraa (1993) | Cattle | Iran | LAT | 142 | 21 (14.8) | 5 |
| 25 | Samad *et al.* (1993) | Cattle | Bangladesh | LAT | 205 | 33 (16.1) | 7 |
| 26 | Arias *et al.* (1994) | Cattle | Costa Rica | IFAT | 601 | 206 (4.4) | 7 |
| 27 | van Knapen *et al.* (1995) | Cattle | Netherland | ELISA | 13256 | 1947 (0.7) | 7 |
| 28 | Zaki (1995) | Cattle | Pakistan | LAT | 100 | 25 (25) | 5 |
| 29 | Adesiyun and Cazabon (1996) | Cattle | Trinidad | DAT | 55 | 15 (27.3) | 5 |
| 30 | HashemiFesharki (1996) | Cattle | Iran | LAT | 2000 | 0 (0) | 6 |
| 31 | | | | IHA | 2000 | 0 (0) | |
| 32 | Matsuo and Husin (1996) | Cattle | Indonesia | LAT | 200 | 18 (9) | 6 |
| 33 | Dubey *et al.* (1998) | Buffalo | Egypt | MAT | 75 | 0 (0) | 6 |
| 34 | Huong *et al.* (1998) | Cattle-buffalo | Vietnam | DAT | 400 | 27 (6.7) | 6 |
| 35 | Navidpour and Hoghooghi-Rad (1998) | Buffalo | Iran | IFAT | 385 | 34 (8.8) | 5 |
| 36 | Gondim *et al.* (1999) | Cattle-Buffalo | Brazil | LAT | 298 | 6 (2) | 7 |
| 37 | Mirdha *et al.* (1999) | Cattle | India | IHA | 50 | 26 (52) | 5 |
| 38 | El-Metenawy (2000) | Cattle | Saudi Arabia | IHA | 60 | 1 (1.7) | 5 |
| 39 | de Souza *et al.* (2001) | Buffalo | Brazil | IFAT | 411 | 205 (9.9) | 6 |
| 40 | Sroka (2001) | Cattle | Poland | DAT | 262 | 141 (3.8) | 7 |
| 41 | Nalbantoğlu *et al.* (2002) | Cattle | Cyprus | SFDT | 98 | 34 (34.7) | 5 |
| 42 | | | | IFAT | 98 | 30 (30.6) | |
| 43 | Joshua and Akinwumi (2003) | Cattle | Nigeria | LAT | 586 | 99 (16.9) | 5 |

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**Table 1.** (*Continued.*)

| No. | Author (Ref) | Hosts | Country | Diagnostic methods | Total individuals (*n*) | Seroprevalence *n* (%) | Quality score |
|---|---|---|---|---|---|---|---|
| 44 | Tutuncu *et al.* (2003) | Cattle | Turkey | IHA | 104 | 8 (7.6) | 5 |
| 45 | Diakou *et al.* (2005) | Cattle | Greece | ELISA | 105 | 21 (20) | 6 |
| 46 | Dubey *et al.* (2005) | Cattle | United States | ELISA | 2094 | 0 (0) | 10 |
| 47 | Ogawa *et al.* (2005) | Cattle | Brazil | IFAT | 385 | 102 (6) | 8 |
| 48 | Chaudhary *et al.* (2006) | Cattle | Pakistan | LAT | 50 | 11 (22) | 5 |
| 49 | Ghazaei (2006) | Cattle | Iran | ELISA | 200 | 18 (9) | 6 |
| 50 | Klun *et al.* (2006) | Cattle | Serbia | MAT | 611 | 466 (6.3) | 9 |
| 51 | Sedlak and Bartova (2006) | Cattle | Czech | IFAT | 46 | 17 (37) | 8 |
| 52 | Hamzavi *et al.* (2007) | Cattle | Iran | IFAT | 125 | 6 (4.8) | 5 |
| 53 | Selvaraj *et al.* (2007) | Buffalo | India | MAT | 99 | 99 (100) | 5 |
| 54 | Sharif *et al.* (2007) | Cattle | Iran | IFAT | 290 | 0 (0) | 6 |
| 55 | Sroka *et al.* (2007) | Cattle | Poland | DAT | 259 | 139 (3.7) | 6 |
| 56 | Yu *et al.* (2007) | Cattle | China | IAT | 263 | 6 (2.3) | 9 |
| 57 | Acici *et al.* (2008) | Cattle | Turkey | SFDT | 96 | 52 (54.1) | 6 |
| 58 | Chandrawathani *et al.* (2008) | Cattle | Malaysia | IFAT | 126 | 8 (6.3) | 5 |
| 59 | Jittapalapong *et al.* (2008) | Cattle | Thailand | ELISA | 186 | 23 (12.4) | 6 |
| 60 | Konnai *et al.* (2008) | Cattle | Philippines | ELISA | 96 | 5 (5.2) | 6 |
| 61 | Liu *et al.* (2008) | Yak | China | LAT | 946 | 112 (1.8) | 8 |
| 62 | More *et al.* (2008) | Cattle | Argentina | IFAT | 90 | 82 (91) | 7 |
| 63 | | | | MAT | 90 | 13 (14.4) | |
| 64 | Nematollahi and Moghddam (2008) | Cattle | Iran | IFAT | 490 | 78 (15.9) | 7 |
| 65 | Sharma *et al.* (2008) | Cattle-buffalo | India | ELISA | 186 | 5 (2.6) | 5 |
| 66 | Ergin *et al.* (2009) | Cattle | Turkey | LAT | 50 | 12 (24) | 5 |
| 67 | Gilot-Fromont *et al.* (2009) | Cattle | France | MAT | 1329 | 103 (.8) | 8 |
| 68 | Ibrahim *et al.* (2009) | Cattle | Egypt | ELISA | 93 | 10 (10.7) | 5 |
| 69 | Santos *et al.* (2009) | Cattle | Brazil | IFAT | 2000 | 1420 | 6 |
| 70 | Yildiz *et al.* (2009) | Cattle | Turkey | SFDT | 557 | 138 (4.7) | 6 |
| 71 | Akca and Mor (2010) | Cattle | Turkey | ELISA | 216 | 202 (3.5) | 7 |
| 72 | Asgari *et al.* (2010) | Cattle | Iran | IFAT | 588 | 119 (0.2) | 6 |
| 73 | Hamidinejat *et al.* (2010b) | Cattle | Iran | MAT | 450 | 71 (15.8) | 7 |
| 74 | Hamidinejat *et al.* (2010a) | Buffalo | Iran | MAT | 300 | 43 (14.3) | 7 |
| 75 | Inpankaew *et al.* (2010) | Cattle | Thailand | LAT | 700 | 66 (9.4) | 7 |
| 76 | | | | ELISA | 700 | 119 (7) | |
| 77 | Panadero *et al.* (2010) | Cattle | Spain | DAT | 178 | 13 (7.3) | 7 |
| 78 | Schoonman *et al.* (2010) | Cattle | Tanzania | LAT | 654 | 22 (3.36) | 7 |
| 79 | Shaapan *et al.* (2010) | Buffalo | Egypt | MAT | 160 | 36 (22.5) | 5 |
| 80 | Silva *et al.* (2010) | Buffalo | Brazil | IFAT | 374 | 4 (1.1) | 6 |
| 81 | Sroka *et al.* (2010) | Cattle | Poland | DAT | 74 | 25 (33.8) | 6 |
| 82 | Albuquerque *et al.* (2011) | Cattle | Brazil | IFAT | 589 | 87 (14.8) | 6 |
| 83 | Al-Mohammed (2011) | Cattle | Saudi Arabia | ELISA | 130 | 6 (4.6) | 5 |
| 84 | Persad *et al.* (2011) | Buffalo | Trinidad | LAT | 333 | 26 (7.8) | 9 |
| 85 | Berger-Schoch *et al.* (2011) | Cattle | Switzerland | ELISA | 406 | 185 (5.6) | 7 |
| 86 | Chikweto *et al.* (2011) | Cattle | India | MAT | 119 | 10 (8.4) | 5 |
| 87 | Costa *et al.* (2011) | Cattle | Brazil | IFAT | 50 | 9 (18) | 7 |

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**Table 1.** (*Continued.*)

| No. | Author (Ref) | Hosts | Country | Diagnostic methods | Total individuals (*n*) | Seroprevalence *n* (%) | Quality score |
|---|---|---|---|---|---|---|---|
| 88 | Song *et al.* (2011) | Cattle | South Korea | LAT | 105 | 4 (3.8) | 5 |
| 89 | Frazao-Teixeira and de Oliveira (2011) | Cattle | Brazil | ELISA | 77 | 38 (49.3) | 6 |
| 90 | Khalil and Elrayah (2011) | Cattle | Sudan | LAT | 50 | 16 (32) | 5 |
| 91 | Lee *et al.* (2011) | Cattle | China | ELISA | 368 | 25 (6.8) | 5 |
| 92 | Liu *et al.* (2011) | Yak | China | IHA | 650 | 228 (5.1) | 6 |
| 93 | Luciano *et al.* (2011) | Cattle | Brazil | IFAT | 459 | 9 (1.9) | 6 |
| 94 | Raeghi *et al.* (2011) | Cattle | Iran | MAT | 120 | 2 (1.6) | 5 |
| 95 | Rahman *et al.* (2011) | Cattle | Malaysia | IFAT | 116 | 3 (2.6) | 5 |
| 96 | Roqueplo *et al.* (2011) | Cattle | New Caledonia | ELISA | 30 | 1 (3.3) | 5 |
| 97 | Shahiduzzaman *et al.* (2011) | Cattle | Bangladesh | LAT | 25 | 3 (12) | 5 |
| 98 | Sroka *et al.* (2011) | Cattle | Poland | MAT | 865 | 111 (2.8) | 6 |
| 99 | | | | ELISA | 865 | 126 (4.6) | |
| 100 | Bao *et al.* (2012) | Cattle | China | IHA | 350 | 24 (6.8) | 6 |
| 101 | Costa *et al.* (2012) | Cattle | Brazil | IFAT | 100 | 3 (3) | 5 |
| 102 | de Macedo *et al.* (2012b) | Cattle | Brazil | IFAT | 60 | 29 (48.3) | 7 |
| 103 | de Macedo *et al.* (2012a) | Cattle | Brazil | IFAT | 120 | 35 (29.1) | 5 |
| 104 | Garcia *et al.* (2012) | Cattle | Brazil | IFAT | 169 | 44 (26) | 6 |
| 105 | Qiu *et al.* (2012) | Cattle | China | IHA | 1803 | 46 (2.6) | 9 |
| 106 | Shabbir *et al.* (2012) | Cattle-buffalo | Pakistan | LAT | 90 | 0 (0) | 5 |
| 107 | Swai and Schoonman (2012) | Cattle | Tanzania | LAT | 51 | 6 (12) | 6 |
| 108 | Wang *et al.* (2012) | Yak | China | IHA | 1603 | 133 (.3) | 9 |
| 109 | Wiengcharoen *et al.* (2012) | Cattle | Thailand | IFAT | 389 | 100 (5.7) | 7 |
| 110 | Liu *et al.* (2012) | Cattle | China | IHA | 646 | 39 (6) | 7 |
| 111 | Xu *et al.* (2012) | Cattle | China | IHA | 875 | 120 (3.7) | 7 |
| 112 | Yang *et al.* (2012) | Cattle | China | ELISA | 572 | 19 (3.3) | 6 |
| 113 | Zhou *et al.* (2012) | Cattle | China | IHA | 350 | 20 (5.7) | 8 |
| 114 | Asgari *et al.* (2013) | Cattle | Iran | MAT | 80 | 44 (55) | 5 |
| 115 | de Santos *et al.* (2013) | Cattle-buffalo | Brazil | IFAT | 290 | 67 (23.1) | 6 |
| 116 | Dehkordi *et al.* (2013) | Cattle-buffalo | Iran | ELISA | 364 | 11 (3) | 9 |
| 117 | Elfahal *et al.* (2013) | Cattle | Sudan | ELISA | 181 | 24 (13.3) | 6 |
| 118 | Fajardo *et al.* (2013) | Cattle | Brazil | IFAT | 1195 | 32 (2.7) | 10 |
| 119 | Garcia-Bocanegra *et al.* (2013) | Cattle | Spain | ELISA | 504 | 420 (3.3) | 5 |
| 120 | Holec-Gasior *et al.* (2013) | Cattle | Poland | ELISA | 4033 | 127 (.1) | 9 |
| 121 | Konrad *et al.* (2013) | Buffalo | Argentina | IFAT | 500 | 127 (5.4) | 7 |
| 122 | Lopes *et al.* (2013) | Cattle | Portugal | MAT | 161 | 12 (7.5) | 7 |
| 123 | Nagwa *et al.* (2013) | Cattle | Egypt | ELISA | 94 | 44 (46.8) | 6 |
| 124 | Ndou *et al.* (2013) | Cattle | South Africa | ELISA | 178 | 37 (20.8) | 5 |
| 125 | Singh *et al.* (2013) | Cattle | India | ELISA | 45 | 13 (28.9) | 5 |
| 126 | Tasawar *et al.* (2013) | Cattle | Pakistan | LAT | 200 | 87 (43.5) | 6 |
| 127 | Ahmad and Qayyum (2014) | Cattle-buffalo | Pakistan | ELISA | 822 | 143 (7.4) | 7 |
| 128 | Alvarado-Esquivel *et al.* (2014) | Buffalo | Mexico | MAT | 339 | 165 (8.7) | 7 |
| 129 | Anees *et al.* (2014) | Buffalo | Pakistan | LAT | 50 | 7 (14) | 5 |
| 130 | Beyhan *et al.* (2014) | Buffalo | Turkey | SFDT | 131 | 115 (9.7) | 6 |
| 131 | Da Silva *et al.* (2014) | Buffalo | Brazil | ELISA | 4796 | 1982 (.3) | 9 |

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**Table 1.** (*Continued.*)

| No. | Author (Ref) | Hosts | Country | Diagnostic methods | Total individuals (*n*) | Seroprevalence *n* (%) | Quality score |
|---|---|---|---|---|---|---|---|
| 132 | | | | IFAT | 4796 | 1715 (0.8) | |
| 133 | Davoust *et al.* (2014) | Cattle | Senegal | MAT | 103 | 13 (13) | 6 |
| 134 | Elfahal *et al.* (2014) | Cattle | Sudan | LAT | 181 | 39 (21.5) | 6 |
| 135 | | | | ELISA | 181 | 24 (13.3) | |
| 136 | Ge *et al.* (2014) | Cattle | China | ELISA | 1040 | 133 (2.8) | 7 |
| 137 | Gharekhani (2014b) | Cattle | Iran | ELISA | 1406 | 32 (2.3) | 6 |
| 138 | Gharekhani (2014a) | Cattle | Iran | ELISA | 85 | 5 (5.9) | 5 |
| 139 | Ibrahim *et al.* (2014a) | Cattle | Sudan | LAT | 1216 | 497 (0.9) | 7 |
| 140 | Ibrahim *et al.* (2014b) | Cattle | Sudan | ELISA | 744 | 371 (9.9) | 7 |
| 141 | Kadle (2014) | Cattle | Somalia | LAT | 28 | 2 (7.1) | 6 |
| 142 | Li *et al.* (2014) | Yak | China | IHA | 1641 | 410 (5) | 8 |
| 143 | Matsuo *et al.* (2014) | Cattle | Japan | LAT | 422 | 31 (7.3) | 6 |
| 144 | Rahman *et al.* (2014) | Cattle | Bangladesh | LAT | 37 | 10 (27) | 5 |
| 145 | Yagci Yucel *et al.* (2014) | Cattle | Turkey | MAT | 132 | 74 (56.1) | 6 |
| 146 | Bartova *et al.* (2015) | Cattle | Czech Republic | ELISA | 546 | 53 (9.7) | 6 |
| 147 | Brasil *et al.* (2015) | Buffalo | Brazil | IFAT | 136 | 17 (12.5) | 8 |
| 148 | Dechicha *et al.* (2015) | Cattle | Algeria | IFAT | 332 | 13 (3.9) | 6 |
| 149 | Furtado *et al.* (2015) | Cattle | Brazil | IFAT | 1245 | 10 (0.8) | 9 |
| 150 | Ibrahim *et al.* (2015) | Cattle | Sudan | LAT | 1216 | 497 (0.9) | 8 |
| 151 | Ichikawa-Seki *et al.* (2015) | Cattle | Indonesia | ELISA | 598 | 44 (7.4) | 8 |
| 152 | Kalita and Sarmah (2015) | Cattle | India | MAT | 60 | 16 (26.6) | 5 |
| 153 | Lahmar *et al.* (2015) | Cattle | Tunisia | MAT | 25 | 3 (12) | 5 |
| 154 | Onyiche and Ademola (2015) | Cattle | Nigeria | ELISA | 210 | 29 (13.8) | 6 |
| 155 | Qin *et al.* (2015) | Yak | China | MAT | 974 | 155 (5.9) | 7 |
| 156 | Singh *et al.* (2015) | Cattle | India | ELISA | 45 | 29 (64.4) | 5 |
| 157 | Sudan *et al.* (2015) | Cattle | India | ELISA | 252 | 181 (1.8) | 6 |
| 158 | Sun *et al.* (2015) | Cattle | China | IHA | 4487 | 470 (0.5) | 9 |
| 159 | Tan *et al.* (2015) | Cattle | China | MAT | 1657 | 80 (4.8) | 7 |
| 160 | Zou *et al.* (2015) | Buffalo | China | IHA | 427 | 32 (7.5) | 7 |
| 161 | de Souza *et al.* (2016) | Cattle | Brazil | IFAT | 1000 | 53 (5.3) | 7 |
| 162 | Fereig *et al.* (2016) | Cattle | Egypt | LAT | 301 | 88 (29.2) | 7 |
| 163 | | | | ELISA | 301 | 85 (28.2) | |
| 164 | Kuraa and Malek (2016) | Cattle-buffalo | Egypt | ELISA | 111 | 82 (73.9) | 7 |
| 165 | | | | LAT | 111 | 39 (35.1) | |
| 166 | Magalhães *et al.* (2016) | Cattle | Brazil | IFAT | 140 | 15 (10.7) | 7 |
| 167 | Oh *et al.* (2016) | Cattle | South Korea | ELISA | 568 | 3 (0.5) | 6 |
| 168 | FK and Shah (2016) | Cattle | Pakistan | LAT | 250 | 35 (14) | 6 |
| 169 | Portella *et al.* (2016) | Buffalo | Brazil | IFAT | 220 | 37 (16.8) | 6 |
| 170 | Zhou *et al.* (2016) | Cattle | Turkey | ELISA | 377 | 15 (4) | 7 |
| 171 | Ayinmode *et al.* (2017) | Cattle | Nigeria | ELISA | 174 | 13 (7.5) | 7 |
| 172 | Bartova *et al.* (2017) | Yak-buffalo-bison | Czech Republic | IFAT | 23 | 5 (21.7) | 7 |
| 173 | | | | ELISA | 23 | 3 (13) | |
| 174 | da Silva *et al.* (2017) | Cattle-buffalo | Brazil | IFAT | 1000 | 464 (6.4) | 7 |
| 175 | Do Carmo EL do Carmo et al. (2017) | Cattle | Brazil | IFAT | 500 | 203 (0.6) | 7 |

(*Continued*)

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**Table 1.** (*Continued.*)

| No. | Author (Ref) | Hosts | Country | Diagnostic methods | Total individuals (*n*) | Seroprevalence *n* (%) | Quality score |
|---|---|---|---|---|---|---|---|
| 176 | Jokelainen *et al.* (2017) | Cattle | Estonia | DAT | 3991 | 743 (8.6) | 8 |
| 177 | Luo *et al.* (2017) | Cattle-buffalo | China | IHA | 595 | 98 (16.4) | 8 |
| 178 | Almeria *et al.* (2018) | Cattle | Spain | MAT | 199 | 37 (18.6) | 7 |
| 179 | De Oliveira *et al.* (2018) | Cattle-buffalo | Brazil | ELISA | 2070 | 741 (5.8) | 9 |
| 180 | | | | IFAT | 2070 | 934 (5.1) | |
| 181 | Dong *et al.* (2018a) | Cattle | China | MAT | 5292 | 102 (0.93) | 9 |
| 182 | Kakooza *et al.* (2018) | Cattle | Uganda | ELISA | 52 | 2 (3.8) | 6 |
| 183 | Khames *et al.* (2018) | Cattle | Algeria | MAT | 295 | 13 (4.4) | 7 |
| 184 | Krzysiak *et al.* (2018) | Bison | Poland | ELISA | 240 | 25 (10.4) | 8 |
| 185 | Majeed and Abbas (2018) | Cattle-buffalo | Iraq | ELISA | 200 | 39 (19.5) | 8 |
| 186 | Pagmadulam *et al.* (2018) | Cattle | Mongolia | ELISA | 1438 | 269 (8.7) | 10 |
| 187 | Sah *et al.* (2018a) | Cattle | Nepal | LFCIA | 92 | 8 (8.7) | 6 |
| 188 | Sah *et al.* (2018b) | Cattle | Bangladesh | ELISA | 252 | 21 (8.3) | 9 |
| 189 | Shadia Ahmed (2018) | Cattle | Sudan | LAT | 96 | 6 (6.2) | 6 |
| 190 | Tilahun *et al.* (2018) | Cattle | Ethiopia | ELISA | 326 | 35 (10.7) | 10 |
| 191 | Udonsom *et al.* (2018) | Cattle | Thailand | ELISA | 250 | 52 (20.8) | 8 |
| 192 | Deng *et al.* (2020) | Cattle | China | IHA | 535 | 33 (6.2) | 9 |
| 193 | Sudan *et al.* (2019) | Cattle | India | ELISA | 258 | 115 (61.5) | 8 |

ELISA, enzyme-linked immunosorbent assay; MAT, modified agglutination test; IFAT, indirect immunofluorescence antibody test; DAT, direct agglutination test; LAT, latex agglutination test; SFDT, Sabin–Feldman dye test; CFT, complement fixation test; LFCIA, lateral flow chromatographic immunoassay; IAT, indirect agglutination test; MPA, micro precipitation in agar gel; IHA, indirect haemagglutination.

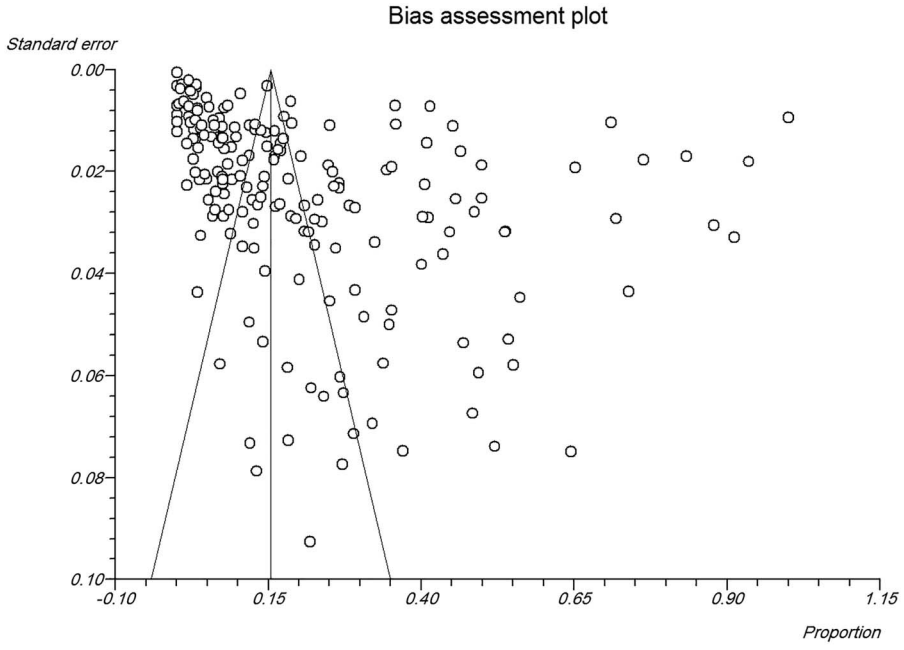


**Fig. 3.** Bias assessment plot from the Egger's test based on standard error.

$P < 0.001$). Moreover, the results of the Begg–Mazumdar and Egger's regression test conducted to determine publication bias indicated no considerable effect on the total prevalence estimate (Begg–Mazumdar: $7.34 \times 10^{-3}$, Egger's bias = 10.56, $P = 0.88$ and $P < 0.001$) (Fig 3).

The global pooled and weighted seroprevalence of *T. gondii* among bovines was 17.91% (95% CI: 15.32–20.6). The forest plot diagram of the present systematic review is illustrated in Fig 4. Moreover, the weighted prevalence of this parasite in bovines based on the host was as follows: cattle 16.94% (95% CI: 14.25–19.81), buffalo 22.26% (95% CI: 16.8–29), yak 23% (95% CI: 14–33) and bison 8.1% (95% CI: 3.9–13.7). Significant geographic differences in pooled *T. gondii* seropositivity rates among bovine were estimated. The seroprevalence was higher in America and Europe, where the *T. gondii* seropositivity rate was 22.2% (95% CI: 15.2–30.1) and 21.93% (95% CI: 15.98–28.53),

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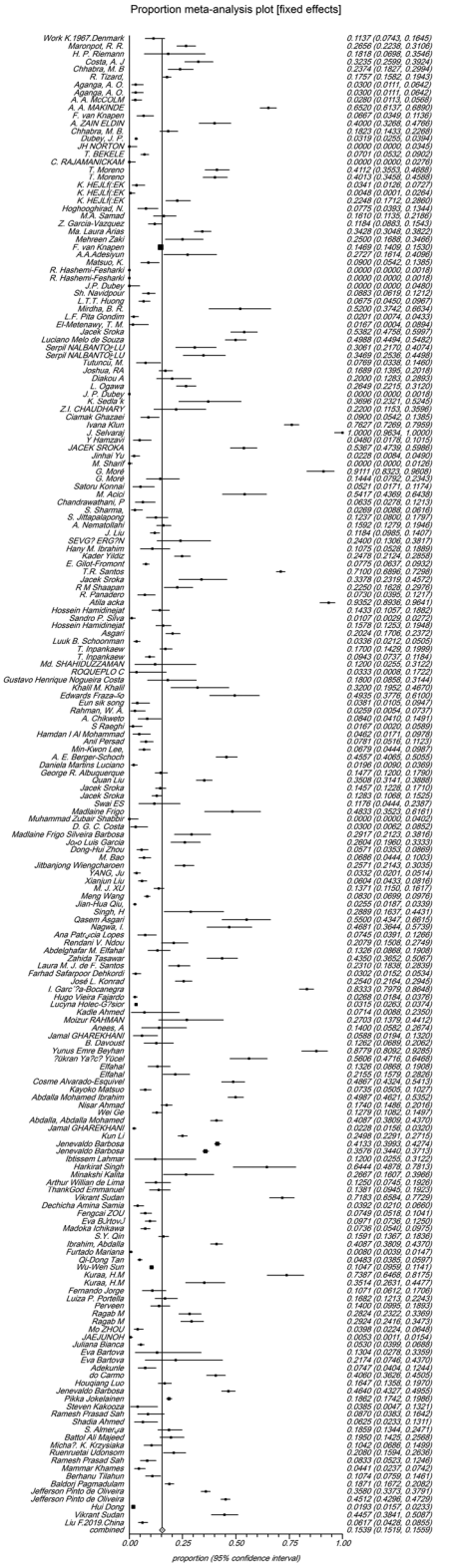


**Fig. 4.** Forest plot displaying the global seroprevalence of *Toxoplasma gondii* in bovines.

respectively. The lowest seroprevalence was estimated in Australia/Oceania with the rate of 1.36% (95% CI: 0.02–7.65). A geographical map summarizing the seroprevalence of *T. gondii* among bovine in the world is shown in Fig 5.

The pooled seroprevalences of *T. gondii* in male and female bovine were 18.9% (95% CI: 13.8–24.7) and 17.78% (95% CI: 13.2–22.86), respectively. In a subgroup analysis based on diagnostic methods, the highest *T. gondii* seroprevalence detected by SFDT was 30% (95% CI: 17–45), followed by DAT 27% (95% CI: 13–43), IFAT 20.3% (95% CI: 13.9–27.6), MAT 19.7% (12.3–28.5), ELISA 18.52% (95% CI: 13.74–23.84), LAT 14.7% (95% CI: 8.9–21.8) and IHA 12.81% (95% CI: 7.82–18.81). The seroprevalence was higher in 2001–2005 and 2005–2010, whereas the *T. gondii* seropositivity rates were approximately 23.5% (95% CI: 6.8–46.3) and 23.5% (95% CI: 14.4–34.1), respectively. The lowest seroprevalence was estimated in ⩽2000 with the rate of 12.36%% (95% CI: 8.19–17.24). In a subgroup analysis based on sample size, the highest *T. gondii* seroprevalence was detected in sample size of 601–900 with the prevalence of 23% (95% CI: 13–35) followed by ⩽300 with the prevalence of 19.23% (95% CI: 15.17–23.63), 301–600 with the prevalence of 16.4% (95% CI: 11.7–21.8) and ⩾901 with the prevalence of 13.6% (95% CI: 8.3–19.9).

Table 2 summarizes the results of subgroup analysis and its details. Based on subgroup analysis, a statistically significant difference was observed in the overall prevalence of *T. gondii* in bovine based on year ($\chi^2 = 1346.94$, $P < 0.001$), continent ($\chi^2 = 4145.1$, $P < 0.001$), bovine species ($\chi^2 = 2632.73$, $P < 0.001$), gender ($\chi^2 = 4.62$, $P = 0.032$), method ($\chi^2 = 2833.23$, $P < 0.001$) and sample size ($\chi^2 = 363$, $P < 0.001$).

## Discussion

Toxoplasmosis is one of the most common parasitic diseases in warm-blooded animals and in livestock poses a risk to the general public health, as the consumption of raw or uncooked meat can facilitate *T. gondii* transmission to humans (Tilahun *et al.*, 2018). Therefore, it is difficult to implement the prevention and control programmes without sufficient information on the prevalence of *T. gondii* infection in animals, because they are the main source of zoonosis. Bovines are one of the most important sources of meat for humans in the world. However, the clinical symptoms of toxoplasmosis in bovines are much milder or more unknown than in the sheep, goats and pigs. However, it seems that accurate estimation on the prevalence of the infection in bovines for large-scale screening is essential in order to elucidate the role of bovines as carriers of *T. gondii* tissue cysts and to clarify the role of beef and milk in transmitting *T. gondii* to humans for health. The purpose of the analysis and interpretation presented in this review is to better understand the global prevalence of *T. gondii* among bovines. Overall, 108 688 bovines including 90 732 cattle, 11 791 buffaloes, 5816 yaks and 349 bisons were investigated by various serological methods. The data demonstrate that the weighted global seroprevalence in bovines was 17.91% and the prevalence range was between 0 and 100. There are numerous differences in the seroprevalence of bovine *T. gondii* infection in the world that could be categorized as follows: (i) biological aspects of parasites including geographical location, climate change, humidity and temperature, which can be effective in the parasitic life cycle and facilitate transmission, (ii) behavioural aspects including animal husbandry industry, the diet in different nations, especially the type of cooking, and public health management, which are considered as important variables in the prevalence of the infection in different communities and (iii) investigative aspects including study population, sample size, type of sampling and diagnostic method, which influences different findings in each study.

To investigate the causes of heterogeneity in the findings of studies included in this systematic review, the subgroup analysis was performed on various variables such as year, continent, and bovine species, gender, diagnostic methods and sample size. Our findings indicated a significant difference between the seroprevalence of *T. gondii* and the bovine species. The pooled seroprevalence of *T. gondii* in yak, buffalo, cattle and bison were 23,

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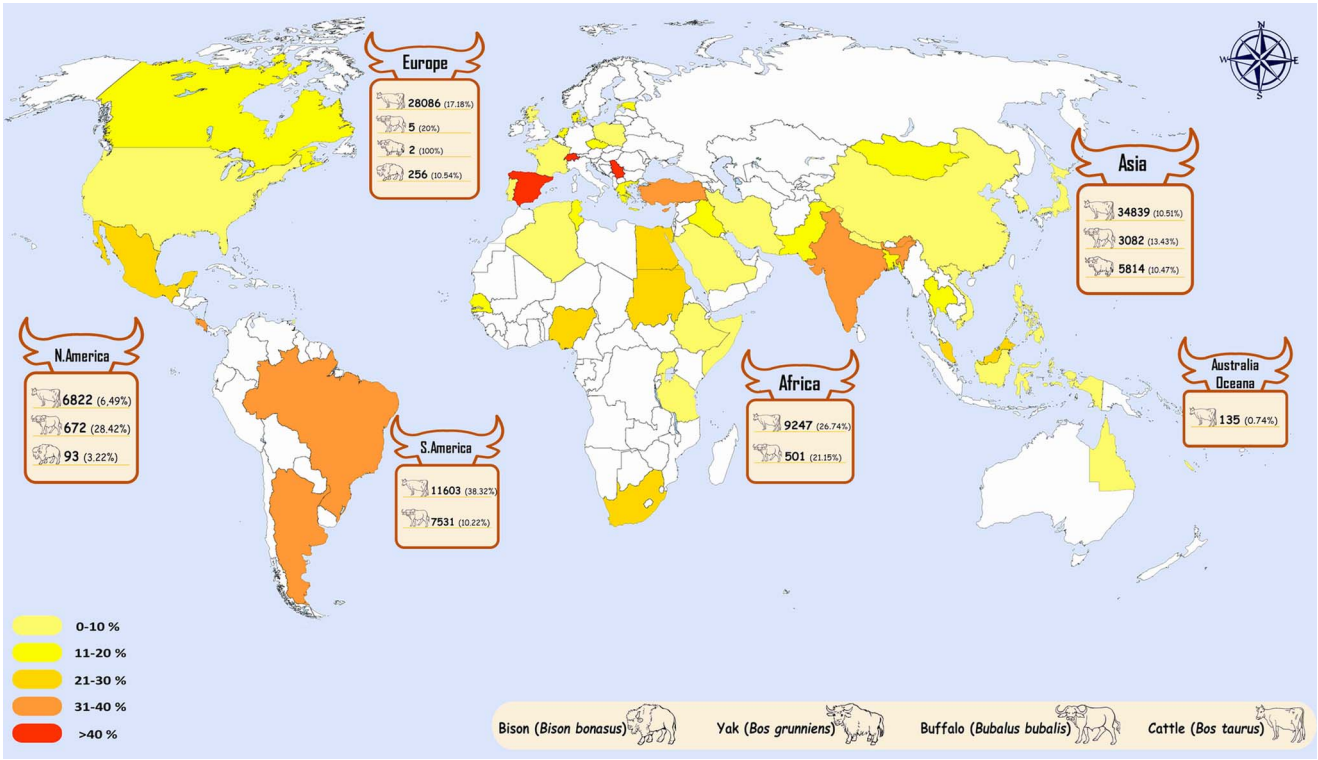


**Fig. 5.** Global distribution map of seroprevalence of *T. gondii* in bovines worldwide.

22.26, 16.9, and 8.1%, respectively. The most prevalent rate was noted in yaks because the animals are free-grazing bovines that live with other wild and domestic animals. Yak (*B. grunniens*) is a long-haired male bovine species that lives in Afghanistan, the Himalayas, the Tibetan Plateau and Mongolia (Liu *et al.,* 2008). Yaks graze in pastures that are exposed to more *T. gondii* oocysts followed by the consequences of increasing the risk of infection (Qin *et al.,* 2015). Also, the investigated population in various studies on yaks (6 data) is less than cattle (155 data) and buffalo (31 data). In the case of buffaloes, although they are similar to yaks in grazing, perhaps this less common difference than in the yaks is related to the more studied population of buffaloes (Alvarado-Esquivel *et al.,* 2014). The prevalence of toxoplasmosis among buffaloes and yaks were almost similar, which is related to their way of life and breeding. These types of livestock are not bred centrally at all and are fed on open grazing in pastures, but cattle are usually kept centrally and are raised industrially. Obviously, in this type of breeding, the animals have much less access to free water or oocyst-contaminated forage. Although in traditional breeding, livestock has high and easy access to pastures, forage and the oocyst-contaminated water. The low prevalence of *T. gondii* in bison (8.1%) could be attributed to the fact that they are less exposed to cats and in contact with less occurrence of parasite life cycle, as a result, less risk of contamination. Of course, the number of studies on bison is much less compared to other bovines. Perhaps, if the population of this animal had been examined in greater numbers, the prevalence could have been changed as well (Wang *et al.,* 2012; Alvarado-Esquivel *et al.,* 2014; Brasil *et al.,* 2015).

Among the studies, there was a slight difference in the rate of infection by sex; therefore, the rate of infection in males (18.9%) was higher than that in the females (17.78%). Although in most studies the seroprevalence is higher in females. It could be attributed to the low immune system in females for the reasons, such as pregnancy and lactation. In most studies, the population of industrial dairy cattle was investigated (Bao *et al.,* 2012; FK and Shah, 2016). When the study population is higher in the industrial farms where cattle are usually not in contact with pastures and are less exposed to the parasites present in pastures. Under this condition, the lower percentage of infection in the male is more reasonable. Differences in the prevalence of *T. gondii* infection in females compared to males may be attributed to differences in sex hormones. Some researchers believe that female bovines are more resistant to infection compared to males, because the female hormones such as oestrogen strengthen and boost the immune system compared to androgen in males. Androgens make males more susceptible to infection due to a weakening immune system (Diakou *et al.,* 2005; Albuquerque *et al.,* 2011; FK and Shah, 2016).

Based on our analysis, the most prevalence rate of *T. gondii* infection in cattle was observed in studies that used the Sabin–Feldman, DAT, IFAT, MAT, ELISA, LAT and IHA, respectively. MAT is more accurate and suitable compared to other agglutination methods but is unsuitable for investigation in the field, because it requires a large number of tachyzoites of *T. gondii* (Jones and Dubey, 2012). ELISA is a simple method for *T. gondii* diagnosis, but it requires species-specific combinations and an ELISA reader device. The sensitivity and specificity of serological assays are varied. Seroprevalence of *T. gondii* in cattle can be up to 90%, while isolation of live *T. gondii* from cattle has generally been unsuccessful (Dubey and Beattie, 1988). Serological tests, especially MAT, IFAT and ELISA are the most common methods for diagnosing *T. gondii* infection in animal products and meat. Serological methods are often used as the first screening method to identify infected animals. The selection of a reliable and precise method can effectively interpret the results of *T. gondii* serological studies (Sharma *et al.,* 2008; Sroka *et al.,* 2011; Fereig *et al.,* 2016).

The prevalence of *T. gondii* in bovines varied in different years. It seems that since the beginning of 2000, with the introduction of different methods, the prevalence has increased slightly compared to the reports prior to 2000. However, this prevalence rate of infection has decreased in the last 5 years, despite numerous

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**Table 2.** Subgroup meta-analysis (variables such as year, continent, bovine species, gender, method and sample sizes) of global seroprevalence of *Toxoplasma gondii* in bovine

| | | Heterogeneity | | | Publication bias | | Chi square test | |
|---|---|---|---|---|---|---|---|---|
| Variables | Pooled prevalence (95% CI) | Cochran *Q* | $I^2$ (%) | *P* value | Egger | *P* value | $\chi^2$ | *P* value |
| Year | | | | | | | | |
| ⩽2000 | 12.36 (8.19–17.24) | 4302.99 | 99.1 | <0.001 | 8.15 | <0.001 | 1346.94 | <0.001 |
| 2001–2005 | 23.5 (6.8–46.3) | 1588.89 | 99.5 | <0.001 | 10.11 | 0.002 | | |
| 2006–2010 | 23.5 (14.4–34.1) | 5755.3 | 99.4 | <0.001 | 12.21 | 0.05 | | |
| 2011–2015 | 18.1 (14.21–22.26) | 10 507.56 | 99.3 | <0.001 | 8.55 | <0.001 | | |
| ⩾2015 | 17.5 (11.9–24) | 4493.87 | 99.3 | <0.001 | 9.4 | <0.001 | | |
| Continent | | | | | | | | |
| Africa | 18.8 (12.9–25.5) | 2338.66 | 98.5 | <0.001 | 6.93 | 0.023 | 4145.1 | <0.001 |
| Asia | 14.89 (11.94–18.11) | 7369.87 | 98.8 | <0.001 | 9.23 | <0.001 | | |
| Australia/Oceania | 1.36 (0.02–7.65) | 2.77 | – | 0.096 | – | – | | |
| Europe | 21.93 (15.98–28.53) | 4172.42 | 99.3 | <0.001 | 7.78 | 0.014 | | |
| America | 22.2 (15.2–30.1) | 10 201.28 | 99.6 | <0.001 | 15.02 | <0.001 | | |
| Bovine species | | | | | | | | |
| Cattle | 16.94 (14.25–19.81) | 22 435.56 | 99.3 | <0.001 | 9.23 | <0.001 | 2632.73 | <0.001 |
| Yak | 23 (14–33) | 327.93 | 98.2 | <0.001 | 7.6 | 0.127 | | |
| Buffalo | 22.26 (16.8–29) | 2619.12 | 98.7 | <0.001 | −1.38 | 0.805 | | |
| Bison | 8.1 (3.9–13.7) | 5.76 | 47.9 | 0.124 | 0.29 | 0.881 | | |
| Gender | | | | | | | | |
| Male | 18.9 (13.8–24.7) | 928.13 | 96.3 | <0.001 | 4.7 | <0.001 | 4.62 | 0.032 |
| Female | 17.78 (13.2–22.86) | 9123.3 | 99.3 | <0.001 | 9.51 | <0.001 | | |
| Method | | | | | | | | |
| DAT | 27 (13–43) | 369.87 | 98.6 | <0.001 | 5.33 | 0.398 | 2833.23 | <0.001 |
| ELISA | 18.52 (13.74–23.84) | 8634.2 | 99.4 | <0.001 | 11.39 | <0.001 | | |
| IFAT | 20.3 (13.9–27.6) | 6404.92 | 99.4 | <0.001 | 11.77 | <0.001 | | |
| IHA | 12.81 (7.82–18.81) | 2803.51 | 99.2 | <0.001 | 9.64 | <0.001 | | |
| LAT | 14.7 (8.9–21.8) | 2523.96 | 98.9 | <0.001 | 6.8 | <0.001 | | |
| MAT | 19.7 (12.3–28.5) | 3495.77 | 99.3 | <0.001 | 11.68 | 0.058 | | |
| SFDT | 30 (17–45) | 465.39 | 98.5 | <0.001 | 10.96 | 0.137 | | |
| Sample size | | | | | | | | |
| ⩽300 | 19.23 (15.17–23.63) | 4728.75 | 97.8 | <0.001 | 6.39 | <0.001 | 363 | <0.001 |
| 301–600 | 16.4 (11.7–21.8) | 3434.93 | 98.8 | <0.001 | 15.47 | <0.001 | | |
| 601–900 | 23 (13–35) | 2455.8 | 99.5 | <0.001 | 41.91 | <0.001 | | |
| ⩾901 | 13.6 (8.3–19.9) | 17 020.23 | 99.8 | <0.001 | 24.64 | <0.001 | | |

ELISA, enzyme-linked immunosorbent assay; MAT, modified agglutination test; IFAT, indirect immunofluorescence antibody test; DAT, direct agglutination test; LAT, latex agglutination test; SFDT, Sabin–Feldman dye test.

studies with higher sample sizes, which may be related to the improvement of health index in animal husbandry, especially industrial breeding of livestock, more attention to animal health, the development of animal and veterinary sciences in the case of chronic diseases in large livestock (De Oliveira *et al.*, 2018). The trend of global climate change, the reduction of rainfall, declining groundwater levels and numerous droughts in different parts of the world had an effective role in this declining trend since the beginning of the 20th century. Environmental and geographical factors, such as temperature, rainfall and geographical coordination can change the prevalence of infection in different populations (de Souza *et al.*, 2016; De Oliveira *et al.*, 2018).

Based on subgroup meta-analysis, there was a significant relationship between sample size and the prevalence of *T. gondii* infection, therefore increase of sample size, is followed by increase of the infection prevalence (Table 2). In the studies with a sample size above 900, the prevalence of *T. gondii* was lower than the other groups under study (Table 2). Most studies that had a sample size of more than 900 were conducted in a wider geographical area (e.g. a country or a vast province or the Tibetan Plateau, etc.) than the other three groups. However, when more livestock are studied in a large area (province or country, etc.), that study naturally notices more geographical and climatic diversity, and as a result, the chances

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of finding positive cases may be lower (Dubey *et al.*, 2005; Santos *et al.*, 2009; Gharekhani, 2014*b*)

The strengths of this systematic review include the quality assessment by a checklist for incidence and prevalence study (the Joanna Briggs Critical Appraisal Checklist for Studies Reporting Prevalence Data), the high sample size in the global area, diversity of studies and analysis of subgroups according to geographical location, sex, sample size, year and type of serological method. In this study, we tried to pay attention to the maximum datasets in the article, despite the existence of 178 studies, the number of datasets reached 194, which indicates the accuracy of data extraction.

The main limitation expressed in the included articles was related to the selection of only English-language studies. For example, in Brazil which is one of the largest producers and exporters of beef in the world due to our limited access to local Brazilian journals, the number of included studies in this systematic review was lower than the number of studies conducted in the country.

On the contrary, the prevalence of *T. gondii* infection in bovines has been evaluated with different serological methods, while the gold standard method for diagnosing *T. gondii* infection in bovines is the bioassay method (Dehkordi *et al.*, 2013). The use of different laboratory diagnostic methods with varying sensitivity and specificity can affect the test results. It is better for researchers to use a reliable and precise serological test to measure the prevalence of *T. gondii* in bovines (Khames *et al.*, 2018). It seems that in order to better understand the prevalence of *T. gondii* in bovines, it is necessary to use more sensitive and accurate methods such as PCR along with demographic screening methods, such as serological methods (Majeed and Abbas, 2018). Although the serological methods have many advantages, but the variation in the cut-off value of each method cannot be a definitive indicator to estimate the infection in the animal population (Sharma *et al.*, 2019). The data presented, showed significant heterogeneity among the included studies based on livestock habitat. Some of these studies investigated the prevalence rate of *T. gondii* in industrial livestock that had fencing and protection and was less access to cats as a final host of this parasite, but other studies used domestic livestock with open grazing and with traditional breeding methods, which were more exposed to feces of cats. Some studies carried out on free-ranging wild bovines, such as bison. These animals not only live next to domestic cats but are also exposed to the wild cat's life cycle.

The type of sampling in most studies is not carried out uniformly or randomly or clustered. In fact, in most studies, it is not clear whether the study population represents the entire community in the region or not. In some studies on industrial livestock sampling, the sampling was performed only from livestock in a farm, the correct sampling or an acceptable estimate of the sample size was not mentioned.

Finally, due to the incomplete data in the included studies, our meta-analysis could not evaluate risk factors, such as breed, storage location, feeding age, type of breeding, etc. Evaluating these risk factors could provide a more comprehensive analysis with better dimensions of the problem.

## Conclusion

To the best of our knowledge, this is the first systematic review and meta-analysis that provides a comprehensive view of the global seroepidemiology of bovine toxoplasmosis. The obtained result of this review showed that the global seroprevalence of bovine *T. gondii* infection is relatively high and it emphasizes the need for implementing screening and management of large animal meat products. This type of review analysis gives us an estimation on the prevalence in the world and completes the puzzle of the challenges facing one of the most important slogans of the World Health Organization, entitled 'Food safety from farm to fork'. Finally, investigation on the role of bovine products, such as milk, meat and oral viscera, known as the source of transmission of infection be examined in detail on a global scale to clear the data on bovine toxoplasmosis and its role in humans.

**Acknowledgements.** The authors thank vice chancellors for research of Mazandaran University of Medical Sciences.

**Financial support.** This research received no grants.

**Conflict of interest.** The authors declare no conflicts of interest.

## References

**Acici M, Babur C, Kilic S, Hokelek M and Kurt M** (2008) Prevalence of antibodies to *Toxoplasma gondii* infection in humans and domestic animals in Samsun province, Turkey. *Tropical Animal Health and Production* **40**, 311–315.

**Adesiyun AA and Cazabon EP** (1996) Seroprevalences of brucellosis, Q-fever and toxoplasmosis in slaughter livestock in Trinidad. *Revue d'élevage et de médecine vétérinaire des pays tropicaux* **49**, 28–30.

**Aganga AO, Belino ED, Adegboye DS and Ilemobade AA** (1981) A serological survey of toxoplasmosis in food animals (cattle, sheep, goats and swine) in two Northern States of Nigeria. *International Journal of Zoonoses* **8**, 57–62.

**Ahmad N and Qayyum M** (2014) Seroprevalence and risk factors for toxoplasmosis in large ruminants in northern Punjab, Pakistan. *Journal of Infection in Developing Countries* **8**, 1022–1028.

**Akca A and Mor N** (2010) Seroprevalence of *Toxoplasma gondii* in cattle in the province of Kars, Turkey as determined by ELISA. *Journal of Animal Veterinary Advances* **9**, 876–878.

**Al-Mohammed HI** (2011) Seroprevalence of *Toxoplasma gondii* infection in cats, dogs and ruminant animals in Al-Ahsa area in Saudi Arabia. *Research Journal of Medical Sciences* **5**, 190–192.

**Albuquerque GR, Munhoz AD, Teixeira M, Flausino W, de Medeiros SM and Lopes CWG** (2011) Risk factors associated with *Toxoplasma gondii* infection in dairy cattle, State of Rio de Janeiro. *Pesquisa Veterinaria Brasileira* **31**, 287–290.

**Almeria S, Cabezon O, Paniagua J, Cano-Terriza D, Jimenez-Ruiz S, Arenas-Montes A, Dubey JP and Garcia-Bocanegra I** (2018) *Toxoplasma gondii* in sympatric domestic and wild ungulates in the Mediterranean ecosystem. *Parasitology Research* **117**, 665–671.

**Alvarado-Esquivel C, Romero-Salas D, Garcia-Vazquez Z, Cruz-Romero A, Peniche-Cardena A, Ibarra-Priego N, Aguilar-Dominguez M, Perez-de-Leon AA and Dubey JP** (2014) Seroprevalence of *Toxoplasma gondii* infection in water buffaloes (*Bubalus bubalis*) in Veracruz state, Mexico and its association with climatic factors. *BMC Veterinary Research* **10**, 232.

**Anees A, Maqbool A, Khan UJ, Yasmin G and Zahra F** (2014) Seroprevalence of antibodies to *Toxoplasma gondii* in butchers and buffaloes at Lahore, Pakistan. *Pakistan Journal of Zoology* **46**, 1479–1483.

**Arias ML, Reyes L, Chinchilla M and Linder E** (1994) Seroepidemiology of *Toxoplasma gondii* (Apicomplexa) in meat producing animals in Costa-Rica. *Revista De Biologia Tropical* **42**, 15–20.

**Asgari Q, Mehrabani D, Moazeni M, Akrami Mohajeri F, Kalantari M, Motazedian MH, Hatam GR and Davarpanah MA** (2010) The seroprevalence of bovine toxoplasmosis in Fars province, southern Iran. *Asian Journal of Animal and Veterinary Advances* **5**, 210–216.

**Asgari Q, Sarkari B, Amerinia M, Panahi S, Mohammadpour I and Sadeghi Sarvestani A** (2013) Toxoplasma infection in farm animals: a seroepidemiological survey in Fars province, south of Iran. *Jundishapur Journal of Microbiology* **7**, e11598. doi: 10.5812/jjm.5195

**Ayinmode A, Akinseye V, Schares G and Cadmus S** (2017) Serological survey of toxoplasmosis, neosporosis and brucellosis among cattle herds in Oyo state, south-western Nigeria. *African Journal of Infectious Diseases* **11**, 95–101.

**Bao M, Tian YM, Zhou DH, Xu MJ, Wu SM, Wang SD, Tang F, Qu LD and Song HQ** (2012) Seroprevalence of *Toxoplasma gondii* infection in dairy cattle, in Jinzhou, Northeastern China. *African Journal of Microbiology Research* **6**, 3932–3935.

https://doi.org/10.1017/S0031182021001116 Published online by Cambridge University Press

**Bartova E, Sedlak K and Budikova M** (2015) A study of *Neospora caninum* and *Toxoplasma gondii* antibody seroprevalence in healthy cattle in the Czech Republic. *The Annals of Agricultural and Environmental Medicine* **22**, 32–34.

**Bartova E, Kobedova K, Lamka J, Kotrba R, Vodicka R and Sedlak K** (2017) Seroprevalence of *Neospora caninum* and *Toxoplasma gondii* in exotic ruminants and camelids in the Czech Republic. *Parasitology Research* **116**, 1925–1929.

**Bekele T and Kasali OB** (1989) Toxoplasmosis in sheep, goats and cattle in central Ethiopia. *Veterinary Research Communications* **13**, 371–375.

**Belluco S, Patuzzi I and Ricci A** (2018) Bovine meat versus pork in *Toxoplasma gondii* transmission in Italy: a quantitative risk assessment model. *International Journal of Food Microbiology* **269**, 1–11.

**Berger-Schoch AE, Bernet D, Doherr MG, Gottstein B and Frey CF** (2011) *Toxoplasma gondii* in Switzerland: a serosurvey based on meat juice analysis of slaughtered pigs, wild boar, sheep and cattle. *Zoonoses and Public Health* **58**, 472–478.

**Beyhan YE, Babur C and Yilmaz O** (2014) Investigation of anti-*Toxoplasma gondii* antibodies in water buffaloes (*Bubalus bubalis*) in Samsun and Afyon provinces. *Turkiye Parazitoloji Dergisi* **38**, 220–222.

**Brasil AW, Parentoni RN, Feitosa TF, Bezerra Cde S, Vilela VL, Pena HF and de Azevedo SS** (2015) Risk factors for *Toxoplasma gondii* and *Neospora caninum* seropositivity in buffaloes in Paraiba State, Brazil. *Revista Brasileira de Parasitologia Veterinaria* **24**, 459–463.

**Chandrawathani P, Nurulaini R, Zanin CM, Premaalatha B, Adnan M, Jamnah O, Khor SK, Khadijah S, Lai SZ, Shaik MA, Seah TC and Zatil SA** (2008) Seroprevalence of *Toxoplasma gondii* antibodies in pigs, goats, cattle, dogs and cats in peninsular Malaysia. *Tropical Biomedicine* **25**, 257–258.

**Chaudhary ZI, Ahmed RS, Hussain SMI and Shakoori AR** (2006) Detection of *Toxoplasma gondii* infection in butchers and buffaloes by polymerase chain reaction and latex agglutination test. *Pakistan Journal of Zoology* **38**, 333–336.

**Chhabra MB and Mahajan RC** (1978) A serological study on toxoplasmosis prevalence in buffaloes in north India. *Rivista de Parassitologia* **39**, 39–43.

**Chhabra MB, Gupta SL and Gautam OP** (1985) Toxoplasma seroprevalence in animals in northern India. *International Journal of Zoonoses* **12**, 136–142.

**Chikweto A, Kumthekar S, Tiwari K, Nyack B, Deokar MS, Stratton G, Macpherson CN, Sharma RN and Dubey JP** (2011) Seroprevalence of *Toxoplasma gondii* in pigs, sheep, goats, and cattle from Grenada and Carriacou, West Indies. *Journal of Parasitology* **97**, 950–951.

**Cook A, Holliman R, Gilbert R, Buffolano W, Zufferey J, Petersen E, Jenum P, Foulon W, Semprini A and Dunn D** (2000) Sources of toxoplasma infection in pregnant women: European multicentre case-control study Commentary: congenital toxoplasmosis – further thought for food. *BMJ* **321**, 142–147.

**Costa AJ, Avila FA, Kassai N, Paulillo AC, Barbosa da Silva M and Galesco H** (1978) Anti-toxoplasma antibodies in bovine serums in Jaboticabal County; Sao Paulo, Brazil. *Arquivos do Instituto Biológico (Sao Paulo)* **45**, 299–301.

**Costa GHN, da Costa AJ, Lopes WDZ, Bresciani KDS, dos Santos TR, Esper CR and Santana AE** (2011) *Toxoplasma gondii*: infection natural congenital in cattle and an experimental inoculation of gestating cows with oocysts. *Experimental Parasitology* **127**, 277–281.

**Costa DG, Marvulo MF, Silva JS, Santana SC, Magalhaes FJ, Filho CD, Ribeiro VO, Alves LC, Mota RA, Dubey JP and Silva JC** (2012) Seroprevalence of *Toxoplasma gondii* in domestic and wild animals from the Fernando de Noronha, Brazil. *Journal of Parasitology* **98**, 679–680.

**Daryani A, Shariatzadeh SA, Pagheh A, Sharif M and Sarvi S** (2018) Cattle toxoplasmosis in the worldwide: a systematic review and meta-analysis. *Prospero*. Available at https://www.crd.york.ac.uk/prospero/record_email.phpID=CRD42019107442

**Da Silva JB, Dos Santos PN, De Santana Castro GN, Da Fonseca AH and Barbosa JD** (2014) Prevalence survey of selected bovine pathogens in water buffaloes in the north region of Brazil. *Journal of Parasitology Research* **2014**, 603484. doi: 10.1155/2014/603484.

**da Silva JB, Nicolino RR, Fagundes GM, Bomjardim HD, Reis ADB, Lima DHD, Oliveira CMC, Barbosa JD and da Fonseca AH** (2017) Serological survey of *Neospora caninum* and *Toxoplasma gondii* in cattle (*Bos indicus*) and water buffaloes (*Bubalus bubalis*) in ten provinces of Brazil. *Comparative Immunology Microbiology and Infectious Diseases* **52**, 30–35.

**Davoust B, Mediannikov O, Roqueplo C, Perret C, Demoncheaux JP, Sambou M, Guillot J and Blaga R** (2014) Serological survey of animal toxoplasmosis in Senegal. *Bulletin de la Société de Pathologie Exotique* **108**, 73–77.

**Dechicha AS, Bachi F, Gharbi I, Gourbdji E, Baazize-Ammi D and Guetarni D** (2015) Sero-epidemiological survey on toxoplasmosis in cattle, sheep and goats in Algeria. *African Journal of Agricultural Research* **10**, 2113–2119.

**Dehkordi FS, Haghighi Borujeni MR, Rahimi E and Abdizadeh R** (2013) Detection of *Toxoplasma gondii* in raw caprine, ovine, buffalo, bovine, and camel milk using cell cultivation, cat bioassay, capture ELISA, and PCR methods in Iran. *Foodborne Pathogens and Disease* **10**, 120–125.

**de Macedo M, de Macedo CAB, de Barros LD, Martins GF, Sandeski LM, Zulpo DL, da Cunha IAL, Taroda A, Cardim ST and Garcia JL** (2012a) Serum occurrence of anti-*Toxoplasma gondii* antibodies in dairy cows slaughtered in an abattoir for human consume. *Ciencia Rural* **42**, 1065–1069.

**de Macedo M, de Macedo CAB, Ewald MPD, Martins GF, Zulpo DL, da Cunha IAL, Taroda A, Cardim ST, Su CL and Garcia JL** (2012b) Isolation and genotyping of *Toxoplasma gondii* from pregnant dairy cows (*Bos taurus*) slaughtered. *Revista Brasileira De Parasitologia Veterinaria* **21**, 74–77.

**Deng H, Swart A, Wu Y, Li X, Li J, Liu M, Opsteegh M and van der Giessen JWB** (2020) Quantitative risk assessment of meat-borne *Toxoplasma gondii* infection in the mainland of China. *Microbial Risk Analysis* **14**, 100090.

**De Oliveira JP, Casseb ADR, Ramos ADS, Filho STR, Nogueira HL, Pinho RO and Pereira WLA** (2018) Risk factors associated with the epidemiology of *Toxoplasma gondii* in cattle and buffaloes in the state of Pará, Brazil. *Semina: Ciencias Agrarias* **39**, 2029–2038.

**de Santos LMJF, Damé MCF, Cademartori BG, da Cunha Filho NA, da Farias NAR and Ruas JL** (2013) Occurrence of antibodies to *Toxoplasma gondii* in water buffaloes and meat cattle in Rio Grande do Sul State, southern Brazil. *Acta Parasitologica* **58**, 334–336.

**de Souza LM, do Nascimento AA, Furuta PI, Basso LMS, da Silveira DM and da Costa AJ** (2001) Antibodies for *Neospora caninum* and *Toxoplasma gondii* in water buffaloes from São Paulo state, Brazil. *Semina: Ciências Agrárias* **22**, 39–48.

**de Souza JB, Soares VE, Maia MO, Pereira CM, Ferraudo AS, Cruz BC, Pires Teixeira WF, Felippelli G, Maciel WG, Goncalves WAJ, da Costa AJ and Zanetti Lopes WD** (2016) Spatial distribution and risk factors for *Toxoplasma gondii* seropositivity in cattle slaughtered for human consumption in Rondonia, North Region, Brazil. *Veterinary Parasitology* **226**, 145–149.

**Diakou A, Papadopoulos E, Haralabidis S, Papachristou F, Karatzias H and Panousis N** (2005) Prevalence of parasites in intensively managed dairy cattle in Thessaloniki region, Greece. *Cattle Practice* **13**, 51–54.

**do Carmo EL, Morais R, Lima MD, de Moraes CCG, Albuquerque GR, da Silva AV and Povoa MM** (2017) Anti-*Toxoplasma gondii* antibodies in beef cattle slaughtered in the metropolitan region of Belem, Brazilian Amazon. *Revista Brasileira De Parasitologia Veterinaria* **26**, 226–230.

**Dong H, Lu YY, Su RJ, Wang YH, Wang MY, Jiang YB and Yang YR** (2018a) Low prevalence of antibodies against *Toxoplasma gondii* in dairy cattle from China's central region. *BMC Veterinary Research* **14**, 1–8. doi: 10.1186/s12917-018-1629-3

**Dong H, Su R, Lu Y, Wang M, Liu J, Jian F and Yang Y** (2018b) Prevalence, risk factors, and genotypes of *Toxoplasma gondii* in food animals and humans (2000–2017) from China. *Frontiers in Microbiology* **9**, 2108. doi: 10.3389/fmicb.2018.02108.

**Dubey JP** (1985) Serologic prevalence of toxoplasmosis in cattle, sheep, goats, pigs, bison, and elk in Montana. *Journal of the American Veterinary Medical Association* **186**, 969–970.

**Dubey JP and Beattie C** (1988) *Toxoplasmosis of Animals and Man*. CRC Press, Inc., pp. 169–174.

**Dubey J and Thulliez P** (1993) Persistence of tissue cysts in edible tissues of cattle fed *Toxoplasma gondii* oocysts. *American Journal of Veterinary Research* **54**, 270–273.

**Dubey JP, Romand S, Hilali M, Kwok OC and Thulliez P** (1998) Seroprevalence of antibodies to *Neospora caninum* and *Toxoplasma gondii* in water buffaloes (*Bubalus bubalis*) from Egypt. *The International Journal for Parasitology* **28**, 527–529.

**Dubey JP, Hill DE, Jones JL, Hightower AW, Kirkland E, Roberts JM, Marcet PL, Lehmann T, Vianna MCB, Miska K, Sreekumar C, Kwok**

https://doi.org/10.1017/S0031182021001116 Published online by Cambridge University Press

**OCH, Shen SK and Gamble HR** (2005) Prevalence of viable *Toxoplasma gondii* in beef, chicken, and pork from retail meat stores in the United States: risk assessment to consumers. *Journal of Parasitology* **91**, 1082–1093.

**El-Metenawy TM** (2000) Seroprevalence of *Toxoplasma gondii* antibodies among domesticated ruminants at Al-Qassim Region, Saudi Arabia. *Deutsche Tierarztliche Wochenschrift* **107**, 32–33.

**Elfahal AM, Elhassan AM, Hussien MO, Enan KA, Musa AB and El Hussein AM** (2013) Seroprevalence of *Toxoplasma gondii* in dairy cattle with reproductive problems in Sudan. *ISRN Veterinary Science* **2013**, 895165.

**Elfahal A, Elhassan AM, Hussein M, Enan K, Musa AB and El Hussien A** (2014) Seroprevalence of *Toxoplasma gondii* in Cattle in Gezira and Khartoum States: A Comparison between ELISA and Latex Agglutination Tests.

**Ergin S, Ciftcioglu G, Midilli K, Issa G and Gargili A** (2009) Detection of *Toxoplasma gondii* from meat and meat products by the nested-PCR method and its relationship with seroprevalence in slaughtered animals. *Bulletin of the Veterinary Institute in Pulawy* **53**, 657–661.

**Fajardo HV, D'Avila S, Bastos RR, Cyrino CD, de Lima Detoni M, Garcia JL, das Neves LB, Nicolau JL and Amendoeira MR** (2013) Seroprevalence and risk factors of toxoplasmosis in cattle from extensive and semi-intensive rearing systems at Zona da Mata, Minas Gerais state, Southern Brazil. *Parasites & Vectors* **6**, 191.

**Fereig RM, Mahmoud HYAH, Mohamed SGA, AbouLaila MR, Abdel-Wahab A, Osman SA, Zidan SA, El-Khodary SA, Mohamed AEA and Nishikawa Y** (2016) Seroprevalence and epidemiology of *Toxoplasma gondii* in farm animals in different regions of Egypt. *Veterinary Parasitology: Regional Studies and Reports* **3–4**, 1–6.

**Ferra B, Holec-Gąsior L and Kur J** (2015) Serodiagnosis of *Toxoplasma gondii* infection in farm animals (horses, swine, and sheep) by enzyme-linked immunosorbent assay using chimeric antigens. *Parasitology International*, **64**, 288–294.

**FK P and Shah H** (2016) Seroprevalence and Risk Factors for Toxoplasmosis in the Cows (Cattle), *Bos indicus* Linnaeus (Mammalia: Eutheria) from Dir Upper, Khyber Pakhtunkhwa, Pakistan.

**Frazao-Teixeira E and de Oliveira FC** (2011) Anti-*Toxoplasma gondii* antibodies in cattle and pigs in a highly endemic area for human toxoplasmosis in Brazil. *Journal of Parasitology* **97**, 44–47.

**Furtado MM, Gennari SM, Ikuta CY, De Almeida Jácomo AT, De Morais ZM, De Jesus Pena HF, De Oliveira Porfírio GE, Silveira L, Sollmann R, De Souza GO, Tôrres NM and Ferreira Neto JS** (2015) Serosurvey of smooth *Brucella*, *Leptospira* spp. and *Toxoplasma gondii* in free-ranging jaguars (*Panthera onca*) and domestic animals from Brazil. *PLoS One* **10**, e0143816. doi: 10.1371/journal.pone.0143816.

**Garcia-Bocanegra I, Cabezon O, Hernandez E, Martinez-Cruz MS, Martinez-Moreno A and Martinez-Moreno J** (2013) *Toxoplasma gondii* in ruminant species (cattle, sheep, and goats) from southern Spain. *Journal of Parasitology* **99**, 438–440.

**Garcia-Vazquez Z, Rosario-Crus R, Diaz-Garcia G and Hernandez-Baumgarten O** (1993) Seroprevalence of *Toxoplasma gondii* infection in cattle, swine and goats in four Mexican states. *Preventive Veterinary Medicine*, **17**, 127–132.

**Garcia JL, Marques FAC, Vidotto O, Navarro IT, Martins GF, Zulpo DL, Da Cunha IAL, Taroda A, Cardim ST and De Carvalho Ewald MP** (2012) Sero-occurrence of anti-*Toxoplasma gondii* antibodies and vertical transmission in slaughtered beef cows (*Bos indicus*). *Semina: Ciencias Agrarias* **33**, 1095–1102.

**Ge W, Sun H, Wang Z, Xu P, Wang W, Mu G, Wei F and Liu Q** (2014) Prevalence and genotype of *Toxoplasma gondii* infection in cattle from Jilin province, Northeastern China. *Vector-Borne and Zoonotic Diseases* **14**, 399–402.

**Gharekhani J** (2014a) Seroprevalence of *Neospora caninum* and *Toxoplasma gondii* infections in aborted cattle in Hamedan, Iran. *Journal of Advanced Veterinary and Animal Research* **1**, 32–35.

**Gharekhani J** (2014b) *Toxoplasma gondii* infection in domestic animals in Hamedan, Iran: a sero-epidemiological study. *Bulletin UASVM Veterinary Medicine* **71**, 68–72.

**Ghazaei C** (2006) Serological survey of antibodies to *Toxoplasma gondii*. *African journal of health sciences* **13**, 131–134.

**Gilot-Fromont E, Aubert D, Belkilani S, Hermitte P, Gibout O, Geers R and Villena I** (2009) Landscape, herd management and within-herd seroprevalence of *Toxoplasma gondii* in beef cattle herds from Champagne-Ardenne, France. *Veterinary Parasitology* **161**, 36–40.

**Gondim LFP, Barbosa HV, Ribeiro CHA and Saeki H** (1999) Serological survey of antibodies to *Toxoplasma gondii* in goats, sheep, cattle and water buffaloes in Bahia state, Brazil. *Veterinary Parasitology* **82**, 273–276.

**Guo M, Dubey JP, Hill D, Buchanan RL, Gamble H, Jones JL and Pradhan AK** (2015) Prevalence and risk factors for *Toxoplasma gondii* infection in meat animals and meat products destined for human consumption. *Journal of Food Protection* **78**, 457–476.

**Hamidinejat H, Ghorbanpour M, Nabavi L, Haji Hajikolaie MR and Razi Jalali MH** (2010a) Seroprevalence of *Toxoplasma gondii* in water buffaloes (*Bubalus bubalis*) in south-west of Iran. *Tropical Biomedicine* **27**, 275–279.

**Hamidinejat H, Ghorbanpour M, Nabavi L, Hajikolaie MRH and Jalali MHR** (2010b) Occurrence of anti-*Toxoplasma gondii* antibodies in female cattle in south-west of Iran. *Tropical Animal Health and Production* **42**, 899–903.

**Hamzavi Y, Mostafaie A and Nomanpour B** (2007) Serological prevalence of toxoplasmosis in meat producing animals. *Iranian Journal of Parasitology* **2**, 7–11.

**HashemiFesharki R** (1996) Seroprevalence of *Toxoplasma gondii* in cattle, sheep and goats in Iran. *Veterinary Parasitology* **61**, 1–3.

**Hejlicek K and Literak I** (1992) Occurrence of toxoplasmosis and its prevalence in cattle in the south Bohemian region. *Acta Veterinaria Brno* **61**, 195–206.

**Hill D and Dubey J** (2013) *Toxoplasma gondii* prevalence in farm animals in the United States. *International Journal for Parasitology* **43**, 107–113.

**Hoffmann S, Devleesschauwer B, Aspinall W, Cooke R, Corrigan T, Havelaar A, Angulo F, Gibb H, Kirk M and Lake R** (2017) Attribution of global foodborne disease to specific foods: findings from a world health organization structured expert elicitation. *PLoS One* **12**, e0183641.

**Hoghooghirad N and Afraa M** (1993) Prevalence of toxoplasmosis in humans and domestic-animals in Ahwaz, capital of Khoozestan province, South-West Iran. *Journal of Tropical Medicine and Hygiene* **96**, 163–168.

**Holec-Gasior L, Drapala D, Dominiak-Gorski B and Kur J** (2013) Epidemiological study of *Toxoplasma gondii* infection among cattle in northern Poland. *The Annals of Agricultural and Environmental Medicine* **20**, 653–656.

**Huong LT, Ljungstrom BL, Uggla A and Bjorkman C** (1998) Prevalence of antibodies to *Neospora caninum* and *Toxoplasma gondii* in cattle and water buffaloes in southern Vietnam. *Veterinary Parasitology* **75**, 53–57.

**Ibrahim HM, Huang P, Salem TA, Talaat RM, Nasr MI, Xuan X and Nishikawa Y** (2009) Prevalence of *Neospora caninum* and *Toxoplasma gondii* antibodies in northern Egypt. *American Journal of Tropical Medicine and Hygiene* **80**, 263–267.

**Ibrahim AM, Ismail AA, Angara TEE and Osman M** (2014a) Area-wide detection of anti-*Toxoplasma gondii* antibodies in dairy animals from the Khartoum state, Sudan. *Journal of Life Sciences* **8**, 723–730.

**Ibrahim AM, Ismail AA, Angara TEE and Osman OM** (2014b) Serological Survey on *Toxoplasma gondii* in Dairy Cows from the Sudan using ELISA.

**Ibrahim AM, Ismail AA and Angara TEE** (2015) Analysis of risk factors associated with seroprevalence of *Toxoplasma gondii* in dairy animals from Khartoum State, Sudan.

**Ichikawa-Seki M, Guswanto A, Allamanda P, Mariamah ES, Wibowo PE, Igarashi I and Nishikawa Y** (2015) Seroprevalence of antibody to TgGRA7 antigen of *Toxoplasma gondii* in livestock animals from western Java, Indonesia. *Parasitology International* **64**, 484–486.

**Inpankaew T, Pinyopanuwut N, Chimnoi W, Kengradomkit C, Sununta C, Zhang G, Nishikawa Y, Igarashi I, Xuan X and Jittapalapong S** (2010) Serodiagnosis of *Toxoplasma gondii* infection in dairy cows in Thailand. *Transboundary and Emerging Diseases* **57**, 42–45.

**Jittapalapong S, Pinyopanuwat N, Chimnoi W, Kengradomkij C, Arunvipas P, Sarataphan N, Aruyama S and Desquesnes M** (2008) Seroprevalence of# *Brucella abortus*, *Neospara caninum*#, and# *Toxoplasma gondii* # infections of dairy cows in South of Thailand.

**Jokelainen P, Tagel M, Motus K, Viltrop A and Lassen B** (2017) *Toxoplasma gondii* seroprevalence in dairy and beef cattle: large-scale epidemiological study in Estonia. *Veterinary Parasitology* **236**, 137–143.

**Jones JL and Dubey JP** (2012) Foodborne toxoplasmosis. *Clinical Infectious Diseases* **55**, 845–851.

**Joshua R and Akinwumi K** (2003) Prevalence of antibodies to *Toxoplasma gondii* in four breeds of cattle at Ibadan, Nigeria. *Tropical Veterinarian* **21**, 134–137.

**Kadle AAH** (2014) Sero-Prevalence of toxoplasmosis in domestic animals in Benadir region, Somalia. *Open Journal of Veterinary Medicine* **4**, 170.

**Kakooza S, Tumwebaze M, Nabatta E, Byaruhanga J, Tayebwa DS and Wampande E** (2018) Risk factors and co-existence of infectious causes of reproductive failures in selected Uganda cattle and goats: a *Brucella* spps-*Toxoplasma gondii* study. *Open Access Library Journal* **5**, 1.

**Kalita M and Sarmah PC** (2015) Seroprevalence of *Toxoplasma gondii* in cattle from Assam. *International Journal of Recent Scientific Research* **6**, 3223–3225.

**Khalil KM and Elrayah IE** (2011) Seroprevalence of *Toxoplasma gondii* antibodies in farm animals (camels, cattle, and sheep) in Sudan. *Journal of Veterinary Medicine and Animal Health* **3**, 36–39.

**Khames M, Yekkour F, Fernández-Rubio C, Aubert D, Nguewa P and Villena I** (2018) Serological survey of cattle toxoplasmosis in Medea, Algeria. *Veterinary Parasitology: Regional Studies and Reports* **12**, 89–90.

**Klun I, Djurkovic-Djakovic O, Katic-Radivojevic S and Nikolic A** (2006) Cross-sectional survey on *Toxoplasma gondii* infection in cattle, sheep and pigs in Serbia: seroprevalence and risk factors. *Veterinary Parasitology* **135**, 121–131.

**Konnai S, Mingala CN, Sato M, Abes NS, Venturina FA, Gutierrez CA, Sano T, Omata Y, Cruz LC, Onuma M and Ohashi K** (2008) A survey of abortifacient infectious agents in livestock in Luzon, the Philippines, with emphasis on the situation in a cattle herd with abortion problems. *Acta Tropica* **105**, 269–273.

**Konrad JL, Campero LM, Caspe GS, Brihuega B, Draghi G, Moore DP, Crudeli GA, Venturini MC and Campero CM** (2013) Detection of antibodies against *Brucella abortus*, *Leptospira* spp., and Apicomplexa protozoa in water buffaloes in the northeast of Argentina. *Tropical Animal Health and Production* **45**, 1751–1756.

**Krzysiak MK, Jabłoński A, Iwaniak W, Krajewska M, Kęsik-Maliszewska J and Larska M** (2018) Seroprevalence and risk factors for selected respiratory and reproductive tract pathogen exposure in European bison (*Bison bonasus*) in Poland. *Veterinary Microbiology* **215**, 57–65.

**Kuraa HM and Malek SS** (2016) Seroprevalence of *Toxoplasma gondii* in ruminants by using latex agglutination test (LAT) and enzyme-linked immunosorbent assay (ELISA) in Assiut governorate. *Tropical Biomedicine* **33**, 711–725.

**Lahmar I, Lachkhem A, Slama D, Sakly W, Haouas N, Gorcii M, Pfaff AW, Candolfi E and Babba H** (2015) Prevalence of toxoplasmosis in sheep, goats and cattle in southern Tunisia. *Journal of Bacteriology & Parasitology* **6**, 1.

**Lee M-K, Park J-S, Kim M-H, Park D-Y, Kim C-H, Kim G-H and Cho J-H** (2011) Seroprevalence of antibodies to *Neospora caninum* and *Toxoplasma gondii* in cattle in northern area of Gyeongnam. *Korean Journal of Veterinary Service* **34**, 245–250.

**Li K, Gao J, Shahzad M, Han Z, Nabi F, Liu M, Zhang D and Li J** (2014) Seroprevalence of *Toxoplasma gondii* infection in yaks (*Bos grunniens*) on the Qinghai-Tibetan plateau of China. *Veterinary Parasitology* **205**, 354–356.

**Liu J, Cai JZ, Zhang W, Liu Q, Chen D, Han JP and Liu QR** (2008) Seroepidemiology of *Neospora caninum* and *Toxoplasma gondii* infection in yaks (*Bos grunniens*) in Qinghai, China. *Veterinary Parasitology* **152**, 330–332.

**Liu Q, Cai J, Zhao Q, Shang L, Ma R, Wang X, Li J, Hu G, Jin H and Gao H** (2011) Seroprevalence of *Toxoplasma gondii* infection in yaks (*Bos grunniens*) in northwestern China. *Tropical Animal Health and Production* **43**, 741–743.

**Liu X, Liu C, Liu Y, Jin H, Zhao Y, Chen J, Yang M and Liu Q** (2012) Seroprevalence of *Toxoplasma gondii* infection in slaughtered pigs and cattle in Liaoning province, Northeastern China. *Journal of Parasitology* **98**, 440–441.

**Lopes AP, Dubey JP, Neto F, Rodrigues A, Martins T, Rodrigues M and Cardoso L** (2013) Seroprevalence of *Toxoplasma gondii* infection in cattle, sheep, goats and pigs from the north of Portugal for human consumption. *Veterinary Parasitology* **193**, 266–269.

**Luciano DM, Menezes RC, Ferreira LC, Nicolau JL, das Neves LB, Luciano RM, Dahroug MA and Amendoeira MR** (2011) Occurrence of anti-*Toxoplasma gondii* antibodies in cattle and pigs slaughtered, state of Rio de Janeiro. *Revista Brasileira de Parasitologia Veterinaria* **20**, 351–353.

**Luo H, Li K, Zhang H, Gan P, Shahzad M, Wu X, Lan Y and Wang J** (2017) Seroprevalence of *Toxoplasma gondii* infection in zoo and domestic animals in Jiangxi province, China. *Parasite* **24**, 7. doi: 10.1051/parasite/2017007.

**Magalhães FJR, Ribeiro-Andrade M, de Alcântara AM, Júnior JWP, de Sena MJ, Porto WJN, Vieira RFC and Mota RA** (2016) Risk factors for *Toxoplasma gondii* infection in sheep and cattle from Fernando de Noronha Island, Brazil. *Revista Brasileira de Parasitologia Veterinaria* **25**, 511–515.

**Majeed BA and Abbas WH** (2018) Serological and molecular detection of *Toxoplasma gondii* in meat and minced meat in Basra City. *Basrah Journal of Veterinary Research* **17**, 491–505.

**Makinde AA and Ezeh AO** (1981) Serological survey of *Toxoplasma gondii* in Nigerian cattle: a preliminary report. *The British Veterinary Journal* **137**, 485–488.

**Maronpot RR and Botros BA** (1972) Toxoplasma serologic survey in man and domestic animals in Egypt. *The Journal of the Egyptian Public Health Association* **47**, 58–67.

**Matsuo K and Husin D** (1996) A survey of *Toxoplasma gondii* antibodies in goats and cattle in Lampung province, Indonesia. *Southeast Asian Journal of Tropical Medicine and Public Health* **27**, 554–555.

**Matsuo K, Kamai R, Uetsu H, Goto H, Takashima Y and Nagamune K** (2014) Seroprevalence of *Toxoplasma gondii* infection in cattle, horses, pigs and chickens in Japan. *Parasitology International* **63**, 638–639.

**McColm AA, Hutchison WM and Siim JC** (1981) The prevalence of *Toxoplasma gondii* in meat animals and cats in central Scotland. *Annals of Tropical Medicine and Parasitology* **75**, 157–164.

**Mirdha BR, Samantaray JC and Pandey A** (1999) Seropositivity of *Toxoplasma gondii* in domestic animals. *Indian Journal of Public Health* **43**, 91–92.

**Montoya JG** (2002) Laboratory diagnosis of *Toxoplasma gondii* infection and toxoplasmosis. *The Journal of Infectious Diseases* **185**, S73–S82.

**More G, Basso W, Bacigalupe D, Venturini MC and Venturini L** (2008) Diagnosis of *Sarcocystis cruzi*, *Neospora caninum*, and *Toxoplasma gondii* infections in cattle. *Parasitology Research* **102**, 671–675.

**Moreno T, Martinez-Gomez F and Becerra C** (1991) The seroprevalence of bovine toxoplasmosis in Cordoba, Spain. *Annals of Tropical Medicine and Parasitology* **85**, 285–286.

**Munn Z, Moola S, Lisy K and Riitano D** (2014) *The Systematic Review of Prevalence and Incidence Data The Joanna Briggs Institute Reviewer's Manual 2014*. Australia: The Joanna Briggs Institute.

**Nagwa I, Shaapan RM, Hassan SE and El Moghazy FM** (2013) High diagnostic efficiency of affinity isolated fraction in camel and cattle toxoplasmosis. *World Journal of Medical Sciences* **8**, 61–66.

**Nalbantoğlu S, Vatansever Z, Deniz A, Babür C, Çakmak A, Karaer KZ and Korudağ E** (2002) Sero-prevalence of *Toxoplasma gondii* by the Sabin–Feldman and indirect flourescent antibody tests in cattle in the Turkish Republic of Northern Cyprus. *Turkish Journal of Veterinary and Animal Sciences* **26**, 825–828.

**Navidpour S and Hoghooghi-Rad N** (1998) Seroprevalence of anti-*Toxoplasma gondii* antibodies in buffaloes in Khoozestan province, Iran. *Veterinary Parasitology* **77**, 191–194.

**Ndou RV, Maduna NM, Dzoma BM, Nyirenda M, Motsei LE and Bakunzi FR** (2013) A seroprevalence survey of *Toxoplasma gondii* amongst slaughter cattle in two high throughput abattoirs in the north west province of South Africa. *Journal of Food, Agriculture and Environment* **11**, 338–339.

**Nematollahi A and Moghddam G** (2008) Survey on seroprevalence of anti-*Toxoplasma gondii* antibodies in cattle in Tabriz (Iran) by IFAT. *American Journal of Animal and Veterinary Sciences* **3**, 40–42.

**Norton JH, Tranter WP and Campbell RS** (1989) A farming systems study of abortion in dairy cattle on the Atherton Tableland. 2. The pattern of infectious diseases. *Australian Veterinary Journal* **66**, 163–167.

**Ogawa L, Freire RL, Vidotto O, Gondim LFP and Navarro IT** (2005) Occurrence of antibodies to *Neospora caninum* and *Toxoplasma gondii* in dairy cattle from the northern region of the Paraná State, Brazil. *Arquivo Brasileiro de Medicina Veterinaria e Zootecnia* **57**, 312–316.

**Oh J, Lee SH, Lee SJ, Kim YH, Park SC, Rhee MH, Kwon OD, Kim TH and Kwak D** (2016) Detection of antibodies against *Toxoplasma gondii* in cattle raised in Gyeongbuk province, Korea. *Journal of Food Protection* **79**, 821–824.

**Onyiche TE and Ademola IO** (2015) Seroprevalence of anti-*Toxoplasma gondii* antibodies in cattle and pigs in Ibadan, Nigeria. *Journal of Parasitic Diseases* **39**, 309–314.

**Pagmadulam B, Myagmarsuren P, Fereig RM, Igarashi M, Yokoyama N, Battsetseg B and Nishikawa Y** (2018) Seroprevalence of *Toxoplasma gondii* and *Neospora caninum* infections in cattle in Mongolia. *Veterinary Parasitology: Regional Studies and Reports* **14**, 11–17.

**Panadero R, Painceira A, Lopez C, Vazquez L, Paz A, Diaz P, Dacal V, Cienfuegos S, Fernandez G, Lago N, Diez-Banos P and Morrondo P** (2010) Seroprevalence of *Toxoplasma gondii* and *Neospora caninum* in wild and domestic ruminants sharing pastures in Galicia (Northwest Spain). *Research in Veterinary Science* **88**, 111–115.

**Persad A, Charles R and Adesiyun AA** (2011) Frequency of toxoplasmosis in water buffalo (*Bubalus bubalis*) in Trinidad. *Veterinary Medicine International* **2011**, 705358. doi: 10.4061/2011/705358.

**Portella LP, Cadore GC, de Lima M, Sangioni LA, Fischer G and Vogel FSF** (2016) Antibodies against *Neospora caninum*, Sarcocystis spp. and *Toxoplasma gondii* detected in buffaloes from Rio Grande do Sul, Brazil. *Pesquisa Veterinaria Brasileira* **36**, 947–950.

**Qin SY, Zhou DH, Cong W, Zhang XX, Lou ZL, Yin MY, Tan QD and Zhu XQ** (2015) Seroprevalence, risk factors and genetic characterization of *Toxoplasma gondii* in free-range white yaks (*Bos grunniens*) in China. *Veterinary Parasitology* **211**, 300–302.

**Qiu JH, Wang CR, Zhang X, Sheng ZH, Chang QC, Zhao Q, Wu SM, Zou FC and Zhu XQ** (2012) Seroprevalence of *Toxoplasma gondii* in beef cattle and dairy cattle in northeast China. *Foodborne Pathogens and Disease* **9**, 579–582.

**Raeghi S, Akaber A and Sedeghi S** (2011) Seroprevalence of *Toxoplasma gondii* in sheep, cattle and horses in Urmia north-west of Iran. *Iranian Journal of Parasitology* **6**, 90–94.

**Rahman WA, Manimegalai V, Chandrawathani P, Premaalatha B and Zaini CM** (2011) Comparative seroprevalences of bovine toxoplasmosis and neosporosis in five states in Malaysia. *Global Veterinaria* **6**, 575–578.

**Rahman M, Azad MT, Nahar L, Rouf SM, Ohya K, Chiou SP, Baba M, Kitoh K and Takashima Y** (2014) Age-specificity of *Toxoplasma gondii* seroprevalence in sheep, goats and cattle on subsistence farms in Bangladesh. *The Journal of Veterinary Medical Science* **76**, 1257–1259.

**Rajamanickam C, Cheah T and Paramasvaran S** (1990) Antibodies to *Toxoplasma gondii* from domestic animals in Malaysia. *Tropical Animal Health and Production* **22**, 61–62.

**Riemann HP, Kaneko JJ, Haghighi S, Behymer DE, Franti CE and Ruppanner R** (1978) The prevalence of antibodies against *Toxoplasma gondii* among hospitalized animals and stray dogs. *Canadian Journal of Comparative Medicine* **42**, 407–413.

**Roqueplo C, Halos L, Cabre O and Davoust B** (2011) *Toxoplasma gondii* in wild and domestic animals from New Caledonia. *Parasite* **18**, 345–348.

**Sah RP, Talukder MH and Rahman A** (2018a) Serodiagnosis of toxoplasmosis using lateral flow chromatographic immunoassay among animals and humans in Sunsari District of Nepal. *World Scientific News* **105**, 145–156.

**Sah RP, Talukder MH, Rahman AKMA, Alam MZ and Ward MP** (2018b) Seroprevalence of *Toxoplasma gondii* infection in ruminants in selected districts in Bangladesh. *Veterinary Parasitology: Regional Studies and Reports* **11**, 1–5.

**Samad MA, Rahman KB and Halder AK** (1993) Seroprevalence of *Toxoplasma gondii* in domestic ruminants in Bangladesh. *Veterinary Parasitology* **47**, 157–159.

**Santos TR, Costa AJ, Toniollo GH, Luvizotto MCR, Benetti AH, Santos RR, Matta DH, Lopes WDZ, Oliveira JA and Oliveira GP** (2009) Prevalence of anti-*Toxoplasma gondii* antibodies in dairy cattle, dogs, and humans from the Jauru micro-region, Mato Grosso state, Brazil. *Veterinary Parasitology* **161**, 324–326.

**Schoonman LB, Wilsmore T and Swai ES** (2010) Sero-epidemiological investigation of bovine toxoplasmosis in traditional and smallholder cattle production systems of Tanga region, Tanzania. *Tropical Animal Health and Production* **42**, 579–587.

**Sedlak K and Bartova E** (2006) Seroprevalences of antibodies to *Neospora caninum* and *Toxoplasma gondii* in zoo animals. *Veterinary Parasitology* **136**, 223–231.

**Selvaraj J, Murali Manohar B, Singh S and Balachandran C** (2007) Seroprevalence of *Toxoplasma gondii* in buffaloes. *Journal of Veterinary Parasitology* **21**, 41–42.

**Shaapan RM, Hassanam MA and Khahl FAM** (2010) Modified agglutination test for serologic survey of *Toxoplasma gondii* infection in goats and water buffaloes in Egypt. *Research Journal of Parasitology* **5**, 13–17.

**Shabbir MZ, Khalid RK, Freitas DM, Javed MT, Rabbani M, Yaqub T, Ahmad A, Shabbir MA and Abbas M** (2012) Serological evidence of selected abortifacients in a dairy herd with history of abortion. *Pakistan Veterinary Journal* **33**, 19–22.

**Shadia Ahmed ML** (2018) Seroprevalence of *Toxoplasma gondii* in cattle, sheep and goats from river Nile state, Sudan. *Multidisciplinary Advances in Veterinary Science* **2**, 332–337.

**Shahiduzzaman M, Islam MR, Khatun MM, Batanova TA, Kitoh K and Takashima Y** (2011) *Toxoplasma gondii* seroprevalence in domestic animals and humans in Mymensingh District, Bangladesh. *Journal of Veterinary Medical Science* **73**, 1375–1376.

**Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P and Stewart LA** (2015) Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. *BMJ* **349**.

**Sharif M, Gholami S, Ziaei H, Daryani A, Laktarashi B, Ziapour SP, Rafiei A and Vahedi M** (2007) Seroprevalence of *Toxoplasma gondii* in cattle, sheep and goats slaughtered for food in Mazandaran province, Iran, during 2005. *Veterinary Journal* **174**, 422–424.

**Sharma S, Sandhu KS, Bal MS, Kumar H, Verma S and Dubey JP** (2008) Serological survey of antibodies to *Toxoplasma gondii* in sheep, cattle, and buffaloes in Punjab, India. *Journal of Parasitology* **94**, 1174–1175.

**Sharma R, Parker S, Al-Adhami B, Bachand N and Jenkins E** (2019) Comparison of tissues (heart vs brain) and serological tests (MAT, ELISA and IFAT) for detection of *Toxoplasma gondii* in naturally infected wolverines (*Gulo gulo*) from the Yukon, Canada. *Food and Waterborne Parasitology* **15**, e00046.

**Silva SP, Mota RA, Faria EB, Fernandes EF, Neto OL, Albuquerque PP and Dias HL** (2010) Occurrence of IgG antibodies anti-*Neospora caninum* and *Toxoplasma gondii* in female water buffaloes (*Bubalus bubalis*) raised in the Brazilian state of Pará. *Pesquisa Veterinaria Brasileira* **30**, 443–446.

**Singh H, Tewari AK, Mishra AK, Maharana BR and Rao JR** (2013) A purified tachyzoite protein based ELISA for the sero-surveillance of *Toxoplasma gondii* specific antibodies in domestic ruminants. *Indian Journal of Animal Sciences* **83**, 20–23.

**Singh H, Tewari AK, Mishra AK, Maharana B, Sudan V, Raina OK and Rao JR** (2015) Detection of antibodies to *Toxoplasma gondii* in domesticated ruminants by recombinant truncated SAG2 enzyme-linked immunosorbent assay. *Tropical Animal Health and Production* **47**, 171–178.

**Song E-S, Jung S-I, Park B-K, You M-J, Kim D-H and Song K-H** (2011) Latex agglutination test based prevalence of *Toxoplasma gondii* in native Korean cattle. *Korean Journal of Veterinary Research* **51**, 59–61.

**Sroka J** (2001) Seroepidemiology of toxoplasmosis in the Lublin region. *Annals of Agricultural and Environmental Medicine* **8**, 25–31.

**Sroka J, Zwolinski J and Dutkiewicz J** (2007) Seroprevalence of *Toxoplasma gondii* in farm and wild animals from the area of Lublin province. *Bulletin of the Veterinary Institute in Pulawy* **51**, 535–540.

**Sroka J, Wojcik-Fatla A, Szymanska J, Dutkiewicz J, Zajac V and Zwolinski J** (2010) The occurrence of *Toxoplasma gondii* infection in people and animals from rural environment of Lublin Region – estimate of potential role of water as a source of infection. *Annals of Agricultural and Environmental Medicine* **17**, 125–132.

**Sroka J, Karamon J, Cencek T and Dutkiewicz J** (2011) Preliminary assessment of usefulness of cELISA test for screening pig and cattle populations for presence of antibodies against *Toxoplasma gondii*. *Annals of Agricultural and Environmental Medicine* **18**, 335–339.

**Sudan V, Tewari AK and Singh H** (2015) Serodiagnosis of *Toxoplasma gondii* infection in bovines from Kerala, India using a recombinant surface antigen 1 ELISA. *Biologicals* **43**, 250–255.

**Sudan V, Tewari AK and Singh H** (2019) Detection of antibodies against *Toxoplasma gondii* in Indian cattle by recombinant SAG2 enzyme-linked immunosorbent assay. *Acta Parasitologica* **64**, 148–151.

**Sun WW, Meng QF, Cong W, Shan XF, Wang CF and Qian AD** (2015) Herd-level prevalence and associated risk factors for *Toxoplasma gondii*, *Neospora caninum*, *Chlamydia abortus* and bovine viral diarrhoea virus in commercial dairy and beef cattle in eastern, northern and northeastern China. *Parasitology Research* **114**, 4211–4218.

**Swai ES and Schoonman L** (2012) A survey of zoonotic diseases in trade cattle slaughtered at Tanga city abattoir: a cause of public health concern. *Asian Pacific Journal of Tropical Biomedicine* **2**, 55–60.

**Tan QD, Yang XY, Yin MY, Hu LY, Qin SY, Wang JL, Zhou DH and Zhu XQ** (2015) Seroprevalence and correlates of *Toxoplasma gondii* infection in dairy cattle in northwest China. *Acta Parasitologica* **60**, 618–621.

**Tasawar Z, Shafiq Z, Lashari MH and Aziz F** (2013) Seroprevalence of *Toxoplasma gondii* in cattle, Punjab, Pakistan. *Global Veterinaria* **11**, 681–684.

**Tilahun B, Tolossa YH, Tilahun G, Ashenafi H and Shimelis S** (2018) Seroprevalence and risk factors of *Toxoplasma gondii* infection among domestic ruminants in east Hararghe zone of Oromia region, Ethiopia. *Veterinary Medicine International* **2018**, 4263470. doi: 10.1155/2018/4263470

**Tizard IR, Harmeson J and Lai CH** (1978) The prevalence of serum antibodies to *Toxoplasma gondii* in Ontario mammals. *Canadian Journal of Comparative Medicine* **42**, 177–183.

**Tutuncu M, Ayaz E, Yaman M and Akkan HA** (2003) The seroprevalence of *Toxoplasma gondii* in sheep, goats and cattle detected by indirect haemaglutination (IHA) test in the region of Van, Turkey. *Indian Veterinary Journal* **80**, 401–403.

**Udonsom R, Sukthana Y, Nishikawa Y, Fereig RM and Jirapattharasate C** (2018) Current situation of *Neospora caninum* and *Toxoplasma gondii* infection among beef cattle in Kanchanaburi, Ratchaburi and Nakhon Patom provinces, Thailand. *Thai Journal of Veterinary Medicine* **48**, 403–409.

**van Knapen F, Franchimont JH and van der Lugt G** (1982) Prevalence of antibodies to toxoplasma in farm animals in the Netherlands and its implication for meat inspection. *The Veterinary Quarterly* **4**, 101–105.

**van Knapen F, Kremers AF, Franchimont JH and Narucka U** (1995) Prevalence of antibodies to *Toxoplasma gondii* in cattle and swine in The Netherlands: towards an integrated control of livestock production. *The Veterinary Quarterly* **17**, 87–91.

**Wang M, Wang Y-H, Ye Q, Meng P, Yin H and Zhang D-L** (2012) Serological survey of *Toxoplasma gondii* in Tibetan mastiffs (*Canis lupus familiaris*) and yaks (*Bos grunniens*) in Qinghai, China. *Parasites & Vectors* **5**, 35.

**Wiengcharoen J, Nakthong C, Mitchaothai J, Udonsom R and Sukthana Y** (2012) Toxoplasmosis and neosporosis among beef cattle slaughtered for food in western Thailand. *Southeast Asian Journal of Tropical Medicine and Public Health* **43**, 1087–1093.

**Work K** (1967) Isolation of *Toxoplasma Gondii* from the flesh of sheep, swine and cattle. *Acta Pathologica Microbiologica Scandinavica* **71**, 296–306.

**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**, 1425–1428.

**Yagci Yucel S, Yaman M, Kurt C, Babur C, Celebi B, Kilic S and Ozen D** (2014) Seroprevalence of brucellosis, listeriosis and toxoplasmosis in cattle in Adana province of Turkey. *Turkiye Parazitoloji Dergisi* **38**, 91–96.

**Yang J, Song L, Zhang M, Song X-J, Ma X-P, Ma L-Y and Li L** (2012) Toxoplasma infection Status of rural residents and animals in Hongsipu district of Ningxia. *Journal of Ningxia Medical University* **1**, 015.

**Yildiz K, Kul O, Babur C, Kilic S, Gazyagci AN, Celebi B and Gurcan IS** (2009) Seroprevalence of *Neospora caninum* in dairy cattle ranches with high abortion rate: special emphasis to serologic co-existence with *Toxoplasma gondii, Brucella abortus* and *Listeria* monocytogenes. *Veterinary Parasitology* **164**, 306–310.

**Yu J, Xia Z, Liu Q, Liu J, Ding J and Zhang W** (2007) Seroepidemiology of *Neospora caninum* and *Toxoplasma gondii* in cattle and water buffaloes (*Bubalus bubalis*) in the People's Republic of China. *Veterinary Parasitology* **143**, 79–85.

**Zain Eldin EA, Elkhawad SE and Kheir HS** (1985) A serological survey for toxoplasma antibodies in cattle, sheep, goats and camels (*Camelus dromedarius*) in the Sudan. *Revue d'elevage et de medecine veterinaire des pays tropicaux* **38**, 247–249.

**Zaki M** (1995) Seroprevalence of *Toxoplasma gondii* in domestic animals in Pakistan. *Journal of the Pakistan Medical Association* **45**, 4–5.

**Zhou DH, Zhao FR, Lu P, Xia HY, Xu MJ, Yuan LG, Yan C, Huang SY, Li SJ and Zhu XQ** (2012) Seroprevalence of *Toxoplasma gondii* infection in dairy cattle in southern China. *Parasites and Vectors* **5**, 1–4. doi: 10.1186/1756-3305-5-48

**Zhou M, Cao S, Sevinc F, Sevinc M, Ceylan O, Liu M, Wang G, Moumouni PF, Jirapattharasate C, Suzuki H, Nishikawa Y and Xuan X** (2016) Enzyme-linked immunosorbent assays using recombinant TgSAG2 and NcSAG1 to detect *Toxoplasma gondii* and *Neospora caninum*-specific antibodies in domestic animals in Turkey. *The Journal of Veterinary Medical Science* **78**, 1877–1881.

**Zou F, Yu X, Yang Y, Hu S, Chang H, Yang J and Duan G** (2015) Seroprevalence and risk factors of *Toxoplasma gondii* infection in buffaloes, sheep and goats in Yunnan province, southwestern China. *Iranian Journal of Parasitology* **10**, 648–651.

https://doi.org/10.1017/S0031182021001116 Published online by Cambridge University Press