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REVIEW

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Toxoplasma Gondii in humans, animals and in the environment in Morocco: a literature review

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Abstract

Toxoplasmosis, caused by *Toxoplasma gondii*, has the unsettling ability to infect nearly every warm-blooded vertebrate. When transmitted from mother to fetus during pregnancy, it can lead to congenital toxoplasmosis in newborns, which may have severe and even fatal outcomes. Moreover, this parasite is a significant cause of reproductive issues in cattle. The aim of this literature review was to compile and synthesize information on the epidemiology and clinical features of naturally occurring *Toxoplasma gondii* infections in both humans and animals, as well as to assess the occurrence of oocysts in the environmental matrices in Morocco. To achieve these objectives, data were sourced from four electronic databases: PubMed, Web of Science, Scopus, and Google Scholar. A total of 32 articles published between January 1, 2000, and January 31, 2024, met the inclusion criteria. The findings indicated that the seroprevalence of *T. gondii* among pregnant women varied by city and appeared to be lower in drier climates. The study identified several risk factors associated with *T. gondii* infection among women in Morocco, including direct contact with soil, failure to wash fruits and vegetables before eating, limited education, and reliance on well water for drinking. Moreover, there is a limited amount of serological data on *T. gondii* in animals. In Morocco, the prevalence of this parasite can reach up to 30% in sheep, while it stands at 8.5% in cattle and goats. Leafy greens are particularly prone to hosting pathogens and are associated with foodborne outbreaks. In Morocco, the prevalence of *T. gondii* in leafy vegetables is around 16%, although soil analyses have not found any oocysts. This review offers a thorough epidemiological overview of *T. gondii* infections in Morocco, serving as a valuable resource for researchers and aiding in the development of control and prevention programs.

Keywords *Toxoplasma Gondi*, Humans, Animals, Environment, Morocco

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Background

Toxoplasma gondii (T. gondii) is an Apicomplexa protozoan first documented in 1908 by Nicolle and Manceaux at the Pasteur Institute in Tunisia, where it was found in the wild rodent *Ctenodactylus gundi*. Simultaneously, Splendore isolated the parasite from rabbits in Brazil. It wasn't until 60 years later that the full natural life cycle of *T. gondii* was uncovered [1]. The life cycle of *Toxoplasma gondii* is complex, culminating in a reproductive phase within the intestines of Felidae family members, which are its definitive hosts. This phase results in the production of oocysts. Meanwhile, the parasite undergoes asexual reproduction in various intermediate hosts [2]. Additionally, *T. gondii* can be transmitted to humans through three primary routes: first, by consuming undercooked meat [3]. Secondly, transmission can occur through the accidental ingestion of oocysts shed by cats. This can happen via contact with contaminated litter, soil (such as that used in gardening), unwashed fruits or vegetables, or contaminated drinking water [4, 5]. Furthermore, the parasite can be transmitted from an infected mother to her developing fetus through the placenta, leading to congenital toxoplasmosis. Infection during the third trimester often results in asymptomatic newborns; however, without adequate treatment, these infants may later experience retinochoroiditis and neurological issues in childhood or early adulthood [6]. In contrast, infection during the first or second trimester poses a higher risk of severe complications, such as miscarriage, intrauterine growth restriction, intracerebral calcification, hydrocephalus, retinitis, and other ocular and neurological disorders [7]. The prevalence of *T. gondii* varies widely due to several factors, including geographic location, climate, environmental conditions, dietary habits, and sociodemographic characteristics. Lower prevalence was observed in regions such as North America, Northern Europe, and East Asia, including Japan, where it reached 10.3% [8, 9]. Conversely, South America and tropical Africa have reported significantly higher seroprevalence rates, with some areas showing up to 95% prevalence [10]. A systematic review and meta-analysis of *Toxoplasma* infection in pregnant women across Africa found a combined prevalence of 77.57%. Central Africa exhibited the highest rates, followed by East Africa at 54.89% and West Africa at 38.38% [11]. Unambiguously, this parasite infects a diverse array of warm-blooded animals, encompassing birds, mammals, and even reptiles [2, 12]. As a natural outcome, numerous studies have delved into how common *T. gondii* is among animals. A comprehensive review *of T. gondii* prevalence in Ethiopian animals revealed striking figures : cats had an estimated infection rate of 87.72%, while small ruminants showed a prevalence of 34.59%. Meanwhile, in Sudan, the overall rate of *T. gondii* infections in domestic animals averaged 38%, with chickens standing out with the highest infection rate of 80% [13, 14]. In well-ventilated, humid, and warm environments, oocysts can transform into infectious forms in less than a day. *Toxoplasma* oocysts, once sporulated, show exceptional toughness, withstanding short bouts of cold and dryness. They spread through the environment carried by the wind, rain, surface water, or contaminated feed [5]. A systematic review on *T. gondii* oocyst contamination across soil, water, fresh produce, and Molluscs bivalves revealed that the parasite's oocysts were present in all these environments globally. Detection rates varied widely, from as low as 0.09% to as high as 100%, depending on whether biological tests or PCR-based methods were used [15]. Significant progress has been made from initially recognizing congenital toxoplasmosis as the primary clinical issue linked to *T. gondii* infection to the current discussions about its potential role in chronic neurological and psychiatric conditions, especially schizophrenia and bipolar disorder. Toxoplasmosis is now regarded as one of the world's most impactful zoonotic diseases, causing a loss of between 2 and 8 million disability-adjusted life years (DALYs). Given its substantial social and economic consequences, toxoplasmosis is considered a major public health challenge [2, 16]. This review aims to provide a comprehensive analysis of *T. gondii* infection, including its prevalence, epidemiological aspects, and clinical impact in both humans and animals, as well as the occurrence of oocysts in the environment, precisely within Morocco.

Materials and methods

Study area

Morocco, a North African country with a population of around 40 million, is divided into 12 regions. Approximately 61% of its population resides in urban areas. The country's climate is shaped by the Atlantic Ocean, the Mediterranean Sea, and the Sahara Desert, resulting in a sub-humid to semi-arid climate in the northern regions and an arid to desert climate in the south [17, 18]. In Addition, The Moroccan economy is diverse, with a significant reliance on agriculture. In 2022, Morocco's livestock included approximately 2,965,200 cattle, 22,011,500 sheep, and 5,980,800 goats [19]. Even though numerous Moroccans still adhere to the traditional Mediterranean diet, characterized by olive oil, high vegetable and fruit consumption, and moderate meat intake, a shift towards a Western-style diet—rich in meat and high in calories—has been observed in major cities and among younger generations [20, 21].

Search strategy and selection criteria

The current review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [22], and systematically searched

four international electronic databases: PubMed (https://pubmed.ncbi.nlm.nih.gov/), Scopus (https://www.scopus.com), Web of Science (https://www.webofscience.com), and Google Scholar (https://scholar.google.com/). The search covered peer-reviewed articles published between January 1, 2000, and January 31, 2024, and was conducted from December 1, 2023, to January 31, 2024, using the keywords: "Toxoplasma gondii" OR "Toxoplasmosis" AND "Morocco" AND "Humans" AND "Animals" AND "Environment." Additionally, websites of local Moroccan journals were included in the search. Inclusion criteria were publications (original papers, short communications, or case studies) written in English or French that involved studies conducted in Morocco. Exclusion criteria were citations, reviews, dissertations, or theses. The search yielded 94 articles, from which 20 duplicates were removed. Titles and abstracts of the remaining 74 articles were then screened based on the inclusion and exclusion criteria. Ultimately, 32 articles met the criteria and were selected as eligible for this review (Fig. 1).

Data extraction

Data from the retrieved studies were independently collected by two authors using a standardized form. Any discrepancies were resolved by the lead investigator. After reviewing the full texts of the articles, relevant data and information were extracted into a specific Microsoft Excel form (version 2016 ; Microsoft Corporation,

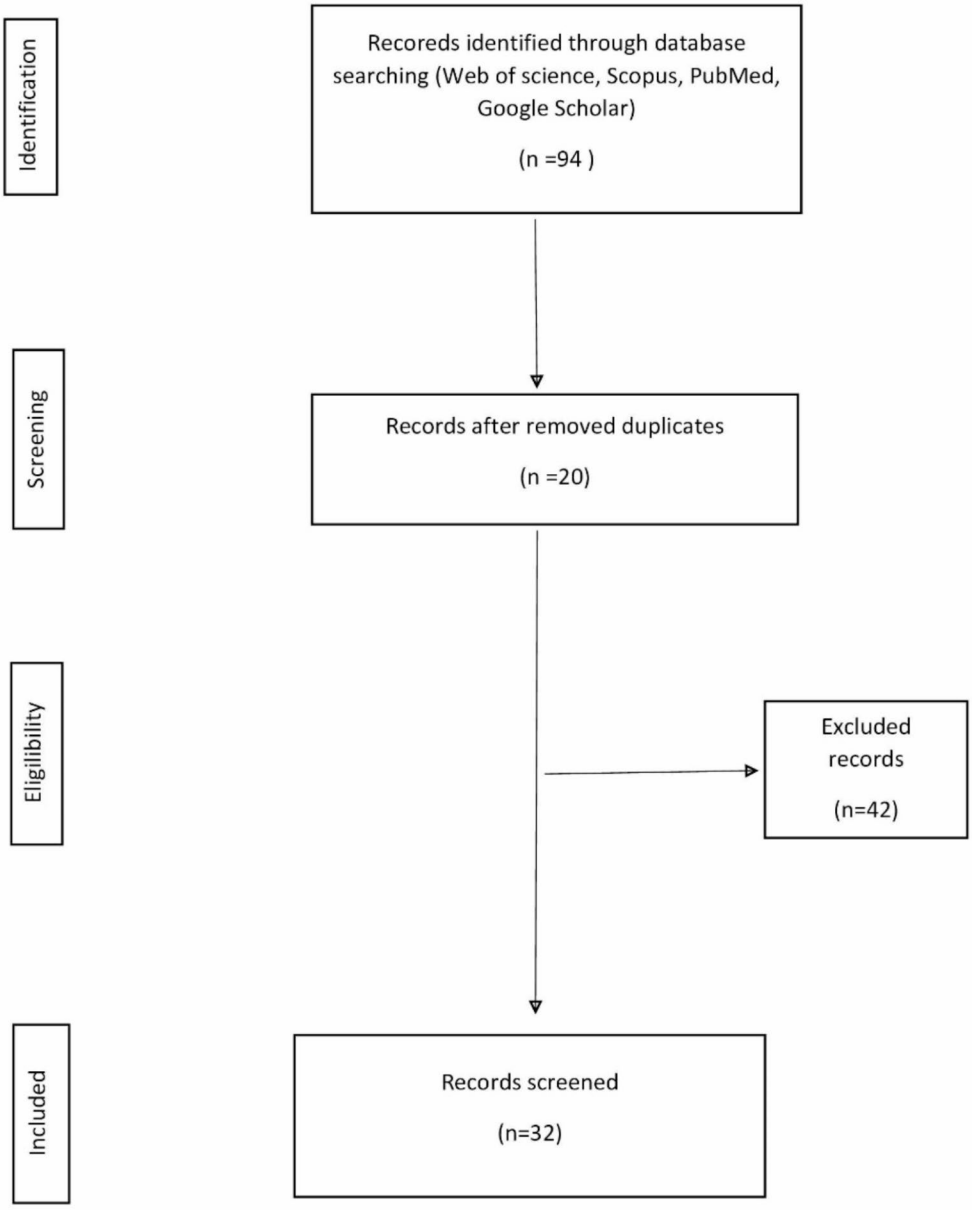

Fig. 1 Flow diagram showing the search and selection methodology used, which follows PRISMA guidelines

Redmond, WA). This included details such as the study title, first author, publication year, population, city, sample size, detection method, number of positive samples, and key findings.

Results

Toxoplasmosis in humans

Serological prevalence, knowledge and risk factors

Studies on the seroprevalence of *T. gondii* antibodies have largely concentrated on specific groups, such as pregnant women and adults with HIV. There is a lack of comprehensive data on the epidemiology of *T. gondii* within the general population. Although toxoplasmosis serology is routinely performed during prenatal consultations, centralized national prevalence data for *T. gondii* are not available in Morocco. Moreover, there is limited knowledge about *T. gondii* infection in the Moroccan Sahara, despite local practices that may facilitate transmission. Inhabitants of this region, including nomadic livestock herders, often consume undercooked mutton and raw goat or camel milk, and face significant challenges related to hygiene and health services. Isolated serological reports from pregnant women and HIV-infected individuals are summarized in Table 1. Higher seroprevalence of *T. gondii* has been observed in HIV-infected patients, with a reported rate of 62.1% [23]. Among pregnant women, the highest prevalence was recorded in 2007 in Rabat, the capital and a coastal city, where an analysis of 2,456 sera using the ELISA (Enzyme-Linked Immuno-Sorbent Assay) technique revealed a seroprevalence of 50.6% [24]. Conversely, the lowest prevalence of 26.28% was found in Marrakech, located in the central part of the country [25].

Research on *T. gondii* infection in Morocco has been limited, with few studies identifying key risk factors (refer to Table 2). The factors associated with higher infection rates include exposure to soil, not washing fruits and vegetables before consumption, lower educational attainment, and drinking water from wells [32, 33]. Awareness about toxoplasmosis among pregnant and postpartum women is notably inadequate, with growing evidence of insufficient knowledge. For instance, a study involving medical, biology, and veterinary students revealed that fewer than half had heard of toxoplasmosis, and only 36.5% correctly identified its causative agent, pointing to significant gaps in understanding [34]. Even health professionals exhibit notable shortcomings in their knowledge of the parasite's diagnosis and transmission [35].

Clinical toxoplasmosis

Approximately 40% of pregnancies in which a mother contracts *T. gondii* for the first-time during gestation experience transplacental transmission of the parasite [36]. Shockingly, the only published study on congenital toxoplasmosis in Morocco dates back to the year 2000 [37], This study covered four cases admitted to the Children's Hospital University of Mohammed V Souissi in Rabat. In two of these cases, prenatal treatment with spiramycin was given following maternal seroconversion. Post-delivery, two of the children suffered severe effects, while the other two showed milder symptoms. Tragically, one of the severely affected children died. The surviving children were treated with pyrimethamine and sulfonamides. Among them, one developed neurological sequelae and another experienced chorioretinitis. Toxoplasmic chorioretinitis, which typically arises from maternal infection in later stages of pregnancy, often

Table 1 Seroprevalence of *T. Gondii* antibodies in pregnant and HIV infected patients tested in Morocco

Population	City	Sample	Detection method	*N°* tested	Ig M positive	Ig G positive	Reference
Pregnant women	Rabat	Blood	Elisa	2456	1.8%	50.6%	[24]
Asymtomatic HIV Infected Pateints	Marrakech	Blood	Elisa/Western Blot	95	-	62.1%	[23]
Pregnant women	Rabat	Blood	Elisa	1169	1.5%	47%	[26]
Pregnant women	Rabat	Blood	Elisa	128	3.9%	42.4%	[27]
Pregnant women	Fez	Blood	Chemiluminescent microparticle immunoassay method	3440	-	39.7%	[28]
Pregnant women	Essaouira	Blood	NM	1798	-	26.7%	[29]
Pregnant women	Marrakech	Blood	-Elisa	1606	-	26.28%	[25]
	Kelaâ des sraghna	Blood	-Microparticle immunological Assay CMIA	666	-	26.49%	
	Essaouira	Blood		1018	-	28.92%	
	Safi	Blood		2288	-	33.84%	
Pregnant women	Rabat	Blood	Elisa	677	3.9%	43%	[30]
Pregnant women	Oujda	Blood	microparticle chemiluminescence immunoassay method	5239	-	41.7%	[31]

NM : No mentioned

Table 2 Knowledge and risk factors associated with *T. Gondii* infection

Population	Location	Number	Knowledges : Main findings	Risk factors	Reference
Pregnant women	Rabat	1020		Contact with soil ; Low level of education ; Lack of knowledge about toxoplasmosis	[32]
Health Professionals	Rabat	96	– 30% believed that water can be a risk factor for the transmission of toxoplasmosis -14.58% health professionals knew about the avidity test		[35]
Women from 17 to 70 years old, including 82 pregnant women	Rabat, Casablanca, Tinghir	632		Contact with soil ; Absence of washing vegetables and fruits before use ; Low educational level ; Drinking water from wells	[33]
Pregnant women	Casablanca	390	– 41.2% reported having heard or read information regarding toxoplasmosis – 13.7% demonstrated awareness that cats serve as the host for toxoplasmosis.	-	[78]
University students	Rabat	230	– 42.6% of the students were aware about toxoplasmosis. – 36.5% were aware that toxoplasmosis is caused by the parasite *T. gondii*. – 32.1% were aware that the definitive host is a cat.		[34]
Post partum women	Rabat	320	– 71% had never heard about toxoplasmosis. – 18.1% o stated knowing the transmission routes for toxoplasmosis. – 90%were unaware of the severity of the congenital infection	-	[79]
Pregnant women	Marrakech	100	– 62% of pregnant women have never heard of toxoplasmosis, -29% of participants have any knowledge of preventive measures.		[80]

Table 3 Clinical manifestations of *Toxoplasma gondii* infection in Morocco

Symptoms	Location	Tested patients	Confirmed patients	Test	Lesion	Reference
Ocular	Ophthalmology department ; Teaching Hospital of Mohammed-V, Rabat	15 1 1	15 1 1	-Ig G+ PCR+ -Ig G +	- Chorioretinal lesion - Chorioretinal lesion -Branch retinal vein occlusion	[39] [40] [41]
	Military teaching hospital Mohamed-V, Rabat	1	1	-Ig G +	- Chorioretinal lesion	[42]
Neurological	Military Teaching Hospital Mohamed-V, Rabat	1 453	1 21 (4.63%)	Stereotaxic biopsy -Ig G +	-Cocarde lesion -Focused neurological deficit (80%),	[81] [43]
	Mohamed VI Teaching Hospital, Marrakech.	1 387	1 115 (30%)	-CT scan Ig G + (Serum +LCR)	Intracranial hypertension signs (42%), seizures (38%). Hypodensity with peripheral enhancement images (33%)	[82] [44]
	Military Teaching Hospital Mohamed-V, Rabat			CT scan LCR CT scan	-Cocarde lesion	
	Ibn Rochd Teaching Hospital, Casablanca				-Cocarde lesion	
Congenital Toxoplasmosis	Children's Hospital, University of Mohammed -V, Rabat	4	4	Ig G + Ig M CT scan	-Death -Triventricular dilatation -Cerebral calcifications -Chorioritinis -Polyadenopathy -Jaunadisse	[37]

CT scan : Computed Tomography scan

remains undetected through prenatal screening due to its isolated nature. Diagnosis relies on ocular fundus examinations performed at birth and during subsequent postnatal check-ups [38]. Additionally, there are few reports of ocular toxoplasmosis in Morocco (see Table 3). Additionally, in 2013, a series of 15 chorioretinitis cases caused by toxoplasmosis were confirmed [39]. Other reports have identified ocular toxoplasmosis through positive serology and the presence of lesions [32–34]. Neurological lesions attributed to toxoplasmosis have

Table 4 Prevalence of *T. Gondii* in livestock animals in Morocco

Animal	Source/Region	No. tested	Positive (%)	Detection method	Reference
Sheep	Slaughterhouse Marrakech Region	50	30	Directly detecting the cysts in the cerebral tissue	[45]
Sheep	Slaughterhouse Marrakech	261	27.6	Elisa	[46]
Sheep	Tetouan and Chaouen	202	20.8	Elisa	[58]
Goats		106	8.5		
Bovines	Meknes Settat	226	7.5 8.5	Direct Agglutination Test	[47]
Ovines		131	7.4 18		

also been documented in several studies (see Table 3). In two instances, a characteristic "cocarde" image on CT scans (Computed Tomography scan) revealed the disease, which was later confirmed biologically and occasionally histologically. A study of HIV-infected patients with suspected or confirmed cerebral toxoplasmosis found that 21 out of 453 met the diagnostic criteria, indicating a prevalence of 4.63% [43]. Similarly, research at the Teaching Hospital Ibn Rochd in Casablanca reported that 30% of patients with neurological symptoms had cerebral toxoplasmosis [44].

Toxoplasmosis in animals

Cats are crucial to the epidemiology of *T. gondii* as they are the definitive host for the parasite. However, there have been no studies published on the excretion of oocysts by cats in Morocco. In contrast, a few studies have focused on intermediate hosts such as sheep, goats, and cattle (see Table 4). Given the popularity of undercooked sheep dishes like 'Kabab' and 'kofta' in Morocco, one investigation that directly detected *T. gondii* cysts in the brain tissue of 50 slaughtered sheep found that 30% of them were infected [45]. In a separate study, 261 serum samples from sheep intended for consumption in Marrakech were tested for anti-*T. gondii* IgG using the Toxoplasma ELISA serology test. Of these samples, 72 (27.6%) were positive [46]. A decade later, Benkirane et al. (2015) examined 308 aborted females, including 202 ewes and 106 does, and found that ewes had significantly higher antibody titres to *T. gondii* (20.8%) compared to does (8.5%). Additionally, a comparative study of *T. gondii* seroprevalence in sheep and cattle from southern and northern Morocco revealed notable differences between the two regions. These discrepancies might be attributed to factors such as the presence of cats and varying meteorological conditions [47].

Table 5 Detection of *Toxoplasma Gondii* in the environment in Morocco

Site	Samples	No. tested	Detection method	Prevalence	Reference
Marrakech	Parsley Coriander Carrot Lettuce Radish	132	Q PCR	42.4% 13.8% 10% 7.1% 6.3%	[49]
Marrakech	Parsley Coriander Lettuce	152	Q PCR	29.6%	[50]
Marrakech	Soil	42	Microscopic detection	0%	[52]

Toxoplasma gondii oocysts in the environment

In Morocco, Berrouch and colleagues estimated the prevalence of *T. gondii* in commonly consumed vegetables. Among 132 vegetable samples, including carrot, coriander, lettuce, parsley, and radish, the cumulative prevalence of *T. gondii* was found to be 16.66% through qPCR analysis [49]. Another study focusing on leafy vegetables such as coriander, parsley, and lettuce revealed a higher contamination rate of 29.6% [50] (see Table 5). *T. gondii* oocysts can remain viable for extended periods in the environment and are resistant to standard chemical and physical treatments used in water purification, like chlorination and ozone treatment [51]. However, the only study conducted in Morocco to detect oocysts in soil returned a negative result. This could be attributed to various factors, including the sensitivity of the detection methods and the presence or absence of cats, which are the primary reservoir for the parasite [52].

Discussion

The prevalence of toxoplasmosis among pregnant women in Morocco varies significantly by city, ranging from 26.28 to 50.6%. This variation suggests that factors beyond diet and hygiene may influence these differences. A systematic review and meta-analysis of global latent toxoplasmosis prevalence in pregnant women reveals a wide range, from 0.7% in South Korea to 92% in Ghana. The highest prevalence rates are found in South America (56.2%) and Africa (48.7%), while the lowest rates are in the Western Pacific region (11.8%) [53].]. Additionally, a recent systematic review focused on the African continent reported a pooled seroprevalence of 42.89% among pregnant women [54]. Further meta-analysis on the impact of geoclimatic factors on toxoplasmosis indicates that higher prevalence rates are associated with regions experiencing elevated temperatures, humidity, and precipitation, highlighting the significant role of environmental conditions in the transmission and prevalence of toxoplasmosis [55].

The immunoenzymatic techniques ELISA such as ELFA (Vidas® Toxo IgG, Mini Vidas ® Toxo IgG) and the microparticle immunological Assay CMIA (Architect Toxo IgG, Access® ToxoIgG) was the serological tests used by the researchers in this review (Table 1).

It is evident from this review that the researchers employed serological tests using immunoenzymatic techniques, including ELISA methods (e.g., ELFA with Vidas® Toxo IgG, Mini Vidas® Toxo IgG) and microparticle immunological assays (e.g., CMIA with Architect Toxo IgG, Access® Toxo IgG) [Table 1]. On the other hand, the enzyme-linked immunosorbent assay (ELISA) is extensively utilized for detecting *T. gondii*-specific antibodies in both animals and humans. This technique requires only a small sample volume and can be semi-automated, making it ideal for large-scale screening. Furthermore, ELISA can differentiate between various immunoglobulin classes, which helps in determining the phase of infection [56]. The ARCHITECT Toxo IgG assay is a fully automated, two-step chemiluminescent microparticle immunoassay (CMIA) that quantitatively measures IgG antibodies to *T. gondii.* Utilizing recombinant antigens, this assay demonstrates exceptional specificity and sensitivity for detecting both acute and past infections [57]. Furthermore, a major challenge in serological diagnosis is distinguishing between acute and latent or chronic infections. To address this, avidity testing is now recommended for determining the timing of infection in IgG/IgM-positive pregnant individuals. High avidity IgG, which typically indicates a past infection, is particularly useful for ruling out recent infections [58]. Recent international studies have offered compelling evidence of a humoral immune response against cyst wall antigens in naturally acquired *T. gondii* infections. This breakthrough provides new insights into the parasite's pathogenesis and lays the groundwork for developing methods that can accurately pinpoint the timing of infection in hosts [58, 59]. A wider array of tests has been developed for humans, including expensive techniques that measure various Ig isotypes, serving as biomarkers for congenital toxoplasmosis. Human studies frequently used commercial methods as reference tests, primarily focusing on IgG to differentiate between acute and chronic infections. In contrast, studies involving animals generally relied on in-house tests that detect IgG [60]. Many current serological tests for *T. gondii* may show some cross-reactivity with related coccidia, such as *H. hammondi* and *N. caninum*. Nevertheless, the identification of species-specific antigens and stage-specific proteins in these parasites holds promise for enhancing diagnostic accuracy and advancing epidemiological research [61]. In Morocco, *T. gondii* has been detected in the brains of sheep slaughtered for human consumption, highlighting the occupational hazards associated with this disease. Toxoplasmosis is recognized as a significant occupational risk for individuals who work with livestock, including farmers raising cows, sheep, goats, and poultry, as well as those employed in slaughterhouses and meat sales [62]. This is supported by a case-control study conducted in Iran, which found that the overall seroprevalence of anti-*T. gondii* IgG among those exposed to slaughtered animals was 46.1%, compared to 31.4% in those not exposed. The study concluded that the risk of *T. gondii* infection was nearly 50% higher in the occupationally exposed group compared to the control group [63]. It is important to note that the veterinary profession faces a higher-than-average risk of occupational diseases compared to many other fields [64]. In Saudi Arabia, a study revealed that 45% of veterinarians had experienced occupational diseases, including toxoplasmosis. Additionally, research conducted in India found a potentially significant association between *T. gondii* seropositivity and occupational exposure to animals [65, 66]. In addition to causing significant economic losses in the livestock industry due to abortion in ruminants, *T. gondii* infection also poses a risk of transmitting infectious and parasitic diseases to humans through the consumption of raw or undercooked meat or milk from infected animals. Our review found a prevalence of *T. gondii* in sheep as high as 30%, compared to no more than 8.5% in cattle and goats. A global systematic review and meta-analysis evaluating the prevalence of toxoplasmosis in various livestock and poultry reported an overall prevalence of 28.3% [67]. In South Africa, a cross-sectional study examining the prevalence of *T. gondii* in sheep and goats found seroprevalences of 19.5% and 10.5%, respectively [68]. Conversely, in India, lower prevalence was reported, with T. gondii DNA detected in only 1.69% of sheep samples and 1.34% of goat samples intended for consumption [69]. Moreover, raw milk consumption has been proposed as another route for *T. gondii* transmission to humans. This is corroborated by a study conducted in Egypt, which found that raw milk was contaminated with *T. gondii* tachyzoites, indicating it could be a source of human infection [70]. Other animals, including rodents, also contribute to the transmission of toxoplasmosis. As a primary food source for many predators, rodents facilitate the spread of T. gondii, leading to increased environmental contamination and a higher risk of infection in humans and other animals. Thus, implementing effective control measures and strategies is crucial to reduce infection rates in these mammals [71]. Fruits and vegetables are essential for a balanced diet and can help prevent serious health conditions such as cardiovascular diseases (CVDs) and certain cancers when consumed in adequate amounts daily. The World Health Organization (WHO) recommends a daily intake of at least 400 g of fruits and vegetables [72]. However, numerous studies have documented parasitic

contamination of fresh produce across various countries, including Riyadh, Saudi Arabia [73], Nakhon Si Thammarat, Southern Thailand [74], Spain and Portugal [51] and Gaza, State of Palestine [75]. Precipitation, moisture, and temperature are critical factors influencing the survival, sporulation, and infectivity of *T. gondii* oocysts in both water and soil, significantly impacting the prevalence of *Toxoplasma* infections in specific regions [53]. The risk of parasitic diseases through water consumption poses a serious public health concern. A recent study in Morocco revealed the presence of *T. gondii* DNA not only in well water but also in tap and spring water samples [76]. underscoring the necessity for enhanced water treatment to mitigate the risk of parasitic transmission. Additionally, the prevalence of *T. gondii* in certain vegetables in Morocco can reach up to 42% in parsley. This variation in prevalence is attributed to several factors identified in a literature review, including the detection method, climatic conditions, geographical location, quality of irrigation water and fertilizers, and whether the vegetables are leafy [77] .

Conclusion

The current study, through a systematic review of research on *Toxoplasma gondii* conducted in Morocco, concludes that the parasite remains a significant public health concern for humans, animals, and environmental matrices. Data indicate a rising prevalence of toxoplasmosis in coastal urban areas, with notably high seroprevalence among HIV patients. Key risk factors identified include contact with soil, inadequate washing of fruits and vegetables, reliance on well water, and low educational levels. Although there are several reports of toxoplasmosis in Morocco, there is a notable absence of comprehensive, statistically robust national prevalence studies. Additionally, information on clinical toxoplasmosis in both humans and livestock is limited. Physicians in Morocco frequently attribute miscarriages and complications in pregnant women to toxoplasmosis; however, the review highlights the rarity of published studies supporting this association. Lastly, the current review study revealed that there is an urgent need for well-designed research to explore congenital toxoplasmosis in Morocco.

Author contributions

I.A and S.B conceived of the presented idea. I.A and S.B verified the analytical methods. O.T. and S.B supervised the findings of this work. All authors discussed the results and reviewed the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Competing interests

The authors declare no competing interests.

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