Archives of Razi Institute Journal
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Research Paper

Identification of *Toxoplasma gondii B1* Gene in Raw Milk from Sistan and Baluchestan Province Using Nested-PCR

Mohammad Mohebbi[1], Mohammad Mirzaei[1*], Bagher Amirheidari[2], Maryam Nooshadokht[3]

1. Department of Pathobiology, Faculty of Veterinary Medicine, Shahid Bahonar University of Kerman, Kerman, Iran.
2. Extremophile and Productive Microorganisms Research Center, Kerman University of Medical Sciences, Kerman, Iran.
3. Department of Pharmaceutical Biotechnology, Faculty of Pharmacy, Kerman University of Medical Sciences, Kerman, Iran.

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How to cite this article Mohebbi M, Mirzaei M, Amirheidari B, Nooshadokht M. Identification of *Toxoplasma gondii B1* Gene in Raw Milk from Sistan and Baluchestan Province Using Nested-PCR. Archives of Razi Institute Journal. 2026; 81(3):655-662. https://doi.org/10.32598/ARI.81.3.3692

https://doi.org/10.32598/ARI.81.3.3692

Article info:
Received: 11 Dec 2025
Accepted: 18 Feb 2026
Published: 01 May 2026

Keywords:
Nested polymerase chain reaction (nested PCR), Raw milk contamination, *Toxoplasma gondii*

ABSTRACT

Introduction: The pathogen of Toxoplasmosis, *Toxoplasma gondii*, is an obligate intracellular protozoan for which all mammals act as intermediate hosts; however, cats are definitive hosts. It is a common zoonotic disease transmitted through various routes, including direct contact with infected animals, environmental contamination with *T. gondii* oocysts, contaminated food, unpasteurized milk, and through the placenta. Toxoplasmosis is one of the leading causes of miscarriage, stillbirth, and congenital infection in humans and animals. Considering the lack of studies conducted on the occurrence of toxoplasmosis in humans and animals in Iran, this research aimed to investigate the genetic prevalence of *T. gondii* in raw milk collected from Sistan and Baluchestan Province.

Materials & Methods: DNA extraction was performed on 224 milk samples from 64 sheep, 64 goats, 64 cows, and 32 camels. These samples were collected and transported to the laboratory, and the presence of the parasite was evaluated by identifying the *T. gondii B1* gene using nested polymerase chain reaction (nested PCR) method.

Results: Twenty-six samples (11.6%) were contaminated with *T. gondii*. The prevalence of infection in raw milk from cows, sheep, goats, and camels was 6.3%, 17.2%, 14.1%, and 6.3%, respectively. The highest molecular incidence of infection was identified in sheep milk.

Conclusion: The overall conclusion is that the *T. gondii* prevalence in raw milk samples, especially in sheep and goat samples, in the study area is very significant. Consuming raw milk containing *T. gondii* DNA increases the risk of transmitting this parasite to humans, therefore, it is necessary to thoroughly boil raw milk or consume pasteurized milk.

*** Corresponding Author:**
Mohammad Mirzaei, Professor.
Address: *Department of Pathobiology, Faculty of Veterinary Medicine, Shahid Bahonar University of Kerman, Kerman, Iran.*
Tel: *+98 (913) 1973203*
E-mail: *dr_mirzaie_mo@uk.ac.ir*

1. Introduction

Toxoplasma gondii is the causative agent of toxoplasmosis. While most mammals act as intermediate hosts, cats are the definitive hosts. Infection in humans and domestic animals frequently occurs via environmental contamination with *T. gondii* oocysts, however, humans are also susceptible to infection through the consumption of contaminated food and unpasteurized milk containing tachyzoites of this parasite [1]. Tachyzoite, which is formed in the infectious stage, is transmitted through animal fluids and may migrate from the bloodstream to milk during the acute stage of infection [2]. Lesions resulting from subacute infection can damage the brain, lungs, liver, heart, and eyes, potentially leading to blindness. Furthermore, central nervous system lesions tend to be more severe in immunocompromised individuals [3]. Major clinical risks of this parasitic infection include congenital transmission and severe fetal malformations, such as hydrocephalus, microcephaly, and miscarriage, as well as milder conditions including psychomotor retardation, intellectual disability, and chorioretinitis. Additionally, toxoplasmosis has been linked to various psychiatric disorders, including schizophrenia, depression, anxiety, aggression, and suicidal behavior [4].

Milk is a livestock product of high nutritional value, comparable to meat, and is consumed globally as a complete food both during childhood and adulthood. However, if this animal's product is consumed raw, it can transmit various infectious diseases to humans and create some problems for its producers [5]. If hygiene is not maintained during milking, transportation, and storage processes, traditional dairy products, including raw milk, may be contaminated with *T. gondii*; cross-contamination is another route by which the parasite can be transferred to those products [6]. In milk, Tachyzoites of this parasite were detectable [7, 8], and their presence has been proven in milk specimens of animals such as sheep, goats, cows, and buffalo. The highest contamination level was observed in sheep and goats milk [9-12].

Since the diagnosis of *T. gondii* based on clinical symptoms is challenging, the main diagnostic methods include cell culture of infected samples to isolate this protozoan (which is time-consuming and expensive) and serological tests detecting antibodies against this parasite, which may involve cross reactions. Due to the disadvantages of the mentioned methods, polymerase chain reaction (PCR)-based methods are now commonly used [12]. The *B1* gene, characterized by 35 tandem repeats, is commonly used for highly sensitive and specific PCR identification of *T. gondii* [13]. When used in nested PCR, this technique has shown advantages such as high speed, accuracy, high sensitivity, specificity, and safety, and has led to the detection of this parasite in milk from ruminants and traditional dairy products in certain regions of Iran [6, 11, 14]. The important issue is that PCR-based technique cannot differentiate between viable and inactive *T. gondii* parasites, as they only confirm the presence of genetic material [15]. Therefore, to definitively prove the viability and infectivity of the parasite, culture methods (in vitro cell culture) or bioassays in mouse models remain essential as gold standard techniques [16]. The lack of research data on the epidemiology of toxoplasmosis in human and animal populations in Iran, particularly in Sistan and Baluchestan Province, has created a significant knowledge gap. This information gap, coupled with traditional animal husbandry practices in the region that facilitates close contact between cats (definitive hosts of the parasite) and livestock (intermediate hosts), as well as the common dietary patterns in some communities in the region that lead to the consumption of unpasteurized dairy products, led to the design and execution of this study on the genetic prevalence of *T. gondii* in raw milk samples from four important animal species in Sistan and Baluchestan Province.

2. Materials and Methods

2.1. Sample collection

During 2024 in Sistan and Baluchestan Province, raw milk from 64 cattle, 64 goats, 64 sheep, and 32 camels was manually (with gloves) milked from the udders of the animals (which were previously disinfected with alcohol), and a total of 224 random samples were collected. The samples were transported individually in sterile glass containers on ice to the laboratory within 2 to 4 hours.

2.2. DNA extraction

Genomic DNA was extracted using a DNA extraction kit in accordance with the manufacturer's instructions (PEX, Pishgam, Iran), and samples were kept at –20 ˚C until the Nested-PCR test.

2.3. Nested-PCR amplification of the *B1* gene

The reaction mixture (25 µL total volume) for the first round of PCR amplification consisted of 12.5 µL 2X PCR Red Master Mix (Pishgam, Iran), 1.5 µL of external Forward primer (10 picomoles), 1.5 µL of external reverse

Table 1. Primer sequences used in the Nested-PCR reaction

Target Gene	Primer Name	Primer sequence	Ref.	Amplicon Size
B1 (primary)	Toxo 1 F	5›-TCAAGCAGCGTATTGTCGAG-3’	[35]	-
B1 (primary)	Toxo 1 R	5›-CCGCAGCGACTTCTATCTCT-3’	[35]	-
B1 (secondary)	Toxo 2 F	5›-GGAACTGCATCCGTTCATGAG-3’	[35]	197bp
B1 (secondary)	Toxo 2 R	5›-TCTTTAAAGCGTTCGTGGTC-3’	[35]	197bp

primer (10 picomoles; primer sequences listed in Table 1), 2 µL of genomic DNA, and 7.5 µL nuclease-free water. PCR was run on a thermal cycler (MWG, Germany). The cycling conditions were set as follows: initial denaturation at 94 ˚C for 30 seconds, followed by 35 PCR cycles consisting of denaturation at 94 ˚C for 15 s, annealing at 45 ˚C for 30 s, and elongation at 72 ˚C for 45 s, with a final extension at 72 ˚C for 10 min. The secondary amplification was conducted with 1 µL of the primary PCR amplicon (DNA template), the second set of primers, and cycling conditions identical to the first round. PCR products were resolved by 2% agarose gel electrophoresis. A bright band of 197 bp in size was observed, confirming the identification of the *T. gondii B1* gene. DNA extracted from tachyzoites of the RH strain and only sterile distilled water served as the positive control and the negative control, respectively.

2.4. Statistical analysis of data

The results were analyzed using SPSS statistical software. The chi-square test was used, and differences were considered significant at ($P<0.05$).

2.5. Ethical considerations

The milk samples used in this research were collected non-invasively during the normal milking process from animals on farms. This procedure caused no pain, suffering, or additional stress to the animals and was Performed in full compliance with the standards for milk production. Special permission was obtained from the owner of the animals during sampling.

3. Result

Agarose gel electrophoresis results of the Nested-PCR products used for the amplification of the *B1* gene of *T. gondii* in milk samples are shown in Figure 1. It is clear that the *T. gondii* result is positive, since a 197 bp band is formed on the gel. A summary of the prevalence of *T. gondii* in samples of milk from different livestock species in Sistan and Baluchestan Province is given in Table 2. Of the total 224 specimens, 26(11.6) tested positive for the *T. gondii B1* gene. The frequency of *T. gondii* contamination in raw milk specimens from cow, sheep, goat, and camel was 6.3%, 17.2%, 14.1%, and 6.3%, respectively, and the highest molecular prevalence of infection was observed in raw sheep milk. Statistical analysis showed that the infection rate among different animals was not significant ($P>0.05$).

Table 2. The prevalence rate of *T. gondii*

Species	No.	No. (%)
	Milk Samples	Positive
Bovine	64	4(6.3)
Ovine	64	11(17.2)
Caprine	64	9(14.1)
Camel	32	2(6.3)
Total	224	26(11.6)
P	0.172	

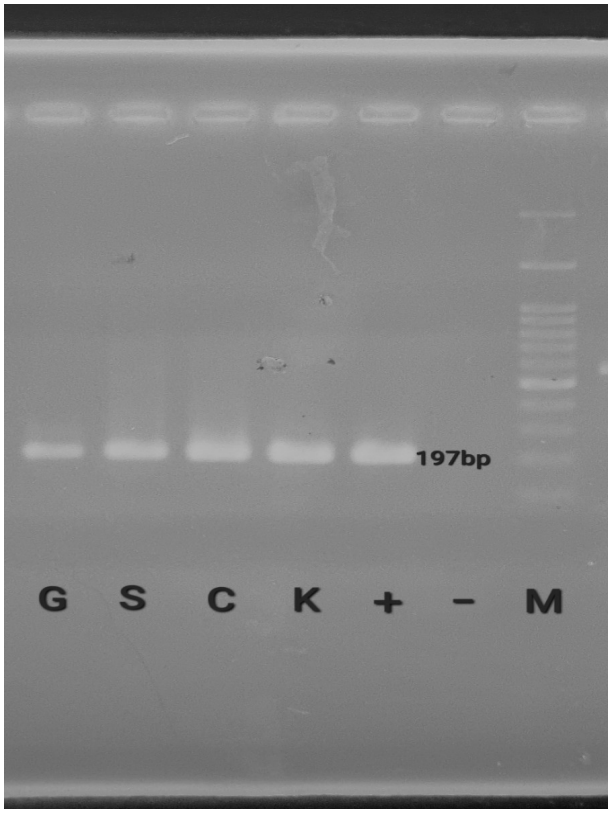

Figure 1. Electrophoresis results of nested-PCR products related to *T. gondii B1* gene amplification

Note: "M" means "marker"; the sings of "–" and "+" indicate "negative control" and "positive control" respectively; K = Camel, C = Cow, S = Sheep, and G = Goat are "positive samples".

4. Discussion

The results of the highly sensitive nested-PCR method for all 224 raw milk samples collected from four livestock species in Sistan and Baluchestan Province showed that *T. gondii* was present in 26(11.6%) of the milk samples. The highest level of contamination was observed in sheep milk (17.2%), because sheep are likely to be more exposed to environments contaminated with cat feces containing oocysts through free- grazing practices, and also some of their physiological features may facilitate parasite excretion through milk [2].

A study in Alborz Province similarly detected *T. gondii* in 12% of sheep milk, 10% of goat milk, and 3.5% of cow milk [12]. These findings support the present study results and highlight the importance of disease control at both the livestock and dairy product levels.

Another study collected raw milk samples from five livestock species across four seasons in Isfahan, Chaharmahal and Bakhtiari, Khuzestan, and Fars Provinces. Nested-PCR analysis revealed *T. gondii* in 26 samples; sheep milk showed the highest contamination rate (8%), while buffalo milk had the lowest (4.28%) [11]. In the current study as well, the highest prevalence was observed in sheep milk samples.

In Fars, Isfahan, and Tehran provinces, PCR analysis detected the *T. gondii B1* gene in 46(5.17%) milk samples. Fars showed the highest prevalence (18 cases, 6.16%), followed by Tehran (15 cases, 4.76%), and Isfahan (13 cases, 4.6%). Among the positive samples, the greatest rate of *T. gondii* infection was found in goat milk (17 cases, 9.44%), followed by sheep 12 cases (6.48%), buffalo (6 cases, 3.65), and cow milk (7 cases, 3.5%), with the lowest prevalence in camel milk (4 cases, 2.5%) [10]. In Northwestern Iran *T. gondii* DNA was detected in sheep (16 cases, 4.63%) and goat (3 cases, 1.07%) milk samples [17]. In East Azarbaijan Province, *T. gondii* was detected in milk specimens from camels (13.33%), cows (3.63%), and buffaloes (3.33%) [18]. In Assiut, Egypt, the *T. gondii B1* gene was detected in raw sheep milk (10.71%) and raw goat milk (22.73%) by PCR assay [19]. Another study in Kayseri Province, Türkiye, examined a total of 200 specimens of cheese and milk from cow, sheep, goat and water buffalo and detected *T. gondii* in goat (4%) and ewe milk (8%) [20].

In our study, the prevalence of *T. gondii* in sheep milk was reported as 17.2%, while lower prevalences have been reported from studies in Pakistan (14.44%), Brazil (12.04%), and Italy (3.4%) [21-23]. In our study, the prevalence of *T. gondii* in goat milk was 14.1%, while similar studies from Italy reported a prevalence of 13%; lower prevalences were reported in Brazil (6.05%), and higher prevalences were reported in Poland (43%), Pakistan (34.8%), and Thailand (27.9%) [21, 24-27]. In our study, the prevalence of *T. gondii* in cow milk was reported as 6.3%, while it has been reported as 20% in Pakistan, 76.3% in Serbia, 71% in Brazil, and 13.3% in Sudan using the ELISA method [21, 28-30]. The high prevalence of *T. gondii* infection in sheep may be due to their free-range exposure to infection. These animals are kept in pastures, and environmental contamination with oocysts increases the infection pressure [2]. Epidemiological studies consistently show that cattle and camels exhibit greater intrinsic resistance to Toxoplasma infection than sheep, and their seroprevalence is lower. This resistance appears to be due to a stronger cellular immune response in cattle, which has a better ability to control parasite proliferation [31]. However, the findings of studies can be different because each research is influenced by multiple factors, such as geographic location, climate, animal age, grazing systems, feed type, farm hygiene, animal species, laboratory protocols, and milk handling and storage procedures [11].

In raw milk or traditional dairy products (e.g. fresh cheese, yogurt, and cream), *T. gondii* tachyzoites survive for several days at refrigerated temperatures, so the potential risk of transmission is very high, especially for raw or unpasteurized dairy products [1, 7, 32, 33]. Since the initial infection probably leads to severe fetal consequences such as microcephaly, hydrocephalus, chorioretinitis, and miscarriage, it vital to pay attention to the threat of transmission for pregnant women, children and immunocompromised individuals [4].

In a systematic review and meta-analysis on the distribution and epidemiological aspects of toxoplasmosis in Iran, the highest prevalence was in sheep at 31%, followed by goats at 27% and cattle at 18% [34]. The lack of serological data is a significant gap in the interpretation of our findings. Serological data are crucial for correctly interpreting the presence of the parasite in milk; these data could have helped determine the previous exposure status and differentiate between acute and chronic infection, as parasite shedding in milk is mainly associated with the acute phase. Unfortunately, due to budget limitations and given that the current study design was cross-sectional, simultaneous access to blood and milk samples was not possible. The reason for using the Nested-PCR technique, as a standard molecular diagnostic tool, in this research for identifying *T. gondii B1* gene is its high sensitivity and specificity. The small sample size in camels was mainly due to the challenges of accessing raw milk samples from scattered animals in nomadic and rural areas of Sistan and Baluchestan Province. Given that this study is the first to investigate the presence of *T. gondii* DNA in the milk of these animals in this specific region, it is recommended that future studies be conducted with larger sample sizes.

5. Conclusion

The overall conclusion is that the *T. gondii* prevalence in raw milk samples, especially in sheep and goat samples, in the study area is very significant. Milk and dairy products are essential parts of the household diet, particularly for children, pregnant women, and lactating mothers, who represent high-risk groups. Therefore, given the zoonotic potential of this parasite and the risk of toxoplasmosis transmission from raw milk, consuming pasteurized milk or thoroughly boiling raw milk is highly recommended. Since cats, the definitive host of this parasite, are commonly found on livestock farms, to prevent infection it is essential to minimize their contact with animals and feed.

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

Study design, methodology, review and editing: All authors; Experiments: Mohammad Mohebbi; Data acquisition: Mohammad Mohebbi and Mohammad Mirzaei; Data analysis: Mohammad Mohebbi; Writing the original draft: Mohammad Mohebbi and Mohammad Mirzaei.

Conflict of interest

The authors declared no conflict of interest.

Data availability

The data that support the findings of this study are available upon request from the corresponding author.

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