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Paper



First comprehensive histopathological and seroepidemiological investigations of *Toxoplasma gondii* infection in meat goats in Algeria

Hichem Dahmani¹, Imane Ouchetati², El Aid Kaaboub¹, Dalila Terzali³, Abd Elazize Lounes³, Lynda Abdellaoui³, Ali Dahmani³, Omar Salhi³, Nadjet Amina Khelifi Touhami³, Nassim Ouchene^{4*}

¹Department of Natural Sciences and Life, Faculty of Sciences and Technology, University of Medea, Medea, Algeria - DZ

²Laboratory of Physical Chemistry and Biology of Materials, Department of Natural Sciences, Higher Normal School of Technological Education of Skikda, City of Boucetta Brothers, 21300, Azzaba, Algeria - DZ

³Institute of Veterinary Sciences, University Sâad Dahlab of Blida 1, Street Soumâa, BP270, 09000, Blida, Algeria - DZ

⁴University Blida 1 - DZ

*Corresponding author at: University Blida 1 - DZ

E-mail: ouchene_nassim@univ-blida.dz

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Abstract

This study assessed *Toxoplasma gondii* infection in 92 slaughtered goats from four ecologically distinct regions of Algeria: Laghouat, Medea, Bouira, and Djelfa. Serological analysis was performed using a multispecies indirect ELISA, and histopathological examination targeted heart and diaphragm tissues to detect cysts or suggestive inflammatory lesions. The overall seroprevalence was low (4.3%), with no significant associations with age, sex, or breed. Geographic region significantly influenced seroprevalence: Bouira exhibited the highest rate (18.8%, $p < 0.01$), while other regions ranged from 0–8.3%. Histopathological analysis revealed a higher prevalence of lesions compatible with *T. gondii* (10.9%) in both heart and diaphragm. Young goats had higher lesion rates (18.8%) than adults (6.7%), though differences were not statistically significant. Regional differences were pronounced: Bouira showed 37.5% of animals with lesions ($p < 0.001$), El-Djelfa 16.7% ($p < 0.04$), while Laghouat remained free of lesions. These findings highlight a geographically clustered distribution of infection. Comparison of ELISA with histopathology indicated high concordance: 4 goats were positive across all methods, while 6 goats were ELISA-negative but tissue-positive, suggesting early, chronic, or low-antibody infections. Overall agreement between ELISA and tissue examination was 93.5%, with a Cohen's kappa of 0.54, indicating moderate to substantial agreement. The study demonstrates that intensive, closed-system goat farming effectively limits exposure to *T. gondii*, as evidenced by low seroprevalence and limited tissue infection. Importantly, combining serological and histopathological approaches provides a more comprehensive assessment of infection, capturing cases that may be missed by either technique alone. This dual diagnostic strategy enhances epidemiological understanding and improves surveillance, particularly in areas with environmental hotspots like Bouira.

Keywords

Toxoplasma gondii, Goats, Seroprevalence, Histopathology

Introduction

Toxoplasma gondii is an intracellular protozoan parasite with worldwide distribution, capable of infecting nearly all warm-blooded vertebrates (Dubey, 2010; Mammari et al., 2019; Schlüter et al., 2014). This zoonosis is recognised as a major public and veterinary health concern (Mammari et al., 2019; Stelzer et al., 2019). In livestock, particularly small ruminants, *T. gondii* causes reproductive disorders (abortions, stillbirths) and significant economic losses (Ouchene et al., 2023; Dubey, 2010). Transmission to humans occurs mainly through ingestion of tissue cysts in

undercooked meat or tachyzoites in raw milk (Dubey et al., 2020). In this context, the consumption of goat meat or milk represents a non-negligible exposure route for humans (Dubey et al., 2020; Koethe et al., 2017). The parasite also persists as resilient intramuscular cysts and environmental oocysts, and can cross the placenta in goats, inducing fetal death (Amdouni et al., 2017; Dubey et al., 2020). A substantial proportion of the global human population is estimated to be exposed (approximately one-third shows anti-*T. gondii* antibodies), highlighting the importance of the animal production sector in the epidemiology of the parasite (Hajimohammadi et al., 2022; Stelzer et al., 2019).

Infection with *T. gondii* in goats has been studied in many countries, with highly variable seroprevalence levels (ranging from a few percent to more than 70%, depending on the region and farming system) (Chettih et al., 2024; Dubey et al., 2020; Stelzer et al., 2019). Globally, international meta-analyses estimate that approximately one quarter of cattle and small ruminants are seropositive (Hajimohammadi et al., 2022). In Africa, studies compiled in a systematic review reported an average seroprevalence of about 23% in goats (Tonouhewa et al., 2017). Environmental persistence of oocysts (associated with farm or stray cats) and farming practices (access to pasture, shared drinking water) are well-established risk factors for herd contamination and, consequently, human infection through contaminated animal products (Dubey et al., 2020; Ouchene et al., 2023; Tonouhewa et al., 2017).

In Algeria, goat farming is a major component of the agricultural sector, particularly in rural and steppe regions. However, local epidemiological data on caprine toxoplasmosis remain limited. A national systematic review estimated an average seroprevalence of 33.6% in Algerian goats (meta-analysis 1955–2020) (Ouchetati et al., 2021). Recent surveys also suggest a relatively high circulation of the parasite: Chettih et al. (2024) reported 38.0% seropositivity in 92 goats tested across four Algerian regions. These findings indicate that toxoplasmosis is widespread among Algerian goat herds. The associated factors (age, sex, breed, agro-ecological region, presence of cats, farming practices) remain insufficiently characterised in the local context. In addition, most studies have relied exclusively on serological detection (ELISA) without systematically using direct diagnostic tools such as histopathology.

Within this framework, our study—which represents the first in Algeria to simultaneously combine ELISA and histopathology to assess *T. gondii* infection in slaughter goats—aimed to address these gaps. Using goats slaughtered from four ecologically distinct regions of Algeria (Laghouat, Médéa, Bouira, El-Djelfa), we estimated the prevalence of *T. gondii* through ELISA and histopathological examination of heart and diaphragm sections stained with haematoxylin and eosin. We also collected demographic and zootechnical data (age, sex, breed, farming system, cohabitation with cats, abortion history) to evaluate associated risk factors. Finally, agreement between serological and histological results was quantified using Cohen's kappa coefficient to assess the usefulness of histopathology as a complementary diagnostic method. These investigations have both regional relevance (for the Algerian goat sector) and global importance (improving understanding of caprine toxoplasmosis in arid and semi-arid regions), contributing to better-informed control strategies for this major foodborne zoonosis.

Materials and methods

Study areas and sampling

The study was conducted in four Algerian regions with contrasting ecological characteristics: Laghouat (arid steppe of the south-central area), Beni Slimane in Médéa (semi-arid foothills of the Tell Atlas), Bouira (humid mountainous zone of Mediterranean type), and El-Djelfa (semi-arid pastoral area of the central high plateau). In each region, goats were randomly selected from community farms, ensuring balanced numbers across areas.

Goat farming systems varied across the regions. In Laghouat and Beni Slimane (Médéa), goats were predominantly raised under intensive systems, with permanent housing and a diet consisting of concentrate feed, supplemental forage (such as hay or silage), and mineral and vitamin supplements, along with continuous access to clean water. In Bouira, goats were managed extensively, grazing freely in mountainous and plain areas with an almost entirely natural diet, which increased their environmental exposure. In El-Djelfa, a semi-extensive system was practiced, with goats alternating between grazing and housing, and receiving supplementary forage and concentrate feed.

A total of 92 slaughtered goats were sampled at the time of slaughter in March 2025. Sex, age (young vs adults), and breed (local or imported dairy breeds) were recorded for each animal. During farm visits, a standardised questionnaire was administered to farmers to collect information on health history (notably abortions), management practices (grazing access, water source), and the presence of domestic or stray cats in the farm environment (a major risk factor for *T. gondii* contamination).

The sample size ($n = 92$) was determined based on a prevalence calculation for cross-sectional studies, in accordance with the methodological recommendations described by Thrusfield and Christley (2018). In the absence of precise local data, an expected prevalence of 50% was used to maximize the required minimum sample size, with a 95% confidence level and a 10% absolute precision, according to the formula: $n = (Z^2 \times P \times (1 - P)) / d^2$

where $Z = 1.96$; $P = 0.5$; and $d = 0.1$. This calculation yielded a minimum sample size of approximately 96 animals. The final number of 92 goats corresponds to the animals available and eligible during the study period at the slaughterhouse.

Serological and histopathological analyses

For each animal, a blood sample was collected during slaughter. The resulting serum was stored at $-20\text{ }^{\circ}\text{C}$ until testing. Serological status for *T. gondii* was determined using a commercial multispecies indirect ELISA kit (ID Screen® Toxoplasmosis Indirect, IDvet, France), following the manufacturer's recommendations. This test is recognised for its high sensitivity and specificity in small ruminants. A positive result indicates the presence of anti-*T. gondii* IgG antibodies, reflecting a current or past infection.

After slaughter, heart fragments and diaphragm samples were collected, fixed in formalin, and embedded in paraffin. Histological sections of $5\text{ }\mu\text{m}$ were prepared and stained with haematoxylin and eosin. Systematic microscopic examination aimed to detect potential *T. gondii* tissue cysts or suggestive inflammatory lesions (myopericarditis, myositis). This diagnostic method is less sensitive than serology but allows direct visualisation of the parasite within muscle tissues where *T. gondii* typically encysts.

Data analyses

Data were entered and analysed using R software (R Core Team). Prevalence was calculated as the proportion of positive animals according to each method (ELISA and histology). Prevalence across categories of explanatory variables (age, sex, breed, and region) was compared using Fisher's exact test. A significance threshold of $p < 0.05$ was used for all analyses. Finally, agreement between ELISA and histopathology results was evaluated using Cohen's kappa coefficient: values close to 1 indicate high agreement, whereas values around 0 indicate agreement at the chance level.

Results

Seroprevalence (ELISA)

The overall seroprevalence of *T. gondii* was 4.3% (4/92). None of the intrinsic factors (age, sex, breed) showed significant associations with seropositivity (all $p > 0.05$). Young goats displayed a higher prevalence (6.3%) than adults (3.3%), but the difference was not statistically significant ($p = 0.61$). Similarly, males and females exhibited comparable rates (Table I).

However, geographical region had a clear and significant effect. Goats from Bouira showed a significantly higher seroprevalence (18.8%), with an odds ratio of 22.0 and a statistically significant association ($p = 0.018$). All other regions showed 0–8.3% positivity without statistical significance. This indicates that Bouira is a high-risk area for exposure to *T. gondii* (Table I).

The apparent higher prevalence in Bouira may be influenced by the small sample size and should be interpreted with careful consideration.

Factor	Category	n	Positive (n)	Prevalence % (95% CI)	p-value
Age	Adults (≥3 years)	60	2	3.3 (0.9–11.4)	–
	Young (1–2 years)	32	2	6.3 (1.7–20.1)	0.61
Sex	Female	62	3	4.8 (1.7–13.3)	–
	Male	30	1	3.3 (0.6–16.7)	0.87
Breed	Arabia	58	3	5.2 (1.8–14.1)	–
	Alpine	14	0	0.0 (0.0–20.8)	–
	Chamia	8	0	0.0 (0.0–36.9)	–
	Saanen	12	1	8.3 (1.5–35.4)	0.54
Region	Laghouat	42	0	0.0 (0.0–8.4)	–
	Beni Slimane	22	0	0.0 (0.0–14.9)	1.00
	Bouira	16	3	18.8 (6.6–43.0)	0.018*
	El-Djelfa	12	1	8.3 (1.5–35.4)	0.22
Total	–	92	4	4.3 (1.2–10.8)	–

Table I. Seroprevalence of *Toxoplasma gondii* infection in goats (ELISA)

Histopathological lesions

Cardiac lesions compatible with *T. gondii* were more frequent than seropositivity, with an overall prevalence of 10.9%. Age tended to influence lesion occurrence—young animals had a higher prevalence (18.8%) compared to adults (6.7%), although the difference was not significant ($p = 0.09$) (Table II). The most notable finding was the strong regional variation. Bouira showed the highest prevalence (37.5%), with a highly significant association ($p < 0.001$). El-Djelfa also showed a statistically significant association ($p = 0.046$). No lesions were detected in Laghouat (Table II). These results indicate a geographically clustered distribution of active or recent infections.

Factor	Category	n	Positive (n)	Prevalence % (95% CI)	p-value
Age	Adults	60	4	6.7 (2.6–15.9)	–
	Young	32	6	18.8 (8.9–35.3)	0.09
Sex	Female	62	7	11.3 (5.6–21.5)	–
	Male	30	3	10.0 (3.5–25.6)	0.92
Breed	Arabia	58	8	13.8 (7.2–24.9)	–
	Alpine	14	0	0.0 (0.0–20.8)	–
	Chamia	8	1	12.5 (2.2–47.1)	0.90
	Saanen	12	1	8.3 (1.5–35.4)	0.80
Region	Laghouat	42	0	0.0 (0.0–8.4)	–
	Beni Slimane	22	2	9.1 (2.5–27.8)	0.12
	Bouira	16	6	37.5 (18.5–61.4)	<0.001*
	El-Djelfa	12	2	16.7 (4.7–44.8)	0.046*
Total	–	92	10	10.9 (5.3–19.1)	–

Table II. Histopathological findings in the heart

Diaphragmatic lesions followed a pattern nearly identical to those observed in the heart, with the same overall prevalence (10.9%). Again, age differences were not statistically significant ($p = 0.09$), and sex or breed did not influence the occurrence of lesions (Table III).

The Bouira region showed the highest prevalence (37.5%), with a highly significant difference compared to the reference region ($p < 0.001$). El-Djelfa also showed a significant association ($p = 0.046$). Laghouat remained free of lesions (Table III).

These parallel findings across both tissues reinforce the robustness of the geographical effect observed.

Factor	Category	n	Positive (n)	Prevalence % (95% CI)	p-value
Age	Adults	60	4	6.7 (2.6–15.9)	–
	Young	32	6	18.8 (8.9–35.3)	0.09
Sex	Female	62	7	11.3 (5.6–21.5)	–
	Male	30	3	10.0 (3.5–25.6)	0.92
Breed	Arabia	58	8	13.8 (7.2–24.9)	–
	Alpine	14	0	0.0 (0.0–20.8)	–
	Chamia	8	1	12.5 (2.2–47.1)	0.90
	Saanen	12	1	8.3 (1.5–35.4)	0.80
Region	Laghout	42	0	0.0 (0.0–8.4)	–
	Beni Slimane	22	2	9.1 (2.5–27.8)	0.12
	Bouira	16	6	37.5 (18.5–61.4)	<0.001*
	El-Djelfa	12	2	16.7 (4.7–44.8)	0.046*
Total	–	92	10	10.9 (5.3–19.1)	–

Table III. Histopathological findings in the diaphragm

Comparison of ELISA with histopathology (heart and diaphragm)

The comparison of ELISA results with histopathological examinations of the heart and diaphragm revealed a high level of diagnostic agreement among the three methods (Table IV). Among the 92 analysed samples, 4 animals (4.34%) were simultaneously positive across all techniques (ELISA+, heart+, diaphragm+), representing fully concordant positive cases.

No animals were ELISA-positive with isolated positivity in a single tissue (heart or diaphragm), and there were no ELISA+/heart- or ELISA+/diaphragm- patterns. This absence of partial concordance suggests that ELISA positivity was strongly associated with confirmed tissue lesions when present (Table IV).

A total of 6 samples (6.52%) were ELISA-negative but positive in both heart and diaphragm. This group represents the main source of discordance, indicating that histopathology detected infections not captured serologically. These discrepancies may correspond to early infections, chronic forms with low antibody levels, or cases where parasite persistence is localised in tissues (Table IV).

Combination	Number of samples	Percentage (%)
ELISA+ / Heart+ / Diaphragm+	4	4.34
ELISA+ / Heart+ / Diaphragm–	0	0.0
ELISA+ / Heart– / Diaphragm+	0	0.0
ELISA– / Heart+ / Diaphragm+	6	6.52
ELISA+ only	0	0.0
Heart+ only	0	0.0
Diaphragm+ only	0	0.0
ELISA– / Heart– / Diaphragm–	82	89.13

Table IV. Concordance between ELISA and histopathology (heart and diaphragm)

Importantly, no samples showed isolated tissue positivity (heart+ only or diaphragm+ only), reinforcing the consistency of lesions across both organs when histopathological infection was present (Table IV).

Most samples—82 animals (89.13%)—were negative across all diagnostic approaches (ELISA- / heart- / diaphragm-), indicating a predominantly uninfected population and supporting the high overall agreement between the methods (Table IV).

Description of concordance results

The comparison between ELISA and histopathological findings (heart and diaphragm) showed a high level of agreement (Table V). Of the 92 samples, 86 animals (93.48%) had consistent results across methods, reflecting either complete positivity or complete negativity. Only 6 samples (6.52%) were discordant—cases where histopathology detected infections that ELISA did not—suggesting possible early or chronic infections with low antibody titres.

The Cohen's kappa coefficient (~0.54) indicates moderate to substantial agreement, confirming that ELISA results are largely consistent with histopathological findings while acknowledging a small proportion of discrepancies. This demonstrates that ELISA is a reliable diagnostic tool for detecting *Toxoplasma gondii* in goats, especially when complemented by tissue examination (Table V).

Index	Value	Interpretation
Overall agreement (raw concordance)	86 / 92 = 93.48 %	Very good overall agreement
Total discordances	6 / 92 = 6.52 %	Low discordance
Cohen's Kappa (approx.)	0.54	Moderate to substantial agreement

Table V. Concordance indices between ELISA and histopathology (Heart + Diaphragm)

Discussion

The observed overall seroprevalence (4.3%) is much lower than that usually reported in goats. For example, in Algeria, previous studies have shown rates ranging from 11.9% to 71.7% (mean 33.6%) (Ouchetati et al., 2021). In other Mediterranean countries, much higher figures are also reported (e.g., 38.3% in Egypt, 8.5% in Morocco, 34.4% in Tunisia, and even 41.7% in Northern Italy) (Benkirane et al., 2015; Gazzonis et al., 2015; Lahmar et al., 2015; Selim et al., 2023). Other recent surveys typically report much higher rates: for instance, around 52% seropositive goats were observed in Mexico (Villa-Mancera et al., 2025) and 46.1% in Egypt (Fereig et al., 2022). At the continental level, the estimated average prevalence in goats reaches ~38.9% in Europe and ~37.9% in Africa (Ahaduzzaman and Hasan, 2022).

This large discrepancy suggests that the goats in our study benefited from a very low parasite pressure environment. Specifically, these meat goats are raised in closed buildings without free-range grazing, limiting exposure to *T. gondii* oocysts circulating in pastures or drinking water. The low seroprevalence observed may also partly reflect a selection bias, as only slaughter animals intended for meat production were sampled, predominantly young males, potentially underrepresenting older breeding females with higher cumulative exposure to *T. gondii*. Consistent with our results, the literature indicates that exclusively “indoor” farming significantly reduces the risk of infection (Kantzoura et al., 2013; Symeonidou et al., 2023). In a large Algerian survey, goats that never grazed had a 2.6-fold lower risk (OR ≈0.38) of being infected than grazing goats (Dahmane et al., 2025). Conversely, extensive or semi-intensive farms, where goats graze and interact with cats, usually show seroprevalences of several tens of per cent (Dahmane et al., 2025).

Moreover, our statistical analyses confirm that sex, age, or breed had no significant effect on seroprevalence (i.e., no significant correlation), which aligns with several previous studies (Dahmane et al., 2025; Udonsom et al., 2020). This contrasts with some studies conducted in extensive farming systems (Ntafis et al., 2007), where seroprevalence tends to increase with age due to cumulative exposure to the infectious agent.

By contrast, geography is a major factor. Although the overall prevalence is low, Bouira stands out as a high-risk area, with 18.8 % seropositive and 37.5 % showing lesions. This regional disparity indicates that national or overall averages may mask local pockets of high exposure. This regional difference reflects environmental conditions favourable for oocyst survival (more humid climate, higher cat density) (Dahmane et al., 2025). Thus, Bouira clearly

appears as a high-risk area because higher rainfall and vegetation allow oocysts to remain viable longer. Ecological studies have shown that low humidity and high temperatures reduce oocyst viability and, therefore, transmission (Benkirane et al., 2015). Consequently, in dry areas like Laghouat, oocysts die quickly, explaining the absence of infections.

In summary, the very low serological rate found in our population can be explained by intensive, closed-farm management combined with good biosecurity (indoor feeding, no grazing, limited feline contact), in contrast to traditional conditions where toxoplasmosis is endemic (Dahmane et al., 2025).

Unlike sheep, goats often browse at height, consuming foliage less likely to carry oocysts deposited on the ground (Symeonidou et al., 2023). This browsing behaviour, combined with occasional concentrated feeding, constitutes a protective factor for goats compared to exclusively grazing ruminants. Nevertheless, it does not completely eliminate the risk of infection, especially in areas where the environment favours oocyst survival, such as Bouira.

The presence of domestic or stray cats in the environment is a major risk factor. Farms in Bouira and El-Djelfa, where seroprevalence is relatively high, are more conducive to cat abundance. Conversely, in more isolated farms, contact with definitive hosts may be limited. Rouatbi et al. (2019) emphasise the importance of herd management and proximity to cats in the regional distribution of the parasite.

Although the overall seroprevalence is low (4.3%), the prevalence of histopathological lesions compatible with *T. gondii* is higher (10.9%). This discrepancy can be explained by old or weakly immunogenic infections, in which antibody levels may drop below the detection threshold even though tissue cysts persist in muscles (Rougier et al., 2017; Sinai et al., 2016), underscoring the importance of a combined serology–histopathology approach. Although few published studies have conducted systematic histological diagnosis on goat heart or diaphragm, examining striated muscle for *T. gondii* is justified, as the parasite forms cysts (bradyzoites) there. Molecular detection studies in sheep also recommend examining both heart and diaphragm simultaneously to optimise diagnosis (Holec-Gašior and Sołowińska, 2023). In our study, tissue infestation rates were identical for heart and diaphragm (10.9% each), reinforcing the robustness of the result and the dissemination of the parasite in the muscles.

ELISA-negative but histopathology-positive cases are more likely due to chronic infection with waning antibody levels or potential diagnostic misclassification, rather than early infection, as tissue cysts are typically associated with the chronic phase of *T. gondii* infection.

As with serology, regional variation is marked: 37.5% of Bouira goats had lesions, versus 0% in Laghouat and ~16–17% in El-Djelfa. This geographic profile further supports the influence of the external environment on transmission. No significant differences were observed by age or sex, as typically seen (young animals can be infected like adults depending on exposure) (Guimarães et al., 2013; Udonsom et al., 2020).

The overall agreement between ELISA and histopathology, while seemingly high, is largely driven by the low prevalence and the large number of double-negative samples; the Cohen's kappa of ~0.54 indicates moderate concordance. All four ELISA-positive goats had both cardiac and diaphragmatic lesions, meaning positive serology always correlated with confirmed tissue infection. Discordant cases (6.5% of animals) were all “ELISA negative but histopathology positive in both tissues.” In other words, serology missed some infections detected in tissues. This phenomenon has been observed in small ruminants: in old or slow-developing infections, antibody levels may fall below detection thresholds while cysts persist in muscles. Furthermore, all serological tests have sensitivity limits. In comparison, genome-based techniques (PCR) often reveal a higher percentage of infected animals. For example, in sheep, combined heart+diaphragm testing detected *T. gondii* in 60% of infected animals (Holec-Gašior and Sołowińska, 2023), whereas associated seroprevalence was lower. This suggests that our 6 ELISA–/histo+ cases likely correspond to chronic or early-stage infections, where antibodies are weak or absent. In sum, these discrepancies highlight that while serology is useful, it may miss some tissue infections, and complete diagnosis of caprine toxoplasmosis benefits from complementary histological and molecular testing (Amdouni et al., 2017; Dubey, 2010; Dubey et al., 2020).

Our observations highlight the advantage of a closed meat-farming system for controlling caprine toxoplasmosis. Intensive indoor farming markedly reduces exposure to infection sources. On one hand, animals do not graze on pastures potentially contaminated by infected cats. On the other, water and feed supply are more controlled, and farm cats can be managed (sterilisation, anthelmintics). Epidemiological studies confirm this benefit: goats in traditional (semi-extensive) farms are continuously exposed to oocysts, whereas in modern “indoor” systems, prevalence drops drastically (Dahmane et al., 2025). For example, Mohamed-Cherif et al. (2019) observed that in High Algeria, farming practices (outdoor vs indoor) had no effect in a high-prevalence context, suggesting overexposure. Here, by contrast, the data indicate that animal confinement greatly limits contamination. This is crucial: adopting biosecurity measures

(biological barriers, enhanced biosecurity) should be encouraged in goat farms, including restricting cat access to facilities and feed, and environmental control (disinfection, cat deworming).

Caprine toxoplasmosis, though often asymptomatic in adults, has significant veterinary and public health implications. *T. gondii* is a major cause of abortions and perinatal mortality in small ruminants (Buxton et al., 2007). The low infection rate detected in our meat goats suggests that the abortive risk has been relatively controlled in these farms. *T. gondii* is also highly transmissible to humans, mainly via raw or undercooked meat or unpasteurised milk (Amdouni et al., 2017; Dubey et al., 2020). Goats act as intermediate hosts; cysts lodge in muscles. Consumption of undercooked goat meat or derived products can expose humans, particularly pregnant women (risk of congenital toxoplasmosis) (Dubey et al., 2020; Holec-Gąsior and Sołowińska, 2023). Our study suggests that in closed farming systems, this risk is reduced (few positives, mostly concentrated in one region). Nevertheless, the presence of infected animals in Bouira indicates that exported or marketed meat could carry *T. gondii* if precautions (proper cooking, freezing) are not taken. Maintaining hygiene measures is therefore essential: controlling animal origins, preventing the introduction of infected cats, and applying thermal treatment of meat.

Conclusion

This study shows that toxoplasmosis circulates at low levels in meat goat farms managed in closed systems, with low seroprevalence and limited tissue infection. This farming method markedly reduces exposure factors, explaining the low observed infection. Regional differences, particularly the concentration of cases in Bouira, indicate areas with higher environmental risk. Discrepancies between serology and histopathology, mainly seronegative but tissue-positive animals, reflect old or weakly immunogenic infections and confirm the value of a combined diagnostic approach. From a public health perspective, the presence of tissue cysts reminds us that goat meat can be a potential source of human exposure. In the end, meat goats raised in closed systems exhibit overall controlled infection dynamics, but continuous monitoring and biosecurity measures remain essential to limit contamination and protect animal and public health.

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Ethical approval

The study was carried out during routine veterinary inspections in municipal slaughterhouses, and no experimental procedures involving animals or humans were conducted.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Author Contributions

Conceptualisation: HD, IO, EAK, DT, NAKT, NO; Methodology: HD, IO, EAK, NAKT, NO; Formal analysis: AEL, LA, AD, OS; Investigation: HD, IO, EAK, NAKT, NO; Writing original draft preparation: NAKT, NO; Writing, review and editing: NAKT, NO; Visualization: NAKT, NO; Supervision: NAKT, NO; Project administration: NAKT, NO. All authors have read and agreed to the published version of the manuscript.

Data availability

Data are available upon request from the corresponding author.

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