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SEROLOGICAL SURVEY AND ASSOCIATED RISK FACTORS ON *TOXOPLASMA GONDII* INFECTION IN GOATS IN MILA DISTRICT, ALGERIA

Dahmane, A.[1,2], Boussena, S.[3], Hafsi, F.[1,4], Ghalmi, F.[1,4]

[1]Higher National Veterinary School of Algiers. Oued Smar, Bab Ezzouar
[2]Exploration and Valorization of Steppe Ecosystems Laboratory
Faculty of Nature and Life Sciences, Ziane Achour University, Djelf
[3]Management of Animal Health and Productions Laboratory
Institute of Veterinary Sciences, University of Constantine 1, Constantine
[4]Management of Local Animal Resources Laboratory
Higher National Veterinary School of Algiers. Oued Smar, Bab Ezzouar, Algeria

dahmanjalil@yahoo.fr

ABSTRACT

Toxoplasma gondii **is a protozoan parasite prevalent in humans and other animals worldwide having medical and veterinary importance on account of reproductive failure causing significant socioeconomic losses. The aims of this study were to estimate the seroprevalence of *T. gondii* infection in goats, determined the possible risk factors associated, and evaluate the performances of the latex agglutination test (LAT) to anti-*T. gondii* antibodies screening using the indirect Enzyme-linked immunosorbent assay as a reference test (iELISA). A total of 184 serum samples from goats reared on 25 farms in Mila district from North-Eastern Algeria were collected and tested for anti-*T. gondii* IgG antibodies using two commercial serological tests (ELISA and LAT). A seroprevalence rate of 71.73 % and 63.58 % was obtained by both ELISA and LAT tests, respectively. The analysis of some factors thought to be related to the onset of this infection such as age, sex, management system, locality and presence of cats showed no significant relationship ($P > 0.05$); these factors did not seem to affect the frequency of the infection. The seropositivity level of *T. gondii* was significantly higher in aborted goats ($P = 0.007$), which suggested that they may play a significant role in pregnancy failure. In the concordance evaluation between the two serological tests (ELISA and LAT), the Cohen's Kappa value was calculated and the results showed a K of 0.519 ($p = 0.000$) belonging to the range of 0.41—0.60 indicating just average agreement. The results of the Mc Nemar test showed that both tests gave significantly different results and seropositivity values ($P < 0.05$). The high prevalence observed in this study indicated a widespread exposure to *T. gondii* from goats and the potential risk of *T. gondii* infection for humans in North-Eastern Algeria. These results elucidate**

the challenges of applying serology to estimate goat exposure to *T. gondii*. The choice between the two serological tests will depend on their performances, as well as the availability of the equipment, laboratory conditions and the number of samples to be tested.

Key words: Algeria; ELISA; goat; LAT; performances; risk factors; *Toxoplasma gondii*

INTRODUCTION

Toxoplasmosis is a cosmopolitan zoonotic disease caused by a protozoan parasite, *Toxoplasma gondii*. It is of economic importance for both veterinary and human medicine [34]. The infection of sheep and goats causes significant losses in reproduction, but also has a major impact on public health, as the consumption of infected products such as undercooked meat and unpasteurized milk facilitates its zoonotic transmission [11]. Fetal mortality rates including goat abortion in the affected flocks can reach 50 % and in subclinical cases, losses are low [55].

Goats are economically important animals in many countries and constitute one of the main sources of meat and milk for Islamic populations and villagers [53]. For example, villagers' consumption of unpasteurized goat milk due to their cultural traditions and dietary habits is an important source of *T. gondii* infection [40]. Seroprevalence studies have been conducted on different animal species in different parts of the world [11, 38]. There are very few reports on the prevalence of toxoplasmosis in goats in different parts of Algeria.

The importance of *T. gondii* disease for public health and the lack of epidemiological data in humans and domestic animals in Algeria led us to conduct this cross-sectional study on goat farms. This study allows us to estimate the prevalence of this infection and to know the main risk factors associated.

Also, the evaluation of serological tests becomes important in order to ascertain the most sensitive and specific tests in epidemiological studies to use in different animal species [51, 72]. In this regard, the objective was also to evaluate the performance of two serological tests (ELISA and LAT) in the detection of anti-*T. gondii* antibodies in goats.

MATERIALS AND METHODS

Study area and the environment

This study was carried out in the province of Mila, in North-Eastern Algeria, from January to April 2017. Mila lies inland about 82 km from the Mediterranean coast. The wilayate (district) is characterized by a varied relief and presents two large distinct zones; to the north, mountains, and hills: M'sid, Aicha, Zouagha and El-Halfa, and to the south, the plains and highlands with an area of 3481 km2.

Our study was conducted in two municipalities in the North of this wilayate; the municipality of Terrai Bainen and that of Zeghaia. The elevation was 185 to 1190 m. The north of this region was home to three large cork oak forests, to the west, there was a large forest of exploitation, and between the two towns is the Beni-Haroun Dam; the largest water dam at the national level which supplies a large part of Eastern Algeria with drinking and irrigation water.

The region has a Mediterranean climate with hot, dry summers and cold, wet winters. The climate is humid in the North, subhumid to semi-arid in the center and semi-arid in the South. The rainfall varies between 600 and 900 mm in the North of the wilayate (920 mm on the mount of Msid Aicha), between 400 and 600 in the centre and less than 400 mm in the South. In the summer, the temperature varies between 25 and 40 °C and the average winter temperatures range from 0 to 12 °C [60].

The breeding season usually starts in July, when daylight begins to decline. The rearing mode is usually semi-intensive or extensive. All herds included in this study grazed during the spring season until the end of December with variations depending on the climatic conditions; these goats feed almost exclusively outside the barn without supplementation. In the winter, goats were housed and fed with straw, barley, and wheat bran. The association between goat and sheep farming is very common in this region.

Study plan and the target population

A cross-sectional study was conducted. According to the data from the Algerian Ministry of Agriculture, there were 8652 herds and about 34 000 goat heads at Mila during the study period. An appropriate number of goats aged 4 to 96 months were sampled by a simple random sampling method.

Also, the number of goats to be taken from each farm

was defined based on the total number of animals. The important thing was to have a representative sample of at least 10 % of all individuals in each farm visited.

The required sample size was calculated according to the following formula with an expected prevalence of 10 % and a 95 % confidence interval [70]:

$$N = [Z2 \times P(1 - P)]/d2$$

Where;

- N is the number of samples to be collected in the study,
- Z is the value of the normal distribution for the confidence interval of 95 % [Z2 = (1.96)2],
- P is the expected prevalence,
- d is the absolute error of 10 %.

A minimum of 100 samples was required. To increase the power of the statistical analysis, the sample size was multiplied by 2. Twenty-five herds were randomly selected and the herd sizes ranged from 5 to 120 heads.

At the individual level, the sample size was determined for each flock to detect the existence of the disease. The calculations were performed according to the formula commonly used in veterinary epidemiological surveys by Thrusfield [72]:

$$n = [1 - (1š - p)1/d] \times [N - (d/2)] + 1$$

Where:

- n is the size of the sample in each flock,
- p is the detection probability of least one seropositive goat,
- N is the size of the flock,
- d is the number of seropositive goats in the herd.

The probability of detecting at least one seropositive goat in a flock was 95 % (p = 0.95), while the number of seropositive goats in each flock (d) was calculated assuming that the herd was equal to 10 %. Finally, 10 to 30 blood samples were collected from each flock, making a total of 210 goats.

Collection of epidemiological data

A pretested structured questionnaire was administered to each farmer under the supervision of the principal investigator before taking any blood samples. The measurable data on herd size, sex, age, breed, history of abortion, presence of cats and management system had been collected previously. The farms sampled consisted mainly of goats of local breeds (100 %). The sample (184 goats tested serologically) included 129 females (70.10 %) and 55 males (29.89 %). The animals were divided into three age groups: ≤ 12 months (24.45 %), 12 to 36 months (29.34 %) and more than 36 months (46.19 %). Of the females selected, 73 (56.58 %) had a history of abortion.

Collection of the blood samples

The blood (5 ml) was drawn from the jugular vein of selected goats using disposable needles and plain vacutainer tubes and transported to the laboratory on ice. Serum samples were harvested by centrifugation at 2,000 × g for 10 min, then stored in labeled Eppendorf tubes at −20 °C until testing.

Laboratory analysis

The detection of anti-*T. gondii* antibodies was conducted in the Microbiology Laboratory of the National Veterinary School of Algiers (ENSV). After the thawing of the sera at room temperature, it proceeded to the serological analyzes of the 184 sera using two commercial serological kits: the ELISA ID Screen® Toxoplasmosis Indirect Multi-species (IDvet, Grabels, France) and the LAT Toxo-Latex® (SPINRER EACT, S. A. Ctra Santa Coloma, Spain) according to the manufacturer's protocol.

ELISA (Enzyme Linked Immunosorbent Assay)

The IgG antibodies against *T. gondii* in the sera were tested by the ELISA test following the instructions of the ID Screen® Toxoplasmosis Indirect Multi-species kit manufacturer. In this procedure, a volume of 10 µl of the test samples was applied to the wells of the 96-well ELISA plate except for 4 wells reserved for the positive and negative controls. Finally, the optical densities at 450 nm were recorded under the ELISA reader.

The ELISA test detects IgG antibodies against the *T. gondii* P30 antigen. For the interpretation of the results, the percent S/P (S: Sample, P: Positive control) was calculated with the following formula:

$$S/P\ \% = (OD \text{ of the sample}/OD \text{ of the positive control}) \times 100$$

where OD is the optical density.

If S/P is less than or equal to 40 %, the result is considered negative; if S/P is between 40 % and 50 %, the result is considered doubtful; if S/P is greater than or equal to 50 % and less than 200 %, the result is considered positive; if S/P is greater than or equal to 200 %, the result was strongly positive. The test was validated if the mean value of the OD of the positive control was greater than 0.350 (OD > 0.350) and the ratio of the OD of the positive controls (DOcp) to the mean of the OD of the negative controls (DOcn) was greater than 3.5.

LAT (Latex Agglutination Test)

The TOXO-Latex reagent is a suspension of polystyrene latex particles coated with *Toxoplasma gondii* soluble antigen. The latex particles allow visual observation of the antigen-antibody reaction. If the reaction occurs, the latex suspension changes and clear agglutination becomes evident due to the presence of antibodies at a concentration greater than 4 $IU.ml^{-1}$. The reagents are checked until they reached room temperature, then shaken gently to disperse the latex particles. Fifty µl of the diluted serum (1 : 10) were pipetted into a circle of the plastic slide, 25 µl of latex beads coated with *T. gondii* soluble antigen (TSA) were added, mixed and shaken for 4 minutes at room temperature using a rotator.

A positive result is presented with a formation of an opaque circular veil whose diameter is equal to or greater than half the diameter of the well. This formation of the veil is explained by the agglutination which must be interpreted as a presence of anti-*T. gondii* IgG. The agglutination model was read in comparison with the positive control (provided in the commercial kit). The data thus collected were analyzed statistically.

Statistical analysis

Data from the field and laboratory surveys were captured and coded with Microsoft Excel® 2010 and analyzed using SPSS 20 for Windows software (SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to summarize the data. The questionnaire survey information was used to define the explanatory variables to be tested in a logistic regression model for any association assessment between goat serological status (dependent variable) and risk factors (independent variables).

Taking into account the ELISA results, these factors were analyzed using a univariate model, so the odds ratio (OR) and 95 % confidence intervals (95 % CI) were used to quantify the association between these risk factors and *T. gondii* infection. Differences in the prevalence of *T. gondii* with different variables such as sex, age, management status, presence of cats, history of abortion and locality were analyzed using a Chi-square test. The differences were considered statistically significant and highly significant at $P < 0.05$ and $P < 0.01$, respectively.

The seroprevalence results obtained by the ELISA and LAT tests were compared using the chi-square test and their concordance was determined by calculating the Kappa coefficient. Using ELISA as a reference test, the sensitivity (Se), the specificity (Sp), the positive predictive value (PPV) and the negative predictive value (NPV) of the LAT test were calculated and interpreted. The agreement with kappa values of 0.00 to 0.20 was considered light, 0.21 to 0.40 fair, 0.41 to 0.60 moderate, 0.61 to 0.80 substantial and 0.81 to 1.00 almost perfect [45].

RESULTS

Seroprevalence in goats

Our investigation showed that specific anti-*T. gondii* IgG antibodies were detected in the sera regardless of the technique applied. An overall prevalence of *T. gondii* of 71.73 % (95 % CI; 64—79.4 %) and 63.58 % (95 % CI; 56.43—70.20 %) were detected by ELISA and LAT tests, respectively, from the sera of 184 goats. Of the 132 ELISA positive sera, 27 (20.45 %) were negative at a dilution of 1 : 10 in the LAT assay. The results of the serological analysis are summarized in Table 1.

Seroprevalence at the flock level

Of the 25 flocks of goats, 24 (96 %) (95 % CI, 83.30—99.92 %) and 25 (100 %) (95 % CI; 78.58—99.21 %) tested positive with ELISA and LAT, respectively, so they contained at least one seropositive goat. On seropositive farms, the seroprevalence of *T. gondii* varied from 0 % to 100 %. Using the indirect ELISA test, each farm housed at least one seropositive animal. In six (06) herds (25 %), all of the animals sampled were positive for *T. gondii*. On the remaining farms, different proportions of animals reacted positively; the majority (29.16 %) being seropositive from 60 to 66.66 %.

Risk factors for *T. Gondii* infection

Data collected from farms using a questionnaire were analyzed to identify the potential risk factors. The seroprevalence of *T. gondii* in male and female goats was 69.1 % and 72.9 %, respectively (Table 1), suggesting that the seroprevalence in of the female goats were slightly higher than that in males, but the difference was not statistically significant (P > 0.05). According to the age, the prevalence values were 68.9 % in kids, 70.4 % in young goats, and 74.1 % in adults; these values did not differ significantly.

The results showed that no statistically significant difference was observed between the prevalence of *T. gondii* infection and the different factors, such as sex, age, location, rearing method and presence of domestic cats (P > 0.05); the history of abortion was significantly associated with seropositivity to *T. gondii* (Table 1).

Comparison of seroprevalence results of LAT and ELISA tests

Overall, the 184 serum samples were tested by both the iELISA (1/100 dilution) and LAT (1 : 10 dilution) kits for comparison. The agreement between the two methods (ELISA and LAT) was determined by the use of the Cohen Kappa test which showed a K coefficient of 0.519 (P = 0.000) belonging to the range 0.41—0.60, which corresponded to an average agreement between these two techniques (Table 2).

A full agreement between the two tests was obtained on

Table 1. Analysis of factors likely to influence the risk of *T. gondii* infection taking into account the results obtained by the ELISA test.

Variables	Number sampled	Number positive [%]	95 % CI on prevalence	Odds Ratio [OR]	95 % CI on OR	P-value
Age						
≤ 12 months	45	31 (68.9)	54.34—80.47	0.93	0.39—2.2	0.792
12—36 months	54	38 (70.4)	57.17—80.86			
> 36 months	85	63 (74.1)	63.91—82.24			
Sex						
Male	55	38 (69.1)	55.97—79.72	0.83	0.42—1.66	0.602
Female	129	94 (72.9)	64.62—79.8			
Management system						
Extensive	19	12 (63.2)	41.04—80.85	0.64	0.24—1.74	0.383
Semi-intensive	165	120 (72.7)	65.48—78.95			
Presence of cats						
Yes	145	107 (73.8)	65.5—82.1	1.58	0.74—3.34	0.235
No	39	25 (64.1)	54.3—82.9			
Town						
Zéghaia	101	70 (69.3)	58.5—80.1	0.76	0.4—1.47	0.419
Terrai Bainen	83	62 (74.7)	63.9—85.5			
Abortion						
Yes	73	60 (82.2)	71.88—89.29	2.99	1.34—6.68	0.007*
No	56	34 (60.7)	47.63—72.42			
Total	**184**					

OR—Odds Ratio; CI—Confidence Interval at 95 %; *—significant; P-value is significant at P ≤ 0.05

Table 2. Comparison of the LAT technique with the indirect ELISA as a reference test in the detection of *T. gondii* infection in goats

Toxoplasma gondii	ELISA indirect		LAT	
			(+)	(-)
Goats	(+)	132	105	27
	(-)	52	12	40
	Total	**184**	**117**	**67**
Intrinsic values	Sp = 76.92 % Se = 79.54 % K = 0.51		Mc Nemar test (P < 0.05) Ra = 78.80 %	

Se—sensitivity; Sp—specificity; Ra—relative accuracy; K—Kappa value

105 (79.54 %) positive samples and 40 (76.92 %) negative samples. However, only 27 and 12 sera were positive for ELISA and LAT respectively.

The comparison of the results of the two tests by the calculation of the Mc Nemar test value indicated that the seropositivity differed significantly between the two tests (P = 0.024). Considering the ELISA test as a reference test, the sensitivity, specificity and positive and negative predictive values of the LAT test were calculated as follows: 79.54 %, 76.92 %, 89.74 %, and 59.70 %, respectively.

DISCUSSION

Toxoplasmosis has a very wide geographic distribution and is considered to be one of the most common parasitic infections of man and other warm blooded animals. Clinical symptoms of toxoplasmosis are not specific. Therefore, the evaluation of serological tests becomes important in order to use sensitive and specific tests in serological surveys [51, 72]. The prevalence of Toxoplasmosis across the world is variable, with prevalence rates from 0 to 100 percent in different countries [54, 68], depending upon their customs, traditions, lifestyles of the inhabitants, weather conditions, age of the animals and husbandry practices [64]. Apart from this, the prevalence rate may also be associated with the presence of cats that excrete oocysts, which after sporulation become infectious to man and other animals [20]. *T. gondii* infections are widespread in some food animals, especially chickens, camels, pigs, sheep, and goats which represent the most consumed animal species in Africa for their meat, and there is a wide disparity between the levels of infection in different animal species [19].

We have hereby reported for the first time, the evidence for *T. gondii* infection and its seroprevalence, risk factors and the serological performance of two different tests in the humid agro-ecological area of Algerian goats. The overall prevalence of 71.73 % and 63.58 % of *T. gondii* antibodies by the ELISA and LAT tests were detected respectively. The results of our study have demonstrated that *T. gondii* infections are widely present in goats in the northeastern area of Algeria. This might indicate actively circulating, recently acquired or recrudescence of previously acquired *T. gondii* infections in goats due to climatic stress, malnutrition and prevalent diseases like brucellosis which reduce the animal's resistance [55]. Previously, *T. gondii* infections in goats were also reported from the central parts of the country [17] and neighboring countries like Tunisia and Libya [6, 44]. However, the high prevalence in goats of this study might be a function of the cumulative effects of the age, related to the absence of regular culling programs [67]. Moreover, the inadequate attention by the government, a local change in landownership and increased farming which necessitate cat keeping to control rodents, might have additionally contributed to the high prevalence.

At the international level, the seroprevalences obtained in this study by both tests were higher than the global average [23, 26, 43]. According to the technique of ELISA, the prevalence rates recorded in our study were high but lower than the level of infections (95.24 %) found in Turkey [10], and in Brazil (92.4 %) [33]. T e s h a l e et al. [69] found an almost similar prevalence (74.8 %) in the goats of Ethiopia.

Thus, it was found to be close to that reported in Zimbabwe (68.59 %) [35]. The prevalence rate in this study regardless of the test applied was higher than those reported by several authors in different areas of the world; prevalence rates of 59.4 % in Giza, Egypt [8], 52 % in Pakistan [66], 51 % in Saudi Arabia [59], 46.0 % in Brazil by the IFAT test [14], 42.8 % in Granada and Carriacou by the MAT test [16], 35 % in southern Tunisia by the MAT test [44], 31 % in Uganda [11], 27.9 % in Satun Province, Thailand [40], 25.4 % in Pakistan [56], and 14.1 % in China [78]. The differences in the prevalence reported by all of these studies could be accounted for based on the host, breed, sex, farm size, environmental and climate conditions, management practices, and density of cats and wild felids [5, 18, 32, 54, 78]. Thus, the variation might be due to the difference in sample size, cut-off values and sensitivity in the serological tests employed [19, 42]. In the study area, goats are one of the most important animals for the production of meat and milk. Attention should be payed to the milk as well as the meat from these animals as they are considered a potential source of human toxoplasmosis especially as the results demonstrated that goats are highly infected [62].

The prevalence of *T. gondii* was 11.64 % (34/184) and 13.35 % (65/184) in males and in females, respectively. The prevalence in females was higher than in males, but the difference was not significant ($P > 0.05$). This supports the findings of previous reports [9, 41, 76]. Some reports indicated that female animals were more infected by *T. gondii* than males [3, 69]. Our results did not coincide with two other studies [12, 24], which indicated that the prevalence of anti-*T. gondii* antibodies was significantly higher in females than in males. This may be explained by the fact that hormonal differences between males and females play an important role in determining the susceptibility to parasitic infection [57]. Thus, the immunity in females may be reduced by various factors such as pregnancy, nutrition, and lactation [49, 50]. Moreover, Z h a o et al. [78] indicated that males were more infected than females. On the other hand, B i s s o n et al. [11] and C a v a l c a n t e et al. [15] observed that sex was not a significant factor in determining the exposure to *T. gondii* infection in goats.

It is widely accepted that animals acquire Toxoplasma infections with the acquisition of age through the ingestion of infective oocysts from the environment [28, 29]. The age of animals is considered to be an important factor in determining the prevalence rate of Toxoplasmosis in animals [25]. Although no statistically significant differences were found in this study, this indicated an equal chance of contracting the infectious agent regardless of the age of the animal ($P > 0.05$). Besides, A h m a d et al. [1] and C h i k w e t o et al. [16] reported a significant increase in seroprevalence with age in small ruminants. The high prevalence obtained in the older age groups may be due to the cumulative effect of age, the long exposure period to infectious oocysts in the environment [69], and low immunity following aging of the immune system [57]. Contrary to our findings, several authors indicated that age influences seropositivity in ruminants [3, 46, 73, 74, 77]. Some studies have recorded, consistently with results of our study, that age does not affect the *T. gondii* infection [7, 22, 31, 43].

In Mila Province, goats are raised extensively in large farms or semi-intensively by individual families. The current study found a higher seroprevalence of *T. gondii* in goats in both the extensive and semi-intensive management systems, but these showed a lower prevalence than those in the extensively reared. The difference was not statistically significant ($P > 0.05$). These findings are consistent with those reported by A h m a d et al. [1] and N e t o et al. [53] suggesting that extensive management in sheep and goats presents a greater risk of *T. gondii* infections. The increases in the prevalence of toxoplasmosis in extensive and semi-intensive practices have also been found in small ruminants from other countries [48, 73, 75]. However, Y o u n i s et al. [77] have shown that seroprevalence has been significantly increased in goats exploited in intensive systems than in extensive and semi-intensive operations, consistently with those recorded by A l - m a b r u k et al. [3] and T z a n i d a k i s et al. [71]. As compared to extensive or semi-intensive management, animals raised intensively were usually caged and received little chance to ingest contaminated food and water by the oocysts of *T. gondii* excreted by cats [4].

Since animals reared under extensive conditions are pastured in comparatively large grazing areas, it is likely that these animals are exposed to *T. gondii* oocysts at a high level and that the oocysts may be highly dispersed but this would depend on the number of cats.

The ingestion of *T. gondii* oocysts may become more likely because storage of fodder may increase the abundance of other intermediate hosts of *T. gondii* such as rodents on the farm and thus also the abundance of cats because farmers often keep cats to get rid of rodents. More-

over, the use of bulk feed or pasture also posed a threat of getting toxoplasmosis. Both practices render animals to come closer in contact with oocysts shed by wild and domestic felids.

In this study, and as found by Ibrahim et al. [37], a statistically insignificant difference in seroprevalence was observed between the two localities (Terrai Bainen and Zéghaia). It might be linked to uniformity of climate that is mild and moist, providing good conditions for the sporulation of *T. gondii* oocysts. This is consistent with the results of previous studies [1, 58]. The high prevalence in goats is probably due to animal, plant and human pressures on the land. As long as the region receives high rainfall, it is more arable and has more households per unit area. Therefore, it probably has a higher percentage of domestic cats, which increases the risk of environmental contamination by *T. gondii* oocysts. The locality factor and essentially climate factor are judged as factors that predisposes and promotes a high susceptibility to infection with the protozoan *T. gondii*. The high humidity and significant vegetation cover characterizing this area protects oocysts from desiccation and promote their survival and sporulation. Also, the diversity of animal species (herbivore, carnivore, and birds) found in these localities ensures a perfect continuity of the parasite's evolutionary cycle in nature and thus its perennial nature. The influence of the environment and wildlife in the epidemiology of toxoplasmosis has been documented by several authors [20, 30, 68].

Felids, in particular the cat, are the only known animal that can excrete environmentally resistant oocysts, playing an important role in the epidemiology of toxoplasmosis [21]. Previous risk factor studies found the presence of cats on farms as a putative risk factor for the transmission of the *T. gondii* infection and increased seropositivity in small ruminants [47, 48, 53]. Interestingly, variables that addressed the presence of cats were specifically associated with these factors. A reason for "the presence of cats" not being a risk factor in this study may be the presence of large numbers of stray cats all over the countryside. In agreement with these results [37, 63, 65], there is no statistically significant association between the presence of cats and the seroprevalence of *T. gondii* in small ruminants. Cats become infected by consuming their prey, especially small rodents, or even birds whose meat contains bradyzoite cysts [18, 39]. These prey are frequently observed around farms in the study area.

The high seroprevalence observed is evidence of a strong environmental contamination by oocysts, which could be due to several factors in combination; on the one hand, the density of domestic cats in the region, the resistance of oocysts excreted by these cats in the wild in relation to the humid climatic conditions favorable to their survival and their sporulation, and which remain viable in the soil for months or years, and the long and repeated contact of goats with the parasite in relation to the frequent grazing pattern [38, 68].

T. gondii infection in small ruminants is not only relevant due to the zoonotic aspects, but also because it is an important cause of ovine and caprine abortion [13, 21, 39]. In our study, Toxoplasmosis was highly significantly increased in aborted goats 60/73 (82.2 %) compared to those with normal births 34/56 (60.7 %). These results were in agreement with those reported by other researchers [2, 36, 61, 77]. According to many authors, the highest prevalence was reported on farms with epizootic abortions [22, 52]. Contrary to our findings, *T. gondii* seropositivity in goats was not statistically significantly associated with the proportion of abortions relative to the number of animals [71].

The evaluation of serological tests is becoming increasingly important in order to be able to use sensitive and specific tests dedicated to epidemiological investigations. The difference in *T. gondii* antibodies screening in goats, by the use of the two serological tests (ELISA and LAT) in our study, may be due to the type of antigen used and the class of antibodies measured. We compared the efficacy of the LAT with that of ELISA (reference test). The calculation of Cohen's kappa coefficient showed a value of 0.59 indicating an average agreement between the two tests. The LAT test showed specificity and sensitivity of 76.92 % and 79.54 %, respectively.

Younis et al. [77] revealed a sensitivity and specificity of the LAT tested in sheep of 87.5 % and 76.5 %, respectively, compared with biological assays in cats. Figueiredo et al. [29] reported that there is a high positive and significant correlation of the IHAT compared to the ELISA, and ELISA compared to the IFAT. Fereig et al. [27] compared to the efficacy of the TgGRA7-based iELISA with that of LAT (reference test). The recorded kappa values were 0.682 in goats indicating a substantial agreement between the two tests. The choice of test will depend on the availability of the equipment, the laboratory conditions and the number of samples to be tested.

CONCLUSIONS

In summary, the results of our study, for the first time, in the northeastern of Algeria, confirmed that *T. gondii* is endemic and that the infection is widely distributed in goats in the area. Extensive management was associated with higher odds ratios for being seropositive for *T. gondii* in goats. Humans can become infected by *T. gondii* through the ingestion of oocyst-contaminated food, water, or undercooked meat. The enhanced prevalence of *T. gondii* antibodies in goats suggested a high contamination of the environment by *T. gondii* oocysts. This indicated that the consumption of raw meat and milk of those animals in Mila province may represent a potential risk factor for human infections.

However, to better understand the nature and significance of these interactions, additional clinical data are needed as well as the isolation and molecular characterization of this etiological agent. Such data are essential to elucidate the relative importance of the various sources of infection for humans and goats and to achieve measures to prevent the infection. As a result, further work is needed to assess whether the soil and water on goat farms or in other regions of Algeria are contaminated by *T. gondii* oocysts.

Our data demonstrated that the serological assays studied in the present investigation can be very useful. Since the utilization of reliable methods for determining the prevalence of *T. gondii* infection in goats is available, it will allow adequate management and control of this infection and associated pregnancy failures.

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