Original article

European Journal of Microbiology and Immunology 5 (2015) 1, pp. 112–115
DOI: 10.1556/EuJMI-D-15-00004

PREVALENCE OF INFECTION WITH *TOXOPLASMA GONDII* IN LANDRACE AND MIXED BREED PIGS SLAUGHTERED IN BAJA CALIFORNIA SUR STATE, MEXICO

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Received: January 18, 2015; Accepted: January 23, 2015

We performed a cross-sectional study to determine the seroprevalence of *Toxoplasma gondii* infection in 308 domestic pigs slaughtered in La Paz, Baja California Sur State, Mexico using the modified agglutination test (MAT, cut off 1:25). Forty (13%) of the 308 pigs were seropositive with MAT titers of 1:25 in 16, 1:50 in 5, 1:100 in 4, 1:200 in 5, 1:400 in 3, 1:800 in 3, 1:1600 in 2, and 1:3200 in 2. Multivariate analysis of pigs' characteristics showed that seropositivity to *T. gondii* was negatively associated with mixed breed (OR = 0.02; 95% CI: 0.003–0.26; $P = 0.001$). Other variables including sex, type of raising, and municipality did not show an association with *T. gondii* seropositivity by multivariate analysis. The frequency of high antibody titers (≥1:400) was significantly higher ($P < 0.001$) in Landrace pigs than mixed breed pigs. The seroprevalence of *T. gondii* infection in pigs for slaughter in Baja California Sur State is low compared with seroprevalences reported in pigs in other Mexican states. Landrace pigs demonstrated higher seroprevalence rates and antibody levels than mixed breed pigs. This is the first report of *T. gondii* infection in pigs raised in a desert climate.

Keywords: pigs, *Toxoplasma gondii,* seroprevalence, epidemiology, Mexico

Introduction

The parasite *Toxoplasma gondii* infects warm-blooded animals including domestic pigs (*Susscrofa*) [1, 2]. Toxoplasmosis, the disease caused by *T. gondii*, can be severe or fatal in pigs [3, 4]. In addition, humans can acquire infections with *T. gondii* by eating raw or undercooked pork infected with *T. gondii* [5, 6]. Even ham can be a source of infection for humans [7]. Strategies to reduce human *T. gondii* infection should include freezing of meat destined for raw or undercook consumption, especially when meat is from nonbiosecure husbandry systems, and the development of a cat vaccine [8]. Postnatally acquired *Toxoplasma* infection in humans in most cases is asymptomatic but can manifest as toxoplasmosis affecting lymph nodes, eyes, and central nervous system: the course of disease can be fatal in immunocompromised patients [9]. *T. gondii* can also be transmitted congenitally [10]. The seroepidemiology of *T. gondii* infection in pigs in Mexico has not been investigated in detail. We have studied the seroprevalence of *T. gondii* infection in domestic pigs in few Mexican states including Durango and Sonora States in the north [11], Oaxaca State in the south [12], and Veracruz State in the east [13]. Seroprevalences of *T. gondii* infection in pigs in these states have varied substantially with the highest (45.3%) seroprevalence found in Veracruz State.

Recently, two independent epidemiological studies in humans showed an association of *T. gondii* seropositivity with consumption of sausages made of raw pork tissues in Mexico [14, 15]. In the present study, we therefore determined the seroprevalence of *T. gondii* in domestic pigs for slaughter in the northwestern Mexican state of Baja California Sur.

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ISSN 2062-509X / $ 20.00 © The Author(s)

Materials and methods

Study design

Through a cross-sectional study, 308 domestic pigs for slaughter in the abattoir of La Paz City in the Mexican State of Baja California Sur were sampled from July to October 2014. La Paz City (24° 08′ 32 N, 110° 18′ 39 W) is the capital of Baja California Sur State. This Mexican state is located in northwestern Mexico in the Baja California peninsula. The Pacific Ocean and The Gulf of California border this state. The climate in Baja California Sur is desert. A questionnaire was used for obtaining the general characteristics of the pigs including age, sex, breed, health status, type of raising (backyard or farm), and municipality of origin. Sampling was performed randomly. Pigs sampled came from two municipalities: La Paz (n = 277) and Comondú (n = 31). All pigs were apparently healthy. Most pigs (n = 291) were raised in backyards in 82 homes and some (n = 17) in three farms. Pigs were 5 to 36 months old, 128 were males and 180 females. The majority of pigs (n = 285) were mixed breed and 23 pigs were pure breed (Landrace).

Serological examination

Blood samples (about 3 ml) were obtained from a jugular vein of the pigs before slaughter. Blood samples were centrifuged, and sera were stored at −20 °C until tested. Serum samples were assayed for *T. gondii* antibodies using 2-fold serial dilutions from 1:25 to 1:3200 with the modified agglutination test (MAT) as described by Dubey and Desmonts [16]. Agglutination results were read after an overnight incubation of serum dilutions at 37 °C. A titer of 1:25 was used as cut off for seropositivity in MAT.

Statistical analysis

Results were analyzed using Epi Info version 7 (Centers for Disease Control and Prevention: http://wwwn.cdc.gov/epiinfo/ and SPSS version 15.0 (SPSS Inc., Chicago, Illinois). We used the Pearson's chi-squared test and the Fisher exact test (when values were less than 5) for comparison of the frequencies among groups. To assess the association between *T. gondii* seropositivity and the pigs' characteristics, the multivariate analysis was used. In the multivariate analysis, the dependent variable was seropositivity by MAT for an individual animal, and the independent variables were pigs' characteristics with a P value of ≤0.25 obtained in the bivariate analysis: municipality, breed, sex, and type of raising. Odds ratio (OR) and 95% confidence interval (CI) were calculated by using logistic regression analysis with the Enter method. To assess the fitness of the regression model, the Hosmer–Lemeshow goodness of fit test was used. A P value of <0.05 was considered as statistically significant.

Results

Antibodies to *T. gondii* were found in 40 (13.0%) of the 308 pigs with MAT titers of 1:25 in 16, 1:50 in 5, 1:100

Table 1. General data of the 308 pigs studied and seroprevalence of *T. gondii* infection

Characteristics	Pigs tested	Seroprevalence of *T. gondii* infection		*P* value
	No.	No.	%	
Age (months)				
5–8	64	6	9.4	0.49
9–12	197	26	13.2	
>12	47	8	17	
Sex				
Male	128	13	10.2	0.21
Female	180	27	15	
Breed				
Mixed	285	35	12.3	0.19
Landrace	23	5	21.7	
Type of raising				
Backyard	291	40	13.7	0.14
Farm	17	0	0	
Municipality				
La Paz	277	40	14.4	0.02
Comondú	31	0	0	

Table 2. Correlation of high (≥1:400) MAT titers and general characteristics of the 40 *T. gondii*-positive pigs studied

Characteristics	Pigs tested	Frequency of high MAT titers		*P* value
	No.	No.	%	
Age (months)				
5–8	6	2	33.3	0.18
9–12	26	8	30.8	
>12	8	0	0	
Sex				
Male	13	6	46.2	0.05
Female	27	4	14.8	
Breed				
Mixed	35	5	14.3	<0.001
Landrace	5	5	100	

in 4, 1:200 in 5, 1:400 in 3, 1:800 in 3, 1:1600 in 2, and 1:3200 in 2. Backyard pigs from 23 (28%) of the 82 homes were seropositive for *T. gondii*. General characteristic of the pigs studied and their correlation with *T. gondii* seroprevalence are shown in *Table 1*. Anti-*T. gondii* antibodies were found only among backyard pigs from one municipality (La Paz). The variables sex, breed, type of raising, and municipality showed *P* values of ≤0.25 by bivariate analysis and were selected for further analysis by logistic regression. Multivariate analysis showed that seropositivity to *T. gondii* was negatively associated with mixed breed (OR = 0.02; 95% CI: 0.003–0.26; *P* = 0.001). Other variables including sex, type of raising, and municipality did not show an association with *T. gondii* seropositivity by multivariate analysis. The result of the Hosmer–Lemeshow test (*P* = 0.98) indicated an acceptable fit of our regression model.

The frequency of high antibody titers (≥1:400) was significantly higher in Landrace pigs than mixed breed pigs *(Table 2)*. Other characteristics of pigs including age and sex did not show a correlation with high antibody titers.

Discussion

The epidemiology of *T. gondii* infection in pigs in Mexico has been scantily studied. In this survey, we determined the seroprevalence and correlates (age, sex, breed, health status, type of raising, and municipality of origin) of *T. gondii* infection in pigs for slaughter in the northwestern Mexican city of La Paz, Baja California Sur. This city has particular environmental characteristics including a desert climate and low altitude (0–27 meters above sea level). Seroprevalence of *T. gondii* infection in backyard pigs for slaughter in the present study was 13.7%. This seroprevalence is lower than the 45.3% seroprevalence found in a recent study in backyard pigs in the eastern Mexican state of Veracruz [13]. It is not clear why pigs in Baja California Sur have a lower seroprevalence of *T. gondii* infection than pigs in Veracruz. However, difference in climates among the states may contribute for the difference in the seroprevalences. Seroprevalence of *T. gondii* infection may be influenced by climate, with higher rate in humid than in dry climates [2]. Both states are close to the sea, but climate is quite different among each state. Baja California Sur has a desert climate whereas Veracruz has a humid climate.

To the best of our knowledge, this is the first study of *T. gondii* infection in pigs raised in a desert climate. The 13.7% seroprevalence in backyard pigs in Baja California Sur is slightly lower than the 16.1 and 17.2% seroprevalences reported in backyard pigs in the northern Mexican State of Durango [11] and the southern Mexican state of Oaxaca [12], respectively.

The presence of *T. gondii* antibodies in 5–36 months old pigs in the present study indicates that infections were acquired postnatally since transcolostrally acquired *T. gondii* antibodies disappear by 3 months of age [3]. We found a higher frequency of high antibody titers (≥1:400) in Landrace pigs than mixed breed pigs. It is not clear why this difference exists among pig breeds. We are not aware of any previous report of this difference. Other pigs' characteristics including age and sex did not correlate with high antibody titers. There are several potential explanations for the observed differences in antibody titers between pig breeds. First, the higher frequency of high antibody titers in Landrace pigs may be due to these pigs having had a more recent infection; secondly, different *T. gondii* strains may have infected these pigs, and thirdly, genetic differences in susceptibility to infection may result in differences in the intensity of the immune response. Genetic differences have been reported to impact on the outcome of infection in rodents and humans [9, 17]. Experimental infections in pigs have shown that anti-*T. gondii* antibody production depends on the pathogenicity of the parasite strain [18]. Multivariate analysis of the pigs' characteristics showed that seropositivity to *T. gondii* was associ-

ated with Landrace breed. This finding correlates with the high antibody levels in Landrace pigs. Further studies to elucidate the high frequency of infection and high antibody levels in Landrace pigs and the parasite strains in the region are needed. Other characteristics of pigs including age, sex, health status, type of raising, and municipality of origin did not correlate with *T. gondii* infection by multivariate analysis.

Our results indicate that the overall seroprevalence of *T. gondii* in pigs for slaughter in La Paz, Baja California Sur is lower than the seroprevalences in pigs reported in other Mexican States. Landrace pigs had a higher seroprevalence and antibody levels than mixed breed pigs. Results will prove useful for the design of optimal preventive strategies against *T. gondii* infection. Results point toward the need of taking actions against *T. gondii* infection in pigs and humans in the region. Backyard pigs should be raised in an environment with proper sanitation, feed with clean water and avoiding cohabitation with cats. On the other hand, to avoid human *T. gondii* infection, pork should be cooked well done, or frozen down when destined for raw or undercook consumption [8].

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