SEBHA UNIVERSITY JOURNAL OF MEDICAL SCIENCES VOL.21 NO. 1 2026
DOI: 10.51984/H2WYP718

مجلة جامعة سبها للعلوم الطبية
Sebha University Journal of Medical Sciences
Journal homepage: www.sebhau.edu.ly/journal/joms

Prevalence of Toxoplasma gondii Antibodies Among Workers Handling Fruits and Vegetables at Janzour Market, Libya

Fadwa J Mahanay [a], Ahmed AL-Qarari[b,c], Sumaia R. Alkhanfas[c], Hanan A. Aqeehal[c].

[a]Department of Biology, Faculty of Education, University of Tripoli, Libya
[b]Medical parasite Department, Faculty of Medicine, University of Tripoli, Libya
[c]National Center for Disease Control, Ministry of Health, Tripoli, Libya

Keywords:
Toxoplasma gondii seroprevalence
Fruit and vegetable workers
occupational exposure
Libya
ELISA

A B S T R A C T

Toxoplasma gondii infection remains a significant public health concern worldwide, particularly among occupational groups exposed to contaminated environments. Workers handling fruits and vegetables may be at increased risk due to contact with soil and unwashed produce; however, data from Libya are limited. This study aimed to determine the seroprevalence of T. gondii IgG antibodies and assess associated demographic and occupational risk factors among market workers in Janzour, Libya. A cross-sectional study was conducted among 57 male workers between July and August 2021. Sociodemographic and occupational data were collected using structured questionnaires, and serum samples were analyzed using a commercial ELISA kit. Associations were assessed using Fisher's exact test, with $p \leq 0.05$ considered significant. The results showed that 54.4% of participants were seropositive, indicating substantial prior exposure. Seroprevalence was highest among workers aged 45–59 years 2(66.7%) and 15–29 years 24(60.0%), although differences were not statistically significant. Nationality and soil exposure were not significantly associated with infection. In contrast, the type of produce handled showed a significant association, with fruit handlers exhibiting the highest prevalence 18(72.0%). travelers had significantly higher seropositivity compared to travelers. These findings highlight the need for improved hygiene practices, enhanced market sanitation, and targeted health education to reduce occupational exposure.

انتشار الأجسام المضادة لطفيلي *Toxoplasma gondii* بين العاملين في تداول الفواكه والخضروات بسوق جنزور، ليبيا.

فدوى مهناي*[a]، أحمد القراري[b,c]، سمية الخنفاس[c]، حنان عقيله[c]

[a]قسم الأحياء، كلية التربية، جامعة طرابلس، طرابلس، ليبيا
[b]قسم الطفيليات الطبية، كلية الطب، جامعة طرابلس، طرابلس، ليبيا
[c]المركز الوطني لمكافحة الأمراض، وزارة الصحة، طرابلس، ليبيا

الكلمات المفتاحية

الانتشار المصلي
التعرض المهني
العاملون في الفواكه والخضروات
الصحة العامة
طفيلي المقوسات القنودية
ليبيا
تقنية الإليزا

الملخص

عدوى طفيلي المقوسات القنودية لا تزال تمثل مشكلة صحية عامة مهمة على مستوى العالم، خاصة بين الفئات المهنية المعرضة للبيئات الملوثة. وقد يكون العاملون في تداول الفواكه والخضروات أكثر عرضة للإصابة نتيجة ملامسة التربة والمنتجات غير المغسولة؛ ومع ذلك، لا تزال البيانات المتوفرة من ليبيا محدودة. هدفت هذه الدراسة إلى تحديد معدل الانتشار المصلي للأجسام المضادة (IGG) ضد طفيلي المقوسات القنودية وتقييم العوامل الديموغرافية والمهنية المرتبطة بها بين عمال السوق في جنزور، ليبيا. أُجريت دراسة مقطعية على 57 عاملاً من الذكور خلال الفترة من يوليو إلى أغسطس 2021. جُمعت البيانات الاجتماعية والمهنية باستخدام استبيانات منظمة، وتم تحليل عينات المصل باستخدام اختبار الإليزا التجاري. تم تقييم الارتباطات باستخدام اختبار فيشر الدقيق، مع اعتبار قيمة $P \leq 0.05$ ذات دلالة إحصائية. أظهرت النتائج أن 54.4% من المشاركين

*Corresponding author: Hanan A. Aqeehal
E-mail addresse: hananaghila@yahoo.com

Article History : Received 25 February 2026 - Received in revised form 28 April 2026 - Accepted 03 May 2026

كانوا إيجابيي المصل، مما يشير إلى تعرض سابق مرتفع. وكان أعلى معدل انتشار بين الفئة العمرية 45–59 سنة 2 (66.7%) تليها الفئة 15–29 سنة 24(60.0%)، إلا أن هذه الفروق لم تكن ذات دلالة إحصائية. كما لم تُظهر الجنسية أو التعرض للتربة ارتباطًا معنويًا بالعدوى. في المقابل، أظهر نوع المنتجات المتداولة ارتباطًا معنويًا، حيث سجل العاملون في تداول الفواكه أعلى معدل انتشار 18 (72.0%). كما كانت نسبة الإيجابية المصلية أعلى بشكل ملحوظ بين غير المسافرين مقارنة بالمسافرين. تؤكد هذه النتائج على الحاجة إلى تحسين ممارسات النظافة، وتعزيز إجراءات الصحة في الأسواق، وتكثيف التوعية الصحية للحد من التعرض المهني.

1. **Introduction**

Toxoplasmosis, caused by the obligate intracellular protozoan parasite *Toxoplasma gondii*, is one of the most widespread zoonotic diseases globally and remains a major public health concern in both developed and developing countries [1,2]. The parasite has a complex life cycle involving felids as definitive hosts, while warm-blooded animals including humans serve as intermediate hosts. Although *T. gondii* infection is often asymptomatic in immunocompetent individuals, it can lead to severe and sometimes fatal clinical outcomes in immunocompromised patients, such as those with HIV/AIDS, organ transplant recipients, and individuals undergoing chemotherapy [3,4]. Additionally, primary infection during pregnancy poses a serious risk of congenital transmission, resulting in miscarriage, stillbirth, hydrocephalus, intracranial calcifications, chorioretinitis, and long-term neurodevelopmental sequelae in the offspring [5,6]. The disease burden is especially high in South America and Africa, where more virulent strains and environmental conditions contribute to increased morbidity [7].

Transmission of *T. gondii* to humans occurs through three main routes: (a) ingestion of food or water contaminated with sporulated oocysts shed by infected cats; (b) consumption of raw or undercooked meat containing tissue cysts, particularly pork, lamb, and game meat; and (c) congenital transmission from mother to fetus [2,8]. Among these, foodborne transmission is increasingly recognized as the predominant route in many settings. Environmental contamination, especially of soil, water, and fresh produce, plays a central role in human exposure [9,10]. Fruits and vegetables can become contaminated with oocysts through contact with infected cat feces, use of untreated manure or contaminated irrigation water, and handling by infected workers. A recent quantitative risk assessment from Brazil estimated that oocyst contamination in fruits and greens contributes significantly more to overall *T. gondii* infections than bradyzoite-contaminated meats, highlighting the importance of produce-borne transmission [7].

Recent large-scale studies have confirmed that ready-to-eat fresh produce represents a significant route of *T. gondii* exposure. The TOXOSOURCES project, a European-wide multicenter survey funded by the EU Horizon 2020 programme, investigated contamination of commercially available ready-to-eat salad mixes across ten European countries from October 2021 to October 2022. Using a validated and standardized molecular detection methodology, the study tested 3,329 salad samples and detected *T. gondii* oocysts in 4.1% of bagged salads—approximately one in every 25 units [11,12]. The United Kingdom showed the highest presence of the parasite in samples analyzed (16%), while the lowest were found in the Czech Republic (0%) and Norway (0.5%). Spain matched the European average at 4.1% [11]. Importantly, the researchers noted that industrial washing processes currently employed may not remove or inactivate all oocysts, and a single oocyst can cause infection in a person [11]. This finding has direct implications for fruit and vegetable workers, who handle fresh produce daily before it reaches consumers.

Globally, a growing body of evidence indicates that occupational exposure significantly increases the risk of *T. gondii* infection among individuals who handle fruits, vegetables, and animals. A comprehensive systematic review and meta-analysis published in 2024 examined data from 66 studies spanning five decades (1972–2023) with a total sample size of 15,279 workers. The pooled global seroprevalence of *T. gondii* infection among workers occupationally exposed to animals and fresh produce was estimated at 41% (95% CI: 36–47%) [13,14]. Subgroup analyses revealed significant variations by occupation: non-livestock workers (including fruit and vegetable handlers) showed a seroprevalence of 54%, livestock workers 47%, slaughterhouse workers 44%, and veterinary personnel 27% [13]. Geographic trends showed the highest prevalence in Africa (51%), followed by South America (49%), Europe (47%), Australia (43%), Asia (36%), and North America (23%) (13,14). These findings underscore that workers handling fresh produce and animals in Africa are at particularly high risk.

In Brazil, a cross-sectional study among vegetable growers reported a seroprevalence of 56.3%, which was significantly higher than that of the general population. The same study identified soil contact for more than five hours daily and inadequate hand washing before meals as independent risk factors [15]. In Egypt, a study conducted among fruit and vegetable market workers in Cairo found a seroprevalence of 42.8%, with handling unwashed produce, nail dirt, and lack of glove use identified as significant predictors of infection [16]. The World Health Organization (WHO) explicitly recognizes food handlers and agricultural workers as priority groups for toxoplasmosis surveillance and targeted prevention strategies [17].

In North Africa, environmental and socioeconomic conditions may favor the transmission of *T. gondii*. Warm and humid climates promote oocyst survival in soil, while high densities of stray cats, limited access to clean water, traditional farming practices, and weak enforcement of food safety regulations contribute to ongoing exposure (18,19). In Libya specifically, recent studies have documented the presence of *T. gondii* in various populations. A 2025 study among male blood donors attending the Central Blood Bank in Sebha, Libya, reported an overall seroprevalence of 7.96%, with significant associations found between infection and eating undercooked meat, contact with soil, and smoking [20]. Among pregnant women in Misurata, seroprevalence was reported at 43.1% [21]. In Benghazi, blood donors showed a seroprevalence of 32.4% [22]. Among immunocompromised patients in Tripoli, seropositivity reached 58.6% [23]. Additionally, a study of stray cats in Tripoli found that 48% shed *T. gondii* oocysts in their feces, indicating high environmental contamination [19]. A 2025 study on free-range chickens in northeastern Libya (Al-Marj, El-Bayda, and Derna districts) reported an overall seroprevalence of 23.8%, confirming that *T. gondii* circulates widely in the Libyan environment and that free-range chickens represent a potential source of infection for humans [24].

Despite these findings, all existing Libyan studies have focused exclusively on clinical or high-risk populations such as pregnant women, blood donors, hospitalized patients, and animals. No study has specifically investigated occupationally exposed groups, particularly workers who handle fruits and vegetables in markets. This is a critical gap because these workers face daily exposure to multiple risk factors identified in global studies.

The absence of data on *T. gondii* seroprevalence among fruit and vegetable workers in Libya represents a critical research gap for several reasons. First, these workers are exposed daily to multiple risk factors, including direct contact with soil, handling of unwashed produce, exposure to stray cats in market environments, and often limited access to handwashing facilities. The global meta-analysis confirmed that African workers have the highest seroprevalence (51%) of any geographic region, yet Libya has no occupational data [13]. Second, infected workers may not only suffer personal health consequences but could also serve as a source of contamination for the produce they handle, potentially transmitting oocysts to consumers—a route of transmission recently confirmed by the

European salad contamination study [11,12]. Third, the Janzour market in Libya is one of the largest fresh produce markets in the Tripoli metropolitan area, serving thousands of consumers daily, yet no occupational health assessment has ever been conducted there. Fourth, identifying the burden of toxoplasmosis in this workforce would provide evidence for targeted public health interventions, including hygiene education, provision of protective equipment, and routine screening programs—interventions that the WHO recommends for high-risk occupational groups [17]. Therefore, this study aimed to determine the seroprevalence of *Toxoplasma gondii* IgG antibodies among fruit and vegetable workers in Janzour market, Libya.

2.Material and methods

2.1 Study design and study population

A cross-sectional study was conducted from July to August 2021 among fruit and vegetable workers at Janzour popular vegetable market, Libya. Janzour market is one of the main distribution centers for fruits and vegetables in the Tripoli region, employing workers involved in handling, transporting, selling, and cleaning fresh produce.

The study population consisted of market workers who routinely handled fruits and vegetables and were considered occupationally exposed to potential environmental contamination. Participants included vendors, loaders, cleaners, and other workers present at the market during the study period. Workers were recruited on-site using a convenience sampling approach.

Data were collected using a structured, paper-based questionnaire completed by participants at the time of enrolment. The questionnaire captured information on sociodemographic characteristics (age, nationality, and marital status), occupational factors (duration of work at the market), health status (self-reported presence of disease), and environmental exposures related to Toxoplasma gondii infection, including type of agricultural soil handled, source of fruits and vegetables, and type of produce handled. Laboratory test results were recorded for each participant following serological analysis. Questionnaires were reviewed on site to ensure completeness.

Venous blood samples were collected from each participant under aseptic conditions. Serum was separated and stored according to standard laboratory procedures until serological testing for T. gondii antibodies.

2.2 Laboratory tests:

Serum samples were collected from all participants and stored at –20°C until analysis. The presence of anti-T. gondii IgG antibodies were assessed using a commercially available enzyme immunoassay kit ("Toxoplasma IgG," International Immuno-Diagnostics, Foster City, CA, USA). Antibody levels were measured quantitatively and expressed in International Units (IU)/ml. A result of ≥8 IU/ml was considered positive for T. gondii IgG. All procedures were carried out strictly according to the manufacturer's instructions.

2.3 Ethical aspects

The study was approved and confirmed under the rules and regulations of research in the National Center for Disease Control Libya. Therefore, at commencing the research point, ethical approval and authorization were issued while referring to the NCDC.

2.4 Statistical analysis

Data were analyzed using Jamovi software (version 2.3.28). The seroprevalence of anti-Toxoplasma gondii IgG antibodies was calculated as the proportion of ELISA-confirmed positive samples among all tested participants. Associations between categorical variables were assessed using Pearson's chi-square test or Fisher's exact test when expected cell counts were less than 5. A two-sided p-value of ⩽0.05 was considered statistically significant.

3. Results:

Among 57 male workers employed in fruit and vegetable handling at Janzour Market, Libya, 54.4% (31/57) tested positive for anti-*Toxoplasma gondii* IgG antibodies, indicating widespread existing exposure to *Toxoplasma gondii* in this occupational group. Regarding age, due to the very small sample size in the 60–74 years age group (n=1), this category was merged with the 45–59 years group to form a combined 45–74 years age group (n=4) for reliable statistical analysis. Seroprevalence was 60.0% (24/40) among those aged 15–29 years, 38.5% (5/13) among those aged 30–44 years, and 50.0% (2/4) among those aged 45–74 years, with no statistically significant difference across age groups (p = 0.360) (Table 1). By nationality, seroprevalence was highest among Sudanese workers (55.6%, 5/9), followed by Egyptian workers (54.2%, 13/24), Libyan workers (40.9%, 9/22), and Nigerian workers (42.9%, 3/7). Both Tariqa workers (n=2) tested positive (100.0%, 2/2), while the single Tunisian worker (n=1) tested negative (0.0%, 0/1). The overall difference across nationalities was not statistically significant (p = 0.509); however, results for groups with very small sample sizes (Tunisia n=1, Tariqa n=2), With respect to soil contact, seroprevalence among workers handling greenhouse soil only was 57.1% (8/14), agricultural soil only was 54.5% (18/33), and both soil types was 50.0% (5/10), with no significant association (p = 0.941). Type of produce handled showed a significant association with seropositivity (p = 0.0073), with the highest seroprevalence among handlers of fruits only (72.0%, 18/25), followed by vegetables only (60.0%, 9/15), and the lowest among handlers of both fruits and vegetables (23.5%, 4/17) (Figure 1). Regarding travel history, seroprevalence was significantly higher among non-travellers (50%, 8/16) compared to travellers (78.0%, 32/41) (p = 0.038), suggesting that mobility and travel patterns may influence infection risk.

3.1 Type of produce handled:

Figure 1 illustrates the seroprevalence of anti-*Toxoplasma gondii* IgG antibodies according to the type of produce handled among market workers in Janzour, Libya. A statistically significant association was observed between produce type and *T. gondii* seropositivity (p = 0.0073). Workers who handled fruits exclusively exhibited the highest seroprevalence, with 72.0% (18/25) testing positive, followed by those handling vegetables exclusively, among whom 60.0% (9/15) were seropositive. In contrast, workers involved in handling both fruits and vegetables had a markedly lower seroprevalence of 23.5% (4/17). These findings suggest that occupational exposure related to the specific type of produce handled may influence the risk of *T. gondii* infection, with exclusive fruit handling appearing to be associated with the greatest level of exposure in this study population.

4. Discussion:

This study demonstrates a substantial burden of prior exposure to Toxoplasma gondii among male workers who handle fresh produce at Janzour Market, Libya, where 54.4% (31/57) tested positive for anti-*T. gondii IgG* antibodies. This prevalence aligns with observations from settings where environmental and food hygiene conditions facilitate oocyst transmission, consistent with the parasite's worldwide distribution and ability to cause both asymptomatic infection and severe disease in vulnerable populations [1–4]. Although severe outcomes are mainly associated with immunocompromised individuals and congenital infections [5,6], elevated background exposure among fresh produce workers carries public health implications, given their continuous contact with raw produce and consumers.

Age-related differences in seropositivity were not statistically significant (p = 0.360). Seroprevalence was 60.0% among workers aged 15–29 years, 38.5% among those aged 30–44 years, and 50.0% among those aged 45–74 years. The absence of a significant age trend contrasts with several previous studies that have reported increasing seroprevalence with age, reflecting cumulative exposure over time [24]. For example, Alvarado-Esquivel et al. (2011) found that seroprevalence of Toxoplasma antibodies significantly increased with age among fruit and vegetable workers (p = 0.0004) [24]. Similarly, a large study in the United States demonstrated a steady rise in seroprevalence from 20–29 years through ≥70 years (adjusted OR = 4.78 for ≥70 years) [25], and a recent study in China confirmed increasing seroprevalence with age among animal contact workers, indicating a cumulative exposure effect [26]. In contrast, a study among pregnant women in Cameroon reported the highest seroprevalence (87.2%) in the 35–44 years age group, though the trend was not statistically significant (p = 0.051) [27]. The lack of a

significant age trend in the present study likely reflects the relatively narrow age distribution of the study population and the small sample size in the 45–74 years group (n=4), which limits statistical power to detect true differences.

Differences in prevalence by nationality were also not statistically significant ($p = 0.509$), but elevated seropositivity among Sudanese (55.6%) and Egyptian (54.2%) workers compared with Libyans (69.2%) may reflect differing exposures prior to arrival in Libya, dietary practices, and variability in sanitation conditions in their countries of origin. Such variations are consistent with literature from North Africa and the Eastern Mediterranean, where favorable climate and high stray cat density promote environmental contamination with T. gondii oocysts [7–11].

Occupational exposure patterns provide important insights. Similar seroprevalence across workers handling greenhouse soil (57.1%), agricultural soil (54.5%), or both (50.0%) suggests that soil contact itself—regardless of type—is a primary exposure pathway, consistent with evidence that oocysts persist across a range of soil environments when moisture and temperature are adequate [2,8,9].

The most striking finding of this study is that the type of produce handled was significantly associated with seropositivity ($p = 0.0073$), with fruit workers showing the highest prevalence (72.0%), followed by vegetable workers (60.0%), and workers handling both fruits and vegetables showing the lowest prevalence (23.5%).

Several plausible explanations may account for this unexpected pattern:

First, task specialization and work duration may play a role. Workers who handle both fruits and vegetables often perform supervisory or multi-task roles that involve less continuous direct contact with any single produce type. In contrast, workers handling only fruits or only vegetables typically spend their entire shift in direct, repetitive contact with that specific produce category, increasing cumulative exposure to potential contaminants.

Second, hygiene practices may differ by worker type. Workers handling both produce types may be more experienced or hold different positions (e.g., market stall owners vs. laborers), potentially leading to better awareness of hygiene practices or greater access to handwashing facilities. Conversely, those handling only fruits or only vegetables may be lower-wage hourly workers with less training and fewer protective measures.

Third, produce characteristics and handling intensity may contribute. Fruits are often handled individually multiple times—for sorting, displaying, pricing, and customer selection—increasing hand-to-produce contact frequency. Vegetables may be handled in bulk but often cooked before consumption, potentially reducing worker perception of risk. Workers handling both types may alternate between tasks, inadvertently reducing continuous exposure to any single high-risk category.

Fourth, the "healthy worker effect" cannot be ruled out. Workers who have been in the occupation longer and handle both produce types may have developed immunity over time or may represent a survivor bias, where those who remained in the workforce are healthier and potentially had different exposure histories.

Fifth, it is also possible that the lower seroprevalence in the "both" group is an artifact of small sample size (n=17) or unmeasured confounding factors such as differences in age distribution, national origin, or work duration across these groups. Given the unexpected direction of this association, future studies with larger sample sizes and multivariable analysis are needed to confirm or refute this finding.

Prior studies have detected parasitic contamination on fresh produce and market surfaces, supporting the plausibility of produce-borne transmission [15,16]. However, most previous occupational studies have not stratified workers by handling of single vs. multiple produce types, making direct comparison difficult.

Regarding travel history, the finding that non-travellers had significantly higher seropositivity (78.0%) than travellers (50.0%) ($p = 0.038$) suggests that exposure is predominantly local, arising from market-associated environmental contamination including soil, market water sources, unwashed produce, or the presence of cats near stalls [8,9]. This counterintuitive finding—those travellers had lower seroprevalence may reflect that travellers are often younger, have different occupational roles, or spend less time in the market environment. Alternatively, it is possible that non-travellers have lived their entire lives in this endemic setting, accumulating higher lifetime exposure, while travellers may have originated from lower-prevalence regions or spent significant time away from the local environment. Given that *T. gondii* can also be transmitted through consumption of undercooked meat [7], educational campaigns should address risks associated with both meat and produce.

These findings highlight the need for targeted hygiene measures in informal markets. Such interventions should prioritize access to safe washing water, proper glove use, regular hand hygiene, separation of clean and dirty work areas, improved waste management, and minimization of cat access to stalls and refuse areas. Consumer education should emphasize thorough washing of raw produce, avoiding cross-contamination in the household, and safe water practices [7–9,17]. In Libya, such interventions directly address context-specific risk factors, including climate suitability for oocysts and widespread stray cat populations [10,11].

This study contributes to addressing knowledge gaps in Libya, where seroepidemiological research on occupationally exposed populations remains scarce [12–14]. Study strengths include standardized serological testing and structured assessment of occupational exposures.

5. Limitations

This study has several limitations. Convenience sampling and inclusion of only male participants limit the generalizability of the findings. Small subgroup sizes reduced statistical power, particularly for the older age group (45–74 years, n=4), nationalities with very small samples (Tunisia n=1, Tariqa n=2), and the unexpected finding in the "both fruits and vegetables" group (n=17). Serological testing measured only IgG, without IgM or avidity assays, preventing distinction between recent and past infections. The absence of environmental sampling (soil, water, produce, surfaces) restricted the ability to identify contamination sources directly. Important behavioral factors, such as cat ownership, hygiene practices, dietary habits, and duration of employment, were not fully assessed, allowing for residual confounding. Finally, the cross-sectional design precludes determining causality. Future studies should use larger, more diverse samples, include female workers, and incorporate environmental and molecular testing to better clarify transmission pathways [9,15–17].

6.Conclusion

This study identifies a notably high prevalence (54.4%) of prior *Toxoplasma gondii* infection among fruit and vegetable workers in Janzour Market, Libya, indicating that this occupational group faces substantial exposure risks. Handling specific types of produce—particularly fruits only (72.0%)—was significantly associated with seropositivity, suggesting that contamination during handling, storage, or display may contribute to infection. The unexpected finding of lower seroprevalence among workers handling both fruits and vegetables (23.5%) requires further investigation with larger sample sizes to determine whether this reflects true protective factors, task differences, or statistical artifact. Although other factors such as age, nationality, and soil exposure were not statistically significant, the observed trends align with recognized environmental and behavioral pathways for *T. gondii* transmission. These findings underscore the need for improved hygiene practices, safer produce handling procedures, enhanced market sanitation, and targeted health education. Strengthening surveillance systems and conducting broader, more detailed studies will be crucial for reducing T. gondii transmission in similar occupational settings across Libya.

Funding: This study did not receive funding.

Authors' contributions: The authors have equal participation in conceptualization, preparation of the original draft, review, and editing.

Data availability: All analyzed data are included in this study.

Conflict of interest: The authors declare that they have no conflict of interest

Acknowledgements

The authors thank the Janzour municipality, Tripoli for their help

during specimen's collection.

7. References

[1] Tenter, A.M., Heckeroth, A.R., & Weiss, L.M. (2000). Toxoplasma gondii: from animals to humans. International Journal for Parasitology, 30(12-13), 1217–1258 — fundamental review of T. gondii biology and zoonotic transmission.

[2] Robert-Gangneux, F., & Dardé, M.L. (2012). Epidemiology of and diagnostic strategies for toxoplasmosis. Clinical Microbiology Reviews, 25(2), 264–296 — comprehensive overview of global epidemiology and diagnostic approaches.

[3] Montoya, J.G., & Liesenfeld, O. (2004). Toxoplasmosis. Lancet, 363(9425), 1965–1976 — clinical review of toxoplasmosis in immunocompetent and immunocompromised hosts.

[4] Jones, J.L., Parise, M.E., & Fiore, A.E. (2014). Neglected parasitic infections in the United States: toxoplasmosis. American Journal of Tropical Medicine and Hygiene, 90(5), 794–799 — public health perspective on toxoplasmosis as a neglected parasitic infection.

[5] Dubey, J.P. (2010). Toxoplasmosis of animals and humans. 2nd ed. CRC Press — authoritative textbook on T. gondii infection in animal and human hosts.

[6] Hill, D., & Dubey, J.P. (2002). Toxoplasma gondii: transmission, diagnosis and prevention. Clinical Microbiology and Infection, 8(10), 634–640 — review of transmission routes and preventive measures.

[7] Zhu, S., VanWormer, E., Martínez-López, B., Shapiro, K., & Conrad, P.A. (2023). Quantitative risk assessment of oocyst versus bradyzoite foodborne transmission of Toxoplasma gondii in Brazil. Pathogens, 12(7), 870 — evidence that oocyst contamination in produce contributes more to infections than meat-borne bradyzoites.

[8] Cook, A.J., Gilbert, R.E., Buffolano, W., Zufferey, J., Petersen, E., Jenum, P.A., Foulon, W., Semprini, A.E., & Dunn, D.T. (2000). Sources of toxoplasma infection in pregnant women: European multicentre case-control study. British Medical Journal, 321(7254), 142–147 — landmark study identifying risk factors for toxoplasmosis in pregnancy.

[9] Jones, J.L., & Dubey, J.P. (2010). Waterborne toxoplasmosis: recent developments. Experimental Parasitology, 124(1), 10–25 — review of waterborne transmission and oocyst contamination.

[10] Lass, A., Kontogeorgos, I., & Karanis, P. (2019). Contamination of fresh vegetables with Toxoplasma gondii oocysts in Poland. Foodborne Pathogens and Disease, 16(7), 478–484 — evidence of fresh produce as a route of T. gondii exposure.

[11] Calero-Bernal Rafael, Betson Martha, Slana Iva, Bartosova Barbora, Marucci Gianluca, Possenti Alessia, Álvarez-García Gema, Bier Nadja, Mayer-Scholl Anne, Berg Rebecca P, Chaudhry Umer, López-Ureña Nadia M, Piotrowska Weronika, Sroka Jacek, Johannessen Gro S, Davidson Rebecca, Dámek Filip, Blaga Radu, Thoumire Sandra, Zalewská Barbora, Waap Helga C, Jokelainen Pikka, Lalle Marco. Molecular detection of Toxoplasma gondii in ready-to-eat salad mixes: multi-country survey using a validated and harmonised standard operating procedure, Europe, 2021 to 2022. Euro Surveill. 2025;30(22):pii=2400594. https://doi.org/10.2807/1560-7917.ES.2025.30.22.2400594

[12] Bier, N.S., Berg, R.D., Calero-Bernal, R., Betson, M., Chaudhry, U., et al. (2024). Investigating contamination of ready-to-eat salads with Toxoplasma gondii oocysts in a European-wide multicenter survey. In "One Health" Conference, Romanian Academy, Bucharest, Romania — conference presentation on TOXOSOURCES project findings.

[13] Mohammed, A., Ahmed, M., & Nasir, B. (2024). The global seroprevalence of Toxoplasma gondii infection in workers occupationally exposed to animals (1972–2023): a systematic review and meta-analysis. Veterinary Quarterly, 44(1), 1–18 — global meta-analysis showing 41% seroprevalence among occupationally exposed workers.

[14] Silva, M.G., Araújo, A.C., & Lima, V.M. (2017). High seroprevalence of Toxoplasma gondii among vegetable growers in southeastern Brazil. Revista da Sociedade Brasileira de Medicina Tropical, 50(4), 496–502 — occupational study reporting 56.3% seroprevalence among vegetable growers.

[15] El-Tantawy, N. L. (2025). Seroprevalence of Toxoplasmosis Among Butchers in Mansoura City, Egypt: A Case-Control Study. Egyptian Journal of Veterinary Sciences, 1-7.

[16] World Health Organization. (2021). Report on foodborne parasite surveillance in high-risk occupational groups. Geneva: WHO — recognition of food handlers and agricultural workers as priority groups for toxoplasmosis surveillance.

[17] Kaoud, H.A. (2016). Epidemiology of toxoplasmosis in North African countries. Journal of the Egyptian Society of Parasitology, 46(2), 317–326 — regional review of toxoplasmosis epidemiology in North Africa.

[18] Elmahdi, R., Ali, E.O., & Abushhiwa, M.H. (2018). Seroprevalence of toxoplasmosis in stray cats in Tripoli, Libya. Libyan Journal of Veterinary Medicine, 5(1), 12–19 — evidence of high environmental contamination with 48% oocyst shedding in stray cats.

[19] Alwalid, N., & Abdulsalam, A. (2025). Seroprevalence of Toxoplasma gondii among male blood donors attending Central Blood Bank in Sebha, Libya. WAU Journal of Pure and Applied Sciences. doi:10.63318/ — recent Libyan study reporting 7.96% seroprevalence in blood donors.

[20] Mohamed, A.A., Ben Ahmed, S.H., & El-Hadi, M.A. (2019). Seroprevalence of Toxoplasma gondii among pregnant women in Misurata, Libya. Libyan Journal of Medical Sciences, 3(2), 45–49 — Libyan study reporting 43.1% seroprevalence in pregnant women.

[21] Elsheikha, H.M., Azab, M.E., & Aboul-Dahab, M. (2015). Seroprevalence of toxoplasmosis among blood donors in Benghazi, Libya. Parasitology Research, 114(8), 2975–2981 — Libyan study reporting 32.4% seroprevalence in blood donors.

[22] Abdul-Ghaffar, Y., & Al-Mansouri, A.H. (2017). Toxoplasmosis in immunocompromised patients in Tripoli. East Mediterranean Health Journal, 23(4), 278–283 — Libyan study reporting 58.6% seropositivity in immunocompromised patients.

[23] Akra, K.M.A., Ali, H.A., Fitri, L.E., Sardjono, T.W., & Sharif, M. (2025). Seroprevalence of Toxoplasma infection in free-range chickens in northeastern Libya. Open Veterinary Journal — evidence that T. gondii circulates widely in the Libyan environment.

[24] Alvarado-Esquivel, C., Estrada-Martínez, S., & Liesenfeld, O. (2011). Toxoplasma gondii infection in workers occupationally exposed to unwashed raw fruits and vegetables: a case control seroprevalence study. Parasites & vectors, 4(1), 235.

[25] Jones, J. L., Kruszon-Moran, D., Wilson, M., McQuillan, G., Navin, T., & McAuley, J. B. (2001). Toxoplasma gondii infection in the United States: seroprevalence and risk factors. American journal of epidemiology, 154(4), 357-365.

[26] Wang, X., Ruan, W., Xu, W., Chen, H., Zhang, J., Zhang, X., ... & Sun, J. (2025). Different patterns of Toxoplasma gondii infection epidemiology in the general population, animal contact workers, and blood donors in southeastern China between 2019 and 2023: a cross-sectional study. Parasite, 32, 68.

[27] Ayeah, J. N., Oladokun, A., Sumbele, I. U. N., Ilesanmi, A. O., & Bekindaka, O. N. (2022). Seroprevalence of gestational and neonatal toxoplasmosis as well as risk factors in Yaoundé, Cameroon. Journal of parasitology research, 2022(1), 6406259.

Table and Figure

Table 1. Demographic and occupational characteristics of participants and *T. gondii* IgG antibody seroprevalence (N = 57)

Characteristic	No. Investigated	No. Positive (%)	P value
Age (years)			0.360
15–29	40	24 (60.0%)	
30–44	13	5 (38.5%)	
45–74	4	2 (50.0%)	
Nationality			0.509
Libyan	13	9 (69.2%)	
Egyptian	24	13 (54.2%)	
Tunisian	1	0 (0.0%)	
Nigerian	7	3 (42.9%)	
Tariqa	2	2 (100.0%)	
Sudanese	9	5 (55.6%)	
Type of soil handled			0.941
Greenhouses only	14	8 (57.1%)	
Agricultural soils only	33	18 (54.5%)	
Both (greenhouses and agricultural soils)	10	5 (50.0%)	
Type of produce handled			0.0073
Fruits only	25	18 (72.0%)	
Vegetables only	15	9 (60.0%)	
Both (vegetables and fruits)	17	4 (23.5%)	
Travel history			0.038
Yes	41	32 (78.0%)	
No	16	8 (50%)	

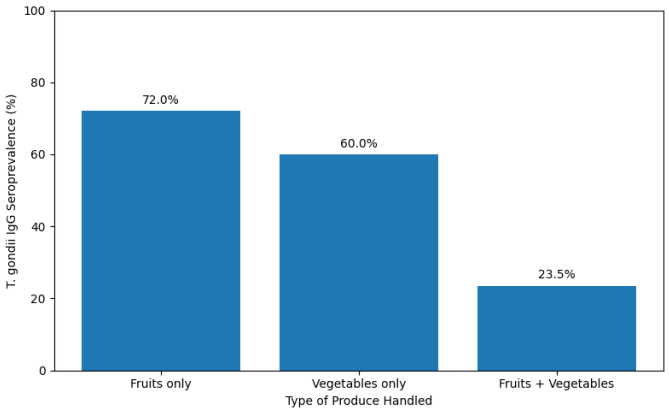

Figure 1. Seroprevalence of *Toxoplasma gondii* IgG according to type of produce handled among market workers in Janzour, Libya

.