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Review paper

Toxoplasma gondii — control measures for reducing risks in the pork production chain

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ABSTRACT

Parasites are highly significant pathogens that are transmitted through food. Their specific life cycles, transmission routes, and usually a lengthy period between infection and the first symptoms of the disease make them a substantial risk to public health. Additionally, there are challenges in detection, diagnosis, and treatment. Toxoplasmosis is considered the most widespread parasitic infection on a global scale. It is caused by the protozoan *Toxoplasma gondii*, one of the most successful parasites of animals and humans due to its ability to parasitize within the nuclei of a wide range of hosts. Because of its importance in both veterinary and human medicine, *T. gondii* is one of the most extensively studied parasites. Existing data show seroprevalences differ across continents, countries, and even within states and among specific communities. Consuming undercooked meat presents one of the greatest risk factors for human infection with the *T. gondii* parasite, with pork being recognized as a dominant source of infection.

1. Distribution of Toxoplasma gondii infection on pig farms

While *T. gondii* infection in domestic animals is generally not a significant clinical issue, it does pose a serious economic problem due to substantial losses resulting from spontaneous abortions. It also presents a public health concern due to a significant zoonotic risk. Consuming meat derived from asymptomatically infected animals is the most notable risk factor for human infection. The presence of *T. gondii* has been documented in all domestic animals used for human consumption, including pigs (*Dubey*, 2010). Pigs are one of the most commonly raised animal species worldwide, and pork constitutes a primary source of protein for millions of people across various cultures and geographic regions. As of April 2022, there were 778.64 million pigs raised worldwide, and in the same year, the European Union produced 134.2 million pigs (*Statista*, 2023). Pork production in Serbia for 2020 amounted to around 300 thousand tonnes (*RZS*, 2021).

Studies based on the detection of specific antibodies in pig serum indicate that the *T. gondii* parasite is present in pigs worldwide, with prevalence differing between continents, from country to country, and even within regions of the same country. Furthermore, prevalence differs depending on the

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category of pigs examined, such as between sows and fattening pigs, as well as between pigs raised on farms with biosecurity systems compared to pigs kept in free-range systems (*Dubey*, 2009; *Roqueplo et al*., 2011). Based on a meta-analysis encompassing samples from five continents, the global seroprevalence of *T. gondii* infection in pigs stands at 19%. Prevalence differs between continents and is highest in Africa and North America (25%), followed by South America (23%), Asia (21%), and is the lowest in Europe, 13% (*Foroutan et al.*, 2019). Prevalences in Europe show a wide range, from 0.9% in Austria (*Edelhofer*, 1994) to 46.8% in backyard-raised pigs in Romania (*Pastiu et al*., 2019). In Serbia, several studies have been conducted regarding the presence of *T. gondii* infection in pigs. In the first seroepidemiological study, *T. gondii*-specific IgG antibodies were detected in 15.2% of fattening pigs and in 40.9% of culled sows (*Klun et al*., 2006), while the latest study conducted showed a similar trend, with a presence in 15.1% of fattening pigs and in 43.6% of culled sows (*Betić et al*., 2022).

2. Impact of *Toxoplasma gondii* on food safety

Given that pigs are a significant reservoir of this parasite due to the presence of numerous tissue cysts in nearly all edible parts (*Dubey*, 1986), it is not surprising that a recent study conducted in the US found the economic burden on pork meat caused solely by the *T. gondii* parasite to be estimated at nearly $US 2 billion (*Scharff*, 2020).

The prevalence of *T. gondii* in animals raised for human consumption is the main indicator for assessing the public health risk of toxoplasmosis. Indirect detection methods (serological tests) are commonly used to estimate the animal infection rate, but they only determine seroprevalence. Although seroprevalence is valuable for epidemiological studies, it often does not correlate directly with the presence of tissue cysts in meat, i.e., with findings from direct detection methods. *Opsteegh et al*. (2016) investigated the correlation between direct and indirect detection in various species of meat animals, and demonstrated that the probability of detecting the parasite in seropositive individuals is highest in pigs, 58.8%. Despite the advantages of serological testing, the negative aspect is that parasites are detected in a certain number of seronegative pigs as well (up to 4.9%), suggesting that a negative serological result does not guarantee parasite-free meat. Therefore, serological testing cannot be used for individual control of pig carcasses.

3. Control measures on farm levels

The differences in seroprevalence across different geographical regions can be attributed to various climatic factors, domestic animal husbandry systems, and the level of biosecurity measures implemented in primary production. Lower seroprevalences within the European continent can be explained by the widespread adoption of intensive pig farming methods, resulting in reduced exposure to infection compared to animals in other continents (*Herrero et al*., 2016). Several studies have shown that implementing biosecurity measures on farms, such as effective rodent control programs, restricting access to cats, maintaining hygiene in production facilities, and using uncontaminated water and feed, can lead to a reduction in the prevalence of *T. gondii* in pigs. Additionally, independent factors influencing infection include farms that rear multiple animal species and smaller pig farms that focus solely on finishing (*Betić et al*., 2022). Animals raised in free-range systems are more likely to become infected with *T. gondii* (*Dubey*, 2009); this likelihood is also directly correlated with the management system and level of biosecurity on farms (*Papatsiros et al*., 2016).

However, as consumer awareness regarding animal welfare, organic and sustainable production, and environmental conservation increases, pork from pigs raised in free-range systems is gaining higher market value, and such systems are becoming more prevalent across Europe (*Zander et al*., 2013). Research has indicated that pigs raised in such systems, in comparison to intensive production, pose a greater risk for transmitting certain pathogenic microorganisms to humans, due to the lesser control inherent in these systems compared to enclosed intensive production systems (*Kuruca*, 2017).

4. Control measures in meat processing

The significance of pork as a reservoir of human infection is also highlighted by a study that ranked the risk of various pathogens in combination with food, where the *T. gondii* parasite in conjunction with pork took a high second place (*Batz et al*., 2012). Based on a study conducted in the United States, pork has a higher likelihood of being contaminated with the *T. gondii* parasite compared to beef

and poultry (*Dubey*, 2005). Since only undercooked meat poses a risk of human infection, adequate cooking temperature is a critical factor in preventing parasite infection. However, a study from 2007 found that approximately 9% of consumers cooked pork at temperatures lower than 48°C, which is insufficient to inactivate *T. gondii* cysts (*Ecolab-Ecosure*, 2007). According to recommendations from the European Food Safety Authority, meat should be treated to reach an internal temperature of at least 67°C before consumption (*EFSA*, 2007).

Various preservation methods are used to produce meat products, including smoking, salting, freezing, heating, irradiation, or high-pressure treatment, which generally contribute to lower contamination of these products with the *T. gondii* parasite compared to fresh meat (*Mie et al*., 2008*; Klun & Djurkovic-Djakovic*, 2021). However, there are instances where the presence of the parasite has been confirmed in processed pork products, such as dry-cured ham and sausages (1.5%) in the United Kingdom (*Warnekulasuriya et al*., 1998). Since some pork products are consumed raw (ham, fermented sausages, cured meat products), such products can potentially serve as a source of parasite infection.

5. Conclusion

Consuming undercooked *T. gondii*-contaminated meat, especially pork, is recognized as one of the most significant risks for human infection with this parasite. It is necessary to observe protective measures on farms in terms of biosecurity measures that effectively reduce the risk of infection, and to introduce monitoring of *T. gondii*. In order for food to be safe for consumers, it is necessary to implement actions and activities to prevent or eliminate food safety hazards in accordance with the Codex Alimentarius (*Codex Alimentarius*, 2005). Finally, it is important to emphasize that the consistent application of preventive measures at all mentioned levels, from farms and slaughterhouses to meat processing and consumers, is crucial for their effectiveness.

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References

Batz, M. B., Hoffmann, S. & Morris, J. G. (2012). Ranking the disease burden of 14 pathogens in food sources in the United States using attribution data from outbreak investigations and expert elicitation. *Journal of Food Protection*, 75, 1278–1291.

Betić, N., Karabasil, N., Djurković-Djaković, O., Ćirković, **V., Bobić, B., Branković Lazić, I., Djordjevic, V. & Klun, I. (2022).** Seroprevalence, direct detection and risk factors for *Toxoplasma gondii* infection in pigs in Serbia, and influence of biosecurity measures. *Microorganisms*, 10(5), 1069.

Codex Alimentarius, (2005). CAC/RCP58 Code of Hygienic Practice for Meat.

Dubey, J. P. (1986). A review of toxoplasmosis in pigs. *Veterinary Parasitology,* 19, 181–223.

Dubey, J. P. (2009). Toxoplasmosis in pigs — The last 20 years. Veterinary *Parasitology*. 164, 89–103.

Dubey, J. P. (2010). Toxoplasmosis of Animals and Humans. CRC Press, Boca Raton, FL, 336.

Dubey, J. P., Hill, D. E., Jones, J. L., Hightower, A. W., Kirkland, E., Roberts, J. M., Marcet, L. P., Lehmann, T., Vianna, M. C. B., Miska, K., Sreekumar, C., Kwok, O. C. H., Shen, S. K. & Gamble, H. R. (2005). Prevalence of viable *Toxoplasma gondii* in beef, chicken, and pork from retail meat stores in the United States: risk assessment to consumers. *Journal of Parasitology,* 91(5), 1082–1093.

Ecolab-Ecosure, (2007). Cold temperature report. Retrieved from http:/foodrisk.org/exclusives/ecosure/ Accessed February 14, 2020.

Edelhofer, R. (1994). Prevalence of antibodies against *Toxoplasma gondii* in pigs in Austria–an evaluation of data from 1982 and 1992. *Parasitology Research,* 80, 642–644.

EFSA, (2007). Scientific opinion of the panel on biological hazards on a request from EFSA on surveillance and monitoring of *Toxoplasma* in humans, foods and animals. *EFSA Journal*, 583,1–64.

Foroutan, G., Koethe, M., Bangoura, B., Geuthner, A. C., Randau, F., Ludewig, M., Maksimov, P., Sens, M., Bärwald, A., Conraths, F. J., Villena, I., Aubert, D., Opsteegh, M. & Van der Giessen, J. (2018). *Toxoplasma gondii* infections in chickens — performance of various antibody detection techniques in serum and meat juice

relative to bioassay and DNA detection methods. *International Journal for Parasitology*, 48(9–10), 751–762.

Klun, I., Djurković-Djaković, O., Katić-Radivojević, S. & Nikolić, A. (2006). Cross-sectional survey on *Toxoplasma gondii* infection in cattle, sheep and pigs in Serbia: seroprevalence and risk factors. *Veterinary Parasitology*, 135(2), 121–131.

Klun, I., & Djurkovic-Djakovic, O. (2021). Toxoplasma gondii in pork & pork products — too much on our plate? *Veterinarski Glasnik*, 75(1), 42–56.

Kuruca, Lj. (2017). *Toxoplasma gondii* infection in pigs: serological, parasitological and molecular findings as meat safety parameters. University of Novi Sad. Doctoral dissertation.

Mie, T., Pointon, A. M., Hamilton, D. R. & Kiermeier, A. (2008). A qualitative assessment of *Toxoplasma gondii* risk in ready-to-eat smallgoods processing. *Journal of Food Protection*, 71, 1442–1452.

Opsteegh, M., Maas, M., Schares, G. & Giessen, J. (2016). Relationship between seroprevalence in the main livestock species and presence of *Toxoplasma gondii* in meat (GP/EFSA/BIOHAZ/2013/01) An extensive literature review, Final report. *EFSA Supporting Publications*, 13, 294.

Papatsiros, V. G., Athanasiou, L. V., Stougiou, D., Papadopoulos, E., Maragkakis, G. G., Katsoulos, P. D., Lefkaditis, M., Kantas, D., Tzika, E. D., Tassis, P. D. & Boutsin, S. (2016). Cross-sectional serosurvey and risk factors associated with the presence of *Toxoplasma gondii* antibodies in pigs in Greece. *Vector-Borne Zoonotic Diseases*, 16(1), 48–53, https://doi.org/10.1089/vbz.2015.1845

Pastiu, A. I., Cozma-Petruț, A., Mercier, A., Balea, A., Galal, L., Mircean, V., Pusta, D. L., Bogdan, L. & Gyorke, A. (2019). Prevalence and genetic characterization of *Toxoplasma gondii* in naturally infected backyard pigs intended for familial consumption in Romania. *Parasites Vectors,* 12**,** 586, https://doi.org/10.1186/s13071-019-3842-8

Roqueplo, C., Halos, L., Cabre, O. & Davoust, B. (2011). Toxoplasma gondii in wild and domestic animals from New Caledonia. *Parasite*, 18, 345–348.

Scharff, R. (2020). Food attribution and economic cost estimates for meat and poultry related illnesses. *Journal of Food Protection*, 83(6), 959–967, https://doi.org/10.4315/JFP-19-548

Statista, (2023). Number of pigs worldwide. Retrieved from http://www.statista.com/statistics/263964/number-of-pigs-in-selected-countries 1. (accessed on 1 June 2023)

RZS [Statistical Office of the Republic of Serbia]. (2021). Statistical Yearbook, 20.10.2021. 54(226), https://publikacije.stat.gov.rs/G2021/Pdf/G20212054.pdf

Warnekulasuriya, M. R., Johnson, J. D. & Holliman. R. E. (1998). Detection of *Toxoplasma gondii* in cured meats. *International Journal of Food Microbiology*, 45, 211–215.

Zander, K., Stolz, H. & Hamm, U. (2013). Promising ethical arguments for product differentiation in the organic food sector: a mixed methods research approach. *Appetite*, 62, 133–142.