

TOXOPLASMA GONDII AND THE ROLE OF PORK

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Background

Toxoplasma gondii is an important zoonotic pathogen. Humans can acquire *T. gondii* infection through foodborne or environmental exposure, and recent estimates suggest that more than 10 million human cases of toxoplasmosis occur globally every year¹. Infections in humans can be post-natal (i.e. acquired toxoplasmosis) or vertical (i.e. congenital toxoplasmosis). Because congenital toxoplasmosis is considered particularly problematic due to the severe health effects it can cause in children since birth and the possibility of fetal death, its public health impact has been more extensively studied than acquired toxoplasmosis, where infection is usually associated with mild flu-like symptoms. However, several newer studies suggest that in some cases ocular disease and severe syndromes such as psychiatric disorders may develop as a result of infection².

The recent “Initiative to Estimate the Global Burden of Foodborne Diseases” of the World Health Organization provided crucial evidence to raise awareness on the importance of toxoplasmosis by estimating the disease burden in terms of incidence, mortality and disability adjusted life years (DALYs). This study ranked toxoplasmosis as number 13th among 31 foodborne diseases globally, also demonstrating regional differences, with e.g. a relative higher importance of toxoplasmosis in the Americas than in Europe¹. While crucial to guide public health policy at the global level, regional disease burden estimates are insufficient to direct intervention strategies that are targeted to the reduction of incidence in the population. To identify and implement effective interventions to reduce the burden of toxoplasmosis, risk managers need knowledge on both the local disease burden and the contribution of the most important sources and transmission routes of infection in each population in that area.

Investigating the role of different sources and transmission routes

Cats and wild felids are the only definite hosts of the parasite, but virtually all warm-blooded animals can act as intermediate hosts, and most species can be carriers of tissue cysts of *T. gondii*. *T. gondii* has been isolated from most livestock species such as pigs, cattle, sheep, poultry, as well as wildlife and game. Like many other foodborne hazards, *T. gondii* can be transmitted to humans through consumption of contaminated foods but also by other routes: through water, soil, or air; by direct contact between people, or by contact between people and animals. The relative importance of exposure from a contaminated environment versus consumption of meat or other foods is unclear.

The process of partitioning the human disease burden of a foodborne infection to specific sources is known as *source attribution*, where the term source includes reservoirs (e.g. animal reservoirs like pigs, cattle, pets) and vehicles (e.g. food products like pork or beef). A variety of methods to attribute foodborne diseases to sources are available, including approaches based on analysis of data of occurrence of the pathogen in sources and humans, epidemiological studies, intervention studies, and expert elicitations. Each of these methods presents advantages and limitations, and the usefulness of each depends on the public health questions being addressed and on characteristics and distribution of the hazard.

Source attribution methods have been extensively used to investigate the contribution of food and animal sources for several diseases, e.g. salmonellosis, campylobacteriosis, and listeriosis. Measuring the proportion of *Salmonella* infections that is attributable to different sources has proven particularly useful in several countries and regions, with Denmark pioneering the *One Health* efforts to guide food-safety interventions based on scientific evidence. Relying on knowledge on the most important sources of salmonellosis in the country in different time periods, policy-makers have implemented and revised *Salmonella* control programmes in broiler, layer and pig production with great success in terms of reducing the burden of disease. But application of source attribution methods for other zoonotic pathogens is often more challenging, which can be due to the characteristics of the pathogen or due to lack of data. In the case of absence of quantitative data, expert elicitations are crucial to fill in gaps and combine knowledge from multiple sources and experts.

Source attribution of toxoplasmosis: what do we know?

Source attribution of toxoplasmosis is particularly challenging due to lack of data, and very few studies conducted so far. To overcome this challenge, WHO's Initiative to estimate the global burden of foodborne disease included a large expert elicitation study to assess the contribution of sources for several diseases, including toxoplasmosis. This study estimated that between 42 and 61% of acquired toxoplasmosis cases globally are due to foodborne transmission, with other important routes being water (11-27%) and soil (18-38%)³. The next step of the source attribution process is to measure the contribution of specific sources within these major transmission routes, which would ideally be based on data on prevalence, contamination and exposure of/to each source.

Opsteegh et al.⁴ measured the relative contribution of three meat types for infection with *T. gondii* in the Netherlands. The authors used a comparative risk assessment approach and concluded that 70% of meat-related infections were due to consumption of beef products, 14% due to sheep meat, and that 11% were attributable to pork products. A case-control study in the United States supported these estimates by finding that the leading foodborne risks associated with toxoplasmosis were eating raw ground beef, rare lamb or processed meats produced and consumed without heat treatment⁵.

To our knowledge, these are the only data-driven published studies on source attribution of toxoplasmosis. Several other studies investigated the prevalence of *T. gondii* in different sources, including meats, and others have estimated the risk of disease through consumption of one specific food type, but have not compared these with the risk of other routes.

So what do we know about the role of pork?

Consumption of pork and pork products has historically been attributed an important role for toxoplasmosis. An expert elicitation ranked this food-pathogen combination second among the top 10 most important in the US⁶, and several epidemiological and prevalence studies have focused on pigs and associated products as an important source. However, more recent studies indicate that other food products, particularly beef and lamb, may play a more important role. In addition, increasing evidence shows that prevalence in pigs is decreasing⁷ worldwide. This is likely to be associated with the intensification of pig production globally - implying indoor production.

Several factors may explain a lower contribution of pork for human toxoplasmosis. On one hand, *T. gondii* seroprevalence in many animal hosts (as in humans) increases with age⁸, and market pigs are relatively young when compared with other livestock. Sows have reportedly a higher prevalence, but their meat is mostly used for processed pork products (such as sausages, salami), and this processing involves high saline content which eliminates viable stages of *T. gondii* in the meat⁹. However, it has also been shown e.g. in studies in the Netherlands¹⁰ and Denmark⁸ that outdoor pigs have a higher prevalence than indoor/intensive-production animals, and the increasing demand for organic and free range animal products may represent an increased risk for the consumer unless the meat is thoroughly cooked prior to consumption.

What are we doing to address knowledge gaps?

In the Nordic countries, efforts have been joined to conduct the first large study of source attribution of toxoplasmosis. In this regional initiative, the lack of data on national level is compensated for, enabling an estimation of the relative contribution of the different sources for infection. We are developing a methodological framework that can be applied by each country to produce evidence for risk management, including prioritization of food safety strategies. We expect that this approach will be useful derive national and regional source attribution estimates for toxoplasmosis, identify differences between countries, and help understanding the reasons for such differences.

References

1. WHO, 2015. Foodborne Disease Burden Epidemiology Reference Group 2007-2015. WHO estimates of the global burden of foodborne diseases. World Health Organization, 2015.
2. Torrey Bartko JJ, et al., 2012. Toxoplasma gondii and other risk factors for schizophrenia: an update. Schizophr Bull, 2012; 38(3): p. 642-7.
3. Hald T, et al. World Health Organization Estimates of the Relative Contributions of Food to the Burden of Disease Due to Selected Foodborne Hazards: A Structured Expert Elicitation. PLoS One. 2016 Jan 19;11.
4. Opsteegh M, et al. A quantitative microbial risk assessment for meatborne Toxoplasma gondii infection in The Netherlands. Int J Food Microbiol 150:103-114.
5. Jones J et al. Risk Factors for Toxoplasma gondii Infection in the United States. CID 49:878-884.
6. Hoffmann S, Fishbeck P. et al., 2007. Using Expert elicitation to link foodborne illnesses in the United States to foods. Journal of Food Protection 70: 1220-1229.

7. Jones JL, et al. *Toxoplasma gondii* infection in the United States, 1999-2004, declined from the prior decade. *Am J Trop Medicine and Hygiene* 77:405-410.
8. Kofoed and Vorlund-Kiær, 2016. Development and assessment of an in-house ELISA for the detection of *Toxoplasma gondii* antibodies in serum and meat juice from Danish pigs. Master Thesis, University of Copenhagen, 2016.
9. Dubey, J.P., 1997. Survival of *Toxoplasma gondii* Tissue Cysts in 0.85-6% NaCl solutions at 4-20 c. *Journal of Parasitology*. 83, 946-949.
10. Kijlstra A, et al., 2004. Animal-friendly production systems may cause re-emergence of *Toxoplasma gondii*. *Njas-Wagenning Journal of Life Sciences* 52-,119-132.