Food Microbiology 64 (2017) 65–71

Contents lists available at ScienceDirect

Food Microbiology

journal homepage: www.elsevier.com/locate/fm

Meat sources of infection for outbreaks of human trichinellosis

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ARTICLE INFO

Article history:
Received 4 August 2016
Accepted 21 December 2016
Available online 22 December 2016

Keywords:
Human trichinellosis
Trichinella spp.
Meat sources

ABSTRACT

Trichinellosis is one of the most important foodborne zoonotic diseases, with worldwide distribution. While human risk for trichinellosis has historically been linked to pork, modern pork production systems and slaughter inspection programs have reduced or eliminated pork as a source for trichinellosis in many countries. While pork may no longer pose a significant risk for trichinellosis, many other animal species may be hosts for *Trichinella* species nematodes and when human consume meat from these animal species, there may be risk for acquiring trichinellosis. This review article describes the various non-pork meat sources of human trichinellosis outbreaks, where these outbreaks have occurred and some of the factors that contribute to human risk. The literature reviewed here provides evidence of the persistence of *Trichinella* as a human health risk for people who eat meat from feral and wild carnivores and scavengers, as well as some herbivores that have been shown to harbor *Trichinella* larvae. It points to the importance of education of hunters and consumers of these meats and meat products.

Contents

1. Introduction

Trichinellosis, a serious and sometimes fatal human disease, is a foodborne zoonotic disease with worldwide distribution. It is caused by the larval stage of tissue-dwelling nematodes of the genus *Trichinella*. Transmission to and survival of *Trichinella* spp. in various hosts occurs through the ingestion of infected meat, mainly through predation or scavenging of meat from an infected animal

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http://dx.doi.org/10.1016/j.fm.2016.12.012
0740-0020/

(Foreyt and Abbott, 2013). Human infection results from consumption of raw or improperly cooked meat containing infective larvae (Pozio, 2015) and it has historically been associated with pork. The course of human infection can be divided into two phases including an intestinal phase and a muscular phase. The main clinical symptoms are diarrhea and abdominal pain in the first stage (intestinal phase) and fever, myalgia, myocarditis, allergic reactions, in particular facial oedemas and encephalitis in the second stage (muscular phase) (Bruschi and Dupouy-Camet, 2014; Faber et al., 2015; Gottstein et al., 2009).

Trichinellosis outbreaks have been reported in 55 countries with an annual global average of 5751 cases and five deaths (Devleesschauwer et al., 2015; Murrell and Pozio, 2011; Pozio, 2007). It is estimated that the global number of disability-adjusted life years (DALYs) due to trichinellosis be 76 per billion persons per year (95% credible interval: 38–129) (Devleesschauwer et al., 2015).

Significant costs are incurred in the prevention of human infection resulting from pork and pork products. It is estimated that the annual cost linked to post-mortem inspection of pigs is approximately US$ 570 million in Europe (Murrell and Pozio, 2000). Additional costs are incurred through processing methods (freezing, cooking, curing) used to inactivate *Trichinella*. Assurances of the safety of pork and pork products relative to *Trichinella* are a major issue in many international trade agreements.

Heretofore, nine species and three genotypes have been documented in the genus *Trichinella* (Bruschi and Dupouy-Camet, 2014; Mitreva and Jasmer, 2006). These *Trichinella* species and genotypes and their epidemiological and biological features are shown in Table 1. Detailed reviews on the history, life cycle, genome, immunology, treatment and the worldwide status of *Trichinella* spp. are available in various publications (Bruschi and Dupouy-Camet, 2014; Bruschi et al., 2002; Foreyt and Abbott, 2013; Gottstein et al., 2009; Mitreva and Jasmer, 2006; Pozio, 2001, 2007).

While *Trichinella* has historically been associated with pork (responsible for 64% of reported outbreaks), in many countries human infection more commonly results from exposure to infected meat of other animals, notably wild boar and bear. These animals pose a high risk for exposure to *Trichinella* based on their eating habits. Human *Trichinella* infection has also been associated with meat from animals which would not typically be considered at risk for harboring *Trichinella* spp. These include horses, and other some other herbivores. While *Trichinella* can develop in many herbivorous, carnivorous and omnivorous animals, routes of natural exposure in herbivores, for example, are not obvious.

The risk of human exposure to *Trichinella* is also influenced by eating habits. People in different cultures and religions consume various type of meat from non-traditional food animals. Meats from many of these animals could be sources of infection in humans.

While improved pig production systems and meat inspection make it possible to reduce or eliminate trichinellosis resulting from ingestion of pork, risk remains for consumers of wild game meats and other meat animals species which may harbor *Trichinella* and for which proper processing or preparation methods are not followed. In this paper, we review non-pork meat sources of outbreaks of human trichinellosis in different areas of the world.

2. Wild boar meat as a source of human trichinellosis

Wild boars are indigenous in many countries and have broad geographic distribution that includes mountainous regions, semi deserts, forest areas and wetlands (Sales and Kotrba, 2013). During the mid-20th century, a dramatically increase was observed in the overlap of the range of wild boars with humans and domestic animals due to changes in human habitation and agricultural practices and rapid growth of world populations (Meng et al., 2009). Wild boars meat harbors many important pathogens that are transmissible to humans, including *Trichinella*. Recreational hunting of wild boars and consumption of wild boar meat in different parts of the world have increased the risk for human exposure to *Trichinella* from wild boar meat (Meng et al., 2009).

Wild boar meat is currently the second most important source of human trichinellosis and has been responsible for many human outbreaks reported in recent years in Europe, Asia, and North and South America (Table 2). Hunters, their families and friends are at high risk of acquiring trichinellosis after consumption of wild boar meat, especially when meat is prepared without proper cooking (Pozio, 2015). Sausages made with meat from domestic pigs mixed with contaminated meat from infected wild boar have also been a source of human infection (Pozio, 2015). *T. spiralis*, *T. britovi* and *T. papuae* are the main species responsible for human outbreaks of trichinellosis related to wild boar meat consumption (Table 2). Franssen et al. (2016), using a Quantitative Microbial Risk Assessment (QMRA) have demonstrated that consumption of wild boar meat is responsible for 55% of modeled cases of human trichinellosis. According to their assessment, *Trichinella* prevalence in wild boar is 4100 times higher than in pigs from non-controlled housing.

3. Horsemeat as a source of human trichinellosis

Horsemeat is considered as a good dietetic alternative for red meat; however, global consumption is very low (Lorenzo et al., 2014). Based on the information provided by the Food and Agriculture Organization of the United Nations (FAO), horsemeat production represents 0.25% of the total worldwide meat production (Belaunzaran et al., 2015; FAO, 2015).

Horsemeat has been responsible for 16% of human trichinellosis outbreaks reported in the literature (Bruschi and Dupouy-Camet, 2014). Between 1975 and 2005, 15 horsemeat-related outbreaks of trichinellosis involving at least 3200 people occurred in France and Italy, two countries with the largest per capita consumption of horsemeat. These outbreaks occurred despite veterinary controls implemented in 1985 (Boireau et al., 2000; Pozio, 2001, 2015) (Table 3). Of these human outbreaks, eight occurred in France involving 2296 people and seven occurred in Italy involving 1038 people; five patients died in France in 1985 (Pozio, 2015). Curiously, the regions in Italy where these outbreaks occurred were historically interested by the French domination which probably has introduced the habit to consume raw horsemeat. The countries of origin of the infected horsemeat causing the outbreaks were reported to be Eastern European countries including Yugoslavia, Poland, Serbia and Romania and from North America including Canada, Mexico and USA (Table 3) (Boireau et al., 2000; Pozio, 2015).

Globally, the prevalence of *Trichinella* in slaughtered horses appears to be very low, however a single infected horse carcass can infect hundreds of consumers if it is not well cooked before consumption. The muscles from the head of the horse including the *Musculus buccinator*, *Lingua*, *Musculus levator labii maxillaris*, and *Musculus masseter* are preferred sites for settlement of *Trichinella* spp. larvae, even more than diaphragm muscle (Pozio, 2001). The head of a *Trichinella* infected horse was the source of a human outbreak in Italy in 1998 (Tamburrini et al., 2001).

T. spiralis, which is the predominant species involved in the domestic cycle of transmission, is the major species responsible for human outbreaks of trichinellosis associated with horsemeat consumption. Horsemeat-related outbreaks of trichinellosis due to *T. britovi* and *T. murrelli*, species found in the sylvatic cycle, have also been reported (Dick et al., 1990; Gill, 2005; Pozio et al., 1987).