

## *Trichinella britovi* as a risk factor for alternative pig production systems in Greece and Europe

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### Abstract

Trichinellosis is an important zoonosis and the most common source of human infection is meat from pigs and wild boars. The European Union (EU) supports alternative pig production systems (organic and free-ranging) as sustainable farming systems. However, these systems that allow outdoor access for farm animals, may create new or reintroduce old risks to public health. During the last years, alternative pig production systems (free-ranging or organic pig) are growing in popularity in Greece due to the increasing interest of consumers for organic products. The majority of the trichinellosis outbreaks in the EU were associated with pork and meat products including wild boars. In Greece, from 2009 to 2012, 37 *Trichinella* spp. positive free-ranging pigs were reported in free-ranging pig farms of Northern-Eastern Greece (31 were identified as *T. britovi*). The recent re-emerging present of the *Trichinella* spp. infections in free-ranging pigs and wild boars are a high risk for the consumers and should alarm the Public Health Authorities in Greece and the EU. During the last years, the organic or free-ranging pig production systems are growing in popularity in the EU. However, these systems increase the risk of *Trichinella* spp. infections, since pigs are possible to be infected by feeding on carcasses or the offal of hunted or dead wild animals. For this reason, it is important for Public Health Authorities to be focused on the training of hunters and farmers in order to avoid the transmission among free-ranging pigs and prevent the cases of human infection.

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### Introduction

Trichinellosis is an important food-borne parasitic zoonosis worldwide and the infection occurs due mainly to the consumption of raw or insufficiently cooked meat of different animal species infected with parasites of the genus *Trichinella*.<sup>1,2</sup> The most common source of human infection is meat from pigs and wild boars (*Sus scrofa*). Trichinellosis has declined significantly as a zoonosis; particularly in developed countries where a reduction of the domestic cycle was observed in the last decades.<sup>3</sup> It remains, however, a potential risk because of the still existing presence of most species of *Trichinella* in wild animals. A large biomass of the parasite continues to exist in developing countries of Central and South America, Europe, and Asia, where the human population movement from the country is increasing.<sup>3</sup> For example, this important demographic factor is responsible for trichinellosis

emergence in some urban areas in China, where the demand for pork is increased, particularly in insufficiently cooked meat dishes such as meat dumplings.<sup>4</sup>

**Pork market from alternative pig production systems and wild boars.** The European Union (EU) supports alternative pig production systems (organic and free-ranging farming) as sustainable forms of agricultural production, providing public goods such as animal welfare, environmental protection, increased biodiversity and contributing to rural development.<sup>5</sup> Generally, the popularity of products from alternative production systems for modern consumers is based on a value-based motivation for environmentally friendly products, ensuring at the same time a high level of animal welfare. Alternative production systems (outdoor, free-range or organic) are widely believed to provide better quality products, even though their real benefits for the environment, animal welfare, and product quality are sometimes

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controversial.<sup>6-8</sup> These alternative production systems that allow outdoor access for farm animals, may create new or reintroduce old risks to public health.<sup>9</sup> However, the outdoor housing arises public health awareness as it is more risk of transfer of zoonotic pathogens to livestock and thus can affect food safety and public.<sup>10,11</sup>

Wild boar meat is traditionally consumed in Europe and Asia and is mainly obtained as a by-product of sport hunting. Therefore, the availability of fresh products is seasonal. Nowadays, there is a growing interest in the production and marketing of wild boar meat and to attend a differentiated consumer demand, the quality attributes of this product should be well established. Wild boar have been increasing in numbers for the last three decades in Europe.<sup>12,13</sup> Several factors such as the absence of natural predators, climate change, rural depopulation, expansion of forest areas and spread of game-managed areas, promoted a widespread intensifying of wild boar densities.<sup>14</sup> Consequently, during the last 10 years, the total wild boars harvest increased by almost 70.00%, with a consistent increase in their meat availability.<sup>15</sup>

#### **The current situation in Greek pork market.**

Alternative pig production systems (free-ranging or organic pig farming) in Greece are growing in popularity over the last years due to the increasing interest of consumers for organic products. The national Greek projects of organic pig farming started in 2002 and since then they have increased, representing 15.00% of the total organic livestock production. Initially, in 2002 launched the program in organic pig farming in our country, joined by producers of Western Greece, Central Greece (Thessaly), North Greece (Central Macedonia) and Crete.<sup>16</sup>

However, a significant reduction has been noticed since 2012, mainly due to the Greek economic crisis and the national funding cuts for organic pig farming. Moreover, in many cases the training and specialization of organic pig farmers and their investments on modernization and equipment/housing facilities were insufficient, resulting in animal health problems, poor growth performance, poor carcass quality and high-cost production.<sup>17</sup>

Based on the official data of Greek authorities (Greek Milk and Meat Organization - Elogak) for the year 2017, the total number of slaughtered pigs from free-ranging pig farms was 1,719 animals in a total number of slaughtered 1,144,723 pigs.<sup>18</sup>

In Greece, wild boar is a native species with a wide distribution in all over the continental part of the country.<sup>19</sup> Its population density has increased in many areas, especially those with shrublands, agroforestry formations in combination with cultivations (cereals). Wild boar is one of the most popular big-game species in Greece with an increasing interest from hunters and can be found in many habitat types.<sup>20</sup>

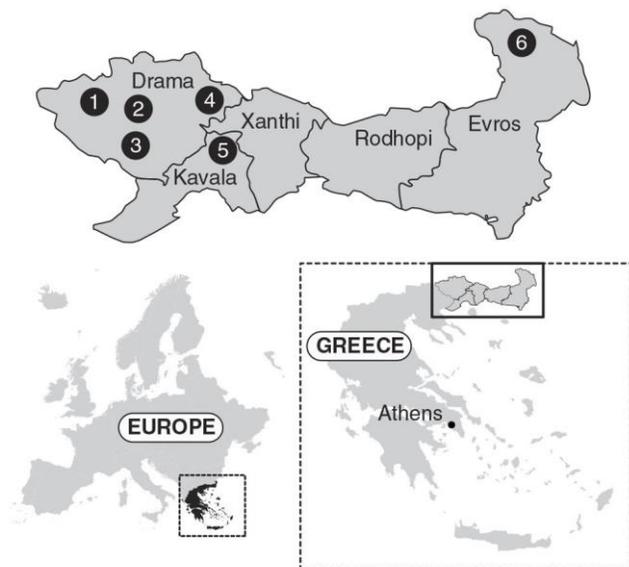
**Human trichinellosis in Europe.** Trichinellosis is a rare but serious human disease in the EU and European Economic Area (EEA). In Europe, four out of 12 recognized species and genotypes of *Trichinella* including *Trichinella spiralis*, *Trichinella britovi*, *Trichinella nativa*, and *Trichinella pseudospiralis* circulate in carnivores such as red foxes, wolves, lynxes and bears, and in omnivores such as wild boars and raccoon dogs.<sup>21</sup> Meat originating from wild boars and pigs under non-controlled housing conditions is the most important source for trichinellosis outbreaks in humans.

For 2017, 15 EU/EEA countries reported 224 cases of trichinellosis, of which 168 cases were confirmed.<sup>22</sup> Bulgaria reported the highest notification rate in the EU/EEA (0.77 cases per 100,000 population), followed by Croatia (0.51), Lithuania (0.32), and Romania (0.24).<sup>22</sup> The overall EU/EEA notification rate was 0.03 cases per 100,000 populations in 2017, increased by 50.00% compared to 2016. Moreover, five countries reported 14 trichinellosis cases as travel-related: two were associated with travel outside the EU/EEA, four with travel within the EU/EEA and eight with unknown travel destinations.<sup>22</sup> The majority of the trichinellosis outbreaks in the EU/EEA during 2017 (due to *T. spiralis* and one due to *T. britovi*) were associated with pork and meat products including wild boar.<sup>23</sup> Consumption of undercooked meat from pigs farmed under non-controlled housing conditions or hunted wild boars constitutes the highest risk for acquiring trichinellosis in the EU/EEA. The recurring peak in trichinellosis cases in January and February may reflect the consumption of various pork products during the Christmas period and the wild boars hunting season.<sup>24</sup> *Trichinella* is commonly detected in wildlife and cases related to hunting may account for higher notification rates observed among adult males. Investigations into domestic pig *Trichinella* infections in EU members identified direct (free-range pigs) and indirect (e.g., farmers who hunted) contacts with wild animals, which are reservoirs of these zoonotic nematodes, as sources of domestic pig infections.<sup>25</sup> In Lithuania, consumption of infected and uninspected pork from small farms accounted for 57.60% of human trichinellosis outbreaks from 2008-2017, and consumption of infected wild boar accounted for 33.30%. For the remainder the source was unknown.<sup>26</sup> In Bulgaria, the consumption of infected wild boar was the main cause of outbreaks in 2013 and 2014, followed by the consumption of infected domestic pig meat.<sup>27</sup>

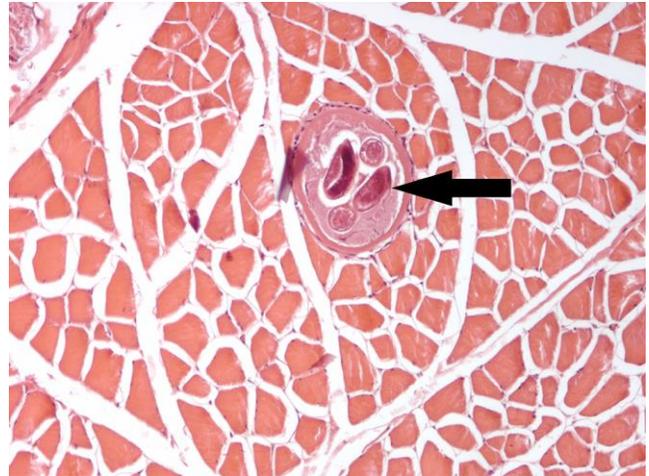
**Current situation of trichinellosis in Greece.** After 22 years, *Trichinella* spp. infections re-emerged in free-ranging pigs and humans in Greece.<sup>17,28</sup> In Greece, human trichinellosis was documented for the first time at the end of World War II.<sup>29</sup> The last human outbreak of trichinellosis involved 14 people in North Greece in 1982.<sup>30</sup> Since then and up to 2009, although the consumption of pork meat considerably increased, it was

believed that trichinellosis had no impact either on the pig industry or public health, due to the lack of *Trichinella* spp. infections in pigs documented by routine testing.<sup>17</sup> In 2009, *Trichinella* spp. infection was documented in two free-ranging pigs from two farms located in the Kavala and Evros counties (Northern Greece).<sup>17</sup> Out of 12,717 free-ranging pigs tested from 2009 to 2012, 37 (0.29%) were found positive for *Trichinella* spp. larvae. The 37 infected pigs were originated from free-ranging farms of three counties (Drama, Evros, and Kavala) in Northern-Eastern Greece (Fig. 1). This is a mountainous area close to the border with Bulgaria where *Trichinella* spp. are circulating with a high prevalence in wildlife.<sup>31,32</sup> The prevalence of *Trichinella* spp. infections in free-ranging pigs increased over the 4 years of sampling ( $p < 0.001$ ). *Trichinella* spp. were not detected in any of 4,521,940 indoor pigs of Greece nor 232 hunted wild boars subjected to routine testing.<sup>28</sup> Larvae from 31 animals out of 37 *Trichinella* spp. positive free-ranging pigs were identified as *T. britovi* (isolate codes were ISS4315-ISS4328 and ISS4557-ISS4570), (Fig. 2).<sup>28</sup> *Trichinella* spp. larvae isolated from six pigs from farms located in the Evros county in 2009 and 2010 were not available for molecular identification.

In a recent study in Greece, serum samples were collected from 94 European wild boars (*S. scrofa*) during the hunting seasons of 2006-2010 from different regions of Greece.<sup>33</sup> The researchers indicated antibodies against *Trichinella* species in 6.40% of the samples. Moreover, the first identification of *T. britovi* in human from Northern Greece was reported in 2017.<sup>34</sup>



**Fig. 1.** Map of Greece showing the villages of the farms where *Trichinella* spp. positive pigs were detected in 2009 (farm No. 5 in Kavala county and farm No. 6 in Evros county), in 2010 (farm No. 6 in Evros county), in 2011 (farms 1, 2, 3 and 4 in Drama county) and 2012 (farms 2, 3 and 4 in Drama county).



**Fig. 2.** *Trichinella britovi* larva detected in the muscle tissue (arrow) from an infected free-ranging pig in Greece (H & E, 10 $\times$ ).

#### ***Trichinella britovi* as a risk factor for alternative pig production systems and public health.**

Trichinellosis is an important food-borne parasitic zoonosis with a yearly incidence of about 3000 clinical cases worldwide in the last decades.<sup>35</sup> Among sylvatic species, *T. britovi* has a wide geographical range, occurring in the wildlife of the temperate areas of the Palearctic region, from the Iberian Peninsula to Kazakhstan and extending southward to Northern and Western Africa.<sup>36-38</sup>

The *T. spiralis* and *T. britovi* are the two most common species of *Trichinella* circulating in Europe.<sup>39</sup> In *Trichinella* spp. infected domestic pigs and wild boars of Europe, *T. britovi* accounts for 20.30% and 43.80% of the infections, respectively.<sup>40</sup> In most countries, *T. britovi* is more widespread than *T. spiralis*, even if *T. spiralis* and *T. britovi* circulate in the same environments: 41.10% and 46.00%, respectively, in agricultural areas, and 45.50% and 46.60% in forested and semi-natural areas.<sup>39</sup> Great numbers of a human case of trichinellosis were caused by this parasite in Europe (e.g., Spain, France, Italy, Greece, Romania, Bulgaria, and the Slovak Republic) mainly by the consumption of wild boar meat, pork from the backyard or free-ranging pigs, horses and rarely by the consumption of meat from carnivores (fox, dog, and jackal).<sup>28,31,35,38,41-45</sup>

Although *T. spiralis* and *T. britovi* can be transmitted by domestic and sylvatic cycles, their epidemiology is strongly influenced by the higher adaptability of *T. spiralis* to swine and of *T. britovi* to carnivores.<sup>21,39</sup> The identification of the etiological agent of *Trichinella* spp. infection as *T. britovi* is a hallmark that the infection originates from wildlife. *T. britovi* is the most important species circulating in European wildlife, mainly in carnivore mammals, but in omnivores.<sup>39</sup> However, it has also been proved that the sylvatic cycle may be influenced by human actions. The common habit of hunters to leave animal carcasses in the field after skinning or removing and discarding the entrails increases the probability of

transmission to new hosts.<sup>46</sup> Furthermore, *T. britovi* can also be transmitted from one to other farmed pig when the owners slaughter pigs in the backyards or on the field, without any veterinary control and use pork scraps to feed other pigs or discard the entrails on the field.<sup>39</sup>

Wild boars (*S. scrofa*) are indigenous in many countries in the world and they have known reservoirs for several viruses, bacteria, and parasites being transmissible to domestic animals and humans. Changes of human habitation to suburban areas, increased use of lands for agricultural purposes, increased hunting activities and consumption of wild boar meat have increased the chances of exposure of wild boars to domestic animals and humans. The recent rapid demographic expansion of wild boar (*S. scrofa*) all over Europe including Greece, may influence the epidemiology of various pathogens that can affect not only livestock but also humans being transmitted and spread by various routes.<sup>33,47</sup> Based on the data of recent studies in Greece, there is a substantial risk of mutual transmission of pathogens between the wild boars and the free-ranging swine populations.<sup>33,47</sup>

In Greece, the recent reports of *T. britovi* infections in free-ranging pigs as well as the report of *T. britovi* infection in human, arise the *T. britovi* as a high-risk factor for the alternative pig production systems.<sup>17,28,34</sup>

## Discussion

The recent re-emerging present of the *Trichinella* spp. infections in free-ranging pigs and wild boars are a high risk for the consumers and should alarm the Public Health Authorities in Greece and EU/EEA. The different risks to acquire *Trichinella* spp. infections between pigs from organic and industrial farms were already stressed by Alban *et al.*, suggesting that focusing all efforts to control *Trichinella* spp. infections only in free-ranging and backyard pigs strongly reduce the costs of control.<sup>49</sup> Through improper farm management, poor hygienic standards or illegal practices, domestic pigs can become infected with *T. spiralis*, *T. pseudospiralis*, and *T. britovi*.<sup>50-53</sup> The *T. spiralis* may be less widely distributed in Northern European countries and the distribution range of *T. britovi* may be concentrated in Eastern European countries.<sup>54</sup> Increasing numbers of wild boar and red foxes as well as the spread of the raccoon dog from Eastern to Western Europe and jackal from Southeastern to North-Western Europe may increase the prevalence of *Trichinella* circulating among wild animals.<sup>23</sup>

In Greece, there was a co-incidence of the increase of free-ranging pigs population between 2006-2011 (Table 1) and the positive results for *T. britovi* in samples<sup>17,28</sup> being tested for *Trichinella* spp. at the slaughterhouses or at the National Reference Laboratory for Parasites of Greece. In countries where the density of wild boars is low and the pig industry follows modern hygiene standards,

the *Trichinella* species transmission cycle is blocked.<sup>54</sup> Unfortunately, a high percentage of wild boars are hunted for their own consumption, do not enter into the official market, and escape the veterinary controls, thus causing infections in humans.<sup>42</sup> Based on hunting bag estimates, the number of wild boars in Greece is increasing year by year and during the last hunting season, it exceeds 25,000 individuals.<sup>33</sup> For this reason, there is a need to educate hunters on the importance of the systematic examination for *Trichinella* spp. larvae of game intended for human consumption to prevent human infection. Furthermore, veterinary services should educate hunters not to spread game carcasses or their scraps and offal in the environment and should organize a system for a proper collection and disposal of these biological samples.<sup>53</sup>

**Table 1.** Number of free-ranging pigs reared in organic farms in Greece during 2002-2017.

Year	Total number of pigs
2002	1,288
2003	3,628
2004	4,469
2005	126,003
2006	110,096
2007	175,004
2008	60,918
2009	54,631
2010	42,991
2011	28,665
2012	6,292
2013	4,797
2014	4,664
2015	4,203
2016	4,710
2017	4,434

Source: Directorate of Organic Agriculture, Hellenic Ministry of Rural Development and Food<sup>48</sup>

The alternative pig production systems (free-range pig farming or organic pig farming) are a more welfare-friendly production and it seems to be a very promising agricultural business.<sup>56,57</sup> Many consumers expect that the pork meat from free-range pig farms to be healthier, with better nutritional value and quality than conventional pork.<sup>58</sup> The environmental concerns surrounding intensified, industrialized production (and its attendant wastes) also drive interest in returning to more traditional forms of husbandry. However, the increasing interest in organic pig farming may bring drawbacks and needs to be tackled with new aspects for preventing *Trichinella* spp. infections.<sup>36</sup> The design of this new animal production system (with outdoor access) requires both a thorough analysis of possible risks and optimal communication of these risks throughout the food chain and appropriate partitioning of responsibility concerning these risks.<sup>59</sup>

During the last years, the organic or free-ranging pig production systems in Greece are growing in popularity due to the increasing interest of consumers for products

considered as traditional. However, this system of pig production increases the risk of *Trichinella* spp. infections, since pigs are possible to be infected by feeding on carcasses or the offal of hunted or dead wild animals. For this reason, Greek Public Health Authorities should focus on the training of hunters and farmers to avoid transmission among free-ranging pigs and prevent the cases of human infection.

Despite the EU directive, which requires wild boars hunted for commercial purposes to be examined for *Trichinella* spp., an infection risk for humans remains due to important reservoirs (wild carnivore mammals).<sup>5,60</sup> In countries where the prevalence of *Trichinella* in wildlife or domestic pork is still high, strict application of EU regulations and adequate control in slaughterhouses might be appropriate. To ensure food safety of products from alternative pig productive systems, monitoring and controlling risk factors for diseases are suggested, as well as the implementation of health herd management based on a Hazard Analysis and Critical Control Points system.<sup>61</sup> All the above is an option requiring a good interaction between the public health sector and the corresponding veterinary sector.<sup>2</sup> Veterinarians' awareness of the features suggestive of trichinellosis, particularly in clustered cases, can hasten early diagnosis, prevent complications and even lead to administration of effective post-exposure preventive measures in other potentially exposed persons. Finally, it is important for authorities to expand the consumer education and particularly the recognition that pork or pork products should be cooked before the consumption.

### Conflict of interest

The authors declare no conflict of interest.

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