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TRICHINELLOSIS OF WILD ANIMALS IN UKRAINE AND ITS DANGER TO THE PUBLIC

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Trichinellosis of Wild Animals in Ukraine and its Danger to the Public. Akimov, I. A., Didyk, Yu. M. — Trichinellosis is one of the most dangerous helminthic diseases common to humans and animals. It is caused by the nematodes from the *Trichinella* complex. *Trichinella* infections found in almost all mammal species, as well as reptiles and birds. In Ukraine *Trichinella* infection was detected in humans, domestic pigs and games. More than 1500 cases of human trichinellosis were found in Ukraine over the past 30 years. Infected game is the main source of human *Trichinella* infection in recent time.
Trichinella infection detected in all regions of Ukraine. Larvae were found in 3 % of investigated wild boars, 15.5 % wolves, 16 % red foxes, 12 % martens, 10 % badgers and 20 % raccoon dogs. Wolves and foxes were found to be the main reservoir of *Trichinella* in a sylvatic cycle. Our studies demonstrate the presence of tree species of *Trichinella* in Ukraine: *T. britovi* (ITRC codes: ISS1590, 1591, 1592, 1593) was found in wild boars, wolves, foxes and martens in all Ukraine; *T. spiralis* (ISS1594) was found in wild boars from Zhytomir and Mykolaiv Regions; *T. nativa* (ISS1595) was found in wolves and foxes from Chernihiv, Sumy, Poltava and Kherson Regions. Mixed infections (*T. britovi–T. spiralis)* were found in southern regions.
Key words: Thichinellosis, natural foci, Ukraine, *Trichinella nativa, T. britovi, T. spiralis.*

Trichinellosis is a globally important food-borne helminthic disease common to humans and animals. It is caused by the nematodes of the *Trichinella* complex. *Trichinella* infects almost all mammal species, as well as reptiles and birds (Gamble, 2000). Up to now, *Trichinella* is a complex of 13 species and genotypes. Based on molecular phylogenetic analyses, the encapsulated clade of *Trichinella* includes 7 species: *T. spiralis* (T1), *T. nativa* (T2), *T. britovi* (T3), *T. murrelli* (T5), *T. nelsoni* (T7), *T. patagoniensis* (T12), *T. chanchalensis* (T13) and three genotypes with unknown classification *Trichinella* T6, T8, and T9. The non-encapsulated clade includes 3 species: *T. pseudospiralis* (T4), *T. papuae* (T10) and *T. zimbabwensis* (T11) (Pozio, Murrell, 2006; Sharma et al., 2020). The agent of *Trichinella* was found in the muscle tissue of a sick person for the first time at the beginning of the

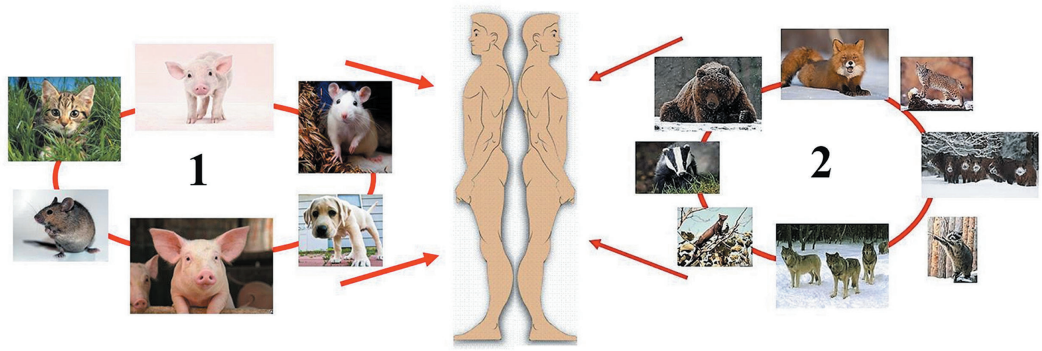

Fig. 1. The domestic (1) and the sylvatic (2) cycles of *Trichinella* in Ukraine.

19th century (Murrell et al., 2000). However, the biological cycle of *Trichinella* was only more or less understood only fifty years later. It was proved that infection occurs after eating *Trichinella*-infected meat or meat products. Trichinellosis is a worldwide anthropozoonosis prevalent in a countries of Europe (mainly Eastern Europe), South-East Asia, North and South America, New Zealand and North Africa. (Troiano, Nante, 2019). Outbreaks have been reported in 55 countries with an annual global average of 5751 cases and five deaths (Rostami et al., 2017).

The biology of *Trichinella* is fully adapted to obligate parasitism inside of an animal organism, with the same animal serving as a definitive host (intestinal trichinellosis) and as an intermediate host (muscular trichinellosis) of the helminth. Trichinellosis is acquired by ingesting meat containing *Trichinella* larvae (fig. 1).

In the stomach, the parasitic capsule (fig. 2), of encapsulated species, dissolves under the influence of gastric fluids, and *Trichinella* larvae enter the intestinal, where they actively penetrate the mucous membrane within an hour. Within a few days after infection, the females release larvae that migrate to the striated muscles where they encapsulated. This process can last from ten to thirty days. The female of *T. spiralis* gives birth to 2000 larvae that enter the circulatory system and spreading throughout the body. Further development of *Trichinella* occurs in the striated muscle tissue only. In two or three weeks after infection, new larvae become infectious, and their host becomes a dangerous source of infection for other individuals (Kapel et al., 1998; Gamble, 2000; McIntyre et al., 2007; Pozio, 2015).

Significant simplification of the *Trichinella* life cycle is the reason for their spreading to all continents. Only 20 % of the countries are free from trichinellosis. Generally, these are the small islands lacking the reservoir animals. The parasites have adapted to an extremely wide range of hosts. More than 150 species of mammals, as well as some reptiles and birds, are susceptible to *Trichinella* (Gamble, 2000; Pozio, 2007).

The pathogenic effect of *Trichinella* on the host organism is due to the harmful effects of metabolism products, as well as symbionts and associated microbiome. For humans, the clinical picture is fever, oedema, abdominal and muscular pain. The severity of the illness depends on the infection intensity. Lethal complications are possible due to the development of sequelae such as pneumonia, myocarditis, and meningoencephalitis induced by *Staphylococcus* symbionts. Specific therapy for the trichinellosis is not developed. Active therapy with large doses of anthelmintic drugs along with steroid hor-

Fig. 2. *T. britovi* larvae in wolf muscle tissue.

mones is used for the treatment of the early stages of human trichinellosis. However, the toxic and allergic reactions are often exacerbated, as well as antioxidant processes in the blood can be violated during treatment. So, hemolysis and impaired microcirculation can be provoked, which would make the clinical picture of infection worse. Treatment for animal trichinellosis is not been developed (Gamble, 2000; McIntyre et al., 2007; Pozio, 2015). The economic losses from animal trichinellosis are significant around the world and in Ukraine.

In Ukraine, 3 species of *Trichinella* have been identified in mammals over the past 15 years (Akimov et al., 2005; Akimov, Didyk, 2017; Akimov, Didyk, 2018). *Trichinella spiralis* is the first described, cosmopolitan, widespread species of *Trichinella*. It is the main etiological agent of trichinellosis in humans in Europe and worldwide (Pozio, 2019). It is likely that this species originated in East Asia, where its genetic variability is much higher than in other areas (Pozio, Murrell, 2006). Scientists believe that *Trichinella* spreads with domestic pigs and rats (*Rattus norvegicus*) and human migration around the world (Murrell et al., 2000; La Rosa et al., 2003). *T. spiralis* is not adapted to low ambient temperatures, so it is spreading slower in cold climate wildlife. *T. britovi* is the most common species of *Trichinella* in the wild animals of the moderate biomes of the Palearctic region (Murrell et al., 2000; Pozio, Murrell, 2006). This species is mainly typical for carnivores (e. g., bear, wolf, fox, marten, raccoon dog, lynx etc.). *T. britovi* associated with human disease resulting from the ingestion of undercooked game meats in Spain, France, Italy, Greece, Romania, Bulgaria and the Slovak Republic (Pozio, 2016). The area of *T. nativa* includes Arctic and Subarctic zones of the Holarctic region above the 45th parallel. *T. nativa* affects wild carnivores and marine mammals mostly. According to literature data, *T. nativa* larvae in muscle tissues can endure freezing for up to 5 years. The pathogenicity of the species for humans is extremely high (Kapel et al., 1998; Murrell et al., 2000; Pozio, 2016). Carnivores are the main reservoir of *T. nativa*. The parasites are able to survive more than 20 years in their muscular tissue (Kumar et al., 1990). *T. nativa* is an important etiological agent of trichinellosis for the low-temperature climate areas, where people consume raw meat of marine mammals and bears traditionally (Moller et al., 2005).

Trichinella prevalence in Ukraine

The important source of *Trichinella* sp. infection for humans in Ukraine remains pork and game. According to the State Research Institute for Laboratory Diagnostic, Veterinary and Sanitary Examination, more than 1000 domestic pigs infected with *Trichinella* larvae were identified over the past 20 years (Reports of the CVL of Ukraine, 1986–2018). According to the official data of the Sanitary and Epidemiological Station of Ukraine, more than 1500 people were infected with trichinellosis over the past 30 years in Ukraine (Reports of the CSE of Ukraine, 1986–2018). According to our research in 2002–2018, *Trichinella* spp. found in all regions of Ukraine (Akimov, Didyk, 2018). *Trichinella* was detected in 3 % of wild boars, 15.5 % of wolves, 16 % of foxes, 12 % of martens, 10 % of badgers and 20 % of raccoon dogs (Didyk, Akimov, 2016; Akimov, Didyk, 2018). The prevalence of *Trichinella* infection in wild boars is 3 %, and in predators — 16 % (Didyk, Akimov, 2016). For carnivores, the infection intensity ranges from 50 to 300 larvae per gram of muscle tissue (Didyk, Akimov, 2016). These rates are very high. We've identified a growing tendency of infection prevalence for carnivores, over the last 30 years in Ukraine: from 3.5 % in I. A. Kondratyev's studies of 1972–1976 and 8.8 % in N. A. Kulikova's works of 1986–1987, up to 15 % nowadays (fig. 3) (Akimov, Didyk, 2017).

Using modern molecular genetic methods, we demonstrate the presence of three species of the genus *Trichinella* in Ukraine: *T. spiralis, T. britovi* and *T. nativa* (Akimov et al., 2005; Akimov, Didyk, 2016). In the sylvatic cycle, *T. britovi* was found in 96 % of the infected animals, *T. nativa* in 3 % and *T. spiralis* in 1 % of wild animals. Our results

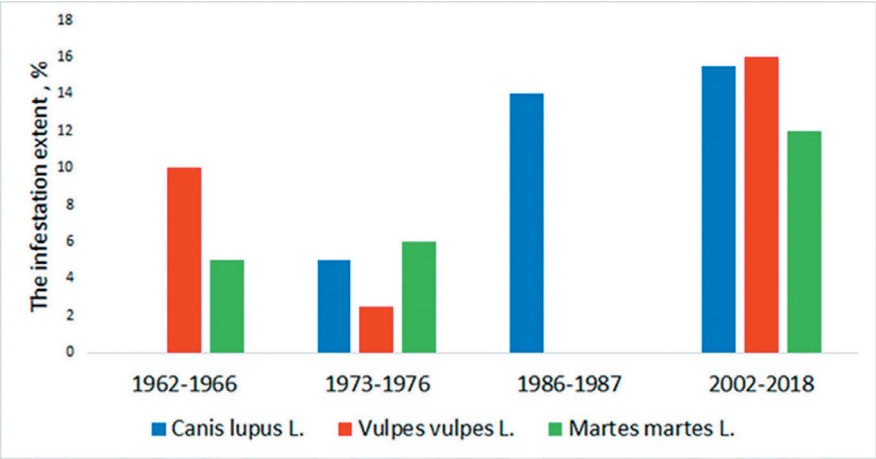

Fig. 3. The infestation extent of wild mammals' trichinellosis in Ukraine.

were confirmed by the International Commission on Trichinellosis (ICT, Italy), adding it to the *Trichinella* global database (*T. spiralis* ISS1594; *T. britovi*: ISS1590, 1591, 1592, 1593; *T. nativa* ISS1595). *T. britovi* is the dominant species in the sylvatic cycle in Ukraine (fig. 4). It was found in all species of wild animals (wild boar, lynx, wolf, fox, marten, raccoon dog and badger).

For the first time, the expansion of *T. nativa* was observed. Among all *Trichinella* species found in Ukraine, this one is the most aggressive against humans. *T. nativa* was detected in Chernihiv, Poltava, Sumy and Kherson Regions in wolves and foxes. *T. spiralis* was found in wild boars in Zhytomyr and Mykolaiv Regions. The cases of mixed infections *T. britovi*–*T. spiralis* were found in carnivores in Kherson Region (Akimov, Didyk, 2016; Didyk, Akimov, 2016).

All *Trichinella* species detected in Ukraine are extremely pathogenic to humans.

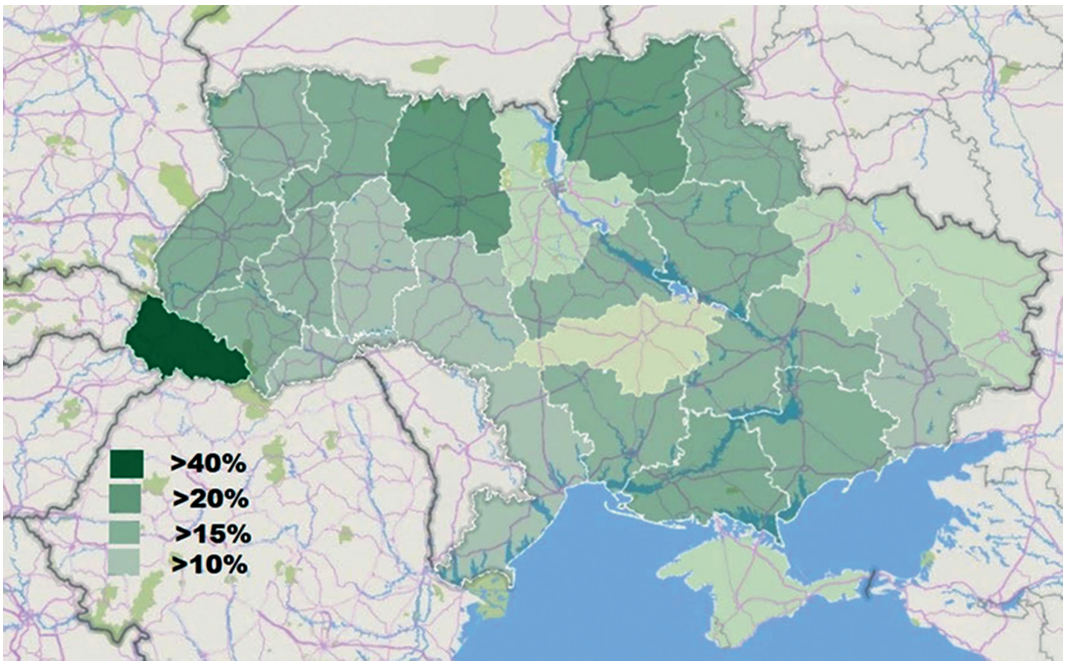

Fig. 4. *T. britovi* occurrence in natural foci of invasion in Ukraine.

The incidence of trichinellosis in Ukraine

There is almost no information about the incidence of human trichinellosis in Ukraine in the current publications (Derbal, 1997; Shelemba, 1999). A. S. Bessonov, the famous researcher of *Trichinella* and trichinellosis, described Ukraine in the early XX century as an area of a stationary synanthropic outbreak of trichinellosis, with the annual mass infestations among domestic swine and mass outbreaks of trichinellosis among the local population (Bessonov, 1970). Vinnytsia, Odesa and Khmelnytskyi Regions were the most dangerous for trichinellosis of pigs. Up to 70 % of animals infected with trichinellosis were annually recorded in these particular areas, as well as the majority of human cases (Bessonov, 1972). From 1946 to 1972, Ukraine ranked second in the incidence of trichinellosis among the population of the ex-Soviet countries. From 40 to 146 cases of human infection were registered annually, the highest number of cases (500–700 patients annually) was recorded in Belarus (Bessonov, 1972; Pavlov, 1972).

The situation changed in the mid-1990s, when the special "Instruction on the diagnosis, prevention and elimination of trichinellosis of animals (No. 23 of May 23, 1995)" was accepted by veterinary medicine experts. Mandatory and strict rules of the disease diagnosis were established in order to prevent infection of humans and animals.

According to the Center for Disease Control and Monitoring of the Ministry of Health of Ukraine, more than 1500 cases of human trichinellosis were recorded in 1986–2018, with the mortality rate of 0.5 %. The figures are very high. The incidence rate of the local population in Ukraine is compared to the "critical one" in Southeast Asia and Africa (Pozio, 2007; Rostami et al., 2017). The largest synanthropic outbreak of trichinellosis related to the consumption of pork meat took place in the Dnipropetrovsk Region (40 % of all cases in the country) in the late XX early XXI century. The level of infection is also high in Mykolaiv, Kyiv, Donetsk, Khmelnytsky and Kharkiv Regions of Ukraine (fig. 5).

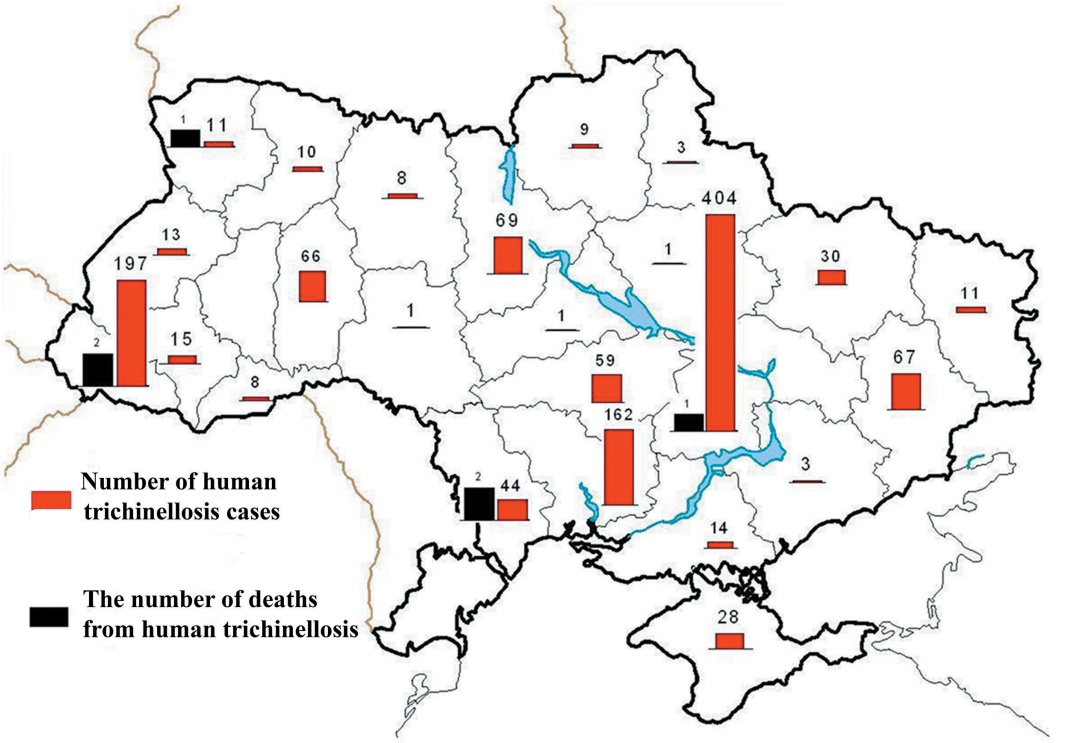

Fig. 5. Frequency of trichinellosis for the population of Ukraine, 1986–2018.

The cases of trichinellosis related to the consumption of infected game were recorded in the Zakarpattia, Odesa, Volyn, Zhytomyr and Kyiv Regions (Reports of the CSE of Ukraine, 1986–2018).

Small but persistent outbreaks of trichinellosis were recorded in Lviv, Ivano-Frankivsk, Chernivtsi, Chernihiv, Cherkasy and Kherson Regions, as well as isolated cases of human infection.

In the European Union, the trichinellosis test of domestic and wild animals and the implementation of measures to prevent infection are given priority. In 2017, 15 EU/EEA countries reported 224 cases of trichinellosis, of which 168 were confirmed and 56 were probable. The overall notification rate was 0.03 cases per 100,000 population. Bulgaria, Croatia and Romania accounted for 73.8 % of confirmed cases. The highest notification rate reported in Bulgaria (0.77 cases per 100,000 population), followed by Croatia (0.51), Lithuania (0.32) and Romania (0.24) (Trichinellosis — Annual Epidemiological Report. 2017). It was found that in 72 % of cases, the human infection was caused by *T. spiralis* and in 28 % by *T. britovi*. Reporting data on the incidence of trichinellosis is mandatory in all European countries it is included in compulsory annual monitoring of zoonoses and zoonotic agents (Directive 2003/99/EC List A). The cases are widely announced and all the necessary measures are taken to prevent the spread of the infection.

Prevention of risk for human trichinellosis

Products derived from pig and wild boar meat remain the most important sources of human trichinellosis. Consuming undercooked meat from pigs or hunted wild animals which have not been tested for *Trichinella* is a main risk factor for trichinellosis in Ukraine. It is vital that relevant information reaches consumers of meat products. According to legislation of Ukraine, it is mandatory for all animals (pig, horse and wild animals) which are potential source of *Trichinella* spp. parasites and are intended for human consumption to be examined for *Trichinella* larvae with one of several approved methods (Instruction on the prevention and control of trichinellosis in animals). The artificial digestion technique is the standard, sensitive, efficient, and cost effective method used to detect *Trichinella* larvae in meat (Rostami et al., 2017; Noeckler et al., 2019).

To help prevent *Trichinella* infection in animal populations, farmers or hunters do not allow pigs or wild animals to eat raw meat, scraps, or carcasses of any animals which may be infected with *Trichinella* larvae.

There are several ways to prevent trichinellosis: cook the meat to a safe temperatures or freeze small pieces of pork for 20 days at –15 °C to kill any worms. Freezing wild game meats, unlike freezing pork products, may not effectively kill all worms because some worm species that infect wild game (*T. nativa*) are freeze-resistant.

Salting, drying, smoking, or microwaving meat alone does not consistently kill infective *Trichinella* worms; homemade jerky and sausage were the cause of many cases of trichinellosis reported in Europe and Ukraine in recent years.

According to official data there were about 50,000 of wild boars and about 10,000 were hunted in 2011, so, 300 animals, or 3 %, could be infected with *Trichinella* (Eger, 2011). Stay away from meat or meat products from domestic and wild animals that have not been tested for *Trichinella*.

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