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Meat Technology — Special Issue 66/3

www.meatcon.rs ▪ www.journalmeattechnology.com

UDK: 616.993

ID: 179218697

https://doi.org/10.18485/meattech.2025.66.3.10

Original Scientific Paper

Meat industry as our best chance for controlling transmission of a tiny but deadly tapeworm

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ARTICLE INFO

Keywords:
Foodborne disease
Livestock
Ungulates
Parasite
Environment

ABSTRACT

Echinoccocosis is a zoonotic disease which can have severe, even lethal consequences for the host, yet multiple effective means of controlling transmission and thus preventing infection, are available. *Echinococcus granulosus* and *E. multilocularis* are the two tapeworm species which are clinically most relevant in Europe and both are endemic in the Balkans. The life cycle of the tapeworm includes intermediate and dead-end hosts, ungulates and humans, as well as definitive hosts, the Canidae and Felidae. Disease caused by *E. multilocularis*, alveolar echinococcosis (AE) is more severe and also difficult to diagnose, especially in animals. Echinococcosis in livestock leads to morbidity and mortality, thereby facilitating economic losses at various levels. Reporting is mandatory, yet under-reporting is a common occurrence as is the failure to identify relevant geographical transmission foci in a timely manner, thus contributing to continuous tapeworm transmission and spread. As echinococcosis is a foodborne disease in animals and humans, the food industry, and particularly the meat industry, are key stakeholders in raising awareness, lobbying government authorities for control measures and improved diagnostics.

1. Introduction

Tapeworms of the genus *Echinoccocus* are endemic in the Balkan region, with *Echinococcus granulosus,* the 'dog tapeworm', presumed to be most frequent. *E. granulosus* is the causative agent of cystic echinococcosis (CE), or hydatid disease, which occurs in domestic and wild ungulates and humans. Echinococcosis is a zoonotic foodborne disease of high significance to public health in Europe (*Bouwknegt et al*., 2018). Aside from *E. granulosus*, which is fairly well known to veterinarians and physicians, the species with the greatest clinical impact currently in Europe is *E. multilocularis,* the 'fox tapeworm', which was detected for the first time in Serbia over a decade ago in an imported beaver (*Ćirović et al*., 2012). Alveolar echinococcosis (AE), the disease caused by *E. multilocularis*, manifests as wide-spread, infiltrative growth which results in tissue lesions and destruction. The first confirmed human case of AE in Serbia was described in 2023, and another in 2024, thus AE may appear to be an

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Paper received Jun 30th 2025. Paper accepted July 18th 2025.
The paper was presented at the 63rd International Meat Industry Conference "Food for Thought: Innovations in Food and Nutrition" – Zlatibor, October 05th-08th 2025.
Published by Institute of Meat Hygiene and Technology – Belgrade, Serbia.

emerging disease (*Lalošević et al*., 2023, *Milošević et al*., 2024). However, echinococcosis has an incubation period of up to 15 years and is difficult to diagnose, which leads to an underestimated case burden and prevalence (*Casulli*, 2020; *Jorgensen et al*., 2008). Treatment is costly and complex; thus transmission control and prevention strategies are critical. To achieve an optimal outcome, the One Health approach must be implemented. In that respect, the meat industry has a vested interest and possesses the necessary economical leverage to push policy makers to enforce existing regulations on prevention, demand diligent reporting, sponsor sophisticated diagnostics and implement active surveillance. This review will highlight the importance of detecting echinococcosis, particularly AE, in food animals, as well as expose key problems in implementing effective transmission control measures proposed by the current legislation.

2. *Echinococcus* tapeworms: Life cycle and transmission

The Canidae and Felidae families are definitive hosts for *Echinococcus* spp., whereas wild and domestic ungulates are intermediate hosts and humans are dead-end hosts. In the intestines of the definitive host, the tapeworm grows into its adult stage and undergoes sexual reproduction to form thousands of infectious eggs, which are shed via feces (*Eckert et al*., 2001). Transmission of eggs occurs via the environment, mediated by soil and water, which facilitates their dispersal in the foodweb. Wild and free-range animals are commonly infected while grazing and possibly drinking from surface water sources contaminated with tapeworm eggs. The eggs reach humans and domestic animals also in trace residues of soil or when directly deposited on plants (vegetables and berries) via spray or foliar irrigation using fecally contaminated water (*Robertson et al*., 2016). A recent European multicenter study demonstrated the presence of *E. multilocularis* and *E. granulosus* eggs on 1.2 % and 1.3 % of tested vegetables and berries, respectively (*Umhang et al*., 2025). Once the eggs are ingested, the tapeworm embryo is released in the intestines. In intermediate and dead-end hosts, the tapeworm cannot develop into its adult form; instead, it penetrates the lamina propria and is transported passively to an internal organ, where it encysts to form the metacestode. Within the cyst, tapeworm larvae reproduce asexually, thereby gradually increasing the size of the cyst. As each larva is a juvenile tapeworm, once a definitive host species consumes an infected intermediate host, the transmission cycle continues (*WHO Team for Control of Neglected Tropical Diseases (NTD)*, 2001).

3. Echinococcosis

Disease begins with the establishment of the metacestode in an internal organ and progresses with cyst growth. The rate of growth is variable and estimates range from 1-50 mm annually in humans with CE (*Brunetti et al*., 2010). The cyst size is only limited by the available space and therefore depends on the localization, but eventually it leads to organ compression and obstruction of physiological processes, which can manifest as various symptoms in humans and animals (*Casulli*, 2020; *WOAH,* 2025). These are usually difficult to interpret and associate with echinococcosis specifically. In animals, CE is almost exclusively diagnosed at slaughter, by visual observation of cysts after evisceration. Unlike CE, the metacestode of *E. multilocularis* infiltrates organ tissue, causes lesions and over time, re-organizes the tissue, much like malignant tumors (*Lundstrom-Stadelmann et al*., 2025). In fact, like cancer cells, the *E. multilocularis* metacestode also has a tendency to metastasize to other organs. Since it is much more aggressive, the outcome for the infected host is uncertain. Due to the unusual disease presentation, even experienced teams in countries with high AE burdens manage to confirm AE in just over half of the human cases (*Grüner et al*., 2017). It is, therefore, likely that AE in animals is hardly ever correctly diagnosed.

3.1 Echinococcosis in food animals

Despite the fact that cysts are not infectious to humans or intermediate hosts, they are a source of infection for definitive hosts. The sanitary codex of the World Organisation for Animal Health (*WOAH*, 2025) mandates the reporting of animal cases of echinoccocosis, a practice which is also legislated by the relevant *Veterinary Law of Serbia* (2019), i.e., *Official Gazette* 91/2005, 2005; *Official Gazette* 30/2010, 2010; *Official Gazette* 93/2012, 2012; *Official Gazette* 17/2019, 2019. While the relevant law and rulebooks outline sound and effective means of discovery of cases and geographical transmission foci, the feasibility of their implementation is questionable (*Serbia*, 2006; *Serbia*, 2024, respectively *Official Gazette* 49/2006, 2006 and *Official Gazette 21/2024,* 2024). A major issue is that abscesses, lesions and other morphological changes in internal

organs are relatively common in food animals, but rarely due to parasitic infections (*Amachawadi and Nagaraja*, 2016; *Valkova et al*., 2023). Thus, a simple visual inspection is often not sufficient to identify echinococcosis (*Amachawadi and Nagaraja*, 2016; *Valkova et al*., 2023). The young age of the majority of slaughter animals (6 months to 3 years) processed at commercial facilities is a confounding factor, as it increases the odds that *E. granulosus* cysts, or lesions due to *E. multilocularis* infection, are not obvious and could be missed by visual inspection. As veterinarians trained in meat inspection are available at commercial facilities, it is certain that any organs with clearly distinguishable morphological changes would be condemned. Thus overall, cases of CE, with which they are more familiar, have a better chance of being detected as opposed to cases of AE, which is of concern. The level of echinococcosis awareness and training in visual inspection of farmers and private individuals who slaugher animals for their own consumption or commercial sale is likely to be inadequate. Thus, they may directly contribute to transmission by failing to inactivate and properly dispose infected offal. Illegal dumping of animal remains and livestock carcasses is a recognized problem in Serbia, while it is impossible to evaluate the extent of the practice of feeding raw offal to dogs.

3.2 Echinococcosis prevention

The most effective transmission control action for echinococcosis is deworming of the definitive hosts, as this stops the formation of eggs. Regular deworming of pets is mandated in Serbia and must be recorded in pet passports (*Serbia*, 2024). It is of note that any entries into the pet passport must be validated by a licensed veterinarian and/or clinic, as it is an official travel document. For travel however, proof of deworming is required only for entry into Malta, Finland and Ireland (*NetherlandsWorldwide*, 2025). In Serbia, antihelminthics with and without tapeworm efficacy in the form of tablets or pills are sold without prescription and can be administered by owners themselves. In practice, it is therefore unclear how regular deworming using drugs effective against tapeworms is to be enforced and monitored in Serbia. It stands to reason that owner would need to have their pets dewormed strictly by veterinarians, which is not mandated. Most importantly, deworming of owned animals only has a symbolic effect on transmission, as the number of stray and/or feral dogs and cats is probably similar to the number of owned pets. Additionally, *E. multilocularis* likely established itself in the domestic environment after a spillover from the sylvatic. Thus, without a more proactive and holistic approach to deworming, which includes all categories of definitive hosts, the number of cases is likely to rise.

Another control approach is vaccination of livestock to prevent infection and subsequent transmission to definitive hosts. An effective vaccine based on EG95 (a tapeworm secretory antigen) was developed in the late 1990's for sheep and since then has been used on livestock in several countries, but not in Serbia (*Lightowlers et al*., 1996, 1999; *Gauci et al*., 2022). The feasibility of implementation in Serbia

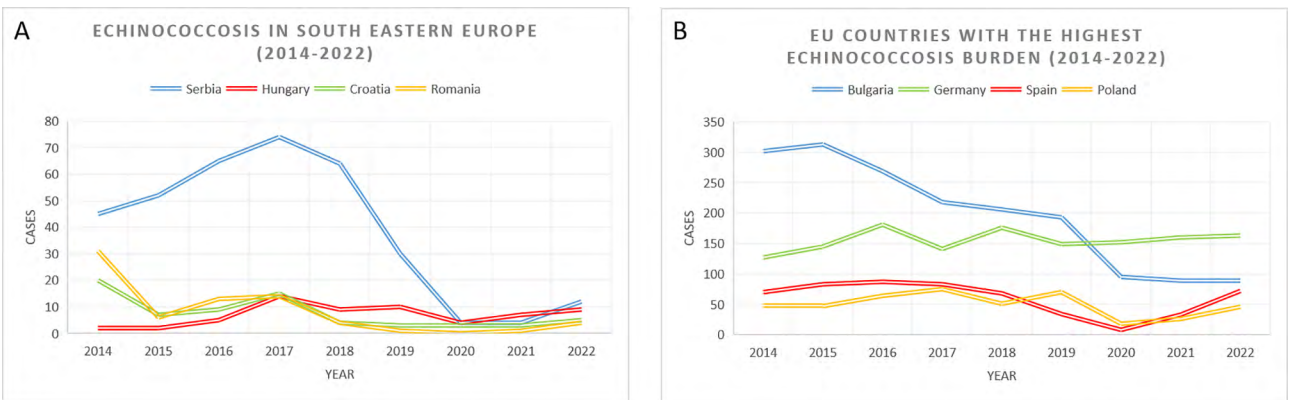

Figure 1. Officially reported human echinococcosis cases in South Eastern Europe (A) and EU countries with the highest echinococcosis burden (B) from 2014 to 2022. The blue line in A and B represents the country with the highest case number. A: Blue (Serbia), red (Hungary), green (Croatia) yellow (Romania). B: Blue (Bulgaria), green (Germany), red (Spain), yellow (Poland). The data from Serbia were extracted from annual epidemiological reports of contagious diseases from the Institute of Public Health of Serbia (IOPHOS), while the data for EU countries were retrieved from the European Centre for Disease Prevention and Control's (ECDC's) annual epidemiological reports collected from the European Surveillance System (TESSy).

must be carefully evaluated, especially as the farming industry heavily involves small farms and backyard farming (*Uzelac et al*., 2023). Based on the case numbers, the current transmission control and prevention measures in Serbia (Figure 1A) and in the EU (Figure 1B) are lacking, while both *E. granulosus* and *E. multilocularis* are abundant in the environment (Figure 2).

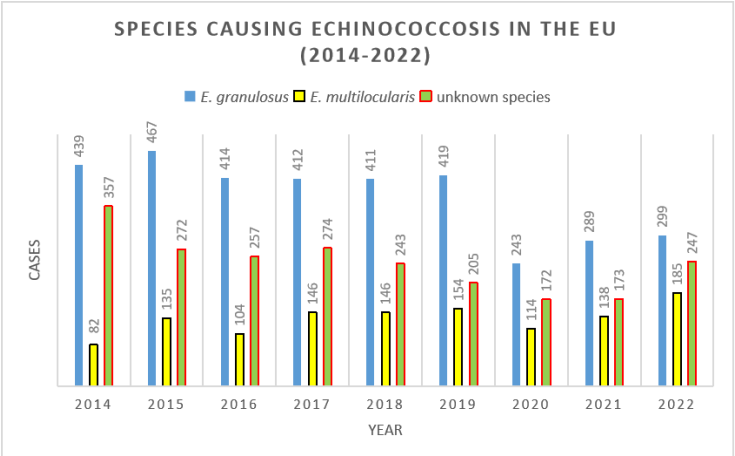

Figure 2. Tapeworm species identification in human samples in the EU (2014-2022). Blue bars are infections due to E. granulosus, yellow are E. multilocularis and green are those designated as unknown species. The data were retrieved from the European Centre for Disease Prevention and Control's (ECDC's) annual epidemiological reports and reflect data from EU countries which submitted results to the European Surveillance System (TESSy) (n = 27).

4. Discussion

Under-reporting of animal echinococcosis cases and failure to identify transmission foci directly facilitate the meat industry incurring economic losses associated with animal morbidity and death. Moreover, failure to prioritize transmission control and prevention in animals by the relevant government authorities and stakeholders will most certainly have negative consequences on public health in Serbia. Due to the high transmission capacity of a single infected definitive host, entire herds can be at risk. Organically reared and free-range animals are especially vulnerable to parasitic infections (*Kijlstra et al*., 2004). The vested interest of the meat industry is thus clear. The leverage mechanisms are its financial assets and its importance to the economy, and with that, the meat industry is ideally positioned to raise awareness on echinococcosis, as well as advocate for control and prevention. Reforms to improve detection of echinococcosis on the slaughter line can be as simple as prioritization of extensively reared animals with respect to requesting confirmatory diagnostics from government authorities and lobbying for mandatory tapeworm speciation. In order to avoid sourcing infected livestock, identification of transmission foci is key. The meat industry can, therefore, push government authorities into action and demand the establishment of a tracking system, which would provide notification on the current geographical status of transmission. These measures are, however, a stop-gap solution, vulnerable and at risk of being ineffective due to the dependency on relevant government authorities for financing, record keeping and information sharing with the meat industry. A real impact on the reduction of echinococcosis cases will only be achieved through complex reforms requiring a proactive approach by the industry though strong collaboration with the government authorities, sponsoring and investing in laboratories and testing facilities. These need to be properly equipped for high throughput, sophisticated detection and speciation with software assisted geographical surveillance of cases. With alarmingly high prevalence of *E. multilocularis* infection in wild canids in the Vojvodina region, implementing any reforms at the national level is an urgent matter (*Miljević et al.*, 2019, 2021).

5. Conclusions

Echinococcosis is a zoonotic disease with serious impact on public health, the farming industry and the economy. Slow cyst growth, a characteristic of CE, and complexity of disease presentation, a characteristic of AE, complicate diagnosis and lead to under-reporting of human and animal cases. Effective transmission control is difficult to implement and costly on a large scale. Thus, targeted and tailored measures, with respect to geography and transmission dynamics, are a better strategy. The key factors for echinococcosis control in Serbia are improved diagnostics on the slaughter line and transmission monitoring. The meat industry has a vested interest to support livestock health and production and has the leverage and financial means to push for and/or implement the necessary actions. As a major stakeholder, the meat industry may be our best chance to establish echinococcosis control and prevention in Serbia.

Disclosure Statement: No potential conflict of interest was reported by the authors.

Funding: This work was supported by the Science Fund of the Republic of Serbia [project #10841, Worm Profiler: Surveillance and Population Genetics of *Echinococcus* in Serbia - WORM_PROFILER].

Acknowledgements: The authors would like to thank our colleagues at the Faculty of Veterinary Medicine of the University of Belgrade and the Faculty of Agriculture of the University of Novi Sad for helpful discussions on the topic of the manuscript.

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