Evaluation of Helminth Infections Identified in Slaughtered Livestock in Iran, 2015-2019

Behzad Kiani

Mashhad University of Medical Sciences

Christine M. Budke

Texas A&M University College Station

Ebrahim Shams Abadi

Islamic Azad University Sabzevar Branch

Soheil Hashtarkhani

Mashhad University of Medical Sciences

Amene Raouf Rahmati

Mashhad University of Medical Sciences

Mostafa Akbarpour

Mashhad University of Medical Sciences

Mehdi Zarean

Mashhad University of Medical Sciences

Bibi Razieh Farash Hosseini

Mashhad University of Medical Sciences

Fatemeh Kiani

Mashhad University of Medical Sciences

Elham Moghaddas (✉ moghaddase@mums.ac.ir)

Department of Parasitology and Mycology, School of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran

Research article

Keywords: Echinococcosis, Dicrocoeliasis, Fascioliasis, Livestock, Spatial analysis, Geographical Information Systems

Posted Date: October 5th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-73118/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Abstract

Introduction: Helminth infections of livestock can result in considerable economic losses. This study aims to evaluate the spatial frequency of cystic echinococcosis (CE), dicrocoeliasis, and fascioliasis in livestock slaughtered in Iran during the years 2015-2019 and estimate direct costs associated with organ condemnation due to these parasites.

Methods: Abattoir data from all 31 Iranian provinces were collected from the Iran Veterinary Organization. Infection prevalence was calculated per year at the province level. The Local Moran's I statistic was performed to evaluate spatial autocorrelation of animals positive at slaughter for the years 2015-2019. Direct costs associated with condemned livers were calculated for each parasitic condition.

Results: Overall prevalence values for the study timeframe were as follows: sheep and goat fascioliasis (1.5%, 910,282/58,393,349), cattle fascioliasis (3.8%, 23,3175/6,038,419), sheep and goat dicrocoeliasis (4.6%; 270,1274/58,393,349), cattle dicrocoeliasis (3.1%; 186,009/6,038,419), sheep and goat CE (5.3%; 3,108,767/58,393,349), and cattle CE (7.2%; 438,534/6,038,419). Northwestern Iran had the highest prevalence of CE and fascioliasis. High infection areas for *Dicrocoelium* spp. included the provinces of Zanjan, Gilan, Qazvin, and Tehran, which are located in northern Iran. Direct economic losses for sheep and goat fascioliasis, dicrocoeliasis, and CE for the study period were US\$13,841,826, US\$41,768,472, and US\$22,801,296, respectively. Direct economic losses for cattle fascioliasis, dicrocoeliasis, and CE for the study period were US\$1,989,582, US\$1,669,289, and US\$2,656,535, respectively.

Conclusion: Our findings provide valuable data for future monitoring of these important parasitic diseases in Iranian livestock. Disease control strategies are required to reduce the economic and public health impact of these helminths.

Introduction

Livestock products provide an important source of protein for people worldwide [1]. Helminth infections are common in livestock and can result in economic losses to the livestock industry [2,3]. Parasite infections can lead to decreased growth, weight, and fertility, which can impact the production and/or quality of meat, milk, and hide/wool [4,5]. For example, financial losses due to fascioliasis in livestock are estimated to total US\$ 3 billion per year globally [6].

Fascioliasis and dicrocoeliasis are two of the most common zoonotic helminth diseases of domestic livestock and both are included on the World Health Organization's (WHO) list of important human foodborne infections [7,8]. These trematodes are found in the gallbladder and bile ducts of ruminants such as sheep, cattle, and goats [9]. Humans can also become infected via inadvertent ingestion of metacercariae on aquatic plants (*Fasciola* spp.) or in ants (*Dicrocoelium* spp.) [10,11]. A systematic review estimated a fascioliasis pooled prevalence of 6.2% (95% CI: 5.8-6.5%) in Iranian livestock, with prevalence values of 3.1% (95% CI: 2.4-3.7%) in goats, 4.2% (95% CI: 3.8-4.5%) in sheep, and 9.0% (95% CI: 8.0-9.9%) in cattle [12]. In northern Iran, large-scale human fascioliasis occurred in 1989 that was the onset of the first largest outbreak of human fascioliasis in the world, involving up to 10000 individuals in Guilan Province. In 1999, the second outbreak that happened about 5000 infected people in the same region. Also, in 2000, there were a reported 1,306 cases of human fascioliasis in the province of Gilan [13].

Dicrocoeliasis is known to be quite common in Iranian livestock. Between 2015 and 2018, 2.9% of 571,991 slaughtered sheep and goats and 0.8% of 80,001 slaughtered cattle were positive for *D. dendriticum* in Tehran Province [14]. Human dicrocoeliasis occurs sporadically in Iran, with only five cases reported in the literature [15].

Cystic echinococcosis (CE), due to infection with the larval form of *Echinococcus granulosus* sensu lato, is a globally important disease caused by zoonotic cestodes that cycle between canid definitive hosts and a variety of livestock intermediate hosts. Humans can act as aberrant intermediate hosts through ingestion of parasite eggs found on infected dogs, contaminated vegetables, or in water [16]. Hydatid cysts can be observed in various parts of the body, but are most commonly found in the liver and lungs [17]. CE is considered an endemic disease in Iran, especially in rural communities [18]. Between 1995 and 2014, 8,518 cases of human CE were recorded in different provinces of Iran, with the largest number of cases from Razavi Khorasan Province. The average annual number of human cases was 277 for this time period [19]. Between 1990 and 2015, a study found that 5.9% of sheep, 8.8% of cattle, and 6.4% of goats in Iran had CE at the time of slaughter [20]. An additional study conducted in Tehran

Province, found that 2.5% of 571,991 slaughtered sheep and 2.2% of 80,001 slaughtered cattle had CE between February 1, 2015, and January 31, 2018 [14]. The objective of the current study was to determine the province-level prevalence, spatial distribution, and direct economic impact of livestock infections with *Fasciola* spp., *Dicrocoelium* spp., and *E. granulosus* s.l. in Iran for the years 2015-2019.

Materials And Methods

Data collection and infection prevalence

Sheep are the most common livestock in Iran, followed by goats, and cattle. In April 2020, there were approximately 4,900,000 cattle, 47,300,000 sheep, and 17,000,000 goats in Iran (<https://www.amar.org.ir>), with the highest livestock populations in the northwestern part of the country (Figure 1) [21]. This retrospective study was conducted by using data from the Iran Veterinary Organization, which is a central repository for all abattoir-based data. In the current study, data from 2015 to 2019 were assessed from all 31 Iranian provinces. The data included total number of slaughtered cattle, sheep, and goats by abattoir location as well as fascioliasis, dicrocoeliasis, and CE infection status. The reporting system does not allow multiple parasitic infections to be recorded for a single animal. Therefore, animals infected with more than one parasite would only contribute to prevalence estimates for one of the infecting parasites. Infection prevalence was obtained by evaluating the number of positive animals divided by the number of animals slaughtered per year.

Spatial analyses

Descriptive maps of the prevalence of animals infected with *Dicrocoelium* spp., *Fasciola* spp., and *E. granulosus* s.l. were created for the years 2015-2019 using natural break classification, with five classes. Natural break classification is a data grouping method designed to determine the best arrangement of values into different classes. This is conducted by seeking to minimize each class's average deviation from the class mean, while maximizing each class's deviation from the means of the other groups. In other words, the method seeks to reduce the **variance** within classes and maximize the variance between classes [22].

The Local Moran's *I* statistic was performed to quantify spatial autocorrelation of prevalence at the provincial level. This test calculates a z-score and p-value to determine whether the apparent similarity (a spatial clustering of either high or low values) or dissimilarity (a spatial outlier) is more pronounced than one would expect in a random distribution. The null hypothesis states that prevalence values are randomly distributed across the study area. high-high and low-low regions indicate that the target area is encompassed by regions with similar prevalence values, while high-low and low-high regions show that the target area is encompassed by regions with dissimilar prevalence values [23]. In other words, the high-high and low-low areas indicate clusters of prevalence at a certain level [24]. ArcGIS 10.5 was used for space-time analyses.

Economic impact

Direct costs associated with offal condemnation due to fascioliasis (liver), dicrocoeliasis (liver), and CE (liver and/or lungs) were estimated. An animal with CE cysts in both the liver and lungs would contribute both organs to the economic estimate, but would only be considered once for evaluation of CE prevalence. The average price of liver and lungs were acquired from the Meisam abattoir in Tehran for the years 2015-2019, with the assumption that there is little variation in price countrywide. These values were then multiplied by the number of condemned organs per year. Costs were converted from the Iranian rial to the US\$ for each study year using the free exchange rate (https://en.wikipedia.org/wiki/Iranian_rial).

Results

Parasite infection prevalence

In total, 3.8% (233,175/6,038,419) of slaughtered cattle and 1.5% (910,282/58,393,349) of slaughtered sheep and goats were infected with *Fasciola* spp. from 2015-2019. Annual prevalence of cattle fascioliasis ranged from 3.2% in 2019 to 3.9% in 2015, while the annual prevalence of sheep and goat fascioliasis ranged from 1.2% in 2015 to 1.6% in 2019 (Figure 2). The highest

number of cases of fascioliasis where in the provinces of Ardabil and East Azerbaijan, which are located in northwestern Iran (Additional File 1).

In total, 3.1% (186,009/6,038,419) of slaughtered cattle and 4.6% (270,1274/58,393,349) of slaughtered sheep and goats where infected with *Dicrocoelium* spp. from 2015-2019. Annual prevalence of cattle dicrocoeliasis ranged from 2.7% in 2019 to 3.0% in 2015, while the annual prevalence of dicrocoeliasis in sheep and goats ranged from 3.7% in 2015 to 4.8% in 2019 (Figure 2). The majority of cases of dicrocoeliasis were found in northern Iran (Additional File 2).

In total, 7.2% (438,534/6,038,419) of slaughtered cattle and 5.3% (3,108,767/58,393,349) of slaughtered sheep and goats where infected with *E. granulosus* s.l. from 2015-2019. Annual prevalence of cattle CE ranged from 5.9% in 2015 to 9.2% in 2019, while the annual prevalence in sheep and goats ranged from 4.0% in 2015 to 6.1% in 2019 (Figure 2). The majority of CE cases were found in northern Iran (Additional File 3).

Spatial analysis

The provinces of East Azerbaijan, West Azerbaijan, and Ardabil, which are all located in northwestern Iran, exhibited high-high cluster patterns for cattle fascioliasis. East Azerbaijan was also identified as a high-risk area for sheep and goat fascioliasis (Figure 3). Dicrocoeliasis was most common in the northern provinces of Zanzan, Gilan, Qazvin, and Tehran (Figure 4). The northern provinces of Isfahan, Chaharmahal, and Bakhtiari exhibited high-high cluster patterns for cattle CE, while sheep and goat CE was common in northwestern Iran (Figure 5). The local Moran's index values and P-values for the maps presented in Figures 3-5 are shown in Additional File 4.

Economic impact

A total of 233,175 cattle livers and 910,282 sheep and goat livers were discarded due to fascioliasis during 2015-2019. These losses resulted in direct cost estimates of US\$ 1,989,582 for cattle and US\$ 13,841,826 for sheep and goats. During this same time period, 186,009 cattle livers and 2,701,274 sheep and goat livers where condemned due to dicrocoeliasis, resulting in losses of US\$ 1,669,289 and US\$ 41,768,472, respectively. In addition, 311,982 cattle livers and 1,500,385 sheep and goat livers were discarded due to CE, resulting in losses of US\$2,573,851 and US\$20,555,274, respectively. Furthermore, 126,602 cattle lungs and 1,608,382 sheep and goat lungs were discarded due to CE, resulting in losses of US\$69,659 and US\$2,203,488, respectively. These condemnations resulted in an estimated direct loss of US\$ 84,727,000 due to the three parasitic infections over the five-year period (Table 1).

Discussion

This is the first spatial analysis of fascioliasis, dicrocoeliasis, and CE prevalence in slaughtered livestock for the entire country of Iran. Slaughtered cattle and small ruminants were more commonly infected with CE compared to the other evaluated parasites during the study timeframe. CE is endemic in the Middle East, with a recent systematic review calculating a weighted prevalence of 15.6% (95% CI = 14.2–17.1%) in livestock (cattle, sheep, goats, buffalos, camels, donkeys, and boars) and 4.2% (95% CI = 3.0–5.5%) in humans from Iran [20]. The mean annual prevalence values for CE in cattle (5.3%) and sheep and goats (7.2%) reported in the current study align with findings from Khalkhali et al. (2018) who reported a prevalence of 8.8% in cattle, 5.9% in sheep, and 6.4% in goats in Iran [20]. We identified high CE prevalence values in the northwestern region of the country, with much lower values in southern Iran. These distributions align with reported high prevalence values for human CE in northern (9%, 95% CI: 4–18%) and western (6%, 95% CI: 3–11%) Iran [25].

Porous international borders make it difficult to control importation of livestock infected with CE, especially when neighboring countries continue to have problems with the parasite. CE prevalence in cattle and small ruminants was found to be 8.0% and 8.9% respectively, in Pakistan [26]. In Iraq, 30% of cattle and 32% of small ruminants were found to be infected with CE [27]. Very limited information is currently available from Afghanistan and Turkmenistan. However, they are both also believed to be endemic for *E. granulosus* [28].

Dicrocoeliasis was the second most prevalent parasite found in this study, which aligns with other abattoir-based surveys conducted in Iran [29,30]. It is believed that *Dicrocoelium* spp. eggs can survive for a longer time on pastures compared to the eggs of *Fasciola* spp. Based on the data presented here, high infection areas for *Dicrocoelium* spp. were identified in northern Iran. A study focused on predicating the spatial distribution and environmental suitability for *Dicrocoelium* spp. identified the littoral of the Caspian Sea as a high-risk area, with regional prevalence values of 36.7% and 6.1% for sheep and cattle, respectively [31]. A temperature range of 10–25°C and high levels of moisture are needed for the development of both *Fasciola* larvae and its intermediate snail host (*Lymnaea truncatula*) [32]. Over the past decade, Iran has experienced a prolonged and severe drought [33]. At present, the northern, northwestern, and western regions of Iran appear to be most suitable for completion of the *Fasciola* spp. life cycle [34,35,12]. Spatial analysis confirmed that northwest Iran was a high prevalence region for fascioliasis. Use of spatial analysis is helpful to highlight regions of concern and to help plan control initiatives.

CE (liver and/or lung infection) was the most prevalent evaluated parasitic infection in slaughtered Iranian livestock, but economic losses were greatest for dicrocoeliasis since the price of liver is approximately 12 times the price of lung. Although few economic assessments have been performed to evaluate costs due to dicrocoeliasis, *D. dendriticum* was responsible for 26% of marketable organ condemnation due to parasite infection in the region of Trikala, Greece. However, since only a small percentage (0.26%) of organs were condemned due to parasitic infections in this region of Greece, the economic impact was negligible [36]. Annual economic losses due to cattle fascioliasis in Iran were estimated to be 28.9 and 9.2 times the losses recorded in Nigeria (US\$13,773) and Ethiopia (US\$43,024), respectively [37,38]. Annual economic losses due to cattle CE were estimated to be 9.1 times the losses in Ethiopia (US\$ 58,114) and 7.3 times the losses in Australia (US\$ 66,893) [39,40].

The study did have some limitations, including the inability to account for infection with more than one parasite. In addition, CE cysts located in organs other than the liver and lungs were likely missed. Therefore, prevalence values may be underestimated. Also, only direct costs were evaluated. These parasitic conditions likely have additional impacts on animal growth and other production measures, which were not assessed in this study. Overall, the prevalence of these three parasites either appears to have remained steady or increased (e.g., cattle CE) between 2015 and 2019. Since these parasites are potential human health hazards, special attention should be given to their control [41].

Conclusion

This study has shown that helminth infections continue to be prevalent in Iranian livestock and result in substantial economic losses. These values reinforce the necessity of developing effective control programs based on regional needs.

List Of Abbreviations

cystic echinococcosis (CE)

Declarations

Ethics approval and consent to participate

The study was approved by the ethics committee of the Research Department of Mashhad University of Medical Sciences protocol number: IR.MUMS.MEDICAL.REC.1398.130.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author (E.M) on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This study was sponsored by Mashhad University of Medical Sciences (Project grant: 971327).

Authors' contributions

Study design, analyse and interpretation of data: B.K, E.M, S.H and C.B; drafting of the manuscript: E.M, B.K and C.B; critical revision of the manuscript for important intellectual content: C.B, B.K and E.M; statistical analysis: B.K and S.H and F.K; Data gathering and cleaning: E.SA, A.RR, M.A, M.Z, F.K and BR.HF. The author(s) read and approved the final manuscript.

Acknowledgements

We thank the Iranian Veterinary Organization for assistance obtaining the data presented in this study.

References

1. Pareviz M, Akberin H (2013) Prevalence of Hydatidosis in slaughtered herbivores in Khomein, Markazi province, Central Part of Iran.
2. Singh BB, Sharma JK, Tuli A, Sharma R, Bal MS, Aulakh RS, Gill JPS (2014) Prevalence and morphological characterisation of *Echinococcus granulosus* from north India. *Journal of parasitic diseases* 38 (1):36-40
3. Martínez-Valladares M, Robles-Pérez D, Martínez-Pérez JM, Cordero-Pérez C, del Rosario Famularo M, Fernández-Pato N, González-Lanza C, Castañón-Ordóñez L, Rojo-Vázquez FA (2013) Prevalence of gastrointestinal nematodes and *Fasciola hepatica* in sheep in the northwest of Spain: relation to climatic conditions and/or man-made environmental modifications. *Parasites & vectors* 6 (1):282
4. Umur S, Kaaden OR (2003) Prevalence and Economic Importance of Cystic Echinococcosis in Slaughtered Ruminants in Burdur, Turkey 1. *Journal of Veterinary Medicine, Series B* 50 (5):247-252
5. Charlier J, van der Voort M, Kenyon F, Skuce P, Vercruysse J (2014) Chasing helminths and their economic impact on farmed ruminants. *Trends in parasitology* 30 (7):361-367
6. Elliott T, Kelley J, Rawlin G, Spithill T (2015) High prevalence of fasciolosis and evaluation of drug efficacy against *Fasciola hepatica* in dairy cattle in the Maffra and Bairnsdale districts of Gippsland, Victoria, Australia. *Veterinary parasitology* 209 (1-2):117-124
7. Organization WH (2011) Report of the WHO expert consultation on foodborne trematode infections and taeniasis. World Health Organization,
8. Organization WH Initiative to estimate the global burden of foodborne diseases. In: First formal meeting of the Foodborne Disease Burden Epidemiology Reference Group. Geneva, 2007.
9. Youn H (2009) Review of zoonotic parasites in medical and veterinary fields in the Republic of Korea. *The Korean journal of parasitology* 47 (Suppl):S133
10. SABZEVARINEZHAD G (2004) Flukes Liver Epidemic Common Between Human and Livestock in Slaughtered and Their Staining.
11. Otranto D, Traversa D (2002) A review of dicrocoeliosis of ruminants including recent advances in the diagnosis and treatment. *Veterinary parasitology* 107 (4):317-335
12. Khademvatan S, Majidiani H, Khalkhali H, Taghipour A, Asadi N, Yousefi E (2019) Prevalence of fasciolosis in livestock and humans: A systematic review and meta-analysis in Iran. *Comparative immunology, microbiology and infectious diseases* 65:116-123
13. Ashrafi K (2015) The status of human and animal fascioliasis in Iran: A narrative review article. *Iranian journal of parasitology* 10 (3):306
14. Pezeshki A, Aminfar H, Aminzare M (2018) An analysis of common foodborne parasitic zoonoses in slaughtered sheep and cattle in Tehran, Iran, during 2015-2018. *Veterinary World* 11 (10):1486

15. Ashrafi K (2010) Human dicrocoeliasis in northern Iran: two case reports from Gilan province. *Annals of Tropical Medicine & Parasitology* 104 (4):351-353
16. Rokni M (2009) Echinococcosis/hydatidosis in Iran. *Iranian journal of parasitology*:1-16
17. Jenkins D, Romig T, Thompson R (2005) Emergence/re-emergence of *Echinococcus* spp.—a global update. *International journal for parasitology* 35 (11-12):1205-1219
18. Hashemnia M, Safavi EAA (2016) A retrospective survey of hydatidosis based on abattoir data in Kermanshah, Iran from 2008 to 2013. *Journal of parasitic diseases* 40 (2):459-463
19. Zeinali M, Mohebbali M, Shirzadi MR, ESBOEI BR, Erfani H, Pourmozafari J, Ghanbari M (2017) Human Cystic Echinococcosis in Different Geographical Zones of Iran: An Observational Study during 1995–2014. *Iranian journal of public health* 46 (12):1623
20. Khalkhali H, Foroutan M, Khademvatan S, Majidiani H, Aryamand S, Khezri P, Aminpour A (2018) Prevalence of cystic echinococcosis in Iran: a systematic review and meta-analysis. *Journal of helminthology* 92 (3):260-268
21. Amiraslani F, Dragovich D (2011) Combating desertification in Iran over the last 50 years: An overview of changing approaches. *Journal of Environmental Management* 92 (1):1-13
22. Kiani B, Raouf Rahmati A, Bergquist R, Moghaddas E (2020) Comparing spatio-temporal distribution of the most common human parasitic infections in Iran over two periods 2007 to 2012 and 2013 to 2018: A systematic quantitative literature review. *The International journal of health planning and management*
23. Goshayeshi L, Pourahmadi A, Ghayour-Mobarhan M, Hashtarkhani S, Karimian S, Dastjerdi RS, Eghbali B, Seyfi E, Kiani B (2019) Colorectal cancer risk factors in north-eastern Iran: A retrospective cross-sectional study based on geographical information systems, spatial autocorrelation and regression analysis. *Geospatial health* 14 (2)
24. Halimi L, Bagheri N, Hoseini B, Hashtarkhani S, Goshayeshi L, Kiani B (2019) Spatial analysis of colorectal cancer incidence in Hamadan Province, Iran: a retrospective cross-sectional study. *Applied Spatial Analysis and Policy*:1-11
25. Khademvatan S, Majidiani H, Foroutan M, Tappeh KH, Aryamand S, Khalkhali H (2019) *Echinococcus granulosus* genotypes in Iran: a systematic review. *Journal of helminthology* 93 (2):131-138
26. Mehmood N, Arshad M, Ahmed H, Simsek S, Muqaddas H (2020) Comprehensive Account on Prevalence and Characteristics of Hydatid Cysts in Livestock from Pakistan. *The Korean Journal of Parasitology* 58 (2):121
27. Alsaady HAM, Al-Quzweeni HAN (2019) Molecular Study of *Echinococcus Granulosus* in Misan Province, South of Iraq. *Indian Journal of Public Health Research & Development* 10 (9):1062-1066
28. Zhang W, Zhang Z, Wu W, Shi B, Li J, Zhou X, Wen H, McManus DP (2015) Epidemiology and control of echinococcosis in central Asia, with particular reference to the People's Republic of China. *Acta Tropica* 141:235-243
29. Najjari M, Karimazar M, Rezaeian S, Ebrahimipour M, Faridi A (2020) Prevalence and economic impact of cystic echinococcosis and liver fluke infections in slaughtered sheep and goat in north-central Iran, 2008–2018. *Journal of Parasitic Diseases* 44 (1):17-24
30. Motazedian M, Najjari M, Zarean M, Karimi G, Karimazar M, Ebrahimipour M (2019) An abattoir survey of hydatid and liver fluke disease in slaughtered cattle in Alborz Province, Iran. *Comparative Clinical Pathology* 28 (1):99-105
31. Meshgi B, Majidi-Rad M, Hanafi-Bojd AA, Kazemzadeh A (2019) Predicting environmental suitability and geographical distribution of *Dicrocoelium dendriticum* at littoral of Caspian Sea: An ecological niche-based modeling. *Preventive veterinary medicine* 170:104736
32. Fox NJ, White PC, McClean CJ, Marion G, Evans A, Hutchings MR (2011) Predicting impacts of climate change on *Fasciola hepatica* risk. *PLoS one* 6 (1)
33. Emadodin I, Reinsch T, Taube F (2019) Drought and desertification in Iran. *Hydrology* 6 (3):66
34. Khanjari A, Bahonar A, Fallah S, Bagheri M, Alizadeh A, Fallah M, Khanjari Z (2014) Prevalence of fasciolosis and dicrocoeliosis in slaughtered sheep and goats in Amol Abattoir, Mazandaran, northern Iran. *Asian Pacific Journal of Tropical Disease* 4 (2):120-124
35. Ezatpour B, Hasanvand A, Azami M, Mahmoudvand H, Anbari K (2014) A slaughterhouse study on prevalence of some helminths of cattle in Lorestan province, west Iran. *Asian Pacific Journal of Tropical Disease* 4 (5):416-420

36. Theodoropoulos G, Theodoropoulou E, Petrakos G, Kantzoura V, Kostopoulos J (2002) Abattoir condemnation due to parasitic infections and its economic implications in the region of Trikala, Greece. *Journal of Veterinary Medicine, Series B* 49 (6):281-284
37. Ola-Fadunsin SD, Uwabuho PI, Halleed IN, Richards B (2020) Prevalence and financial loss estimation of parasitic diseases detected in slaughtered cattle in Kwara State, North-central Nigeria. *Journal of Parasitic Diseases* 44 (1):1-9
38. Zewde A, Bayu Y, Wondimu A (2019) Prevalence of Bovine Fasciolosis and Its Economic Loss due to Liver Condemnation at Wolaita Sodo Municipal Abattair, Ethiopia. *Veterinary Medicine International* 2019
39. Guduro GG, Desta AH (2019) Cyst Viability and Economic Significance of Hydatidosis in Southern Ethiopia. *Journal of parasitology research* 2019
40. Wilson CS, Jenkins DJ, Brookes VJ, Barnes TS, Budke CM (2020) Assessment of the direct economic losses associated with hydatid disease (*Echinococcus granulosus sensu stricto*) in beef cattle slaughtered at an Australian abattoir. *Preventive Veterinary Medicine* 176:104900
41. Ekong PS, Juryit R, Dika NM, Nguku P, Musenero M (2012) Prevalence and risk factors for zoonotic helminth infection among humans and animals-Jos, Nigeria, 2005-2009. *Pan African medical journal* 12 (1)

Tables

Table 1: Direct costs (in US\$) associated with livestock infection with fascioliasis, dicrocoeliasis, and CE in 31 Iranian provinces, 2015-2019.

Year		Cattle fascioliasis	Sheep and goat fascioliasis	Cattle dicrocoeliasis	Sheep and goat dicrocoeliasis	Cattle CE	Sheep and goat CE	Total infections
2015	Number of condemned livers	50,367	158,928	39,258	495,729	47,358	233,556	1,025,196
	Number of condemned lungs					28,416	293,555	321,971
	Cost (US\$)	598,564	3,408,890	466,544	10,633,027	635,560	5,310,312	21,052,897
2016	Number of condemned livers	47,479	222,568	53,337	695,224	47,591	290,481	1,356,680
	Number of condemned lungs					38,073	372,481	410,554
	Cost (US\$)	598,365	5,000,157	672,192	15,618,730	702,390	6,927,359	29,519,193
2017	Number of condemned livers	54,782	206,655	34,674	592,604	86,517	393,890	1,369,122
	Number of condemned lungs					8,702	353,890	362,542
	Cost (US\$)	469,560	3,160,605	297,205	9,063,355	757,474	6,283,751	20,031,950
2018	Number of condemned livers	47,634	182,990	30,339	497,118	66,883	294,405	1,119,369
	Number of condemned lungs					20,049	340,404	360,453
	Cost (US\$)	201,121	1,355,481	128,098	3,682,355	300,389	2,303,322	7,970,766
2019	Number of condemned livers	32,913	139,141	28,401	420,599	63,633	288,053	972,740
	Number of condemned lungs					31,412	248,052	279,464
	Cost (US\$)	121,971	916,693	105,250	2,771,005	260,722	1,976,552	6,152,193
Total	Number of condemned livers	233,175	910,282	186,009	2,701,274	311,982	1,500,385	5,843,107
	Number of condemned lungs					126,652	1,608,382	1,734,984
	Cost (US\$)	1,989,582	13,841,826	1,669,289	41,768,472	2,656,535	22,801,296	84,727,000

Free exchange rates (Iranian rials to US\$): 2015- 34,500 rials to 1 US\$, 2016- 36,500 rials to 1 US\$, 2017- 59,500 rials to 1 US\$, 2018- 135,000 rials to 1 US\$, and 2019- 170,000 rials to 1 US\$ (https://en.wikipedia.org/wiki/Iranian_rial).

Figures

Figure 1
Average number of livestock (cattle, sheep, and goats) per year in 31 Iranian provinces, 2015-2019 (<https://www.amar.org.ir>).

Figure 2

Annual prevalence of fascioliasis, dicrocoeliasis, and CE in livestock slaughtered in 31 Iranian provinces, 2015-2019.

Figure 3

Cluster analysis of fascioliasis in cattle (left panels) and in sheep and goats (right panels) in 31 Iranian provinces, 2015-2019.

Figure 4

Cluster analysis of dicrocoeliasis in cattle (left panels) and in sheep and goats (right panels) in 31 Iranian provinces, 2015-2019.

Figure 5

Cluster analysis of CE in cattle (left panels) and in sheep and goats (right panels) in 31 Iranian provinces, 2015-2019.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [AdditionalFile1.docx](#)
- [AdditionalFile2.docx](#)
- [AdditionalFile3.docx](#)
- [AdditionalFile4.xls](#)