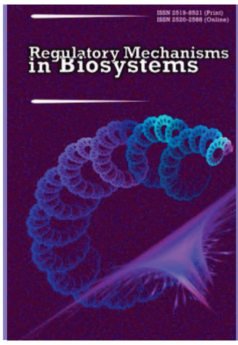

Regulatory Mechanisms in Biosystems

ISSN 2519-8521 (Print)
ISSN 2520-2588 (Online)
Regul. Mech. Biosyst.,
2023, 14(1), 77–85
doi: 10.15421/022312

Current epizootological and epidemiological aspects of brucellosis in Ukraine

L. Y. Korniienko*, V. V. Ukhovskyi*, O. A. Moroz*, O. M. Chechet*, G. B. Aliekseieva*, T. M. Tsarenko**, M. S. Karpulenko*, N. P. Nenych***, M. L. Radzykhovskyi****

**State Scientific and Research Institute of Laboratory Diagnostics and Veterinary and Sanitary Expertise, Kyiv, Ukraine*
***Bila Tserkva National Agrarian University, Bila Tserkva, Ukraine*
****Chernihiv Regional State Laboratory of the State Service of Ukraine on Food Safety and Consumer Protection, Chernigiv, Ukraine*
*****National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine*

Article info

Received 20.01.2023
Received in revised form 14.02.2023
Accepted 15.02.2023

State Scientific and Research Institute of Laboratory Diagnostics and Veterinary and Sanitary Expertise, Donetska st., 30, Kyiv, 03151, Ukraine. Tel.: +38-066-789-85-19. E-mail: uhovskiy@ukr.net

Bila Tserkva National Agrarian University, Soborna st., 8/1, Bila Tserkva, 09117, Ukraine. Tel.: +38-068-353-63-69. E-mail: taras.m.tsarenko@gmail.com

Chernihiv Regional State Laboratory of the State Service of Ukraine on Food Safety and Consumer Protection, 1 May st, 180, Chernigiv, 14034, Ukraine. Tel.: +38-096-311-29-25. E-mail: leonid.kornienko.09@googlemail.com

National University of Life and Environmental Sciences of Ukraine, Heroiv Oborony st., 15, Kyiv, 03041, Ukraine. Tel.: +38-067-725-65-07. E-mail: nickvet@ukr.net

Korniienko, L. Y., Ukhovskyi, V. V., Moroz, O. A., Chechet, O. M., Aliekseieva, G. B., Tsarenko, T. M., Karpulenko, M. S., Nenych, N. P., & Radzykhovskyi, M. L. (2023). Current epizootological and epidemiological aspects of brucellosis in Ukraine. Regulatory Mechanisms in Biosystems, 14(1), 77–85. doi:10.15421/022312

The analysis of monitoring studies for brucellosis among farm and wild animals for the period 2004–2021 in Ukraine was performed. The total number of tests on brucellosis during this period among cattle amounted to 62,917,946 animals, small ruminants – 10,898,075, pigs – 4,146,751, horses – 116,668, wild pigs – 22,306, roe deer – 11,548, hares (only the last two years were studied) – 430 animals. During the same period, camels, deer, dogs, cats, rabbits, poultry, zoo animals, wild animals including moose, foxes and badgers were examined in case of suspicion or request. During this period, seropositive animals were found among cattle – 607, small ruminants – 84, pigs – 219, horses – 4, dogs – 2, wild boars – 52, hares – 7. There were years when no positive animals were detected (2012, 2015), 1–3 animals were detected in 2008, 2010, 2013, 2014, 2016, 2017. The largest number of animals positive for brucellosis was detected in 2004 and 2006, respectively 107 and 328 animals. Some regions stand out among others with a significant number of positive results. Thus, in Sumy region, positive animals were isolated in 2004, 2005, 2007, 2009, 2010, 2011, 2013, 2019, 2020, 2021 (a total of 45 animals), in Dnipropetrovsk region in 2004, 2016, 2017, 2018 (a total of 11 animals). The results of the analysis showed that human brucellosis in Ukraine is registered sporadically (single cases). During the analyzed period, 32 cases of human brucellosis were detected, during the period 1994–2021, the diagnosis of brucellosis was confirmed in 45 people. Approximately 50% of human brucellosis cases in Ukraine are introduced from abroad. The vector role of wild animals-reservoirs in the spread of the brucellosis pathogen in the direction of farm animals and from them to humans is confirmed. Among the regions, the most disadvantaged were Chernihiv (cases in 2009, 2011, 2014, 2015), Lviv (2005, 2011, 2021) and Kyiv (2008, 2014, 2021). During the period 1994–2021, the disease was not registered in people at all in the Autonomous Republic of Crimea, Volyn, Vinnytsia, Transcarpathian, Zaporizhzhia, Kirovohrad, Rivne, Ternopil, Cherkasy regions.

Keywords: *Brucella*; cattle; pigs; small ruminants; horses; wild boars; roe deer; hares; humans; serological monitoring.

Introduction

Brucellosis is an endemic zoonotic, mainly chronic infectious disease that manifests itself in females mainly by abortion, retention of afterbirth, endometritis, and in males by orchitis and epididymitis. In addition, disorders of the musculoskeletal system (bursitis) and reproductive function are recorded in animals. The periodic occurrence of brucellosis in certain areas and the emergence of new foci are often associated with wildlife reservoirs or the movement of sick pets from disadvantaged areas to advantaged ones (Schumaker, 2013; Pedersen et al., 2014; Roop et al., 2021).

Although brucellosis is endemic in many countries, it is often simply not diagnosed and therefore underreported. Often, even healthcare providers either misdiagnose brucellosis or do not associate less than typical clinical signs with the disease (Christopher et al., 2010). According to Madkour (2001), approximately 2% of people with undiagnosed brucellosis die from it. Hence, researchers point out that the official number of brucellosis cases in the world is significantly underestimated (Dean et al., 2012). There are often situations when sick people are reported in the absence of the disease in animals (Godfroid et al., 2005). The WHO called this disease one that was neglected and forgotten by many countries and professionals, but it has returned. Consequently, this disease poses a significant risk to people and their health. Human infection with the brucellosis pathogen often occurs after consuming unpasteurized milk and dairy products that are not produced centrally, where there is a lack of sanitation and satisfactory veterinary services. Human and animal migration and trade in animal products contribute to the spread of the disease in previously safe regions (Korniienko et al., 2009; Khurana et al., 2021). At the end of the last century, more than 90,000 people in the Middle East suffered from brucellosis annually (Korniienko et al., 2009). Every year, more than 500,000 new cases of human brucellosis are detected worldwide (Pappas et al., 2006; Johansen et al., 2017; Barki et al., 2018).

According to some researchers, the real incidence of brucellosis is 10–25 times higher than the reported cases, as the infection is often not recognized or patients do not report the disease to health authorities (Sabra et al., 2021). Some scientists estimate the real incidence of brucellosis in the world at 5,000,000–12,500,000 cases per year (Hull & Schumaker, 2018). The highest incidence rates of brucellosis among humans were observed in countries such as Mongolia (391.0 cases per 100,000), Tajikistan (211.9), Syria (160.3) (Hull & Schumaker, 2018), Kenya (203.07 cases per 100,000), Yemen (89.96), Greece (42.96), Eritrea (21.82) (Wang & Jiang, 2020), Iran (18.6) (Musallam et al., 2016). In 2017, 381 cases of brucellosis were reported in 28 countries of the European Union, with an average rate of 0.09 cases per 100,000 people. Mexico had the highest number of outbreaks in 2014 with 5,514, followed by China with 2,138, Greece with 1,268, and Brazil with 1,142 (Hull & Schumaker, 2018). In Africa and South/Southeast Asia, the average range of seroprevalence in sheep and goats was 0–88.8%, in cattle 0–68.8%, in camels 4–20%, in pigs and dogs 0–12.9% (McDermott et al., 2013). In Latin America, the seroprevalence of bovine brucellosis ranged from 0.5–10% (Lucero et al., 2008). Since the 1990s, the incidence of brucellosis in China has been increasing and peaked in 2014, and from 2008 to 2018, the disease was included in the list of the 10 most common infectious diseases in this country (Lai et al., 2017). In Africa and Asia, a significant prevalence of the disease (more than 11%) was found among people who professionally work with animals (veterinarians, livestock breeders, slaughterhouse workers, etc.) (McDermott et al., 2013), in Spain, 12% of people with brucellosis were laboratory workers who worked with the pathogen (Bouza et al., 2005; Köse et al., 2014).

The causative agent of this disease can be transmitted to humans by aerosolization (10–100 bacteria are enough to infect). Infection results in the development of chronic, severe illness, requires modern approaches to treatment (combination of drugs), manifests forms of the disease that seem to be erased and patients often do not have classical forms of the disease (Pappas et al., 2006). Human brucellosis is mainly caused by *B. melitensis*, *B. abortus*, *B. suis* and *B. canis* (Lai et al., 2021), but it has been proven that humans can be infected with any type of pathogen, a significant number of them overcome the protective barriers in the susceptible organism, and in principle, each species is potentially dangerous (Sohn et al., 2003; Covert et al., 2009; Olsen & Palmer, 2014). Transmission of the pathogen to humans from animal reservoirs is the leading route of human infection, as the human-to-human transmission is rare (Olsen & Tatum, 2016).

In general, brucellosis is endemic in many countries around the world. Countries and territories with high-risk areas are considered to be: Mexico, South and Central America, Eastern Europe, Asia, Africa, the Caribbean, the Middle East, and the Mediterranean (Portugal, Spain, Southern France, Italy, Greece, Turkey, and North Africa). Tourists and travelers in these regions face a significant risk of infection in cases of contact with livestock, and consumption of raw animal products (meat, unpasteurized dairy products, etc.) (Brucellosis Reference Guide, 2017). Brucellosis is mostly reported in low-income countries, and goats and sheep are the predominant livestock species kept by people for subsistence (Rossetti et al., 2017).

Currently, international bodies have developed regulations and laws that regulate animal trade on an international and local scale and prevent the active spread of this pathogen. The OIE International Terrestrial Animal Code also regulates the methods and procedures for monitoring studies and related quarantine measures (Zhang et al., 2018). Prevention of this disease is based on the surveillance of productive animals susceptible to brucellosis, and the control of reservoir species in the wild (wild boars, elk, roe deer, hares, etc.). For this purpose, modern methods of serological diagnostics and molecular research methods are used. In some countries, vaccines are used to control this infection. In Ukraine, vaccines for the prevention of brucellosis are prohibited from use (Korniienko et al., 2009; Moreno, 2014; Kneipp et al., 2019).

In our country, the eradication of brucellosis in farm animals through mass diagnostic studies of animals and organizational and economic control measures were introduced centrally in 1949. In 1975, brucellosis was officially eliminated in Ukraine. During the period of elimination of this disease in Ukraine, a significant number of disadvantaged locations were recorded in Kyiv – 498, Sumy – 328, Khmelnytskyi – 280, Poltava – 280, Donetsk – 251, Dnipro – 234, and Odesa – 208 regions. In the period 1975–1990, sporadic cases of this disease were registered (in all cases, there was bacteriological confirmation) in Donetsk, Khmelnytskyi, Mykolaiv, Luhansk, Ternopil, Chernihiv, and Lviv regions. It was indicated that such animals were mostly found on farms where brucellosis had previously been recorded, and rehabilitation was carried out using live vaccines. The authors of the study noted that the possible sources of the infectious agent were vaccinated animals, which were latent carriers of the pathogen (Busol et al., 1991). Based on the previously mentioned, we set ourselves the task of studying the epizootic and epidemiological situation with brucellosis in Ukraine for the period 2004–2021. Particular attention was focused on monitoring studies of farm and wild animals in the system of prevention of this disease in animals and humans.

Materials and methods

A retrospective analysis of the incidence of brucellosis in animals and humans in Ukraine for the period 2004–2021 was conducted. The source of data for the analysis of animal morbidity was the reports of regional laboratories of state veterinary medicine of the State Service of Ukraine for Food Safety and Consumer Protection and data from the State Research Institute for Laboratory Diagnostics and Veterinary and Sanitary Expertise (Srildvse, Kyiv, Ukraine) (reporting form No. 2-vet.). Data on diseases of different species of animals were systematized, grouped by year and animal species, and analyzed. The period for data analysis was 18 years.

The source of data for the analysis of human brucellosis incidence was the reports of the Public Health Center of the Ministry of Health of Ukraine. A retrospective epidemiologic analysis of human brucellosis was conducted for the period 1996–2021. Data from the reports were extracted, grouped and analyzed.

The analysis did not include data on the occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol and part of the temporarily occupied territories in Donetsk and Luhansk regions. Such data is currently unavailable.

Data on the total number of susceptible animals by species were obtained from statistical reports of the State Statistics Service of Ukraine (http://ukrstat.gov.ua). Geoinformation mapping analysis was performed using Quantum GIS 3.16.0 software, which is available free of charge at www.qgis.org/ru/site/forusers/download.html. Vector layers for the borders of Ukrainian regions were also used from the resource www.diva-gis.org/Data. To distribute the data, we chose a quantile classification with 5 data classes, with each class including an equal number of regions.

Results

The plans for mandatory preventive research on brucellosis in Ukraine include domestic animals: cattle, pigs, horses; wild boars and roe deer (Fig. 1–19).

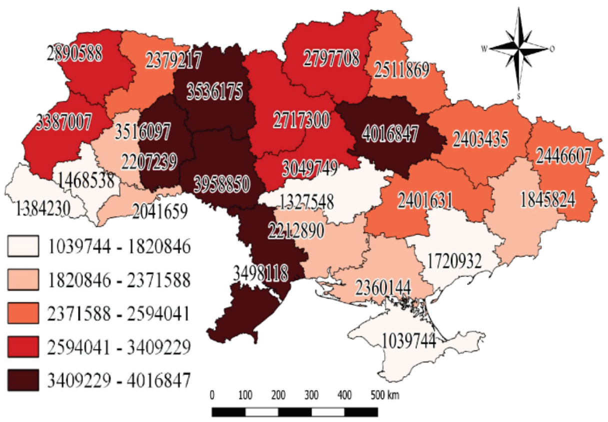

Fig. 1. The number of bovine blood serum samples tested for brucellosis in Ukraine in 2004–2021

Recently, hares have been added to the mandatory surveys (Fig. 18–20). For the period 2004–2021, the actual number of brucellosis tests among cattle was 62,917,946 head, small ruminants–10,898,075, pigs–4,146,751, horses–116,668, wild pigs–22,306, roe deer–11,548, hares (only the last 2 years were studied)–430 head. The volume of serological diagnostics of cattle for brucellosis in Ukraine for the period 2004–2021 is shown in Figures 1–3.

The analysis of cattle testing for brucellosis showed that during the period 2004–2021, the largest number of positive animals was detected – 607 head compared to all species. In some years, no positive animals were detected (2012, 2015), and 1–3 animals were detected in 2008, 2010, 2013, 2014, 2016, 2017. The largest number of brucellosis–positive animals was detected in 2004 and 2006, 107 and 328 animals, respectively. Some regions stand out among others with a significant number of positive results. For example, in Sumy region, positive animals were detected in 2004, 2005, 2007, 2009, 2010, 2011, 2013, 2019, 2020, 2021 (45 animals in total), in Dnipropetrovs'k region in 2004, 2016, 2017, 2018 (11 animals in total).

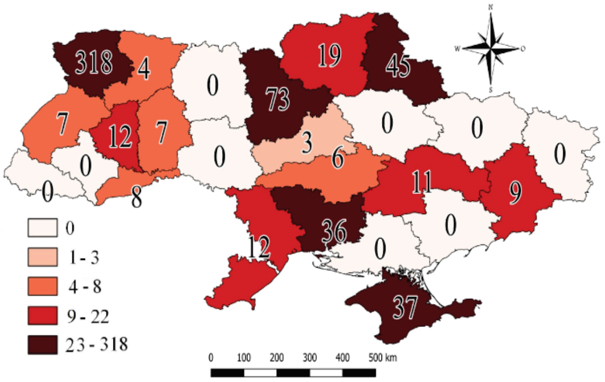

Fig. 2. Map of cases of registration of seropositive cattle for brucellosis in Ukraine in 2004–2021

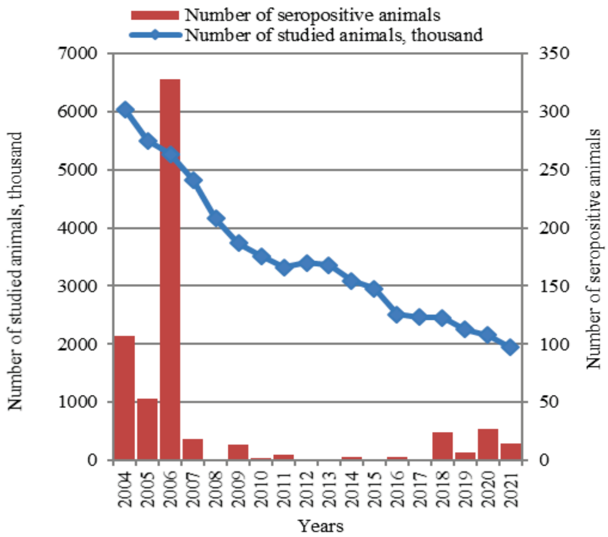

Fig. 3. Dynamics of the number of cattle seropositive to brucellosis in Ukraine (2004–2021)

The volume of serological diagnostics of small ruminants for brucellosis in Ukraine for the period 2004–2021 is shown in Figures 4–6.

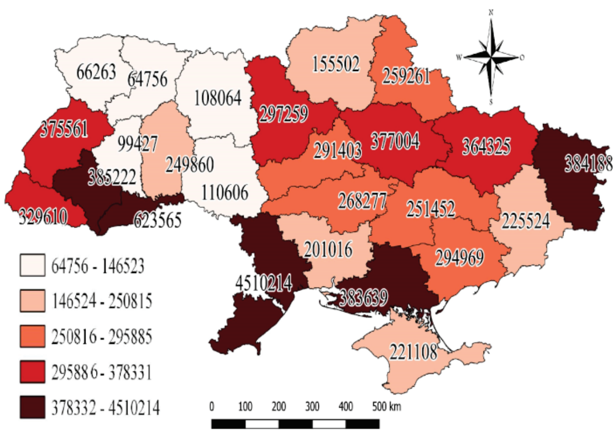

Fig. 4. The number of blood serum samples of small ruminants tested for brucellosis in Ukraine in 2004–2021

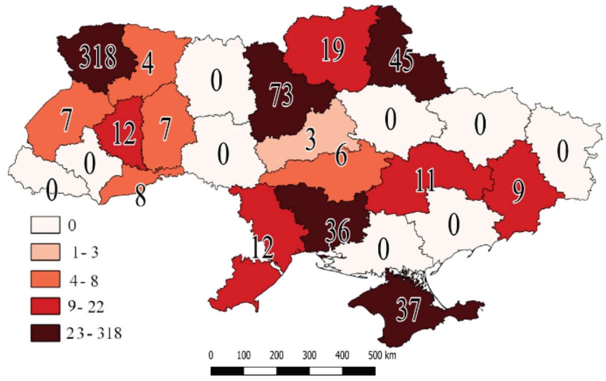

Fig. 5. Map of registration of small ruminants seropositive for brucellosis in Ukraine in 2004–2021

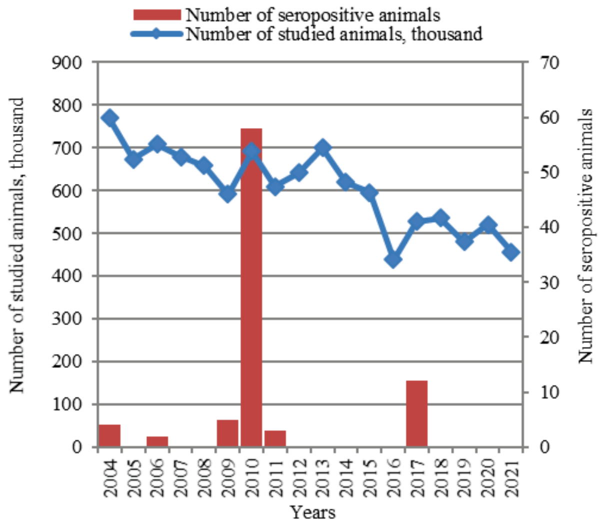

Fig. 6. Dynamics of the number of small ruminants seropositive for brucellosis in Ukraine (2004–2021)

The serological studies of small ruminants (sheep and goats) (Fig. 6) showed that 84 seropositive animals were detected during the years 2004–2021. For the period 2013–2016, and 2018–2021, no seropositive animals were detected at all. Even during this period, the number of tests (770,202 head in 2004) decreased (456,292 head in 2021) by 40.8%.

The volume of serological diagnostics of pigs for brucellosis in Ukraine for the period 2004–2021 is shown in Figures 7–9.

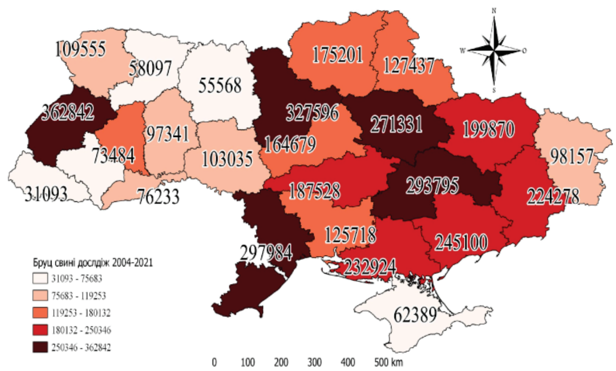

Fig. 7. The number of pig blood serum samples tested for brucellosis in Ukraine in 2004–2021

Analyzing the results of serological tests for brucellosis in pigs (Fig. 9), it was found that 219 positive animals were detected during the period 2004–2021. The largest number of seropositive pigs were found in the Odesa region – 144 and 48 animals, respectively, in 2005 and 2008. It should be noted that after 2013, no positive animals were detected at all. The latter is explained by the introduction of the latest technologies in pig breeding and compliance with the biosecurity system. After all, 15–20 years ago, sows were also kept in summer camps with piglets on most farms. Today, such farms practically do not exist anymore, which ensures that domestic pigs do not come into contact with wild and other animals and therefore do not come into contact with the pathogen.

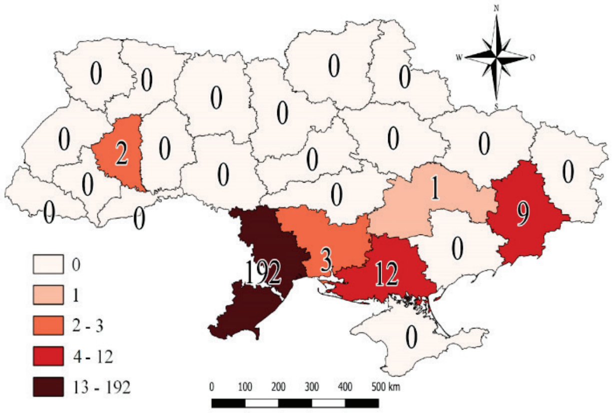

Fig. 8. Maps of registration of pigs seropositive for brucellosis in Ukraine for 2004–2021

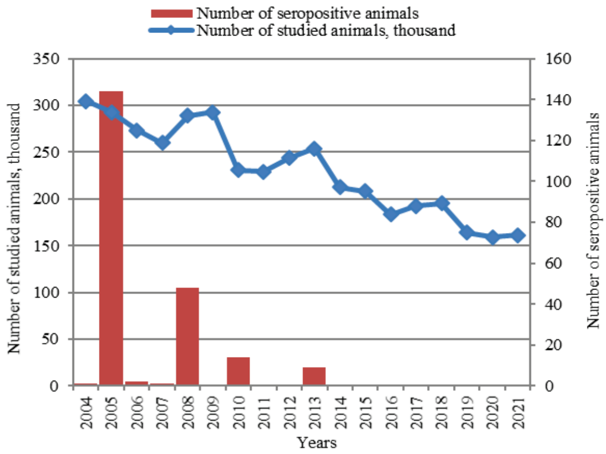

Fig. 9. Dynamics of the number of pigs seropositive for brucellosis in Ukraine (2004–2021)

The volume of serological diagnostics of horses for brucellosis in Ukraine for the period 2004–2021 is shown in Figures 10–12.

The materials of Figure 12 show that over the 18-years of serological studies of horses for brucellosis, only 4 positive animals were detected. Positive animals were found in Sumy (3 animals in 2020) and Dnipro (1 animal in 2016) regions. It should be noted that in these regions a significant number of positive animals were detected among cattle. The small number of positive animals among horses is explained by the isolation of their life from other species and the small number of horses in Ukraine (the lowest number tested among farm animals).

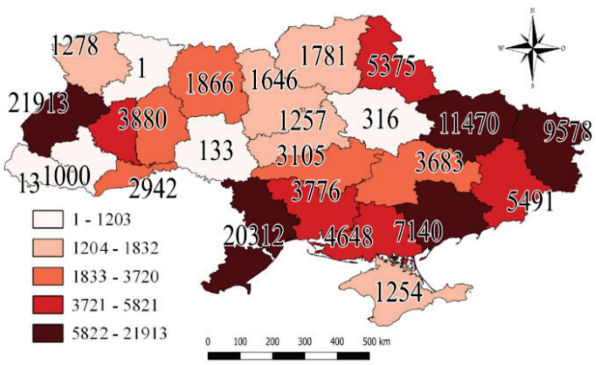

Fig. 10. The number of horse serum samples tested for brucellosis in Ukraine in 2004–2021

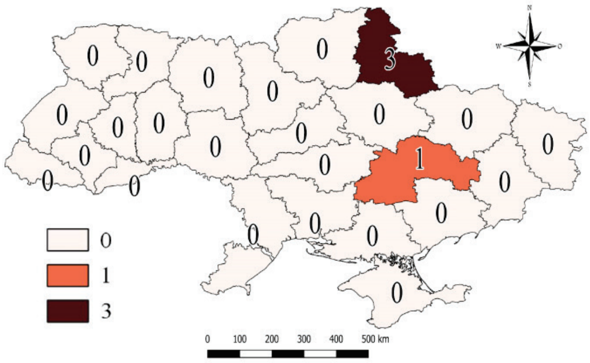

Fig. 11. Map of registration of brucellosis seropositive horses in Ukraine for 2004–2021

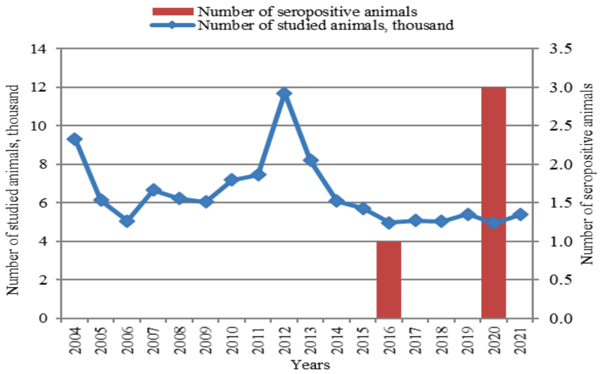

Fig. 12. Dynamics of the number of brucellosis seropositive horses in Ukraine (2004–2021)

The volume of serological diagnostics of wild boars for brucellosis in Ukraine for the period 2004–2021 is shown in Figures 13–15.

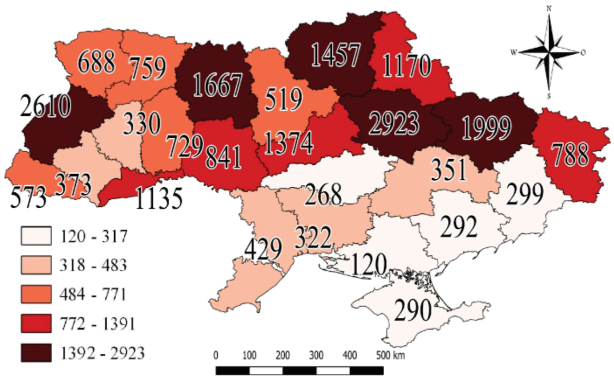

Fig. 13. The number of wild boar blood serum samples tested for brucellosis in Ukraine in 2004–2021

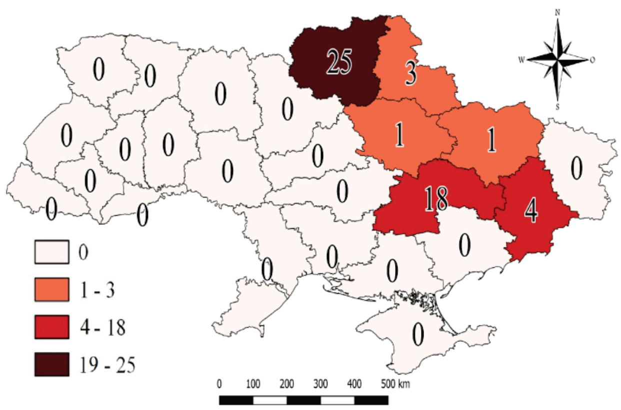

Fig. 14. Map of registration of wild boars seropositive for brucellosis in Ukraine in 2004–2021

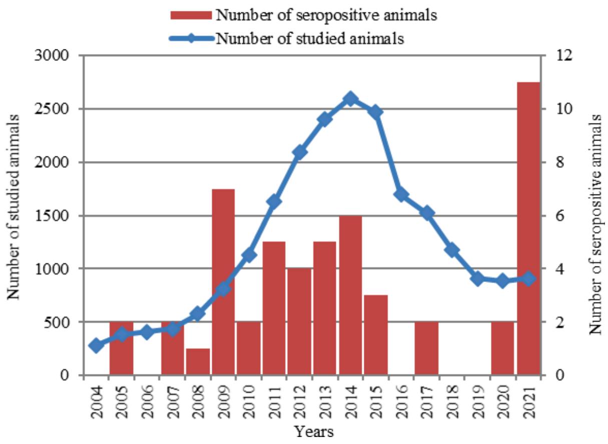

Fig. 15. Dynamics of the number of wild boars seropositive for brucellosis in Ukraine (2004–2021)

The results of the analysis of Figure 15 show that wild boars are the leading reservoir species among wild animals and are carriers of pathogens, often contaminating pastures, water bodies, etc. from which other species of wild and farm animals can be infected. In 18 years, no positive wild pigs were detected only in 2004, 2006, 2016, 2018, 2019. A total of 52 positive animals were detected in the period 2004–2021. A significant number of positive animals (25 head) were detected in Chernihiv region in 2009, 2010, 2011, 2012, 2013, 2014, 2020. In this case, there is a parallel between the largest number of people who fell ill in this region during the analyzed period. In Dnipropetrovsk region, positive animals were detected in 2010, 2011, 2012, 2014, 2015 2021 (18 animals), and in Sumy region in 2005, 2008 and 2017 (3 animals). At the same time, there are certain parallels in the greatest disadvantage of Sumy and Dnipro regions in terms of ASF among farm animals and wild boars.

The volume of serological diagnostics of roe deer for brucellosis in Ukraine for the period 2004–2021 is shown in Figures 16–17.

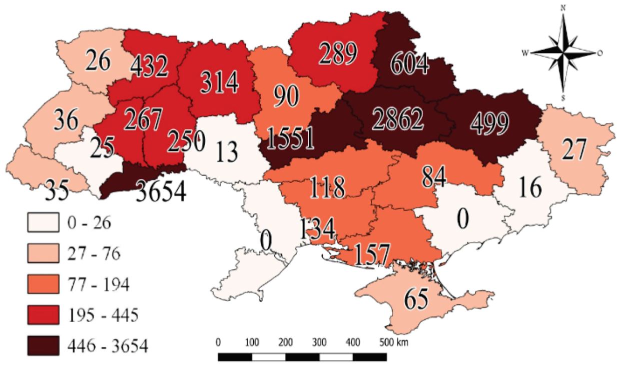

Fig. 16. The number of roe deer blood serum samples tested for brucellosis in Ukraine in 2004–2021

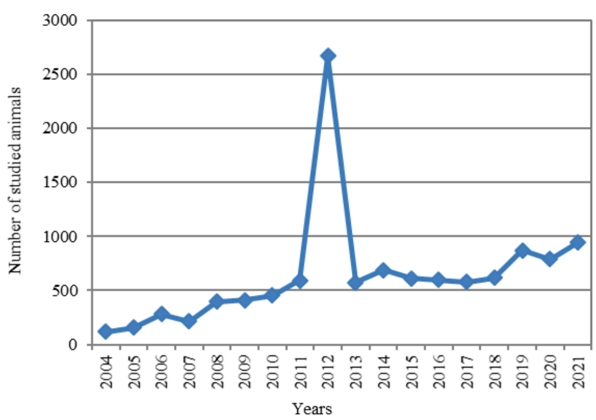

Fig. 17. Dynamics of the number of roe deer blood serum samples tested for brucellosis in Ukraine (2004–2021)

Over the 18 years, no animals positive for brucellosis were found among the roe deer studied.

The data of serological diagnostics of hares for brucellosis in Ukraine for the period 2004–2021 are shown in Figures 18–20.

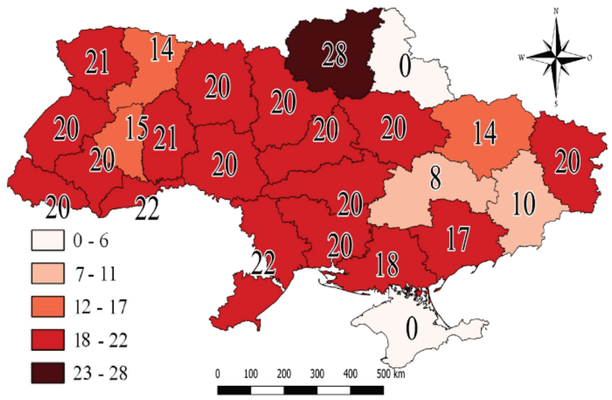

Fig. 18. The number of hare blood serum samples tested for brucellosis in Ukraine in 2004–2021

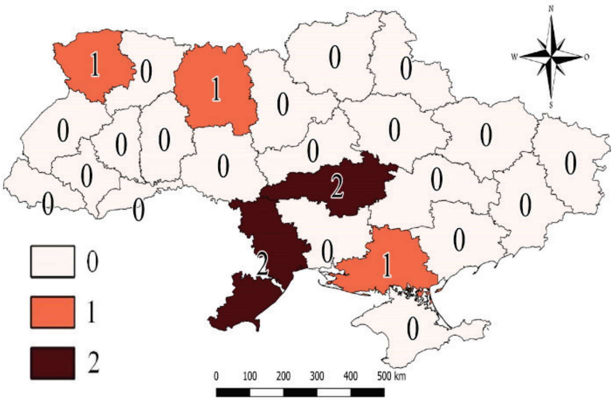

Fig. 19. Map of registration of brucellosis seropositive hares in Ukraine for 2004–2021

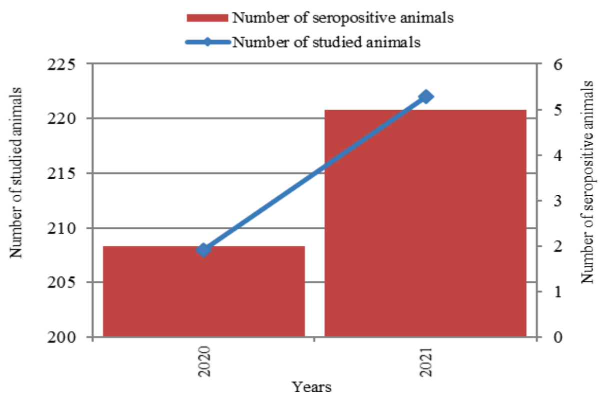

Fig. 20. Dynamics of the number of brucellosis seropositive hares in Ukraine (2004–2021)

Mandatory monitoring studies of hares have been conducted only for the last two years. In total, 7 positive results were obtained during this period. In 2020, 1 animal was detected in Volyn and Kherson regions. In 2021, 2 animals were detected in Odesa, 2 animals in Kirovohrad, and 1 animal in Zhytomyr regions.

Based on the results of the analysis, we found that the largest number of seropositive animals was found among cattle – 607 head, pigs – 219 head, small ruminants – 84 head, and horses – 4 head. In the vast majority of countries in the world where brucellosis is currently recorded, cattle and small ruminants are the most commonly seropositive animals. In our case, pigs were in second place. This situation is explained by the small number of small ruminants in our country.

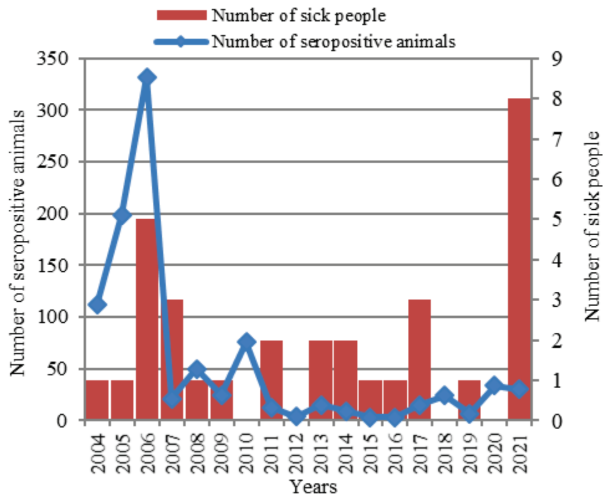

Fig. 21. The number of seropositive animals (cattle, small ruminants, domestic pigs, wild pigs, horses, hares) in Ukraine during the period of monitoring serological studies in 2004–2021 and the number of people who fell ill during this period

The data in Figure 21 show that almost every year there are animals seropositive for brucellosis among domestic and wild species, and almost every year there are isolated cases of brucellosis in humans. However, given the fact that more than 50% of human cases of this disease are imported to the territory of our country, it should be noted that the incidence among people in Ukraine is also affected by the deterioration of the situation in other countries. Thus, the global nature of today's world shows how the well-being of one country can affect the well-being of another.

The results of the analysis showed that human brucellosis in Ukraine is registered sporadically (in single cases). During the period 1994–2021, 45 people were diagnosed with brucellosis. The highest incidence rates were recorded in 2000, 2006, and 2021 (7, 5, and 8 patients, respectively). In 1996, 2004, 2005, 2008, 2009, 2012, 2015, 2016, and 2019, one sick person per year was detected, 2 sick people per year were detected in 1998, 2002, 2011, 2013, and 2014, 3 cases per year in 2007 and 2017. During the analyzed period, the disease was not registered in 1994, 1995, 1997, 1999, 2001, 2003, 2010, 2018, and 2020. Among the regions, Chernihiv (cases in 2009, 2011, 2014, 2015), Lviv (2005, 2011, 2021), and Kyiv (2008, 2014, 2021) were the most unfavourable. In 2000, 5 people fell ill during an outbreak in the Mykolaiv region, and in 2021, 6 people fell ill in Kyiv. In the period 1994–2021, the disease was not registered at all in the Autonomous Republic of Crimea, Volyn, Vinnytsia, Zakarpattia, Zaporizhzhia, Kirovohrad, Rivne, Ternopil, and Cherkasy regions.

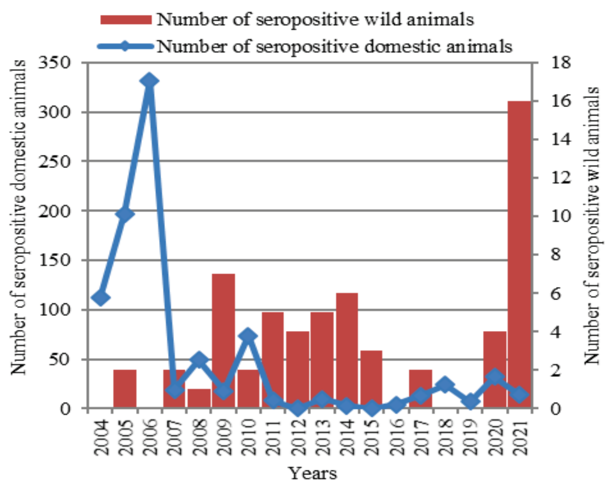

Fig. 22. The number of seropositive domestic animals (cattle, small ruminants, domestic pigs, horses) and the number of seropositive wild animals (wild pigs, hares, roe deer) in Ukraine for the period of monitoring serological studies in 2004–2021

The data in Figure 22 confirm the thesis that seropositivity among wildlife and domestic animals is linked. The trend lines for the actual number of tests show a significant decrease in actual monitoring studies in cattle (more than 3 times), small ruminants (41% decrease), and pigs (48% decrease). The decrease in the number of tests is explained by a significant reduction in the number of animals in the livestock population in Ukraine.

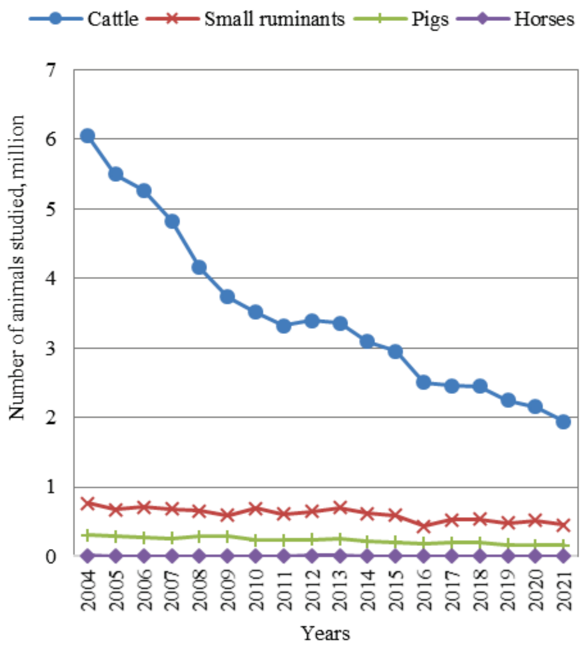

Fig. 23. Dynamics of the actual number of serological tests of farm animals (cattle, small ruminants, pigs, horses) for brucellosis

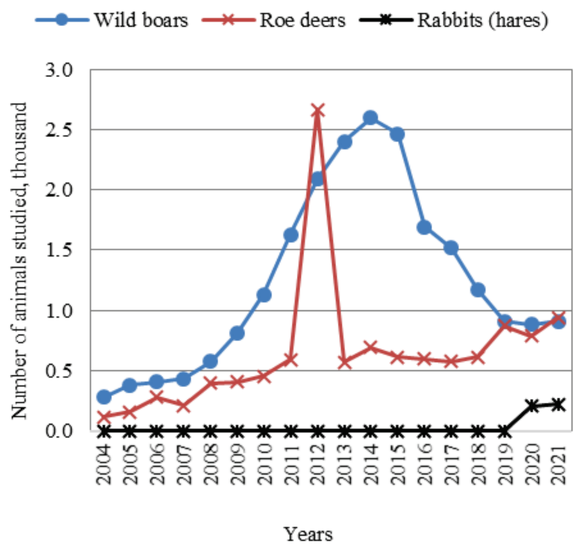

Fig. 24. Dynamics of the actual number of serological tests of wild animals (wild boars, roe deer, hares) for brucellosis

The results of the analysis of Figure 24 showed that the number of tests among wild pigs decreased compared to the number of tests oin 2011–2019, although it is higher than the number of tests in 2004–2010. In general, the number of roe deer tests is increasing every year (2013 was the peak year). Monitoring studies of hares for brucellosis are becoming regular.

The diagram in Figure 25 clearly shows the dominance of cattle, pigs, small ruminants, and wild pigs among brucellosis seropositive animals. Other categories of animals studied during the analyzed period included camels, deer, dogs, cats, rabbits, poultry, zoo animals, wild animals including elk, foxes, and badgers. The data from 2004 to 2021 show fluctuations in the number of animals studied in this category by year. The largest number of wild animals and other wildlife was studied in 2009–1,034 individuals, and the smallest in 2019 – 2 individuals. Most animals were studied in such regions as Dnipropetrovsk, Kherson, and Kyiv, with the exception of 2019, when animals from the Cherkasy region were studied.

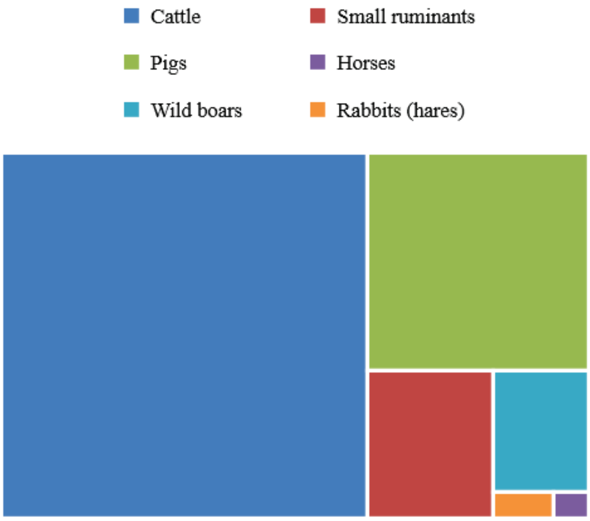

Fig. 25. The number of seropositive animals in Ukraine during the period of monitoring serological studies, 2004–2021

There are data on foxes surveyed in different regions of Ukraine from 2004 to 2013. The number of tested foxes varies by year, with a peak in 2012, when 27 animals were tested in Luhansk region. The lowest number of foxes tested in one year was in 2010 when two foxes were tested in Chernihiv region. The data also show that most foxes were tested in Luhansk, Kharkiv, and Zakarpattia regions, with the exception of 2009, when foxes were tested in several regions, such as Chernivtsi, Khmelnytskyi, Kyiv, Luhansk, Chernihiv. In 2013 and 2012, foxes were tested only in the Luhansk region.

In the period from 2004 to 2019, 22 elk were studied in Poltava, Chernivtsi, Kharkiv, and Rivne regions. In 2018–2021, 234 deer were tested, 100 of them in 2018 in the Volyn region, and the rest in the central and western regions of the country.

From 2017 to 2021, 133 of the park animals were studied, most of them in 2019 in the Dnipro and Kherson regions (56 animals) and the least in 2017 in the Chernihiv region (1 animal).

The smallest number of camels (6 animals) and cats (8 animals) were examined in Ukraine during the analyzed period.

All of the above studies of different animal species were negative.

Particular attention should be paid to the data on canine brucellosis testing in different regions of Ukraine from 2005 to 2020. The number of dogs tested for brucellosis has fluctuated over the years, with a general downward trend in the number of studies. The highest number of dogs tested in one year was in 2010 – 286 dogs in Lviv and Chernivtsi regions. The smallest number of dogs studied in one year was in 2017 – 3 dogs in Donetsk and Dnipro regions. In general, most dogs were examined in Dnipro, Odesa, and Chernivtsi regions, with the exception of 2010 and 2006, when the largest number of dogs was examined in the Lviv and Chernivtsi regions. These data indicate that the number of dogs tested for brucellosis in different regions of Ukraine varies over the years, but has a general downward trend. Seropositive dogs for brucellosis were detected only in 2017 in the Donetsk region, where 2 heads of 2 dogs were studied.

Thus, two positive cases of brucellosis in dogs were detected among the species not required for research.

Discussion

Brucellosis pathogens are important pathogens of humans and animals, and human brucellosis is a fairly common zoonosis globally. The pathogens are predominantly intracellular parasites in animals and humans, they have an immunosuppressive effect on the host and survive and multiply in macrophages and placental trophoblasts (Głowacka et al., 2018). The researchers point out that two important determinants of virulence have played a crucial role in the evolution of Brucella. These are the type IV secretion system, which secretes effector molecules into the host cell cytoplasm that control the intracellular movement of brucella and modulate host immune responses, and the lipopolysaccharide part, which is poor at stimulating the body's inflammatory responses. These factors are not the least in explaining why it is so difficult to fight this zoonosis in the modern world (Roop et al., 2021), even using the approaches of the One Health concept. Researchers note that brucellosis also exhibits cyclical characteristics of possible transmission to humans, pets, and wildlife (Assenga et al., 2015). In the history of Ukraine, the maximum number of cases of brucellosis in humans was registered in 1952 (fresh forms of brucellosis) – 1107 cases. An analysis of the epidemic situation in our country showed that during the period 1994–2021, 45 cases of human brucellosis were registered, and approximately half of these cases were imported brucellosis. There are 1.7 cases of brucellosis per year, which means that cases are mostly sporadic. According to reports (Markovych, 2020), it was found that in general, over more than 20 years, the incidence of brucellosis among people in Ukraine amounted to 0.07 per 100,000 people. In 2000, 5 human cases were reported in Mykolaiv region during one local outbreak from a local source of infection. It is also reported (Chemych et al., 2017) that a significant proportion of human brucellosis cases in Ukraine are imported. For example, in 2007, two people who had previously been in rural areas of Turkmenistan developed acute brucellosis in the Sumy region. In the same year, a resident of the Kyiv region who had been in rural India and consumed dairy products from local cattle fell ill. In 2008, a case of brucellosis was registered in a Kyiv resident who had previously spent a long time in Azerbaijan. The results of epidemiological studies for the period 2010–2017 indicate that out of 11 people who became ill, 8 were infected abroad (Central and Eastern Asia, the Caucasus, the North Caucasus, India, Bulgaria, and Russia) (Novokhatnii et al., 2017). In our country, such cases of "foreign" infection have also been reported in Odesa (2013), Kyiv (2014), and Donetsk regions (2017). There is no doubt that persistent seropositivity among wild animals (a constant source of the infectious agent) contributes to seropositivity among farm animals, and the latter is the source of infection for humans.

An analysis of the epidemic and epizootic situation with brucellosis in the world according to the ProMed database (http://promedmail.org/promed-posts) for the period 2000–2021 showed that almost all cases of human infection are associated with animals and animal products. This includes the consumption of dairy products, mainly cheeses and contaminated milk from different species of animals, infection of veterinary laboratory workers while working with biological material, and infection of slaughterhouse workers while working with infected and diseased animals. Animals with brucellosis are often identified during monitoring serological studies. There have been cases of importation of animals-reservoirs of the pathogen to zoos from disadvantaged areas (from Myanmar to Germany in 2013). Almost all human cases in Sweden, for example, occurred as a result of travel to brucellosis-prone countries. There have even been cases of infection in domestic animals (dogs, cats) after they have consumed insufficiently sterilized animal feed. Wild animals that are reservoirs of the pathogens of this disease are represented by deer, caribou, elk, chamois, wild boars, bison, buffalo, and marine mammals. Among domestic and domestic animals, the disease was mostly recorded among sheep, goats, cattle, camels, pigs, and dogs. In general, during this period, the disease was recorded in the Americas (USA, Canada, Mexico, Argentina, Chile, Venezuela, Panama, Paraguay, Uruguay, Bolivia, Honduras, Costa Rica), Oceania (Australia, Fiji, New Zealand, etc.), Asia (South Korea, North Korea, Kazakhstan, India, Pakistan, Sri Lanka, China, Turkey, Iran, Indonesia, Japan, Tajikistan, Kazakhstan, Kyrgyzstan, Thailand, Uzbekistan, Azerbaijan, Malaysia, Taiwan, Nepal, Oman, etc.), Europe (Finland, Estonia, Hungary, Iceland, France, Great Britain, Italy, Spain, the Netherlands, Portugal, Austria, Croatia, Cyprus, Greece, Germany, Romania, Czech Republic, Georgia, Bulgaria, Ireland, Latvia, Lithuania, Luxembourg, Malta, Poland, Slovakia, Slovenia, Norway, Belgium, Sweden, Armenia, the Russian Federation, Bosnia, and Herzegovina, etc.), Middle East (Saudi Arabia, Kuwait, Israel, Syria, Iran, Iraq, etc.), Africa (UAE, Algeria, Libya, Sierra Leone, Botswana, South Africa, Uganda, Kenya, Egypt, Eritrea, Nigeria, Sudan, etc.).

As noted by leading researchers of brucellosis, the use of such components as serological diagnostic tests, vaccination (in case of a significant spread of the disease in the country), and rejection allow us to bring the disease under control and eliminate it (Rossetti et al., 2022). In our country, serological monitoring and culling are used to keep the incidence at the level of sporadic cases in animals and humans; effective prevention measures also include continuous surveillance, prevention of the spread of the pathogen and its transmission to humans, and effective control of pathogen reservoirs.

Given the fact that no reliable and safe vaccine has been developed to prevent this disease in humans (Li et al., 2017), the most reliable approach is to prevent brucellosis in animals, combined with monitoring studies and surveillance of both wild and domestic animals, targeted measures to improve the safety of animal products, occupational health and safety, and the safe work of laboratory workers. According to the WHO global concept of One Health, more than 60% of all pathogens of infectious and invasive human diseases originate from animals (zoonotic). Inspection and eradication of infectious diseases of farm and wild animals is a prerequisite for the control and eradication of human diseases (Ko & Splitter, 2003). Therefore, inter-sectoral and interdisciplinary cooperation at the state level of medical and veterinary services (Zinsstag et al., 2011), and the involvement of the latter in the prevention and control of this dangerous zoonosis is extremely important (Asiimwe et al., 2015; Bamaiyi, 2016). Ukraine, like any other country facing brucellosis in animals and humans, spends significant funds on public health, diagnostic testing and therapy, and public education to prevent and reduce disease transmission. In practical terms, the One Health concept itself should include public education, development of infrastructure for disease monitoring, appropriate reporting in both human and veterinary medicine, and continuous surveillance and control of susceptible domestic and wildlife species (Musallam et al., 2016; Franc et al., 2018). Highlighting brucellosis as a dangerous zoonosis, continuous training of livestock producers and veterinarians, pasteurization of milk, and good heat treatment of meat before consumption are the leading criteria for prevention. Reliable sterilization of equipment and laboratory instruments are essential requirement to protect laboratory workers (Roy et al., 2011; Khan & Zahoor, 2018).

During the period under review, 607 animals were identified in Ukraine as seropositive for brucellosis among cattle, 84 among small ruminants, 219 among pigs, 4 among horses, 2 among dogs, 52 among wild pigs, and 7 among hares. Seropositivity among farm animals (cattle, small ruminants, horses) (Nevolko, 2017) and wild boars (Pyskun et al., 2019) in our country has been reported by other domestic researchers. In addition to controlling wildlife reservoirs of the pathogen, special attention should be paid to stray dogs. In our analysis, we drew attention to the isolation of two seropositive animals in the Donetsk region in 2017. After all, the brucellosis pathogen from wild animals can get to stray dogs, and from them to dogs kept by people in apartments and houses, as other Ukrainian scientists have also pointed out (Bolotin et al., 2020).

A positive factor in the control and prevention of brucellosis in our country is the immediate slaughter of all seropositive cattle. However, bacteriological tests of seropositive animals are often not performed. The problem of human medicine in this regard is mainly that its employees ignore the animal reservoir of infection, and after diagnosis, much attention is paid to the treatment of individual patients using various antibiotic regimens (Hull & Schumaker, 2018).

Thus, sporadic but almost annual cases of brucellosis in humans in Ukraine indicate the constant presence of the pathogen on its territory (reservoir role of wild animals). Continuous serological monitoring of farm animals (in case of purchase, sale, for preventive purposes) and immediate slaughter in case of positive test results is a justified measure (Moreno, 2014; Zhang et al., 2018; Kneipp et al., 2019; Khurana et al., 2021). Most developed countries also use serological monitoring and strict rejection based on serological testing. Thanks to this work, there is no brucellosis in Ukraine in epidemically significant species of cattle and small ruminants. The State Food and Consumer Service of Ukraine ensures reliable control over the movement of animals and livestock products both within the country and from abroad. At the state level, efforts are constantly being made to inform the public about the dangers of brucellosis, ways of human infection and health risks, and the prevention of this disease. In Ukraine, legislation provides for separate quarantine of imported breeding animals (cattle, sheep and pigs). After that, such animals are monitored for at least 12 months, until calving, lambing or farrowing, with the exclusion of brucellosis after receiving negative serological results. In case of detection of brucellosis in animals in farms, herds, settlements, etc., they are declared brucellosis-unsafe and quarantine measures are introduced. A farm, herd or settlement is considered to be free from the disease only when all sick and suspected animals have been slaughtered, together with their offspring, and after a set of sanitary and anti-epidemic and special veterinary measures have been taken (Korniienko et al., 2009).

Conclusion

In Ukraine, the following animals are subjected to continuous monitoring studies for brucellosis: cattle, pigs, and horses; wild animals: roe deer, wild boars, and hares. Dogs, cats, rabbits, poultry, zoo animals, elk, foxes, badgers, and other wild animals are tested periodically or as needed. During the period 2004–2021, the following number of seropositive animals were detected during serological studies in Ukraine: cattle – 607, small ruminants – 84, pigs – 219, horses – 4, dogs – 2, wild boars – 52, hares – 7.

In the period 1994–2021, 45 people fell ill with brucellosis in Ukraine (32 cases in the period 2004–2021). About 50% of human brucellosis cases are "imported" from abroad.

There is a definite link between seropositivity among wild animals (mainly wild boars), seropositivity among domestic animals, and the incidence among humans. For example, during the analyzed period, 25 seropositive wild boars were detected in Chernihiv region in 2009, 2010, 2011, 2012, 2013, 2014, and 2020. This coincides with the largest number of seropostitive people in the region during the analyzed period. A significant number of seropositive wild boars (18) were detected in Dnipro region (2010, 2011, 2012, 2014, 2015, 2021) and Sumy region – 3 in 2005, 2008, 2017. In this case, there are certain parallels in the disadvantage of these regions in terms of brucellosis in farm animals.

The authors would like to express their gratitude to the specialists and heads of regional institutions of the state veterinary service, veterinary laboratories, and the Center for Public Health of Ukraine for their assistance in organizing the data collection.

The authors declare that there is no conflict of interest.

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