

African swine fever (ASF) and ticks. No risk of tick-mediated ASF spread in Poland and Baltic states

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Abstract

Infectious diseases of swine, particularly zoonoses, have had a significant influence on nutritional safety and availability of pig meat as high-energy protein product since the time that pigs were domesticated back in the 7th century BC. The main sources of swine infectious diseases include the so-called primary sources (direct infection, *i.e.* through contact with infected and sick animals) and secondary sources (contaminated meat products, slaughter products, and vectors, including ticks). At present, the most serious epidemiological and economic threat to swine breeding in Europe is African swine fever (ASF). This disease, originally coming from Africa, is incurable and causes death of infected pigs and wild boars during 7–10 days after infection. Among the various factors that influence the spread of ASF, important role is played by ticks from the genus *Ornithodoros*, mainly from the species *Ornithodoros moubata*. Research on the ASF indicates that other species of ticks can also transmit the virus to healthy pigs in laboratory conditions. Sylvatic and domestic cycles of ASF virus transmission, which have been described so far, require further studies and updating in order to point the potential new vectors in the Caucasus and Eastern Europe affected by the ASF. Effective methods of control and biosecurity may significantly slow down the spread of ASF, which undoubtedly is a major threat to world pig production and international swine trade.

Keywords: African swine fever, ASF virus, ticks, vector.

Introduction

Swine diseases have long been an important problem, leading to the decrease in livestock resulting in serious economic and agriculture losses, and negatively affecting the nutritional safety of people around the world (3, 9). The sources of swine infections include primary sources of infection, connected with direct infection from sick animals as well as carriers of disease, and secondary sources associated with meat products and post-slaughter products, as well as with vectors such as arthropods, including ticks (3). The reservoir for pig diseases can be related to both human environment (*i.e.* slaughterhouses, piggeries, meat distribution) and animal environment, together with natural conditions occurring in a given area, including the presence of *i.e.* wild boars and ticks (3, 6). At present, the most serious threat to global food

safety including Europe, is African swine fever (ASF), whose new outbreaks have occurred in the eastern part of the old continent (14, 27, 32).

African swine fever virus (ASFV). ASFV is an *Asfivirus* belonging to the *Asfviridae* family (dsDNA virus). Its genome has a size of 170–190 kbp. Until recently, 22 different genotypes of this virus were distinguished based on p72 sequencing (26, 31); however, a new ASFV genotype (XXIII) has been lately discovered in Ethiopia (1).

ASFV is very solid and resistant to a wide range of different physical and chemical factors. It is stable in pH range from 4 to 10. It survives the process of meat smoking, drying, and freezing (stable up to six months). The virus is also resistant to high temperatures and can only be inactivated by heating at 60°C for at least 20 min (3).

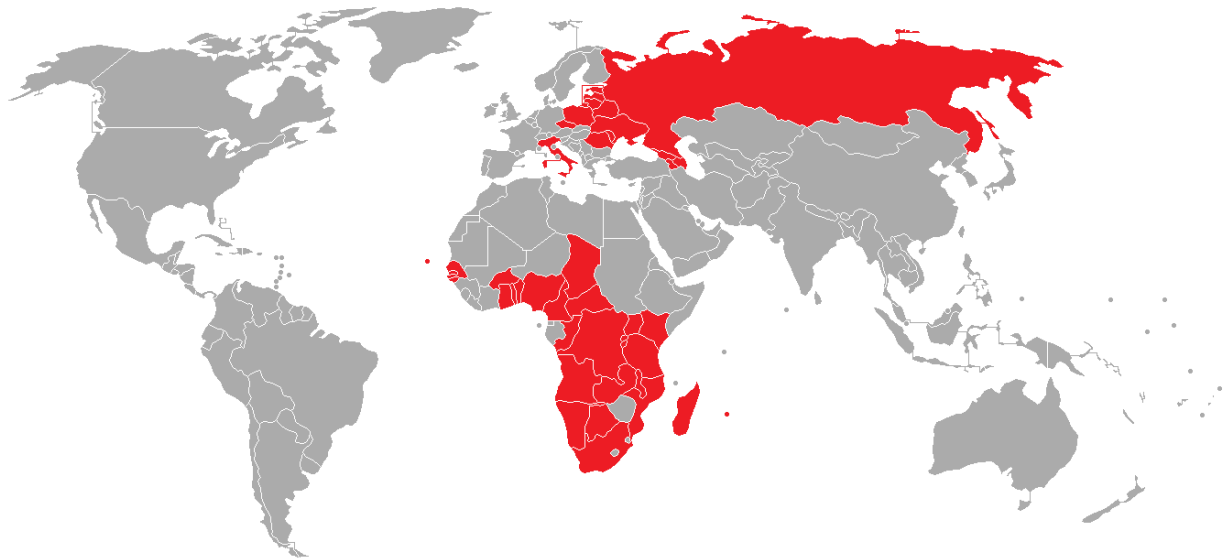


Fig. 1. Countries where ASFV has been confirmed over the last years (red)

Known hosts of the virus include domestic pigs, wild pigs (including warthogs, bushpigs, giant forest hogs, wild boars), and ticks (6). ASFV chooses monocytes and macrophages as the main target (26). Animal death occurs within 7–10 days after infection (3). Infected and recovered pigs are a very important factor that influences the spread of ASF in the herd. In Africa, warthogs are the main reservoir for this virus and are considered to be the original source of porcine ASFV origin. In Europe, wild boars, which are as susceptible to ASF as pigs, are its primary reservoir (6).

ASFV originally comes from Africa (endemic in sub-Saharan Africa) (6), where the first case was described in 1921 in Kenya. The virus left the African continent for the first time in 1957 and appeared in Lisbon, Portugal, causing almost 100% mortality of infected pigs. Later the virus moved to Spain, Malta, Italy (Sardinia), Brazil, Dominican Republic, Haiti, and Cuba. In 1998 ASFV was discovered in Madagascar and in 2007 in Mauritius (the second island in the Indian Ocean) (2). Also in 2007, the virus reached Georgia through the Black Sea, spreading to Armenia, Azerbaijan, and the Russian Federation. From Russia, the virus moved on to Ukraine, Belarus, the Baltic States (Lithuania, Latvia, Estonia), and Poland in 2014, where the disease spread mainly through contaminated meat and wild boars (18, 24, 27, 31, 32).

ASF continues to be endemic in Sardinia and in sub-Saharan countries (6, 16, 26). The current confirmed incidence of ASFV in the world is shown in Fig. 1, with the last outbreaks in Moldova (11), Czech Republic (13) and Romania (12).

Ticks as vectors. Vector-borne diseases are defined as those that are transmitted from a source of infection to the new individual organism by various

biological relays (mainly arthropods) (8, 19). Arthropods are vectors for almost every major group of pathogens, including viruses, bacteria, protozoa, and helminths. Transmission of the disease occurs mainly infected blood-sucking insects, either through mechanical vector biological vector. The mechanical transfer of the disease occurs when the vector is only a temporary carrier of the pathogen (*e.g.* in insect mouthparts), whereas the biological vector involves a prolonged infection of the insect that in many cases may become a part of the pathogen development cycle (19). Viruses transmitted by arthropods are called arboviruses (ARthropod-BORne virus). ASFV is the only known DNA arbovirus (22).

Ticks, among other factors, are responsible for the transmission of ASFV in the environment. The formerly mentioned ticks from the genus *Ornithodoros* are the main source of infection (6, 5, 26). The first documented case of ASFV isolation in ticks (*O. erraticus*) was recorded in Spain in the sixties (5). In Africa, the *O. moubata* ticks (both for domestic pigs and wild pigs) are the main reservoir of this virus (6). In Western Africa (Senegal), ASFV was found in *O. sonrai*, but their role in ASFV transmission is limited (30). The occurrence of *O. moubata* ticks was mainly confirmed in southern and eastern Africa, *O. erraticus* in Mediterranean countries (10, 20, 28, 29), and *O. sonrai* predominantly in northern Africa (30) (Fig. 2).

Studies on other ticks from *Ornithodoros* genus have shown that under laboratory conditions five different tick species have the potential to transmit ASFV. Four of them are from Central and North America (*O. coriaceus*, *O. turicata*, *O. parkeri*, and *O. puertoricensis*), while one is from the North African desert (*O. savignyi*) (6, 10).

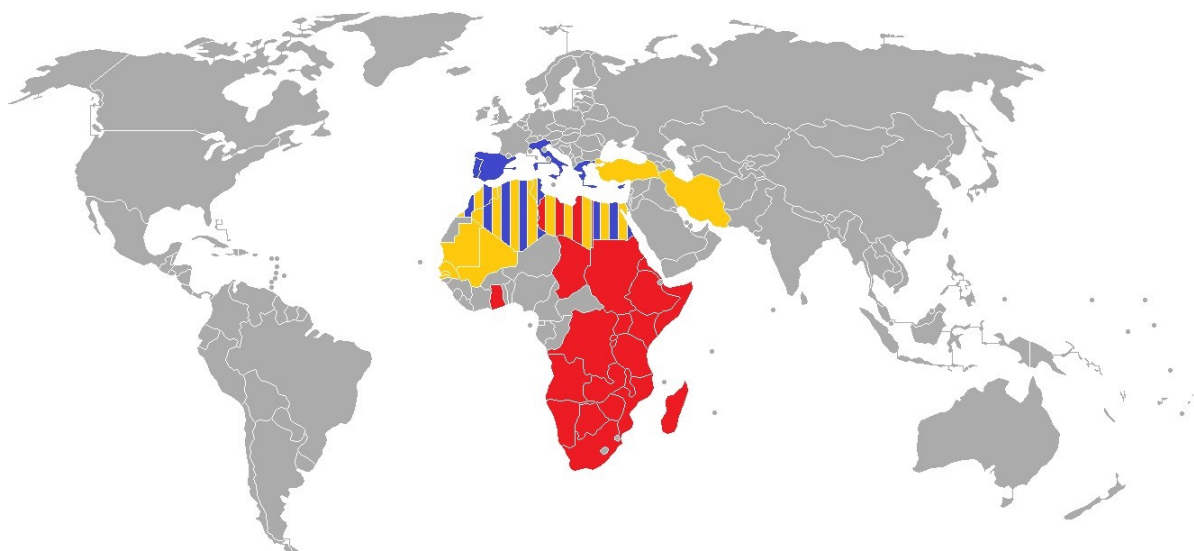


Fig. 2. Geographical distribution of *O. moubata* (red), *O. erraticus* (blue), and *O. sonrai* (orange)

Some authors hypothesise the co-evolution of the ASFV together with the tick of the genus *Ornithodoros*. Similarities in some genomic telomeres between ASFV and the *Borrelia burgdorferi* sharing the same host in Africa (*Ornithodoros*) have been confirmed, suggesting that the virus may initially have evolved to function in the soft tick only (15).

Ticks and ASFV transmission cycle. It is well known that the ASFV can be transmitted directly from an infected pig, wild swine, or products made from them to other individuals (3, 6, 9). In African countries and parts of the Mediterranean countries, the ticks of the genus *Ornithodoros* are also responsible for the transfer of the virus to new individuals. These arthropods can pass on ASFV in several ways (5, 6).

Ticks can spread the infectious agent through transstadial way (transition from immature to adult), transovarial (from the mother to the offspring), through sexual contact, and directly to susceptible animals. The virus can survive in the tick population itself, without contact with the swine population for many years, constituting a permanent source of danger (10, 19).

Laboratory data indicate that ASFV can remain in *O. moubata* for up to three years (transstadial, transovarial, sexual, and direct to animal – three years), while in *O. erraticus* for up to five years (transstadial, sexual, and direct to animal – 588 days post infection (DPI)) (10). For the remaining laboratory-infected species (potential new ASFV vectors), the persistence of the ASFV was observed for species *O. coriaceus* – up to 502 days (transstadial, direct to animal – 502 DPI), *O. turicata* – up to 23 days (direct to animal – 23 DPI), *O. parkeri* – up to 70 days (transstadial), *O. puertoricensis* – up to 239 days (transstadial, direct to animal – 239 DPI) and *O. savignyi* – up to 106 days (transstadial, direct to animal – 106 DPI) (6, 10).

Sylvatic cycle. There are many factors involved in sylvatic cycle of ASFV. The cycle was best described

and investigated in Africa (South and East), where it consists mainly of *O. moubata* ticks and warthogs (5, 6, 26). Some researchers also indicate the participation of bushpigs in the sylvatic cycle (5). Young warthogs are infected by the infected ticks during the short period of viraemia. The virus is transmitted to uninfected ticks by sucking infected blood (5, 6, 26). Warthogs remain asymptomatic carriers of ASFV throughout their whole lives, but they cannot transmit the disease between other representatives of their species either horizontally or vertically, so the survival of the virus in the wild environment in Africa is dependent on ticks (6). Furthermore, the virus can spread in the tick population through transstadial, transovarial, and sexual transmission (5). Long maintenance of virus in tick population allows its transmissions to warthogs in the next season (6). In areas of Africa where both these species occur, a high level of ASFV infection is observed; however, it is not the rule for the whole continent. In West Africa, despite the presence of warthogs and *O. moubata* ticks, the sylvatic cycle is much less involved in the spread of the ASFV (6, 26).

In the case of North Africa and the Mediterranean, it has been proven that the *Ornithodoros* ticks present in the area may be involved in the sylvatic cycle. *O. erraticus* can transmit ASFV to domestic swine (4, 17). In the area of Senegal and sub-Saharan Africa, *O. sonrai* may play the role in maintaining ASFV in the sylvatic cycle (17, 30).

Sylvatic cycle associated with the transmission of the virus in the Caucasian area, the Russian Federation, Belarus, the Baltic States, and Poland is slightly different. The presence of native ticks in the ASFV transmission or its reservoir has not yet been proven. In the mentioned Eurasian area, the presence of wild boar populations is mainly responsible for the transfer and survival of the virus (14, 25–27, 32). Studies conducted in Poland have clearly indicated a link between

increased ASFV incidence and increased population density of wild boars (the first 12 months of the epidemic) (27). Research conducted by the Laboratory for African Swine Fever at the National Veterinary Research Institute in Pulawy, Poland, over the years 2015–2016 has shown that most of wild boars are dying rapidly after infection, spreading the virus at a distance of no more than 10 km. However, two cases of wild boars (hunted), which survived the initial infection and despite the low Ct obtained in the RT-PCR were serologically positive, and therefore capable of spreading the virus (32).

Domestic cycle. Once introduced to the swine population, ASFV is impossible to remove. It can spread locally through clothing of pig workers, shoes, equipment and agricultural vehicles, secretions and excreta of pigs, direct contact between pigs, or their meat (lack of biosecurity) (3, 4, 6, 14). It has been proven that *O. erraticus* can transmit the disease between pigs (23). The mortality rate among the swine reaches 100% after approximately 10 days, while recovered pigs can continue to transfer the virus to healthy animals. Transmission through direct contact may occur for 30 days after infection or within eight weeks in case of a contact with the contaminated blood (fighting and mating). ASFV can be present in pepperoni sausage and salami up to 30 days, and in Parma ham even 100 days (7).

Analytical studies indicate several factors that increase the probability of ASFV spread in the domestic swine population: free fallout, earlier presence of the disease on a farm, presence of infected pigs in the area, veterinary visits (Africa) (6).

The connection between cycles. The border between sylvatic cycle and domestic cycle is not impenetrable and factors such as ticks of the genus *Ornithodoros* have a good chance to move between forest and domestic pig farm, spreading ASFV in the African continent and in southern Europe (3, 6, 26).

Ornithodoros ticks are often found in domestic pigs, both in Africa and in the Iberian Peninsula, transmitting the virus from the sylvatic cycle to the domestic cycle (6, 4, 26). Due to the long persistence of ASFV in soft ticks (from several months to several years), ticks are a serious threat to swine, even in a few years from the last confirmed case of ASF in a given area (6). An example can be *O. erraticus*, which in 1999 caused a single ASF outbreak in Portugal after the eradication of this disease in the country (4, 23, 26). Another example of the danger associated with the tick may be Madagascar, where the ASFV was isolated from ticks found on the farm where the pigs had not been raised for at least four years (6).

The presence of ASFV among wild boars in the area surrounding the piggery greatly increases the risk of transmission of the virus from the forest to the pigs, by direct contact with infected animals or the meat of these wild animals (Eurasia) (14, 32). Fig. 3 shows the relationship between the cycles.

Eurasia – new border. In 2007, ASFV entered Georgia with a transport of virus-contaminated meat from East Africa or Madagascar. Since then, the genotype II of the virus has spread from the Caucasus region to Eastern Europe, mainly through the lack of effective biosecurity and wild boars which can easily cross national borders (14, 25, 26, 31, 32). Scientific data indicate the presence of *Ornithodoros* ticks in the new area of ASFV (*O. alactagalis* – Armenia, Azerbaijan, Georgia, Northern Caucasus; *O. asperus* – Caucasus, *O. coniceps* – Ukraine, *O. lahorensis* – Armenia, Russian Federation; *O. tholozani* – Ukraine; *O. verrucosus* – Armenia, Georgia, Russian Federation), but most of these ticks do not infect domestic pigs and wild boars as their carriers. In addition to the *Argasidae* family, except the genus *Ornithodoros*, only four species of soft ticks have been confirmed in this area; however, they are parasites of birds, humans, or bats (*Argas persicus*, *Argas polonicus*, *Argas reflexus*, *Argas vespertilionis*) (21). A laboratory study confirmed that ASFV strain Georgia 2007/1 can replicate in *O. erraticus* (23, 25), whereas the role of local *Argasidae* ticks in the transmission of ASF in the Caucasus and Eastern Europe has not been proven so far (14, 21, 23).

In Central Europe and in the Baltic States, soft ticks are almost absent, while hard ticks are a large and major group of these parasites in this area (14). So far, the studies have been conducted only on a few members of *Ixodidae* family (*Rhipicephalus bursa*, *Hyalomma* spp. – European ticks; *Rhipicephalus simus*, *Amblyomma variegatum*, *Amblyomma americanum*, *Amblyomma cajennense*) to determine their ability to become new ASFV vectors. Field studies have not demonstrated the presence of ASFV in the tick. Under laboratory conditions, ASFV remained for five–six weeks in *R. simus*, and in the case of *A. americanum* and *A. cajennense* from four to seven days after the contact with the infected blood. None of the analysed species demonstrated the ability to transmit ASFV to pigs (8).

Among hard ticks commonly found in Europe, in a new region of ASFV prevalence, two species are distinct: *Ixodes ricinus* and *Dermacentor reticulatus* (8, 14). These species are involved in the transfer of other infectious diseases: *I. ricinus* – TBEV (tick-borne encephalitis virus) and *D. reticulatus* – OHFV (Omsk haemorrhagic fever virus). Scientific studies indicate that there is no ASFV replication in the organism of these ticks, but viral DNA can persist from six up to eight weeks, allowing them to become potential mechanical vectors, but excluding the possibility of their occurrence as biological vectors (8).

For other arthropods present in the region, the potential of the *Stomoxys calcitrans* (stable fly) was observed in the transmission of ASFV in pigs as a mechanical vector (up to 24 h) (8, 14). ASFV has also been identified in *Haematopinus suis* (hog louse) under laboratory conditions after feeding on ASF pigs (14).

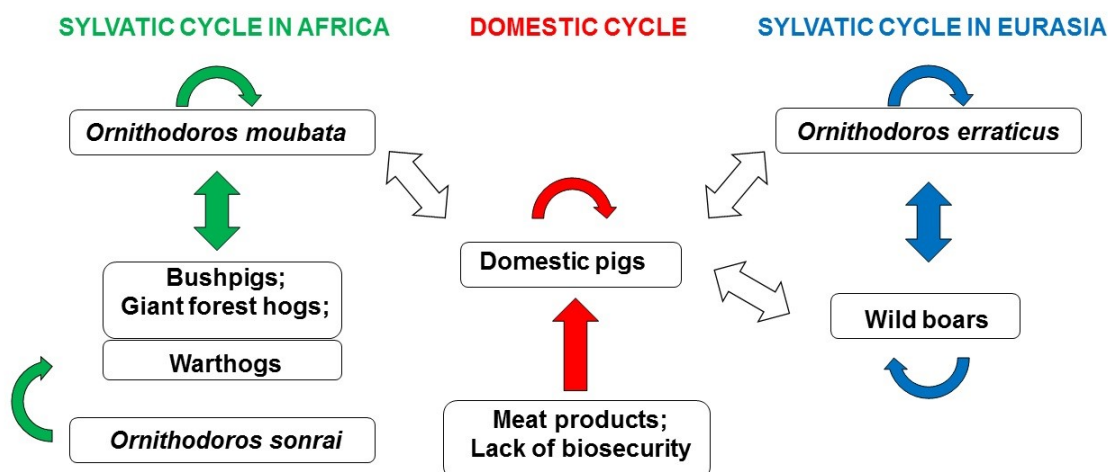


Fig. 3. The relationship between sylvatic and domestic cycles in ASFV spread (green arrows – sylvatic cycle in Africa, blue arrows – sylvatic cycle in Eurasia, red arrows – domestic cycle, white arrows – connections between cycles)

In conclusion, ASF is a serious economic and agricultural problem. Sources of the infection affecting the spread of this contagious disease in pigs are well described and understood. Effective preventive and biosafety measures have a significant impact on limiting the spread of ASFV, but forest-based transmission cycles are a separate and very difficult problem to tackle. On the African continent, *O. moubata* and *O. erraticus* (also found in the southern part of Europe) play a significant role in the continued presence of the virus in this part of the world through long-term maintenance and easy transmission. Systematic research indicates that more and more ticks can become a biological vector for ASFV, but the virus seems to be the main host for the *Argasidae* family ticks of the genus *Ornithodoros*. Current scientific studies indicate that the *Ixodidae* family, which is the largest group of ticks on the European continent, is not likely to play a significant role in ASFV transmission, providing only a potential but not explicitly documented mechanical vector. A sylvatic cycle, consisting of wild pigs and various ticks, may continue to be a significant problem in the control of ASF and may cause new outbreaks of this disease in new regions of the world.

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