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AFRICAN SWINE FEVER: NEW CHALLENGES AND MEASURES TO PREVENT ITS SPREAD

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***Summary**: African swine fever (ASF) is one of the most important diseases of pigs, caused by a complex DNA virus that produces no neutralising antibodies in infected animals. After being introduced into a seaport in Georgia in 2007 through contaminated food waste, ASF has spread rapidly through countries of Eastern Europe, underscoring the extreme threat posed by the disease, not only to the European Union but to all the world's major pig producing regions.*

ASF also continues to spread, sometimes unchecked, on the African continent. Many ships, trucks and aircraft travel daily from Africa and infected countries in Europe to every continent, raising fears that the scenario of ASF introduction into Georgia could be repeated in other regions of the world. This article summarises the potential risk of the ASF virus entering the European Union and China from both epidemiological scenarios (Eastern Europe and the African continent).

Key to controlling ASF are: risk analysis-based prevention and surveillance; application of strict biosecurity measures; slaughter and destruction of sick and carrier animals and their contaminated products; and joint work and collaboration among all sectors involved (farmers, veterinarians, hunters, government departments). Lack of a vaccine and an effective treatment severely hampers control of the disease, posing the greatest scientific challenge of our time. However, it is possible to eradicate the disease, even without a vaccine, as evidenced by a number of countries in Europe, Latin America and the Caribbean, which did so in epidemiological and social circumstances very similar to those observed in affected areas today.

***Keywords**: African swine fever – Challenges – Epidemiology – Risk analysis.*

1. Introduction

Since African swine fever (ASF) was described by Montgomery in Kenya in 1921, the disease has spread outside the African continent on only three occasions. The first time, when it spread to Portugal in 1957, the outbreak was quickly brought under control; the second time, in 1960, when it broke out in Portugal once again, it failed to be controlled and spread to a number of European countries (1960-1994), as well as to the Caribbean and South America in the 1970s. ASF has been eradicated from all these countries, except the island of Sardinia (Italy). The third and last time the virus spread outside Africa was in 2007, in this case to countries in the Caucasus and Russian Federation (Beltrán-Alcrudo *et al.*, 2008). In spite of the many years that have elapsed since 1960 and great strides in understanding the disease, the ASF virus (ASFV) continues its relentless advance, exposing the failure of current prevention and control strategies (Sánchez-Vizcaíno *et al.*, 2012).

More countries and areas of sub-Saharan Africa are now affected than ever before in the disease's history, the vast majority endemically. Similarly, since ASFV was introduced into Georgia in 2007, the disease has spread widely to Armenia, Azerbaijan and throughout the Russian Federation, from where it has continued it spread westwards (Sánchez-Vizcaíno *et al.*, 2013), with the first outbreak in Ukraine reported in 2012 and in Belarus in 2013. On 24 January 2014, the World Organisation for Animal Health (OIE) was notified that two wild boar had been found dead from ASF in Lithuania, just 15 kilometres from the border with Belarus. On 14 and 17 February the same year, a further two wild boar were found dead in Poland, a mere 900 metres and 3 kilometres respectively from the border with Belarus, which also tested positive for ASF (OIE, 2014). This new challenge highlights the important and pressing need to bring the disease under control.

2. Main characteristics of African swine fever

African swine fever is one of the most complex of all animal diseases, and its specific characteristics should be taken into account for well-designed prevention and control programmes. It is caused by a double-stranded DNA virus with a complex structure and high genetic variability, of which 22 separate genotypes have been described to date (Bastos *et al.*, 2003), along with a large number of proteins that do not induce fully neutralising antibodies.

African swine fever virus affects swine of every kind, both domestic and wild, of all breeds and age groups. It affects no other mammals and is not zoonotic. However, ASFV is able to replicate in a type of soft tick of the genus *Ornithodoros* (Plowright, 1970; Sánchez Botija, 1963).

African swine fever virus infection in pigs usually occurs by the oro-nasal route, primarily through direct contact with sick or carrier animals or through ingestion of contaminated products or feed. Viraemia usually begins 2-3 days (and up to 8 days) post-infection and, in the absence of neutralising antibodies, persists for many days, or even months (Sánchez-Vizcaíno and Arias, 2012).

The clinical signs of ASF can vary widely, depending on the type of isolate, dose and route of infection. Most ASFV isolates currently circulating are the peracute or acute form, with haemorrhagic lesions on the skin and internal organs of infected animals. The clinical picture and lesions may resemble those caused by other swine diseases. It is therefore especially important to make a differential diagnosis with classical swine fever and erysipelas. African swine fever can also be confused with certain acute forms of salmonellosis (Sánchez-Vizcaíno and Arias, 2012).

Laboratory diagnosis is always required to confirm ASF. A range of different diagnostic techniques are currently available for every epidemiological circumstance. The most commonly used early detection technique is polymerase chain reaction (PCR), while enzyme-linked immunosorbent assay (ELISA) for detecting antibodies is used in surveillance programmes in affected areas. Viral isolation and sequencing of the PCR product are recommended for confirming any new outbreak in ASF-free zones (Sánchez-Vizcaíno and Mur, 2013).

3. Routes of transmission and current risk

African swine fever virus is transmitted mainly through direct contact (between an infected animal and a healthy animal), indirect contact through fomites (such as contaminated products, people or trucks) or biological vectors (soft ticks of the genus *Ornithodoros*).

To analyse the current risk of ASFV spreading to free territories, the authors considered the current distribution of the disease in Africa and Eastern Europe, pig densities in ASFV-free countries, as well as their geographical proximity and trade relations with areas where ASF persists (Fig. 1).

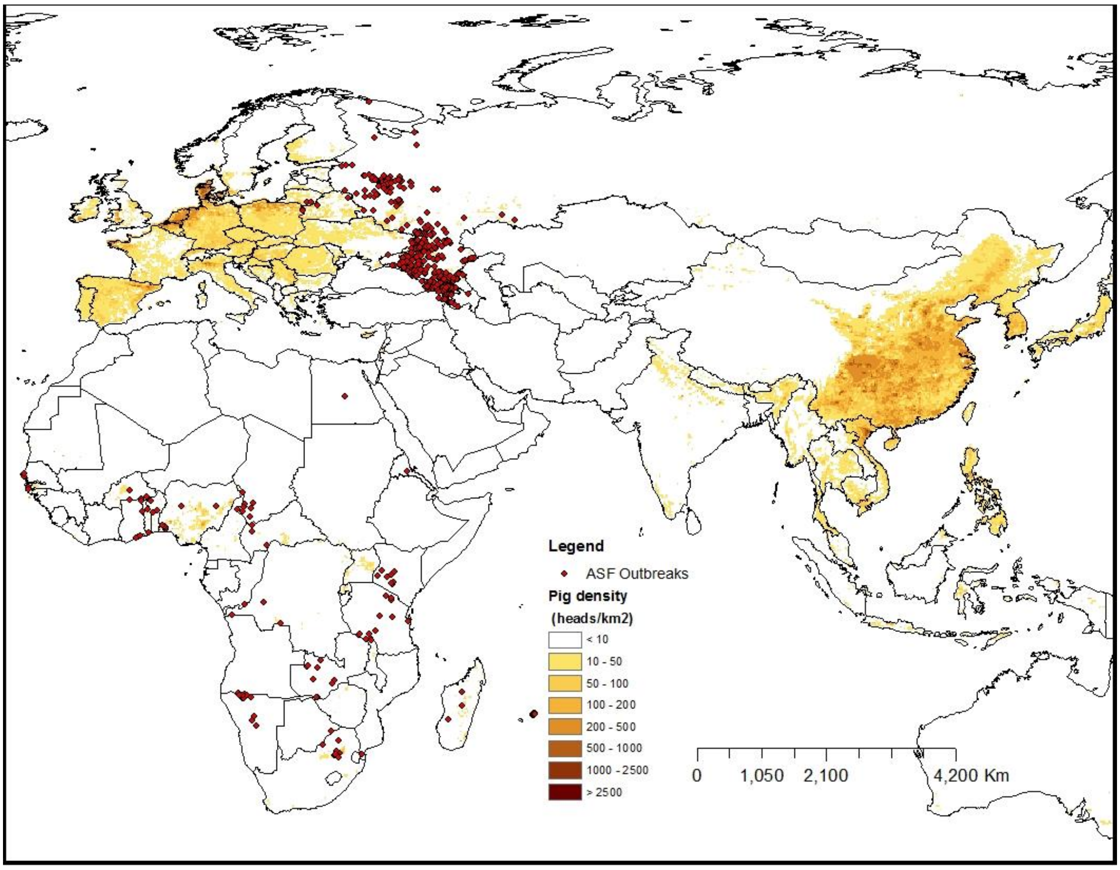


***Figure 1**: Pig density (Global Livestock Production and Health Atlas [GliPHA] of the Food and Agriculture Organization of the United Nations [FAO]) and African swine fever outbreaks in Europe, Asia and Africa notified to the OIE between 1997 and April 2014 (Handistatus II, World Animal Health Information Database [WAHID], OIE, 2014)*

Based on these parameters, a number of risk analyses were made of potential ASFV introduction into the European Union and Asia from Africa and Eastern Europe through several routes of entry. The results of these risk assessments in the two regions are detailed below.

4. European Union

Three routes of ASFV entry into the European Union were analysed: legal imports of pigs and pig products during the high-risk period; illegal imports of pig products; and introduction through transport-associated contaminated fomites and wild boar movements. The studies did not analyse the risk of introduction by ticks because, owing to the ecology of these ticks, which remain attached to the host for only a short time, this route was assumed to pose a negligible risk. Given the low estimated risk for ASFV introduction by legal imports (Mur *et al.* 2012a), these data were not included in the studies.

4.1. Illegal imports of pig products

A semi-quantitative risk assessment was made of illegal imports of contaminated products from Africa and Eastern Europe for commercial purposes and personal consumption, by combining various parameters and using expert opinion. Based on this analysis, the European Union countries with the highest risk values for potential ASFV introduction by illegal imports of pig products were found to be France, Germany, Italy and the United Kingdom (Costard *et al*., 2013).

In the case of personal consumption, the most important factor was the number of residents from ASFV-infected areas (who might bring back contaminated products from their home countries). In the case of illegal trade, the determining factor was geographical position (distance and number of links between countries), coupled with price differentials between products (making illegal trade profitable).

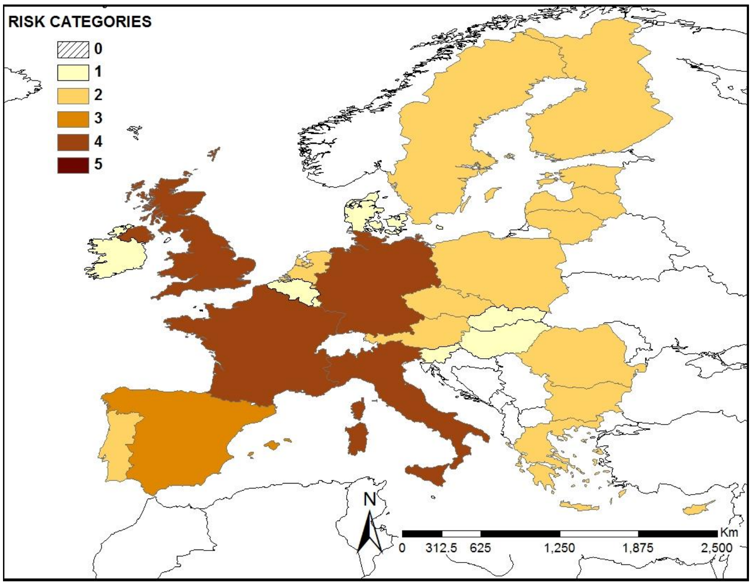


***Figure 2**: Risk map of African swine fever virus introduction into the European Union through illegal imports of pig products from Africa and Eastern Europe (Costard* et al.*, 2013).*

4.2. Transport-associated contaminated fomites

A semi-quantitative analysis was made of the risk of contaminated trucks or international means of transport (ships and aircraft) carrying contaminated food waste from Africa and Eastern Europe (Mur *et al.*, 2012b). The overall results for the three routes analysed revealed that the European Union countries at highest risk of ASFV introduction by transport-associated contaminated fomites are Poland and Lithuania, followed by Finland, Estonia and Germany.

Of all the routes analysed, the greatest potential risk arose from contaminated trucks and was concentrated heavily in Poland and Lithuania. The second highest risk came from ships, especially passenger ships (ferries), followed by cargo ships for which Finland posed the highest risk. The lowest risk came from aircraft and was concentrated in countries with the largest trade flows (Germany, France and United Kingdom).

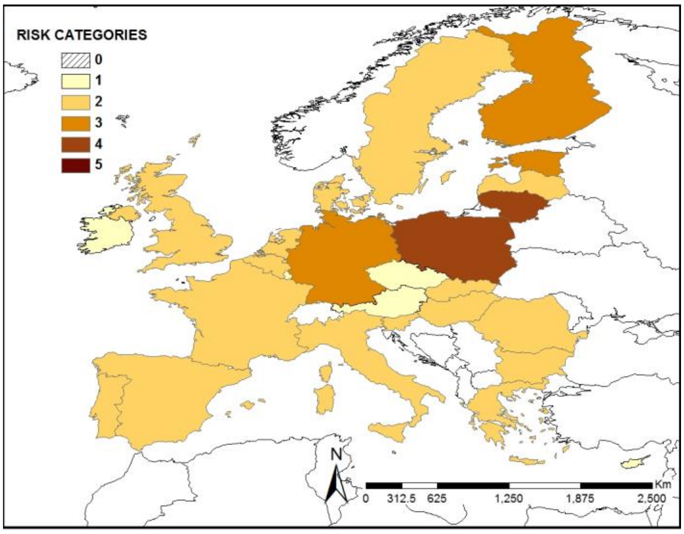


***Figure 3**: Risk map of African swine fever virus introduction into the European Union through transport-associated contaminated fomites from Africa and Eastern Europe (Mur* et al.*, 2012b).*

4.3. Wildlife movements

A semi-quantitative methodology was used, similar to that for the above routes, to assess the risk of ASFV introduction into the European Union from wild boar movements (De la Torre *et al.*, 2013). The results of the analysis, based on data updated in December 2013, revealed that Poland and Finland are at highest risk of introduction by wildlife movements, followed by Lithuania and Latvia.

The final results revealed the biggest risk factor to be the presence of favourable habitat for wild boar, followed by ASF outbreak densities among domestic and wild pigs.

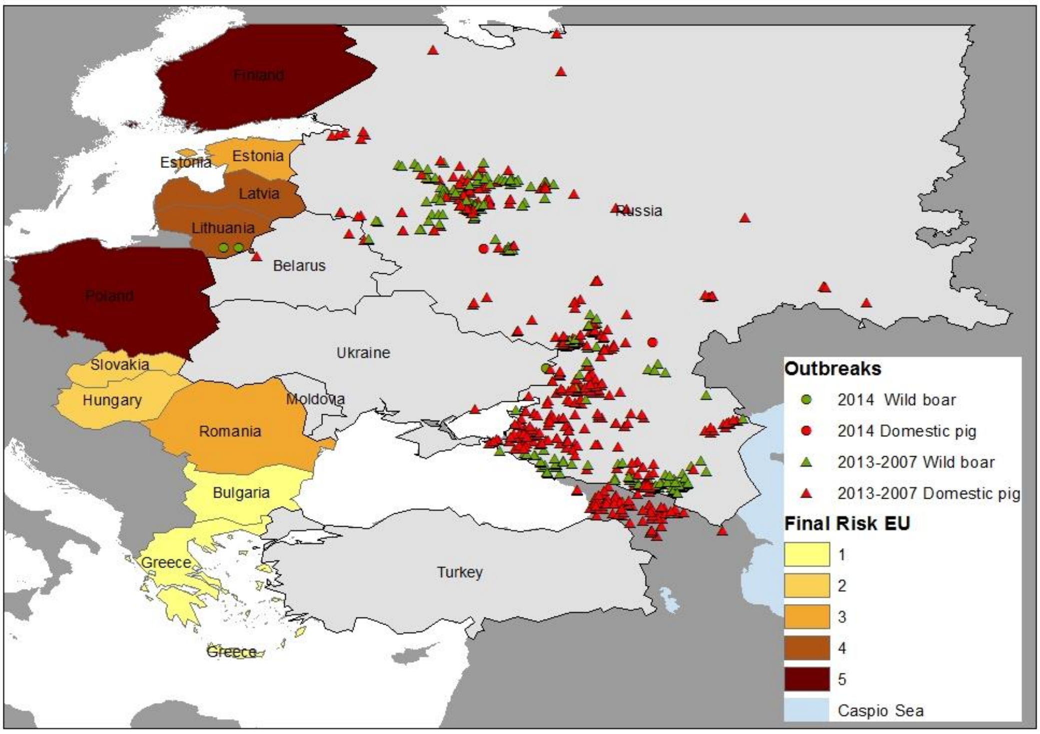


***Figure 4**: Risk map of African swine fever virus introduction into the European Union through the movement or entry of wild boar.*
(Data updated in December 2013 [de la Torre et al., 2013])

5. Asia

In considering the possible evolution of ASF, it would be useful to study potential spread of the disease to the Asian continent, from both Africa and Eastern Europe. Asia is the world's biggest pig producing region, led by China, which slaughtered more than 679 million pigs in 2012 (FAOSTAT, 2014). Asia is also the world's biggest pork importer, with 57% of the global pork trade destined for Asian countries (China, Japan and South Korea).

Moreover, since China signed a cooperation agreement with most of Africa in 2010, Chinese investment has increased dramatically, especially in certain African countries. ASF is endemic in some of these countries, including Angola, Congo, Kenya, Nigeria and South Africa (Forum, 2013). This has led to a large increase in trade (imports and exports), air and sea links and flows of people (Forum, 2013). As a result, the number of Chinese nationals living in Africa has grown significantly, with more than 50,000 Chinese residents in countries like South Africa and Nigeria.

For all these reasons, the authors conducted a preliminary qualitative analysis of the risk of ASFV introduction into China. To do so, they took into account the main risk factors identified in previous publications (Costard *et al.*, 2013; De la Torre *et al.*, 2013; Mur *et al.*, 2012a and 2012b). Below are the results of this analysis.

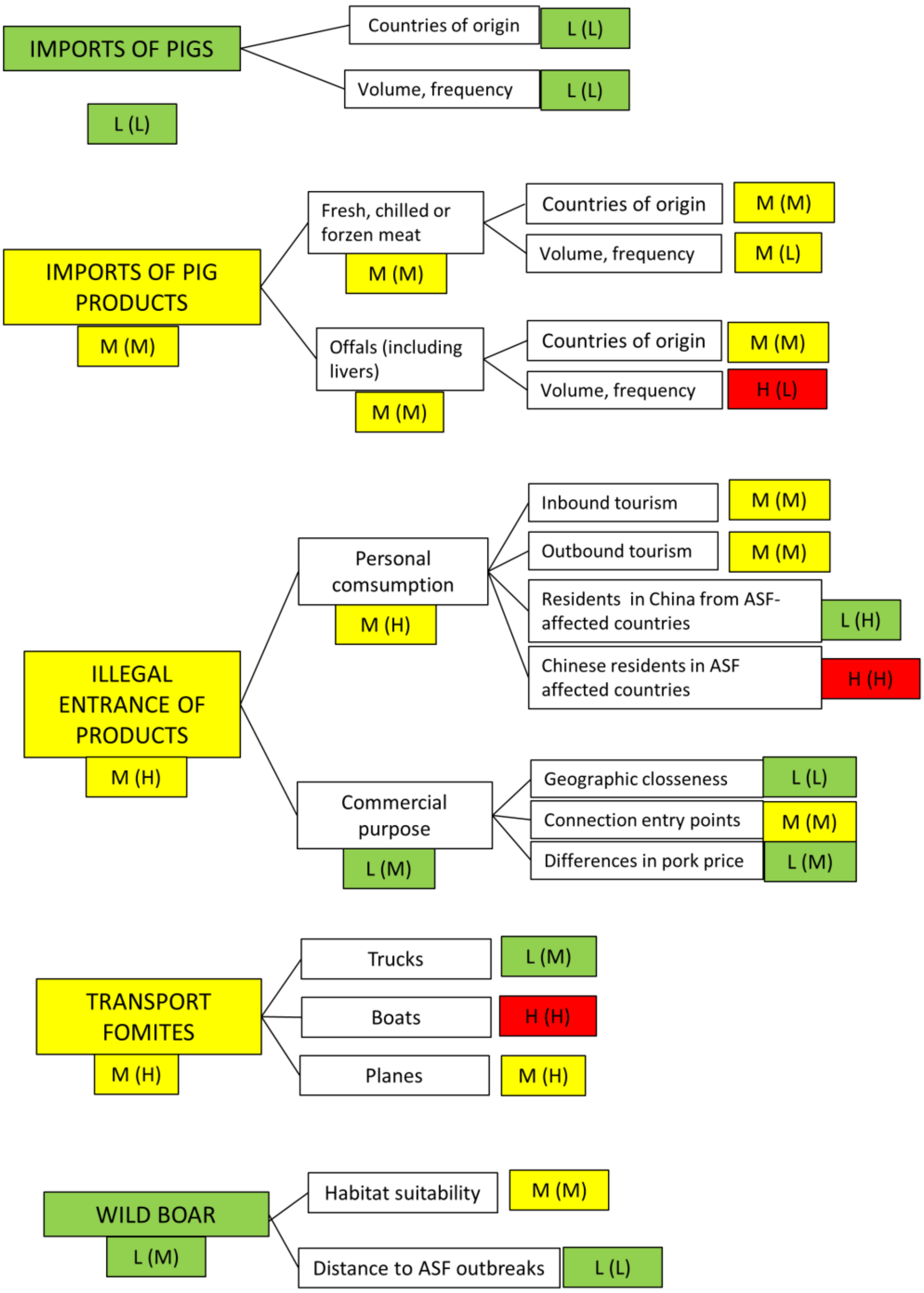


Figure 5*: Risk chart of African swine fever virus introduction into China*
Note: "X(Y)": "X" represents the risk of introduction and "Y" represents the uncertainty associated with the estimate. The values correspond to: H (high), M (moderate), L (low).

According to the analysis, one of the routes that currently poses the greatest risk to China is trade in pig products, especially offal, from many countries (more than 840 million kilograms from 14 different countries) (FAOSTAT, 2014).

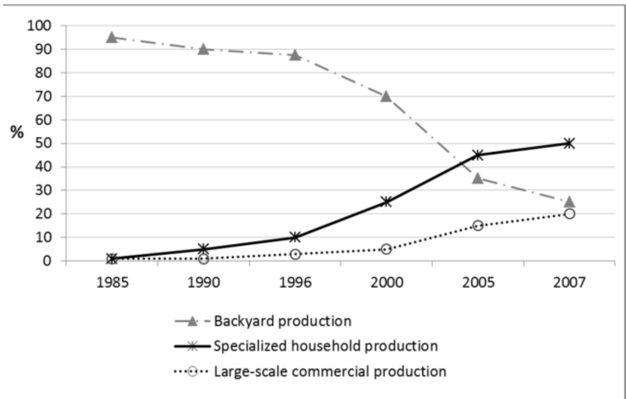
It also points to the potential risk of illegal imports of products from the many Chinese workers employed in Africa, as well as growing tourism between China and Africa.

Despite the lack of detailed data on transport, available information indicates a significant risk of ASFV being introduced by ship, due to extensive trade and a large number of links. Contaminated aircraft and trucks seem to pose less of a risk, although more qualitative and quantitative information on overland trade routes (such as the former Silk Road) is needed to confirm this.

Lastly, despite the great distance between China's borders and the ASF-infected area in the Russian Federation, the risk of spread should not be dismissed, especially via contaminated trucks and wild boar movements.

A point of note is that this analysis included only the risk of ASFV introduction, without taking into account exposure of the susceptible swine population once the virus has entered the country. Any exposure assessment would need to consider the characteristics (management and biosecurity) of Chinese pig farms. In recent years, the trend, encouraged by the Chinese Government, has been towards reducing the number of backyard farms and replacing them with medium-sized or factory farms (Schneider and Sharma, 2014). Nevertheless, there are still many backyard farms without biosecurity or with limited biosecurity measures (30-40% of pig production), which probably practise swill feeding.

Furthermore, Chinese factory farms are usually closed-cycle and many have no quarantine for incoming animals and no effective separation between age groups. The consequences of ASFV being introduced into farms would therefore be catastrophic, much as in 2007, when more than 50 million pigs were infected with porcine reproductive and respiratory syndrome, classical swine fever and porcine circovirus type 2 (McOrist *et al.*, 2011). These factors, coupled with limited knowledge and experience of ASFV among veterinarians and farm managers, and the presence and continued risk of other viral diseases (classical swine fever and foot and mouth disease) that might hinder differential diagnosis, place China at high risk of exposure to pathogens of all kinds.



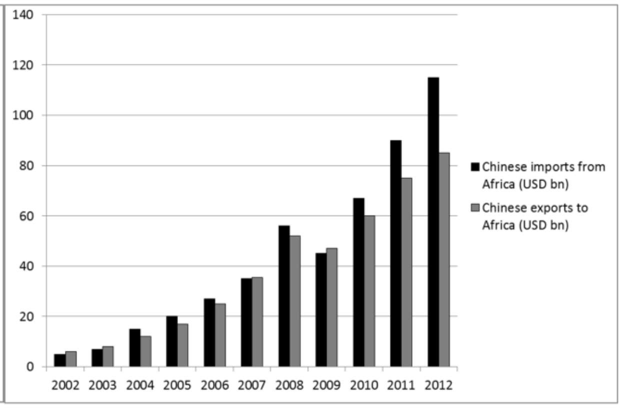


Figure 6: *Trend in pig production systems in China (left); Chinese imports from Africa and Chinese exports to Africa (right). Source: Schneider and Sharma, 2014; Forum 2013)*

6. New challenges and measures to prevent the spread of African swine fever

African swine fever is spreading through Africa and Eastern Europe and control measures do not seem to be working. In both scenarios there are currently endemic countries and/or areas where both domestic and wild pig populations are infected. Some neighbouring areas are also at high risk of becoming endemic in the near future.

After years of study, there is now fairly extensive knowledge of the disease and its mechanisms of introduction and spread. This knowledge, coupled with data from the various risk analyses and the excellent diagnostic techniques available, are major assets in meeting the challenge of ASF control. These tools can be used to develop ASF early-detection strategies and rapid-response programmes backed by contingency plans to curb its spread, together with effective control and eradication programmes. However, ASF prevention and early detection is the primary challenge at present. This will require the cooperation of all sectors involved with Veterinary Services, including farmers, private veterinarians and hunting associations, in view of the important role that wild boar can play in spreading ASF.

A further major challenge is to learn more about the role of wild boar in ASF spread and maintenance, as well as to design systems for the proper control of wild boar populations. Studies to date have shown that wild boar do not play an important role in maintaining ASF unless they are re-infected by domestic pigs (Laddomada *et al.* 1994; Mur *et al.*, 2012c). This means that the disease is self-limiting in wild boar populations, especially in low-density areas with fewer than 10 wild boar per square kilometre. However, the situation may be more complicated in areas with a high density of wild boar and high probability of contact among them, including where enclosures, feeders and waterers are used to artificially increase wild boar density and contact for hunting purpose,. Also, where the disease is present in domestic pigs, their potential contact with wild boar would facilitate maintenance of the disease, hindering its eradication.

Another problem is lack of uniform and reliable data on the real size of Europe's wild boar population, which would allow the above epidemiological scenarios to be compared. In areas with a high wild boar density, programmes should be implemented to control and reduce their density, and animal concentration points (feeders and/or waterers) should be avoided. The options available are controversial because, while hunting can be a useful population management tool, if used properly, it may also greatly increase animal dispersal and movements, favouring the spread of ASFV to other areas. Selective trapping is one of the other techniques that have proved effective in closed populations (Alexandrov *et al.*, 2011) and may be worth considering. It is also essential to work more closely with hunting associations to promote good hunting practices and prevent transmission via potentially contaminated fomites. In addition, hunters play a key role in detecting dead animals (those most likely to be infected) and collecting samples for analysis, making their collaboration critical for both passive and active surveillance.

Another major challenge is to develop non-invasive sampling methods for wild boar, although there are promising solutions in place. The usefulness of oral fluid as a biological sample in diagnosing ASF has already been demonstrated (Mur *et al.*, 2013). Oral fluid sampling in wild boar would provide a much more accurate picture of the status of ASF in wild populations, without the need for hunting or direct intervention on animals.

Also, there need to be more studies on the distribution and epidemiological role of ticks of the genus *Ornithodoros* in Europe. It is known that *O. erraticus* can be infected by the Eastern European ASFV isolate and is able to replicate it (Diaz *et al.*, 2012). However, the role of other *Ornithodoros* species in the transmission of ASFV and their distribution in Europe is still unknown, even though data from preliminary serological studies by ELISA, using tick salivary gland preparations as an antigen, would point to their presence in affected countries (Mur *et al.*, personal communication). Such knowledge would be extremely helpful for designing control programmes in backyard and extensive pig production areas, as was done in Spain in the 1980s and 1990s.

Lastly, research should continue into ASF treatment and prophylaxis using a potential new vaccine, as well as antivirals. There is no effective treatment or safe vaccine currently available for the disease. Trials with inactivated vaccines have demonstrated no efficacy against virulent viruses. Viral proteins, virus deletions (Lewis *et al.*, 2000) and DNA vaccines (Argilaguet *et al.*, 2011) have also proved ineffective, or else gave very limited protection. The most promising results to date have been achieved with naturally attenuated virus isolates (King *et al.*, 2011) or cell passages, similar to those used in Portugal and Spain in the late 1960s (Manso-Ribeiro *et al.*, 1963). In these cases, it reduced viraemia and even eliminated it in some animals, although virus was usually detected in some lymphoid organs and bone marrow after challenge. The issue now is to improve knowledge of these protective mechanisms and the antigens that actually do induce it. Several epitopes have been identified that stimulate cytotoxic lymphocytes (Takamatsu *et al.*, 2013) and some not totally neutralising antibodies. Identifying the genes responsible for this protection could lead to the development of a safe vaccine at some time in the future, although this seems unlikely in the short to medium term. Meanwhile, a point to be borne in mind is that ASF can be controlled and eradicated without a vaccine, as a number of countries of in Europe, Latin America and the Caribbean have shown.

It would be advisable to introduce pilot control programmes in areas currently affected by ASF in order to start controlling spread of the disease and establishing free zones. It is possible to control and eradicate ASF by following the standards in the OIE *Terrestrial Animal Health Code* and *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* in spite of existing difficulties, including: lack of coordinated control programmes; lack of financial compensation for farmers; large backyard pig populations; swill feeding of pigs; illegal movements of pigs and pig products; lack of cleaning and disinfection of vehicles and other fomites; ease of contact between domestic and wild animals; and, even more importantly, people's increasing ability to live with the disease.

7. Conclusions

African swine fever, one of the most important diseases of pigs, is spreading widely across both Africa and Eastern Europe. This poses a major risk to the global pig industry, especially for the European Union and major world producers such as China.

In spite of the lack of an effective treatment or vaccine, it is possible to control and eradicate ASF. ASF control programmes should be introduced into affected areas urgently because the risk of spread into new territories all around the world is growing all the time. The key is to raise awareness and educate all sectors involved (including farmers, veterinarians, government departments and hunters) to ensure that they realise the alarming socio-economic impact of the disease in endemic areas, prioritise action and grasp the importance of controlling and eradicating this terrible disease.

From a scientific standpoint, there should be further research into the epidemiology of the disease in the different scenarios. It is necessary to improve understanding of the role of wild boar in high- and low-density situations, as well as the distribution and potential role of the genus *Ornithodoros* in maintaining the disease in newly infected areas. Further encouragement should also be given to developing a potential vaccine and an effective treatment against ASF.

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