An African swine fever update for food scientists

by

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Abstract

African swine fever virus (ASFV) is a highly contagious pathogen that causes African swine fever (ASF) disease in both wild and domestic swine, with mortality rates up to 100%. The potential for this virus to have a significant economic impact on the pork industry classifies it as a high-consequence pathogen. The global food system has become increasingly interconnected. ASFV poses a risk not just to the pork supply but to other market sectors that rely on byproducts from swine production or that provide goods and services to both the animal agriculture and food processing industries. Effective monitoring and surveillance activities are critical in preventing ASF in regions free from the virus. Implementation of multiple mitigation strategies can facilitate a swift and effective response to ASF if it occurs, to limit damage.

This report examines the existing literature regarding ASF and its impact on the food system. First, a profile of the virus, clinical disease presentations, and a brief history of outbreaks will provide background on the overall issue. A further examination of transmission routes reveals potential ways to employ both proactive and reactive mitigation strategies to combat the risk of the disease to the global food system. As with any disease-causing pathogen, diagnostics are a critical piece of preventing and/or responding to a potential ASF outbreak and must be developed proactively so that an adequate response plan can be executed. Many aspects of diagnosis make testing for ASF complex, and mitigation strategies may not be effective when employed in different contexts. Finally, an assessment of the current knowledge gaps can be utilized to inform not only future research but also to improve the existing mitigation frameworks for ASF and other pathogens that may pose a risk to the global food system.

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Acknowledgements

"I was taught that the way of progress was neither swift nor easy." – Marie Curie

First and foremost, I want to express my deepest gratitude to women in STEM, past and present, for fighting for a seat at the table, making space for others, and inspiring the next generation. I stand here today on the shoulders of giants.

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1. Introduction

African swine fever virus (ASFV), the causative agent of African swine fever (ASF), is a highly infectious double-stranded DNA virus that affects wild and domestic Suidae that has spread globally, causing significant agro-economic impact on the pork industry (Galindo & Alonso, 2017; Sanchez-Cordon et al., 2018; Sanchez-Vizcaino et al., 2012). ASF does not pose a zoonotic risk to humans, nor has it been found to infect other mammalian species (Mohan et al., 2021; Penrith et al., 2024; USDA-APHIS, 2023b).

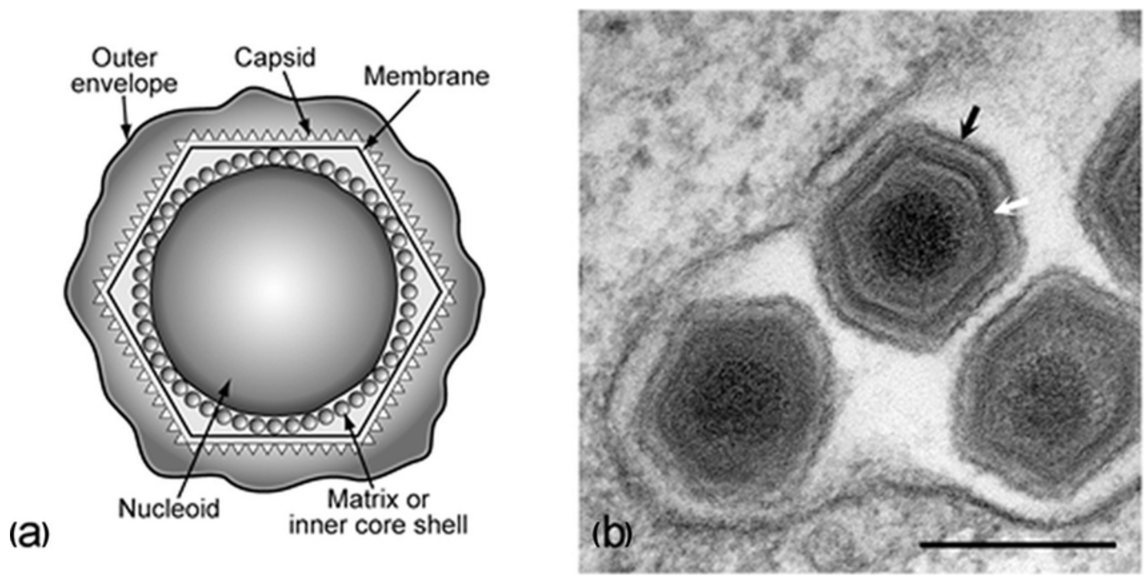
From a food production and international trade perspective, ASF is a notifiable disease to the World Organization for Animal Health (Health, 2025), which requires animal health professionals to notify WOAH of all instances or suspected instances within 24 hours (Health, 2021; USDA-APHIS, 2025). The impact of a confirmed ASFV incursion in swine is broad, affecting all aspects of pork production and the larger food production system (Shurson et al., 2022). Many other aspects of agricultural production and general societal function are also intimately involved once ASF has been suspected or identified in a herd or locale. One Health is an approach that recognizes the interconnectedness between the health of humans, animals, plants, and the environment and utilizes collaboration from professionals from various fields to achieve balance. Food production relies on each of these sectors, and thus, potential food production issues must be resolved from that perspective.

This review will focus on the unique challenges ASFV poses to the larger agricultural food system, the impact an ASF event would have on One Health through food security, and mitigation strategies that could be implemented in the event of an incursion of ASF into the United States.

1.1 African Swine Fever Virus

First identified in Kenya in 1921, ASFV is a large enveloped, double-stranded DNA virus ranging in length from 170 to 190 Kbp and is the only member (genus) of the family Asfarviridae (Alonso et al., 2018; Eustace Montgomery, 1921). Structurally, ASFV virions are icosahedral in shape and made up of layers, including the outer envelope, capsid, membrane, inner core shell, and nucleoid (Fig. 1). The capsid is comprised of about 2000 hexagonal capsomers, the major component of which is the p72 protein, which differentiates strains.

Figure 1. Virions of ASFV (a) Schematic of the extracellular virion, indicating major components. (b) Scanning Electron Microscope (SEM) image of extracellular virions, black arrow indicates outer envelope, and white arrow indicates membrane. Bar: 200 nm (Alonso et al., 2018).



Traditionally, research has characterized ASFV into 24 different genotypes, based on the C-terminal end of the B646L gene, which encodes the p72 protein. Recently, research has advocated for only six separate genotypes due to a lack of defined criteria for classification or accurate comparison with existing genotypes, partly due to changes in sequencing technology. This novel methodology for classifying genotypes employs three criteria that examine the entire protein sequence for differences. The proposed criteria are 1) that genotypes will be based on the predicted protein sequence, 2) at least one sequence must be obtained from Next-Generation Sequencing (NGS) or contain multiple complete sequences from different isolates, and 3) no more than two amino acid variations when compared to a validated sequence (Spinard et al., 2023).

1.2 Disease Symptoms

Following animal infection by the virus, ASF symptoms present between 2 and 19 days post-infection, depending on the isolate and the route of infection, with a mortality rate of up to 100% (Mebus, 1988). Clinical symptoms include fever, decreased appetite, vomiting, diarrhea, depression, and hemorrhaging in tissues and from orifices (Mebus, 1988; Yoon et al., 2020). Peracute disease presentation from ASFV, as seen with the Georgia 2007 isolate, may include high fever, anorexia, respiratory distress, abortion, diarrhea, and hemorrhage, but is often observed as sudden pig death with no previous clinical signs (Sanchez-Cordon et al., 2018; Solikhah et al., 2025). Mortality of peracute infections approaches 100% and, after the appearance of clinical signs, infections may last 1-3 days before death (Mebus, 1988).

Acute or severe infections typically present symptoms for 2 to 13 days, while moderate or sub-acute infections may last up to 30 days (USDA-APHIS, 2023a). Severe infections often have 100% mortality within 1-3 days (Mebus, 1988). Generally, a positive correlation exists between the severity of symptoms and the mortality rate (USDA-APHIS, 2023a; Zhu et al., 2024).

Infection with less acute isolates can result in chronic or latent ASF, resulting in animals being infectious and symptomatic for months; these chronic infections also typically have lower mortality rates (<30%) (Solikhah et al., 2025). Symptoms for chronic or latent infections may include subtle fever, weight loss, arthritis, and skin necrosis (Solikhah et al., 2025; Yoo et al., 2020). Less acute isolates are particularly troublesome for ASF eradication efforts as they can cause persistent sub-clinical infections to occur, as exhibited in Spain and Portugal in the 1980s and 1990s, making identification of infected individuals difficult and time-consuming (Yoo et al., 2020).

2. Disease Transmission

Spread of ASFV can be facilitated by direct, indirect, and vector-borne transmission (Fig. 2). Historically, vector-borne viral transmission via soft ticks, specifically *Ornithodoros* species (Burrage, 2013; Sanchez-Vizcaino et al., 2012), allowed ASFV to be transmitted between hosts through a process known as the sylvatic cycle (Nielsen et al., 2021; Patterson, 2022; Solikhah et al., 2025; Spickler, 2025). Wild warthogs, the natural reservoir of ASFV, are infected through tick-borne transmission but do not display clinical signs of disease. The passage of ASFV between wild swine and tick populations, as well as domestic swine, facilitates ASF being regionally endemic in Africa (Jori et al., 2013).

Outside of the sylvatic cycle, ASFV can also be indirectly transmitted between animals from bodily fluids, aerosols, and contaminated fomites. ASFV is persistent and retains infectivity in many matrix types for prolonged periods at various temperatures (Davies et al., 2017; Fischer et al., 2020; Niederwerder et al., 2022). Swine are naturally curious and explore with their noses, allowing for ASFV exposure through contact with bodily fluids and shared resources, food, water, housing, and equipment (Olesen et al., 2020). The primary means by which ASFV outbreaks in the early 2020s has spread is through the movement of contaminated pork products, feed, and fomites, like soil (Patterson, 2022; Solikhah et al., 2025; Torremorell, 2024a). Direct consumption of contaminated feed or meat incorporated into food waste via swill feeding also perpetuates the spread of the disease (Patterson, 2022; Solikhah et al., 2025).

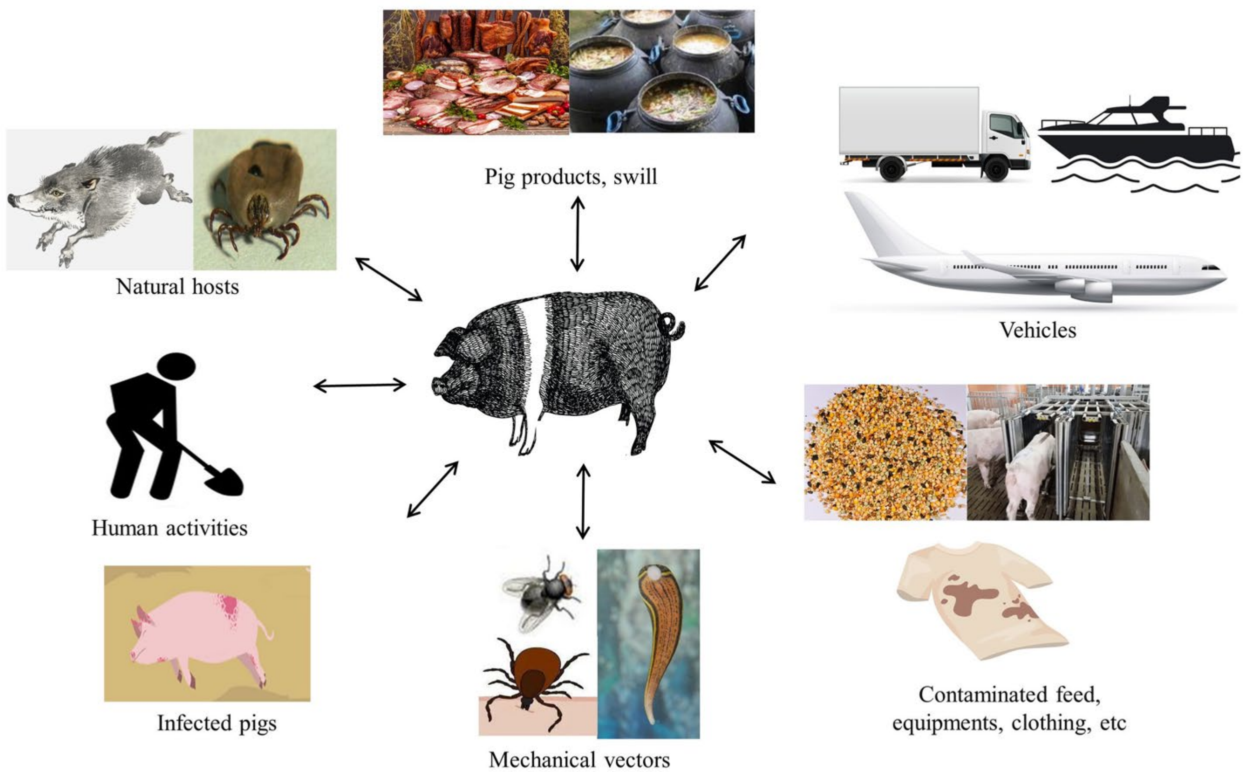


Figure 2. Possible transmission routes for ASFV (Zhang et al., 2023).

Humans have played a crucial role in the spread of ASFV through indirect transmission, as represented in Fig. 2 by human activities. The Georgia outbreak occurring in the early 2020s has been largely spread through the transportation of infected swine and pork products (Flannery et al., 2020; Jurado et al., 2019; Kim et al., 2019; Wang et al., 2019). This has made indirect the most likely route for the introduction of ASFV to a new location (Olesen et al., 2020). Ensuring that swine feed sources are safe and utilizing farm biosecurity are critical to preventing a cascade of ASF transmission following disease incursion.

2.1 Geographical Distribution of the Virus

As the name implies, ASFV was historically confined to sub-Saharan African countries since its discovery in Kenya in 1921 (Costard et al., 2013; Eustace Montgomery, 1921). Outbreaks outside of Africa have occurred, with notable outbreaks listed chronologically in **Table 1**. In 1957, an outbreak of ASF was detected and extinguished in Portugal, with additional outbreaks arising in subsequent years due to separate introductions. ASF persisted in Spain and Portugal until 1995, facilitated by the sylvatic cycle and the mutation of strains used in an unsafe live attenuated vaccine (Penrith & Kivaria, 2022; Sanchez-Vizcaino et al., 2012). In the following decades, the spread of ASFV continued throughout European countries, South America, and the Caribbean. Introductions to new locations were primarily from feeding infected imported pork products to swine, with further transmissions perpetuated through domestic swine (Sanchez-Vizcaino et al., 2012).

Table 1. Current and historical outbreaks of ASF, where they occurred geographically, during what years, and the genotype.

Geographic Location	Year(s)	Genotype
China	2023	Recombinant I, II
Italy	2022	II
Hispaniola	2021	II
China	2018-2019	II

Republic of Georgia	2007	II
Hispaniola	1978	I
Italy	1978	I
Portugal	1957	I
Sub-Saharan Africa	1921 - current(endemic)	I - XXIV

In 2007, ASFV was confirmed in the Republic of Georgia. This isolate has since spread to Europe, Asia, and the Caribbean, as seen in Fig. 3 (Blome et al., 2020; Ratnawati et al., 2025; Schambow et al., 2025; Wang et al., 2023). In 2018, ASFV spread into China, home to half of the swine in the world, and the largest producer of pigs globally (Dixon et al., 2020). As a result, swine production decreased 40%, and more than 43 million swine were estimated to have been lost to the disease or stamping-out efforts in the first year of outbreak alone (Juszkiewicz et al., 2023; Nguyen-Thi et al., 2021; Qu et al., 2022). China realized over $111B in losses in 2019 due to the ASF outbreak, accounting for 0.78% of China's gross domestic product (GDP) (You et al., 2021). The next few years saw the transmission of ASFV throughout Asia and Oceania via various transmission routes (Wang et al., 2023), creating a significant impact on the global pork trade (Juszkiewicz et al., 2023; Li et al., 2022). Between 2018 and 2020, pork exports from the European Union (EU) into China increased nearly 2.5 times, despite China banning imports from several countries with ongoing outbreaks (Gale et al., 2023). Since January 2022, 65 countries or territories have reported cases of ASF, 12 of those being first occurrences, with a total of 1,010,901 cases in domestic pigs and 36,805 total cases in wild boar globally (Health, 2025).

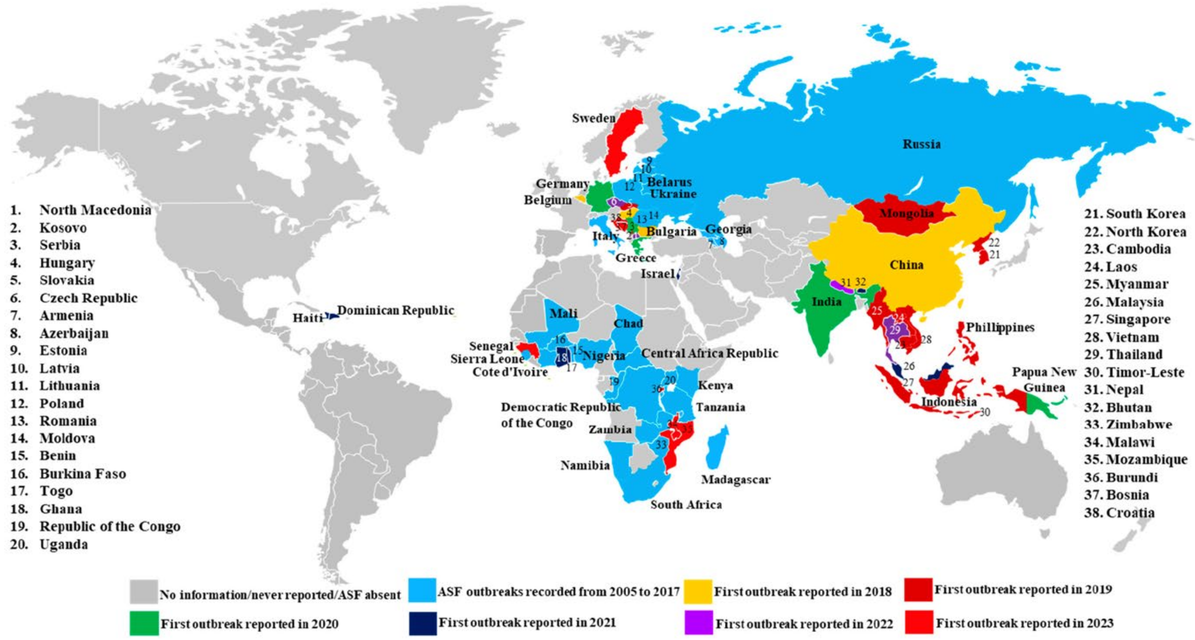


Figure 3. Countries with reported ASF outbreaks 2005-2023. Numbers correspond to the names of countries, while colors correspond to the first recorded outbreak. Countries with ongoing outbreaks are categorized by the year of their first outbreak (Wang et al., 2023).

2.2 Sample Stability

The stability of a virus in a sample indicates how long it can be detected but may not indicate whether or not the virus is still infectious in that sample. Samples that are stable and infectious present a greater risk as the virus can continue to be transmitted through them. ASFV is hardy and notably stable in samples or on multiple different surfaces in a variety of environmental conditions, as is evidenced in **Table 2**. Sample types that naturally occur in swine environments and can transmit infectious viruses are numerous, making viral spread difficult to manage. Infectious virus can persist in excretions and blood for days to years, depending on temperature. Additionally, the surrounding environment, for example, compound feed and penning, can harbor infectious virus for weeks. Contaminated feed and water can perpetuate transmission if consumed by other uninfected animals.

The infectious stability contributes to its overall risk via viral persistence in carcasses and food products that may then be consumed by wild boar or fed to domestic swine as swill. In 2014, the European Food Safety Authority (EFSA) published a review of stability data for ASFV from multiple studies, concluding that meat could harbor infectious virus for 16 to 1,000 days depending on its storage temperature (Authie et al., 2014). Similarly, a review by Olesen et al. (2020) notes the stability of infectious virus in several common processed pork products such as hams, sausages, and casings. Processing steps may impact the overall infectious viral stability of ASFV, depending on what the processing steps are and their duration. Furthermore, the combination of ingredients and processing steps may complicate understanding the effect of each on viral infectivity. Some common processing methods include salting, curing, smoking, and fermentation. Certain products have requisite processing steps with recommended durations; for example, Serrano hams may be cured for 180-365 days. (Mebus et al., 1993). In some cases, the viral infectivity may be less than the standard processing time, as is seen in the Serrano hams; others may pose a greater risk by persisting longer than the standard processing time, like pork belly or loin (Mebus et al., 1993; Olesen et al., 2020). One study examined the stability of ASFV in pepperoni and salami and found that infectious virus was able to be detected after smoking, but not after one month had elapsed from the smoking step (McKercher et al., 1987). Narrow research on specific products and processes may alleviate concerns for exposure through certain routes, like casings (Jelsma et al., 2019; Petrini et al., 2024; Petrini et al., 2019; Wieringa-Jelsma et al., 2011).

Table 2. Stability of ASFV in different sample matrices stored at various temperatures.

Sample Matrix	Stability Range	Storage Temperature	Resource
Meat	84-155 days	4-8°C	(Authie et al., 2014)
Meat and organs	103-1000 days	Frozen (variable)	(Authie et al., 2014)

Blood	540 days	4°C	(Authie et al., 2014)
Feces	11 days	Room temperature	(Authie et al., 2014)
	159 days	4-6°C	(Authie et al., 2014)
	5-98 days	4°C	(Davies et al., 2017)
	3-35 days	Room temperature	(Davies et al., 2017)
Urine	15 days	4°C	(Davies et al., 2017)
	2-3 days	37°C	(Davies et al., 2017)
Yard soil	7 days	4°C	(Carlson et al., 2020)
	2 days	25°C	(Carlson, 2020
Porous Fomite	14-22 days	25°C	(Nuanualsuwan et al., 2022)
Non-porous Fomite	11-17 days	25°C	(Songkasupa et al., 2022)
Nasal aerosol	14-19 minutes	Room temperature	(de Carvalho Ferreira et al., 2012)
Water	50 days	Room temperature	(Sindryakova et al., 2016)
	60 days	4-6°C	(Sindryakova et al., 2016)
Compound feed	30 days	Room temperature	(Sindryakova et al., 2016)
	60 days	4-6°C	(Sindryakova et al., 2016)
Corned meat	16 days	Room temperature	(Sindryakova et al., 2016)
Liver	16-56 days	Room temperature	(Sindryakova et al., 2016)
Serrano ham	140 days	--	(Mebus et al., 1993)
Salami	9 days	11.7°C	(McKercher et al., 1978)
Pepperoni	8 days	11.7°C	(McKercher et al., 1978

2.3 Predictive Modeling

Disease and outbreak modeling can serve as invaluable tools to anticipate the potential impacts of ASF introduction on an economy. Due to infrastructure differences, it is necessary to select an appropriate outbreak to use as a comparable model. Geographic regions that lack a reliable stream of resources and established infrastructure will have diminished capability to respond to an outbreak of ASFV compared to places where these support systems already exist and are secure (Penrith et al., 2024). These differences in a country's capacity to adapt have the potential to change the overall impact the incidence of disease has on surrounding communities. A study of Vietnam's 2019 outbreak highlights that the negative effects of ASFV may be greater on medium- and large-scale producers than on smaller producers, although the latter typically have fewer biosecurity practices (Nguyen-Thi et al., 2021). Additionally, this study estimates that the impact on other market spaces, including foodstuffs, veterinary services, and downstream services, can range between just under 2% and 15% (Nguyen-Thi et al., 2021).

Predictive modeling of how an ASF outbreak within the United States would proceed can be done by utilizing domestic swine production information combined with case studies from previous ASF incursions. Fig. 4 depicts a 2018 projection of how different culling scenarios may impact certain pork-producing countries. In Vietnam in 2019, after the spread of ASF from China, almost six million swine were culled in just five months, equating to more than 20% of Vietnam's total swine population (Nguyen-Thi et al., 2021). The estimated economic impact of ASF in India between January 2020 and July 2021 totals just over 40 million USD for animal loss, foregone revenue, and the cost of clean-up and disposal of production sites (Mohan et al., 2021). A study from Iowa State University examined two potential scenarios for an ASF outbreak in the U.S., one lasting two years and the other lasting ten years (Carriquiry et al., 2020). The two-year scenario estimates a $15B loss to the pork industry and over $50B and 140,000 jobs lost in the ten-year scenario (Carriquiry et al., 2020).

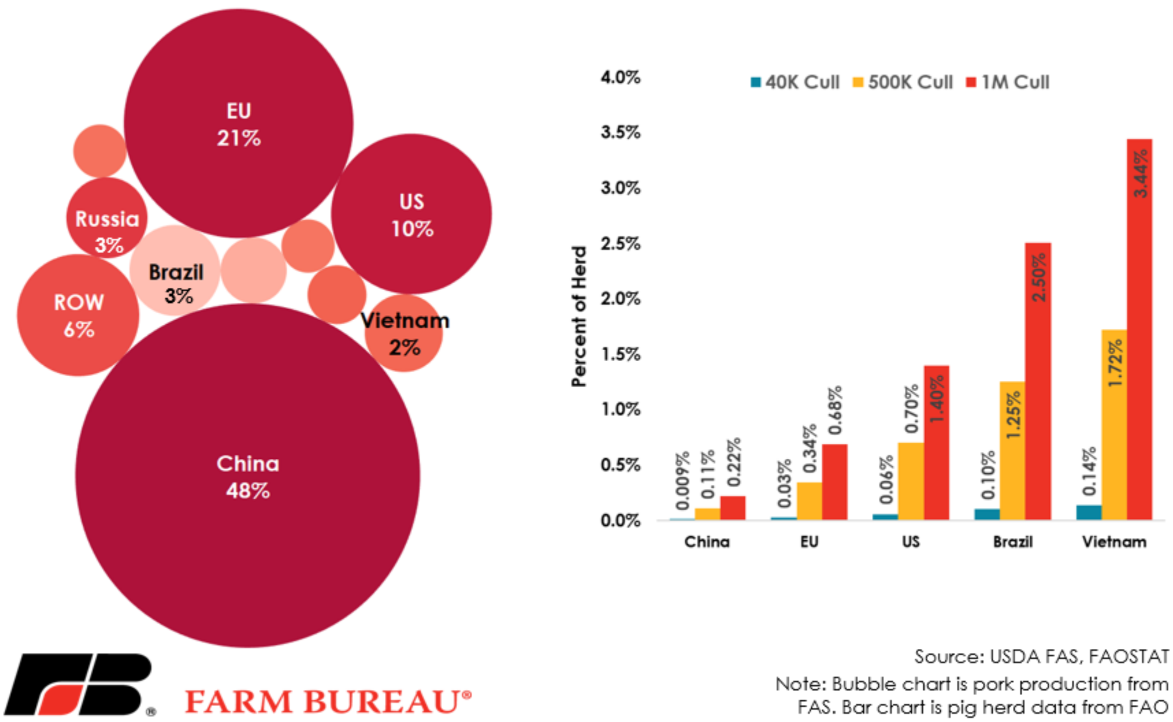


Figure 4. Impact of Culling on the World Pork Market. The bubble chart (left) indicates the portion of the world pork production market derived from each country. The bar chart (right) shows the potential impact on pork-producing countries given different culling scenarios (Nepveux, 2018).

3. Impact of ASF

3.1 Economic Impact

The economic impact of an ASF outbreak is expansive, potentially impacting all sectors of food production since outbreaks and subsequent containment methods can lead to loss of jobs and animal depopulation. Trade barriers that accompany an ASF outbreak can lead to loss of market share for producers. By-products from swine production, such as animal feed, biofuels, or fertilizer, can also be affected by an ASF outbreak (Ferronato et al., 2021). By-products from swine account for 44% of the live weight of the animal, most of that being used to produce animal feed or fertilizers (Lapena et al., 2018). Common products made from swine by-products are displayed in Fig. 5 and include cosmetics with collagen and hydroxyapatite used in biomedical settings like bone grafts, or environmental settings like cleaning up wastewater (Borges et al., 2022). Many swine by-products themselves are economically low-value but add value to many other products in multiple market spaces by contributing essential materials or attributes to existing products (Bah et al., 2016).

Figure 5. By-products created from different parts of swine (Virginias, 2023).

3.2 Environmental Impact

Disinfection and disposal of infected material can lead to environmental damage. When animals are depopulated or culled in response to the threat of a biological pathogen, carcasses must be disposed of in ways that will likely destroy or inactivate the pathogen (USDA-APHIS, 2014). Common disposal methods include burying, incinerating, rendering, open burning, or composting carcasses. In the case of ASF, carcasses can be disposed of in multiple ways, but only rendering and composting methods produce useful byproducts (USDA-APHIS, 2019). Rendering uses a combination of high temperature and pressurized steam to break down carcasses into simpler components and is sufficient to inactivate ASFV. Composting as a method for disposal combines animal carcasses with carbon-rich organic material and utilizes heat and microbes for decomposition. It may be necessary to control specific aspects like time, temperature, and composition, although for ASFV, it is not yet proven to sufficiently inactivate the virus (USDA-APHIS, 2019).

Beyond disposal and disinfection of ASFV-infected premises, the loss of significant numbers of food animals may indirectly change human behavioral patterns (Mohan et al., 2021), while the downstream effects of the loss of swine and its byproducts can also impact economies and trade, both critical aspects of the food system. Finally, outbreaks and associated mitigation practices (such as herd depopulation) often result in a high burden on the mental and emotional health of producers (Griffin et al., 2024; Kollias et al., 2023; Long, 2024; Ungur et al., 2022).

4. Proactive Mitigation

The premature nature of proactive mitigation strategies makes them an attractive for infectious disease pathogens. Particularly in the case of pathogens that spread quickly and have severe consequences, like ASFV, investing time in strategizing how to prevent spread and contain a pathogen can dampen the impact (Li & Zheng, 2025). Additionally, planning logistical inputs required to carry out a response can illuminate potential shortcomings in a response plan. In-depth analysis of complex issues ahead of time may reveal unintended consequences of a planned response and facilitate making changes to prevent such consequences. Below are some commonly considered proactive mitigation strategies.

4.1 Regulations

One way to proactively prevent the spread of ASFV is to regulate the routes through which it might spread. The development and implementation of regulations aim to reduce this risk by holding trade partners accountable for adhering to a set of rules designed to protect both the trade and food systems (Organization, 2025b; *Sanitary and phytosanitary measures*). The Sanitary and Phytosanitary (SPS) Agreement, as laid out by the World Trade Organization (WTO), outlines a set of rules that balance the safety of plants, animals, and humans for importers with the accessibility of trade for exporters (Organization, 2025a). In addition, WOAH provides resources and guidance to trading countries and global citizens for precautions and biosecurity measures that can be taken to reduce the risk of transmitting pathogens like ASFV. Frameworks like disease-free zones and regionalization, meaning that specific areas are certified to be disease-free, can be established, with adequate proof, that aim to make trading with certified entities easier. These programs also provide entities with confidence that trade partners are doing their due diligence in protecting others from potential risks, as partners must adhere to a set of rules laid out by the WTO to claim these disease-free statuses. Non-compliance from trading partners can lead to larger issues, like retaliatory sanctions or disputes to be settled by the WTO. Regulations, including the Food Safety Modernization Act, the Swine Health Protection Act, and the New Swine Slaughter Inspection System, exist to prevent transmission at the processing stage for pork and feed. Safeguards like implementing animal inspections at abattoirs and having written hazard analysis and preventive control plans are a few examples of concrete protection methods initiated by regulations. However, these regulations often have exemptions for small-scale producers and other entities that meet specific criteria, like slaughtering their own livestock (Regulations, 2025; USDA-FSIS, 2019). Additionally, these regulations can be difficult to control outside of formal trading, like people traveling internationally with food products (Kim et al., 2019; Sugiura et al., 2020).

4.2 Collaboration

Since the potential impact of an ASF outbreak is widespread, groups interested in mitigation should begin collaboration before an outbreak. Stakeholders for ASFV planning and response include epidemiologists, virologists, and veterinarians, as well as groups focused on production, including farmers, processors, transporters, and business owners. In the United States, both government representatives and non-governmental groups collaborate to research, mitigate, and diagnose ASFV (Agriculture, 2023). Within government, the United States Department of Agriculture (USDA) has multiple agencies whose work addresses ASFV, including the Agricultural Research Service (Flannery et al., 2020), the Animal and Plant Health Inspection Service (APHIS), and the Food Safety and Inspection Service (USDA-FSIS). Food entities in the U.S., like the National Pork Board, National Pork Producers Council, and the Foundation for Food and Agriculture Research (Wurtz et al., 2016), also contribute to ASFV mitigation by acting as advocates for producers and providing funding for research. Internationally, groups such as the World Organization of Animal Health (Health, 2025), the North Atlantic Treaty Organization (Ferronato et al., 2021), and the World Trade Organization (WTO) collaborate to find both proactive and reactive mitigation strategies to ASFV. One example of collaboration is the National Association of State Departments of Agriculture (NASDA), which is a conglomeration of government agricultural representatives that partners with larger global entities, like the WTO, as well as industry partners, like Corteva Agriscience and Pork Checkoff, to engage on agricultural issues. (Agriculture, 2022).

Much can be learned from previous ASF outbreaks, and established relationships between collaborators facilitate sharing knowledge, so that others may be more prepared. The Swine Health Information Center (SHIC) is a collaborative effort that brings many different partners together to share information and fund research necessary to protect and enhance swine health. One such effort funded by SHIC is Global Swine Disease Monitoring Reports, a series of reports compiled from numerous sources that aim to provide near-real-time information about swine diseases across the globe. Information like this can deliver crucial communications needed to assess and plan a response to swine pathogens (Center, 2025). Another tangible example of multiple entities cooperating to achieve a shared goal is the USDA establishing a Protection Zone in U.S. territories in the Caribbean. This effort aims to protect the pork exports from the U.S., as well as to contribute to surveillance efforts and increased outreach (Webb, 2021).

4.3 Vaccination

One of the most common mitigation strategies that can be used proactively to address the spread of disease is vaccination. Vaccines can be used both to prevent disease in animals where disease does not exist, as well as to lessen the impact of disease in regions and animals where it has already occurred (Zhang et al., 2023). As is evident with diseases like influenza, it can be difficult to match vaccine strains to actively circulating strains of virus, which directly correlates to how effective a vaccine is on a particular disease (Revilla et al., 2018). Viruses naturally mutate to adapt to host defenses and ensure their survival. These mutations can be exacerbated by geographic separation and potential for viral recombination if multiple strains of ASFV are circulating, creating another hurdle for effective vaccination strategies (Revilla et al., 2018; Zhang et al., 2023). Administering vaccines in sufficient time to reach vulnerable populations before exposure can be challenging due to the nature of wild boars, as well as the logistics of vaccinating large domestic swine populations. Effectively containing and monitoring these animals for signs of disease or to vaccinate can be both time and labor-intensive for potentially minimal return. Finally, as with all drugs, the stability of the vaccine product must be ensured to be transported and stored appropriately in various settings for a sufficient period to be administered, presenting another hurdle, especially in rural areas, where resources may be limited (Espinoza et al., 2024).

The development of a vaccine against ASFV that is both safe and effective is a significant challenge for many reasons, including genomic complexity, risk of reversion for a live attenuated vaccine, differentiating infected from vaccinated animals (DIVA), strain diversity, and a reliable cell line for mass production. The three main groups of vaccines for ASF are live attenuated vaccines (LAVs), subunit vaccines, and inactivated vaccines. Live attenuated vaccines offer full homologous and partial heterologous protection, while being limited by potential reversion to virulent strains, persistent clinical symptoms, and scalability (Arias et al., 2017; Chu et al., 2024; Revilla et al., 2018; Sereda et al., 2025; Wu et al., 2020). Another type of vaccine, a subunit vaccine, uses specific, small pieces of the virus instead of the entire virus, and in contrast to LAVs, safeguards against viral reversion and allows for differentiating infected from vaccinated animals (DIVA). However, drawbacks for subunit vaccines include some chronic infections and only partial protection (Gaudreault & Richt, 2019; Ntakiyisumba et al., 2025; Wu et al., 2020). Similar to LAVs and subunit vaccines, inactivated vaccines are antigenic, but do not produce enough immune response, even with the addition of adjuvants, and are not considered to be a viable vaccine option (Blome et al., 2014; Wu et al., 2020). Currently, there is no approved, licensed vaccine for ASF in the U.S., although three LAVs are licensed in Vietnam (Tham & Hoc, 2025). The Pirbright Institute in England is conducting testing on animals using a live-attenuated vaccine candidate (Rathakrishnan et al., 2025).

4.4 Biosecurity

Management of both animal and human movement is crucial to preventing ASFV spread. Pathogens are categorized according to the degree of risk; as pathogen risk increases, so do biosecurity safeguards (Services, 2020). Biosecurity measures aim to reduce the likelihood and frequency of these risks by utilizing three levels of biosecurity: conceptual, structural, and procedural. Conceptual biosecurity primarily addresses locale and separating sites and animals. Structural biosecurity focuses on physical barriers, while procedural biosecurity ensures work at a site prevents transmission, like decontaminating equipment (Torremorell, 2024b). Layers of biosecurity measures have an additive effect, although the implementation will likely look different in different settings. Fig. 6 summarizes some biosecurity practices for people and facilities alike that can be implemented for interaction with swine (Davis, 2024).

Figure 6. Recommendations for biosecurity practices in a swine setting (Davis, 2024).

At both animal and feed production sites, biosecurity practices are imperative to maintaining swine health and preventing transmission of disease pathogens. Biocontainment practices in all settings are designed to separate infectious material from other potentially infectious material (Dickmann et al., 2015). In the case of animal production sites where ASF does not exist, preventing its incursion primarily involves controlling what swine have contact with (Alarcon et al., 2021). Separating domestic swine from wild boar populations and limiting contact of animals in different housing facilities addresses potential direct transmission (Guinat et al., 2016). Other biosecurity practices, like disinfecting clothing, boots, and equipment before use with separated swine, are crucial, especially on large domestic production sites (USDA-APHIS, 2014). One modeling study suggested that implementation of biosecurity practices within 2 weeks of an epidemic onset can reduce swine deaths by up to 74% (Barongo et al., 2016).

Biosecurity methods at feed and food animal processing sites are similar to those at production sites, including proper hygiene for personnel and processing equipment and movement control (Juszkiewicz et al., 2023). One study found that ASFV genetic material introduced during the mixing of ASFV-inoculated feed was able to be detected after running four subsequent batches of uninfected feed, though the infectivity of the recovered genetic material is unknown (Elijah et al., 2022). A viral inactivation step, for example, UV treatment or irradiation, implemented during the processing of feed and food products, can mitigate ASF transmission via the consumption of infected feed (Jackman et al., 2025).

Biosafety concepts are necessary in a laboratory setting to study pathogens like ASFV in food products and may be akin to biosecurity safeguards in processing and production settings. For example, the biosecurity concept of separation is demonstrated in the use of barriers, such as biosafety cabinets (BSCs). In lab settings, work is frequently conducted on more than one pathogen at a time. Cross-contamination of pathogens, or the release of infectious material outside the lab, could have significant implications for diagnostic results, sample integrity, and the safety of lab workers and their close contacts (Cornish et al., 2021). At lower risk levels, lab biosafety practices often include titer flow between ‘clean’ and ‘dirty’ lab spaces, depicted in Fig. 7, working in some degree of containment, such as a biosafety cabinet, and personal protective equipment (PPE) (Services, 2020). A common example of work conducted in an analytical lab setting is the concentration of a potentially infected sample for diagnostic testing. While ASFV is not a direct risk for humans, work with the virus requires biosafety level 3 (BSL-3) lab containment due to its risk to swine. At this biosafety level, safeguards implemented to prevent the spread of concentrated pathogenic material outside of labs can include decontamination showers and personnel quarantine from susceptible species (Services, 2020).

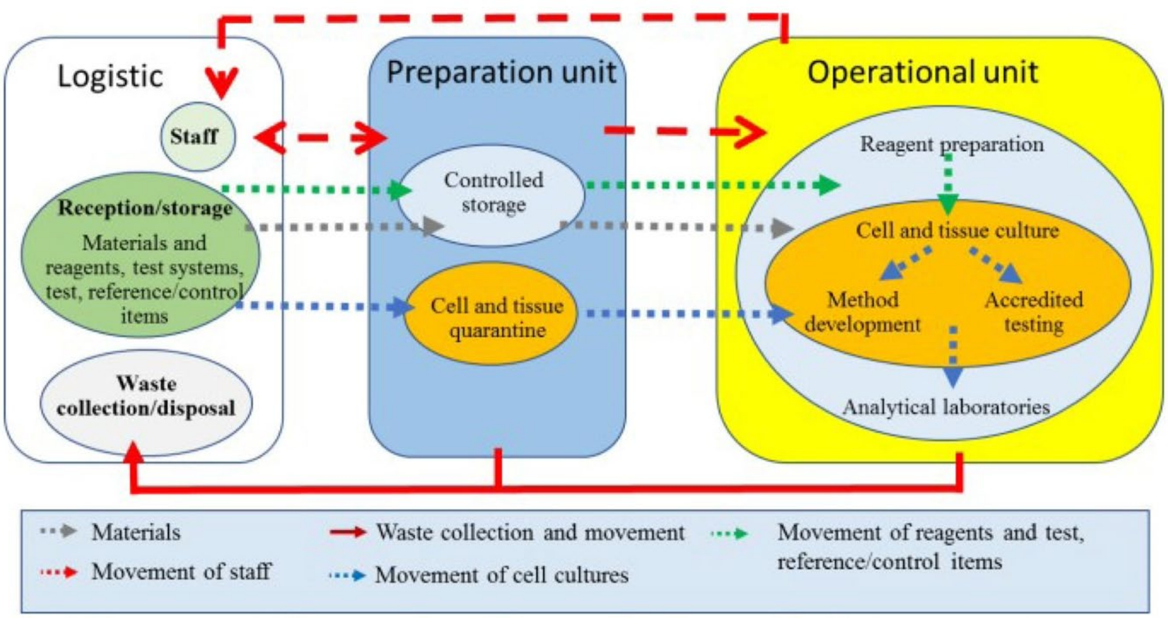


Figure 7. Flow of people and materials with biosafety practices through separated lab spaces to decrease potential for cross-contamination events (Chandra, 2023).

5. Reactive Mitigation

Proactive mitigation strategies, like vaccines, used to combat disease pathogens can have a significant impact on quelling the effects of disease outbreaks on society, but often, some aspects cannot be anticipated or adequately mitigated ahead of time, like viral mutation or supply chain issues. For this reason, reactive mitigation strategies, like diagnostic tests, are equally important when addressing a disease strategically. Diagnostic testing for ASFV encompasses a wide range of assay types, including the detection of infectious and non-infectious virus, as well as utilizing both animals and food products for sampling (Lee et al., 2022; Muzykina et al., 2024). Each method of testing is relevant within different contexts.

An infectious virus is useful in characterizing active infections and investigating transmission and potential contacts. Data from non-infectious virus can be helpful when studying clinical aspects or retroactively examining viral movement and utilizing those patterns to help predict future migration. One example is genetic sequences obtained from tissue samples; analyzing sequencing data has led to retrospective identification and typing of circulating isolates (Rai et al., 2024). These datasets can highlight similarities in ASFV-positive samples and help to identify genetic similarities that may aid in tracking isolate spread geographically. Additionally, PCR tests, detecting viral genetic material, performed on inoculated feed samples aid in the examination of potential transmission routes (Cresci et al., 2024; Dee et al., 2022; Lee et al., 2022).

Viruses mutate over time as a means of survival. These mutations may affect how they infect a host, how they replicate, and how they respond to a host's natural defenses (Sanjuán et al., 2012). Since many of these mutations occur organically and can affect the overall threat of the virus, response strategies that are flexible and can adapt accordingly are also a critical part of

ASF response (Li & Zheng, 2025). For any communicable disease, animal or human, robust diagnostic capabilities that are resilient in the face of a changing virus are integral to combating spread. If a virus mutates, and that mutation renders the virus undetectable to the diagnostic assay, it is no longer useful. Both diagnostics and vaccines should attempt to premeditate and address these variations (Chen et al., 2024).

5.1 Response Plan

The U.S. has a Foreign Animal Disease Preparedness and Response Plan (FAD PReP) already established by USDA-APHIS to guide management if a presumptive positive case of ASF occurs in domestic swine or wild boar populations in the United States (USDA-APHIS, 2023b). FAD PReP are comprehensive plans written to provide a strategic framework for responders to foreign animal disease events to act in an outbreak while limiting its overall impact. The plan outlines activities for the entire duration of response from initial case identification and diagnostic testing, through depopulation and recovery of a disease-free status. In an overview of the response plan, USDA-APHIS indicates the goals of the plan are to control and eliminate the disease as quickly as possible, while stabilizing affected market spaces to minimize disruption to the food system (USDA-APHIS, 2020). A response to an outbreak event would require coordination between numerous entities at national/state/local/tribal levels, including producers, veterinarians, epidemiologists, and government groups. Much of this response occurs in the animal health space, before it reaches the food system; however, a collaborative effort is necessary as the two are interdependent. Lessons learned from other animal disease outbreaks, as well as planned exercises, have informed and improved these plans (USDA-APHIS, 2023b).

Critical Activities and Tools for Containment, Control, and Eradication

- Public communication and messaging campaign *(3.4.2)*
- Swift imposition of effective quarantine and movement controls *(4.6)*
- Stringent and effective biosecurity measures *(4.10)*
- Rapid diagnosis and reporting *(4.3)*
- Epidemiological investigation and contact tracing *(4.5)*
- Increased surveillance in domestic and feral swine populations *(4.4)*
- Continuity of business measures for non-infected premises and non-contaminated animal products (*4.7, also Secure Pork Supply Plan*)
- Mass depopulation and euthanasia *(4.11)*
- Effective and appropriate disposal measures *(4.11)*
- Virus elimination measures (*4.11*)
- Feral swine population reduction *(4.12)*

Figure 8. A list of Critical Activities and Tools for Containment, Control, and Eradication for ASF Response with corresponding sections of the plan and links (USDA-APHIS, 2023b).

The plan acts as a guide for all kinds of responders, from veterinarians to people managing communications, by highlighting key tasks and objectives, as well as detailing how to carry out those activities. Fig. 8 is a box from the response plan listed on the first page of the section regarding specific critical activities and tools for response, which highlights certain tasks and references the subsections with additional details, with provided links for easy use. Details and criteria that are crucial for an appropriate response, like types of samples to be collected for diagnostic testing and how to ship them, as well as the criteria required for animal movement in different outbreak zones, are all included in the plan. To be most useful, especially in an emergency situation, tools like this plan need to provide comprehensive information with clear directions. Where additional resources are needed, or existing information is already published, the plan references where to find it and provides links for easy navigation. Additionally, the plan is formatted such that the most critical pieces of information are communicated clearly and concisely, and often highlighted in some kind of figure, such as a box like Fig. 8, a timeline, or a flow chart.

6. Diagnostics

Many details about diagnostic testing should be considered beforehand to ensure that the data obtained accurately reflects the information being sought. Depending on whether the target is an infectious virus and what the appropriate sample matrix is, there may be multiple options for how to test for ASFV. Different types of assays exist for different purposes; for example, viral isolation can determine whether an infectious virus is in the sample, while PCR can detect specific pieces of genetic material from a virus, but doesn't indicate its infectivity (Payne, 2017). Additional aspects of diagnostic testing to consider are when and how often to perform the testing. The frequency of testing may be influenced by several factors, including regulations, the likelihood of detection, the samples available, test sensitivity and specificity, and the context of the diagnostic test (Beemer et al., 2019; Muzykina et al., 2024). Sample matrices used for testing will yield different sensitivities and may be paired with specific pre-treatment steps or assay types to get a reliable test result (Kwon et al., 2024b; Niederwerder & Hefley, 2022). For this reason, it is crucial to match the sample matrix with a diagnostic assay validated specifically for that matrix type.

Pathogens with high mortality can have consequences on economies of all sizes, and new cases or spread may induce some degree of fear or panic in those who may be affected. Diagnostic testing capabilities must be sensitive, specific, and reliable so that epidemiology data accurately reflect the situation without additional burden on producers and the economy in terms of time or money (Auer et al., 2022; Elnagar et al., 2022; Penrith et al., 2024). In the context of ASFV detection in swine, a confirmed positive case often triggers culling, which can have a significant negative economic impact on the local market (Mohan et al., 2021; Nguyen-Thi et al., 2021). Therefore, a balance must be struck when utilizing diagnostic tests between adequately protecting the food supply and not unnecessarily raising the alarm on a pathogen. Two ways to achieve this are to have reliable and accurate testing methods and systematic screening (Fan et al., 2020; Flannery et al., 2020; Qiu et al., 2021). WOAH publishes comprehensive ASFV detection information that recommends certain tests for certain applications and offers guidance for how to proceed with test results.

6.1 Sample Matrices

In the context of animal health, sample matrices for diagnostics are likely biological specimens or environmental samples, like feed or water samples. Samples may be utilized for surveilling healthy animal populations or tracing potential routes of transmission. The goal of the diagnostic test will guide what type of assay should be used, and subsequently, selecting the appropriate sample matrix. Some assays can use a variety of sample matrices, while others may require a specific type. Other considerations for assay and matrix selection include ease of collection, sensitivity, and required clean-up steps.

Biological samples for ASFV testing are any samples that may come from swine and can include tissues, bodily fluids, and excretions that may be taken from specific animals or as a pooled sample. Samples can be taken actively, for example, a blood draw, or passively, like saliva from a chew rope, and collected either ante- or post-mortem (Beemer et al., 2019; Mai et al., 2025; Niederwerder & Hefley, 2022). Necropsy samples have the benefit of being traceable to specific animals but are time and labor-intensive to collect, compared to feces or saliva that may offer a glimpse into overall herd health (Beemer et al., 2019). Biological samples are used in a variety of assays, like genetic sequencing, immunoassays, or culture-based assays, and certain types may be more useful for specific assays, like tissue samples used with viral isolation. Biological matrices, like spleen, may have increased detection compared to something like blood, but they also may require more preparation or clean-up steps to test.

Many different sample types are used to monitor the environment due to the potential for environmental transmission of ASFV. Feed and water samples can serve as useful sample matrices for screening before crossing a boundary, like into a new country or out of a feed production site. ASFV can also be transmitted through the air, so air samples are another potential sample matrix (de Carvalho Ferreira et al., 2013). In the context of animal production, dirt or water runoff can be a useful sample type for environmental monitoring (Kwon et al., 2024a). Environmental samples from food processing may be swabs from the surface of processing equipment or a sample of water used to clean the facility. Due to the nature of environmental samples, detectable virus may only be present in trace amounts, so it is important to use sensitive assays with cleanup that won't strip away trace amounts of detectable virus (Kwon et al., 2024b). Additionally, environmental samples have the potential to induce very high consequences, for example, in a feed processing setting where other products may share equipment products may become contaminated.

Matrix types for detecting ASFV in food products may come from any stage of processing and can include ingredients or raw materials produced from swine, like casings, muscle tissue, fat, blood, or finished products like aged hams, cured products like salami, or ground sausage, destined for export to countries without ASF. Samples obtained from food products can be difficult to clean up because of the many components or potential interferants, like protein or fat, that can decrease diagnostic sensitivity or affect viral inactivation (Kalmar et al., 2018; Petrini et al., 2019). Accommodations to the sample preparation and clean-up steps may facilitate the use of a variety of sample types with flexible diagnostic assays (Flannery et al., 2020; Krzyžánková et al., 2023; Onyilagha et al., 2022; Serdena et al., 2025).

6.2 Sample Clean-up

For many different types of assays, cleaning up the sample is a prerequisite to testing. In complex matrix types, these steps remove interferents, so that viral material can be more easily detected; however, in other sample types where there is only a trace amount of viral material, cleanup steps may strip precious material crucial to accurate detection (Kwon et al., 2024a, 2024b). The sensitivity of an assay, or its ability to detect trace amounts of viral material, can be improved if samples are pre-treated by centrifugation, filtration, or extraction (Carlson et al., 2020; Lee et al., 2022; Mai et al., 2025). Depending on the matrix type and the intended assay, sample cleanup steps may be the most time and labor-intensive part of testing. Pre-treatment steps for both animal samples and feed samples often include homogenizing the matrix, adding an appropriate liquid, mixing, and removing supernatant (Elijah et al., 2022; Niederwerder & Hefley, 2022; Nishi et al., 2022). Additional steps may include tissue mincing, filtration, or incubation (Niederwerder & Hefley, 2022; Nishi et al., 2022).

6.4 Assays

Diagnostic tools for ASF may be useful in both food and animal health contexts. A wide range of diagnostic assays is available and can be utilized in various settings for different contexts. Point-of-care diagnostics are tests that target either viral antigens or DNA and can be used pen-side as a quick check of animals (Elnagar et al., 2022). Other diagnostic assay types are detailed in **Table 3**. WOAH also recommends confirmatory testing using the gold standard PCR and/or serology assays like immunofluorescence or enzyme-linked immunosorbent assays (ELISAs) (Health, 2024). WOAH also provides a brief overview of the assays available, complete with a table providing a high-level comparison of various attributes, including cost, specimen type, and time to diagnosis (Inui et al., 2022). **Table 3** outlines a brief comparison and contrast of five of the most common diagnostic assays. Additionally, their ASF Lab guidelines provide detailed protocols for 5 different types of PCR assays (Health, 2024).

Table 3. Comparison of 5 different types of diagnostic assays. Assays are listed with detection type, compatible sample types, and a brief analysis of costs and benefits.

Assay Type	Detection Type	Sample Types	Pros	Cons	Sources
Polymerase Chain Reaction (PCR)	DNA	Pork samples, wet markets, biological specimens (blood and tissue), ticks, cell culture	Gold standard, high sensitivity and specificity, quick, low sample purity required	Costly, moderately complex, equipment	(Inui et al., 2022; Qiu et al., 2021; Serdena et al., 2025)
Loop-mediated isothermal amplification (LAMP)	DNA	Oral fluid from swine	High sensitivity and specificity	Costly, moderately complex, equipment	(Inui et al., 2022; Mai et al., 2025)
Enzyme-linked immunosorbent assay (ELISA)	Antigen	Blood, tissue	High sensitivity and specificity, less equipment	Costly, complex	(Inui et al., 2022; Muzykina et al., 2024; Qiu et al., 2021)
Viral Isolation (VI)	Viral	Biological specimens (blood and tissue)	Gold standard, high sensitivity and specificity	Costly, slow, labor intensive, complex	(Muzykina et al., 2024; Qiu et al., 2021)
Lateral Flow Assay (LFA/LFI)	Antibody, Antigen	Blood	Quick, cheap, easy to perform, no equipment, high specificity	Limited sensitivity	(Aira et al., 2024; Inui et al., 2022; Muzykina et al., 2024)

7. Conclusion

The deadly threat of African Swine Fever is not new to swine producers and affiliated industry sectors; however, it does present a modern and evolving threat to the global food system. The potential for food animal diseases to weaken the security of the food supply is exacerbated by our increasingly complex and interconnected pork production network (Wang & Dai, 2021). The geographic proximity of ASF outbreaks in the Dominican Republic and Haiti beginning in 2021 are a serious concern for the United States. To address the problem, we must have a multi-front attack by utilizing both proactive and reactive strategies. With so much at risk, all stakeholders in swine production, animal health, and food/feed processing sectors must understand the issue and engage in mitigation strategies. Without reliable diagnostics, it is impossible to understand the scope and movement of ASFV. Studying ASFV and its impact on the global food system from outbreaks in other countries may help to improve prior planning and prevent future risks to our food supply. Food scientists are invested in the health, safety, and security of our nation's food supply and thus should be versed in potential threats, like ASF.

8. Future Work

Research surrounding ASF has answered many questions in just over 100 years of its discovery, but many questions remain, especially regarding diagnostics. Accessible and reliable diagnostics can lower response times for such a high-risk disease; however, inaccurate results can potentially have devastating effects on multiple market spaces. To achieve this balance of reliable results and quick response times, the U.S. restricts animal health testing to only a few approved labs and assays. As it relates to imported food products, the U.S. approach is not to test for ASF, but to dispose of illegally imported products or suspicious shipments. If you do not test for ASF, then there is no potential for the country to report a positive sample, which could have huge implications for trade. While it may reflect an accurate picture of animal health, it leaves the food system vulnerable to introduction via unmonitored routes of ASFV introduction.

Many options currently exist for ASFV diagnostic assays, but further development could enhance response efforts. In countries where there are fewer restrictions regarding ASFV diagnostics, a reliable point-of-care diagnostic assay could reduce the time to results. Putting diagnostics in the hands of producers would require a less complex, more rugged, and cheaper assay than the reliable assays that currently exist. Ideally, a diagnostic assay for ASFV could accommodate testing various sample types, encompassing food, animal, and environmental samples. The feasibility of this is unlikely due to the varying amount of detectable pathogenic material in each sample and other sample components that can require additional pre-treatment steps.

Finally, for traded pork and pork products, the responsibility of testing is shared by importers and exporters, with some degree of trust that the other party has done necessary due diligence. Previous studies have demonstrated that trade has contributed to the spread of ASF and is the most likely route of transmission to a new country (Olesen et al., 2020). The current geographic spread of ASF suggests that the volume of traded products that are sufficiently and reliably tested by both importers and exporters to ensure ASF-free status is lacking, leaving significant vulnerabilities. As many groups have a vested interest in keeping the U.S. ASF-free, additional international collaboration, funding, and testing could support an increase in diagnostic implementation in order to safeguard against ASFV incursion into the U.S, but there must be a balance between preventative efforts and incurred protection.

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