THE AFRICAN SWINE FEVER CRISIS: EPIDEMIOLOGY, PATHOLOGY, AND CONTROL

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ABSTRACT

African Swine Fever (ASF) has emerged as a catastrophic transboundary veterinary crisis, with its recent incursion into the Indian subcontinent posing a severe threat to the national porcine sector. This review synthesizes the current epidemiological dynamics, pathobiology, and socio-economic impacts of ASF, with a specific focus on the Indian context. Since the initial 2020 outbreaks in Northeastern India, molecular characterization has confirmed the circulation of highly virulent ASFV Genotype II, sharing complete nucleotide homology with contemporary Eurasian strains. The virus, characterized by its extreme environmental resilience and sophisticated immune evasion capabilities, primarily targets the myeloid lineage, resulting in an acute hemorrhagic fever. Clinical manifestations—including severe pyrexia, centripetal cyanosis, and profound hemorrhagic splenomegaly—are clinically indistinguishable from Classical Swine Fever, necessitating rapid molecular diagnostics like qPCR for definitive confirmation. Despite these capabilities, the absence of accessible point-of-care diagnostics in resource-limited regions exacerbates transboundary spread. Currently, disease management relies almost exclusively on stringent biosecurity protocols and aggressive stamping-out policies. However, the development of experimental DIVA-compatible marker vaccines, such as the ASFV-G-ΔI177L/ΔEP402R mutant, offers a promising avenue for future eradication programs without disrupting international trade. Ultimately, the rapid dissemination of ASF has inflicted profound socio-economic devastation upon India's unorganized backyard farming sector, severely destabilizing rural livelihoods and regional food security. Mitigating this escalating crisis requires sustained international collaboration, targeted financial interventions for vulnerable smallholder farmers, and the accelerated deployment of next-generation immunization strategies.

Keywords: African Swine Fever; ASFV Genotype II; Veterinary Epidemiology; DIVA Marker Vaccines; Socio-economic Impact

INTRODUCTION

African Swine Fever (ASF) is a highly fatal, infectious viral disease of domestic and wild pigs that manifests as an acute hemorrhagic fever (Gaudreault *et al*., 2020). Since its first clinical description in 1921 in Kenya, ASF has evolved from a regional concern in sub-Saharan Africa into a global veterinary emergency (Penrith, 2020). The recent introduction and rapid spread of the virus within India have caused significant alarm among veterinary authorities and pig farmers alike (Patil *et al*., 2020).

ETIOLOGICAL AGENT

The causative agent, African Swine Fever Virus (ASFV), is a unique and complex double-stranded DNA virus. It is characterized by a multi-layered structure consisting of an internal nucleoid, an inner membrane, a capsid, and an outer lipid envelope (Wang *et al*., 2019; Gaudreault *et al*., 2020). The viral genome is relatively large, ranging from 170 to 190 kbp (Dixon *et al*., 2013). ASFV is classified into 24 distinct genotypes based on the sequencing of the B646L gene, which encodes the p72 major capsid protein (Qu *et al*., 2022). While genotypes I and II have been widely reported outside of Africa, phylogenetic analysis confirms that all Indian ASFV isolates to date belong to Genotype II (Rajukumar *et al*., 2021). These Indian isolates share 100% nucleotide sequence similarity with contemporary strains found in China, South Korea, and parts of Europe, suggesting a common expansion of ongoing outbreaks from these regions (Senthilkumar *et al*., 2022).

GLOBAL AND NATIONAL EPIDEMIOLOGY

The global and national epidemiology of ASF has shifted dramatically since the 2007 introduction of the highly virulent genotype II into Georgia and its subsequent 2018 arrival in China (Penrith, 2020). Globally, ASF is now endemic in most sub-Saharan African countries and has established a widespread presence from the Caribbean to the Asia-Pacific region, markedly impacting trade, livelihoods, and food security (Ruiz-Saenz *et al*., 2022). In Europe, wild boar populations serve as major reservoirs and drivers of transmission, particularly in countries where recent farm-level outbreaks continue to escalate in 2026 (Friedrichs *et al*., 2026). In India, the epidemiological picture changed significantly in May 2020 when the first outbreaks were recorded in Arunachal Pradesh and Assam (Mahajan *et al*., 2022). Genetic characterization of Indian isolates has confirmed the presence of ASFV genotype II, showing 100% nucleotide sequence similarity with contemporary Eurasian strains (Mahajan *et al*., 2022; Das *et al*., 2024). The disease predominantly affects backyard and commercial pig populations, and recent molecular analysis has focused on the diversity and evolution of these Indian isolates (Das *et al*., 2024). Despite strict biosecurity efforts, the disease has spread to several states, including recent reports of acute outbreaks on the west coast of India, which have provided new pathological and molecular perception into the virus's spread within the country (Narnaware *et al*., 2025).

TRANSMISSION AND PATHOGENESIS

The transmission and pathogenesis of ASF are characterized by the virus's exceptional environmental stability and its complex interactions with the porcine immune system. Transmission occurs primarily through direct contact between infected and susceptible animals, where oronasal exposure to viral particles in secretions serves as the major natural pathway for infection (Dixon *et al*., 2020). Beyond direct animal-to-animal contact, the virus is efficiently spread through indirect routes, including the ingestion of contaminated "swill" (untreated food waste) or contact with contaminated fomites such as vehicles, equipment, and clothing (Niederwerder, 2021; Bora *et al*., 2020). It can be transmitted via biological vectors, specifically through the bites of infected soft ticks belonging to the genus *Ornithodoros*– namely *Ornithodoros moubata* and *Ornithodoros erraticus* (Pereira, 2018; Niederwerder, 2021). Once the virus enters the host, it primarily targets cells of the myeloid lineage, specifically monocytes and macrophages (Salguero, 2020). The pathogenesis of acute ASF is marked by widespread vascular injury and disseminated hemorrhages, resulting from the infection of endothelial cells and the massive release of inflammatory mediators (Salguero, 2020). This leads to the characteristic gross lesions such as hemorrhagic splenomegaly and the "turkey egg" appearance of the kidneys due to cortical petechiae (Salguero, 2020; Narnaware *et al*., 2025). To achieve rapid systemic spread, ASFV relies on a diverse set of viral genes designed to suppress interferon signaling and interfere with host cell apoptosis, thereby subverting the host's primary innate immune defenses (Salguero, 2020).

CLINICAL MANIFESTATIONS AND PATHOLOGY

Acute ASF is characterized by severe pyrexia (up to 42°C), profound lethargy, anorexia, and a tendency for affected pigs to huddle together (Galindo & Alonso, 2017; Abedin *et al*., 2020). Systemic viral dissemination causes striking cutaneous erythema and cyanosis on the extremities and abdomen, often accompanied by conjunctivitis, ocular discharge, and dysentery (Salguero, 2020). Upon necropsy, gross pathology reveals massive endothelial damage and multiorgan hemorrhage typical of a viral hemorrhagic fever (Galindo & Alonso, 2017). Hallmark diagnostic lesions include severe hemorrhagic splenomegaly—a dark, friable, massively enlarged spleen—and "marbled" lymph nodes caused by intense medullary bleeding (Salguero, 2020). Additionally, the kidneys display a petechiated "turkey egg" appearance, which frequently co-occurs with hemorrhagic endocarditis and pulmonary edema (Salguero, 2020).

DIAGNOSIS AND CHALLENGES

Clinical diagnosis of ASF is challenging because its severe manifestations such as pyrexia, hemorrhage, and high mortality, are clinically indistinguishable from other diseases, particularly Classical Swine Fever (CSF) (Dixon *et al*., 2020; Blome *et al*., 2020). A thorough differential diagnosis must also exclude Swine Erysipelas, Acute Salmonellosis, and severe PRRS (Gallardo *et al*., 2019; Salguero, 2020). Consequently, any acute hemorrhagic fever in swine necessitates immediate laboratory confirmation to trigger outbreak control measures (Penrith, 2020). Rapid laboratory testing is the cornerstone of effective containment (Gaudreault *et al*., 2020). Diagnostic samples primarily include whole blood or serum from live animals, and target tissues like the spleen, lymph nodes, kidneys, and lungs from necropsies (Penrith, 2020). While real-time PCR (qPCR) is the gold standard for early, highly sensitive viral detection (Gaudreault *et al*., 2020), significant challenges persist in remote or resource-limited farming regions. In these areas, the lack of accessible molecular laboratories and validated point-of-care (penside) tests frequently delays definitive diagnosis, hampering immediate quarantine efforts and facilitating rapid transboundary spread (Urbano and Ferreira, 2022).

PREVENTION AND CONTROL STRATEGIES

ASF management relies almost entirely on stringent biosecurity and aggressive stamping-out policies, due to lack of a globally approved vaccine (Dixon *et al*., 2020). Preventing viral introduction into naïve herds requires strict movement restrictions on live pigs and banning uncertified pork imports (Urbano and Ferreira, 2022). Farm-level biosecurity must include limiting visitor access, thoroughly disinfecting vehicles and equipment, and strictly quarantining new animals (Penrith, 2020). Prohibiting "swill feeding" is a critical preventive measure due to the virus's prolonged survival in contaminated meat (Bora *et al*., 2020; Niederwerder, 2021). During an outbreak, rapid containment requires immediate culling of all infected and in-contact pigs, followed by deep burial or incineration of carcasses to prevent environmental persistence (Dixon *et al*., 2020). While live-attenuated vaccines (e.g., NAVET-ASFVAC in Vietnam) have recently received localized authorization, their widespread international deployment awaits further rigorous safety evaluations (Tran *et al*., 2022).

To support these emerging immunization efforts, the development of DIVA (Differentiating Infected from Vaccinated Animals) marker vaccines is a critical priority, as they enable serological surveillance to distinguish vaccinated herds from naturally infected populations without jeopardizing international trade status (Zhang *et al*., 2023). While a commercial DIVA system is pending, experimental gene-deleted candidates successfully incorporate these vital diagnostic markers; for example, the ASFV-G-ΔI177L/ΔEP402R mutant deletes the EP402R gene to enable distinct serological differentiation while maintaining full protective efficacy against virulent strains (Gladue & Borca, 2022; Borca et al., 2024). Looking ahead, long-term experimental solutions include genetically engineering domestic pigs to introduce innate viral resistance traits found in natural African hosts like warthogs (Urbano & Ferreira, 2022).

SOCIO-ECONOMIC IMPACT

ASF exerts a devastating socio-economic toll globally, driven by mass animal mortality and the immense costs of outbreak containment (Mason-D'Croz *et al*., 2020). Affected nations face severe trade restrictions, losing billions in export revenue and destabilizing international commodity markets (Dixon *et al*., 2020). By decimating a primary global protein source, ASF threatens international food security and triggers sharp spikes in domestic pork prices (Ceruti *et al*., 2025). This burden disproportionately impacts rural smallholder farmers who rely on pigs as critical financial assets (Penrith, 2020). For these vulnerable communities, sudden herd losses without adequate government compensation often lead to acute financial ruin and regional economic destabilization (Ceruti *et al*., 2025). Within the Indian context, the economic losses are particularly severe because the national pork industry is overwhelmingly driven by the unorganized, backyard farming sector, predominantly in the North-Eastern states (Bora *et al*., 2020). In regions such as Assam, Arunachal Pradesh, and Mizoram, pig rearing is deeply intertwined with tribal livelihoods and socio-cultural traditions, making the massive culling of herds a direct threat to community resilience (Patil *et al*., 2020). The rapid spread of the virus has forced prolonged bans on inter-state pig transport and the closure of local meat markets, severely disrupting domestic supply chains and trade (Rajukumar *et al*., 2021). Consequently, the catastrophic loss of this vital income source, compounded by the logistical challenges of distributing financial compensation, has pushed thousands of marginalized Indian farming households toward severe poverty and threatened localized food security (Parthiban *et al*., 2023).

CONCLUSION

ASF remains a formidable transboundary threat to the global swine industry (Gaudreault *et al*., 2020). The virus's environmental resilience, immune evasion capabilities, and the lack of a universally approved vaccine make eradication exceptionally challenging (Dixon *et al*., 2020). Consequently, disease management must continue prioritizing strict biosecurity, rapid molecular diagnostics, and aggressive stamping-out policies to mitigate catastrophic losses (Urbano and Ferreira, 2022). Ultimately, securing global pork production requires sustained international collaboration, financial support for vulnerable farmers, and accelerated development of DIVA-compatible marker vaccines and genetically resistant pig breeds (Ceruti *et al*., 2025; Tran *et al*., 2022).

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