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African Swine Fever in Pigs: Recent emergence and Indian Perspectives

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ABSTRACT

African Swine Fever disease is an economically important disease of pigs caused by *Asfivirus* of *Asfarviridae* family. The disease is characterized by acute haemorrhagic fever with a mortality rate of 100% in which pigs of all age groups are susceptible to the infection. Wild pigs and *Ornithodoros* soft ticks are the natural reservoir host transmitting the infection to the domestic pigs and also by direct contact with the infected animal. The three patterns of infection in ASF are sylvatic cycle, tick-pig cycle, domestic pig cycle and wild boar habitat cycle. ASF presents four clinical forms such as peracute, acute, subacute and chronic forms depending upon the virulence nature of the virus. Recently in the year 2020, India reported an ASF outbreak in two North-eastern states Assam and Arunachal Pradesh during which around 3701 deaths were evidenced. North eastern states of India contribute 9% of the pig population and also has a permissible border with other countries like China, Bhutan, Bangladesh, Nepal, Myanmar which permits the emergence of transboundary diseases. The possible reason or transmission route involved in the outbreak of ASF is still inconclusive. As no commercial drugs or vaccines are available for the control of ASF, improved sanitation and biosecurity measures will protect the swine population in developing countries like India in order to sustain the pig population which is the major economy for the people of North eastern states.

1. Introduction

African Swine Fever (ASF) is an acute, highly contagious, viral disease infecting pigs with a high mortality rate. ASF is an economically important disease affecting pigs has been listed as a notifiable disease and has been prioritized among any other diseases of pigs by OIE (Dixon *et al.*, 2005). The ASF is the only vector borne disease caused by DNA virus - African Swine Fever Virus (ASFV) belonging to the *Asfivirus* genus under the family *Asfarviridae* (Blome *et al.*, 2020). The vector involved in the transmission of ASFV is a soft tick, *Ornithodoros* spp. ASFV is an enveloped, linear, double stranded DNA virus with icosahedral symmetry whose genome length is 170-190 kbp (Dixon *et al.*, 2013). The target host cells for the virus are monocytes and macrophages in which they undergo cytoplasmic replication and are released by budding through the plasma membrane. Based on the capsid protein p72, a major structural protein, 24 different genotypes of ASFV had been described to date by sequencing the gene C-terminal B646L coding it (Bastos *et al.*, 2003; Chapman *et al.*, 2008). The virus can be easily inactivated by heating at 60°C for 20 minutes/ 56°C for 70 minutes, exposing it to chemical agents like hypochlorites, NaOH, formalin, iodine and 3% ortho-phenyl phenol for 30 mins also inactivates the virus. At the same time, the virus can remain viable under low temperatures, in the blood, faeces and undercooked meat of infected animals for longer periods of time (Dutta *et al.*, 2019).

North Eastern states of India is highly populated with pigs as most of them consume pork. At the same time, North East India has a unique geographical location that shares international boundaries with Bangladesh, Bhutan, Myanmar, China favouring the permeability of transboundary diseases, ASF being one of them. The first report of ASF among the domestic pig population in India has been reported on May 2021 in Assam and Arunachal Pradesh with deaths numbered 3701 (Bora *et al.*, 2020; Patil *et al.*, 2020). Considering the economic importance of the disease in

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context to North Eastern India, this article will throw a light on this important disease.

2. Epidemiology

ASF is endemic in most of the sub-Saharan African countries. The pattern of infections of ASF is unique in different continents like Africa, Europe, Asia viz., sylvatic cycle, tick–pig cycle, domestic, and wild boar–habitat cycle involving wild pigs, domestic pigs, *Ornithodoros* ticks, pork and its products (Chenais *et al*., 2018). In the sylvatic transmission cycle i.e. the warthogs, bush pigs, other wild suids like giant forest hogs and ticks, are infected but with no observant clinical signs as warthogs being natural reservoir hosts for the virus. This sylvatic cycle was first predicted in Africa (Plowright *et al*., 1994; Guberti *et al*., 2018). In the tick-pig cycle, soft ticks act as the biological reservoirs for the virus to multiply, maintains the infection and is then transmitted to the domestic pigs, in spite of little or no contact with wild boars, clearly stating the Ornithodors ticks' role in disease transmission among the domestic pigs. Thus, an assumption that soft ticks are the actual hosts of ASFV and the domestic pigs would be the accidental hosts (Wilkinson 1984; Dutta *et al*., 2020). In domestic cycle, the transmission and infection is among the domestic pigs and by other factors by pork (Chenais *et al*., 2019). The wild boar–habitat cycle, was newly reported in Europe which involves direct transmission between the wild boars and also the indirect transmission through their habitat, their carcasses in which the virus is maintained and transmitted to the domestic pigs (Chenais *et al*., 2018). It was hypothesised that this wild boar-habitat cycle might be the reason for the transmission of infection of ASFV from wild pig to domestic swine/feral pigs in new areas/regions like national parks or sanctuaries (Bora *et al*., 2020).

3. Hosts

All the members of *Suidae* family are the susceptible hosts for ASF irrespective of age (Mulumba-Mfumu *et al*., 2019). The host species considered as the target for ASFV are wild pigs, domestic pigs and *Ornithodoros* ticks. African warthogs (*Phacochoerus aethiopicus/ Phacochoerus africanus)* are considered to be an important reservoir host of ASFV in Africa. Other natural reservoir hosts which are primarily infected by ASFV in Africa are giant forest (*Hylochoerus meinertzhageni*), bush pigs (*Potamochoerus* sp) and *Ornithodoros* spp. ticks which maintain and transmit the infection to the susceptible hosts (Chenais *et al*., 2019; Golnar *et al*., 2019; King *et al*., 2003; Sanchez-Vizcaino *et al*., 2009). Vertebrate hosts in which the disease is actually demonstrated with clinical illness are American wild pigs, European wild pigs and domestic pigs (*Sus domestica*) (Dixon *et al*., 2020). The disease transmission by ticks in India is not clearly determined yet. Patil *et al*. (2020) has hypothesized that the infection in domestic pigs /outbreak in India would be due to movement of personnel or through fomites from the contaminated habitat and the role of ticks in disease transmission is yet to be investigated.

4. Transmission and Transboundary spread

The disease transmission occurs by direct contact of susceptible pigs with infected ones, by the bite of an infected *Ornithodoros* tick, and indirectly consumption of pork or pork products from an infected animal, when undercooked as the virus can survive and remain infectious for about 3-6 months period (Penrith and Vosloo 2009; Dutta *et al*., 2020). The disease is also indirectly transmitted by blood, urine, faeces of an infected pig which contaminants the habitat and is then transmitted to the susceptible host pigs through fomites like personnel clothes, vehicles, implements etc., (de Carvalho Ferreira *et al*., 2013a; 2013b; Gallardo *et al*., 2015). The disease transmission to domestic pigs from the wild suids is mainly through the biological vector *Ornithodoros spp.* and is considered to be the most common route of transmission. The virus replicates in the tick vector and is transmitted among the tick population transovarially, transtadially and transsexually. The tick while feeding on the wild pigs (Warthogs, bush pigs) transmits the virus, leading to persistent infection in them and remain asymptomatic. Whereas, transient viremia may develop in young infected pigs without developing the disease in order to infect the new ticks (Plowright *et al*., 1974; 1970; Endris and Hess 1994; Hess *et al*., 1987; Kleiboeker *et al*., 1999). The stable fly (*Stomoxys calcitrans*), are also found to be involved in the transmission of ASFV among the pig population. The stable fly acts as a mechanical vector, in which the virus can survive for up to 48 h after the virus is ingested by the bite of an infected pig (Mellor *et al*., 1987).

Africa was the first country to record and report ASF, where the disease is endemic and is re-emerging (Montegomery 1921). The first transcontinental spread of ASFV occurred in Portugal and then to other European countries followed by spread to Russian Federations, Poland, Belgium and finally China (2018) which holds half of the world's pig population (Sanchez-Vizcaino *et al*., 2012a; Bironт *et al*., 1987; Terpstra *et al*., 1986; Swaney *et al*., 1987; Wilkinson *et al*., 1980; FAO 2018). From China, the top most producer of pork among the Asian countries, the virus disseminated to Vietnam, Mongolia, South Korea, Philippines and other Asian countries (OIE 2020). In history, ASF are not more common in Asian countries restricting the transboundary spread, because of strict rules and regulations in trades, improved sanitary measures, but the periodic outbreak of other swine diseases like hog cholera, swine flu and BSE has been reported (Costard *et al*., 2013; Ozawa *et al*.,

2006). In recent years, many Asian countries like Hong Kong, Cambodia, Papua New Guinea, India (Penrith 2020; OIE 2020) reported the outbreak of ASF. In India, pork production is highly concentrated only in the NE states which is surrounded by international borders like China, Myanmar etc., creating a potential threat of transboundary spread of ASF. As the production of pork is only 9%, India imports the processed pork products from Italy, Belgium, Sri Lanka posing a threat for disease spread and further outbreaks (USDA 2016; DAHD 2020; Bora *et al.*, 2020). Thus, illegal trade of pork and pork products, men movement enables the entry of ASFV into new zones leading to transboundary transmission of ASF apart from the wild boar and tick involvement.

5. Pathogenesis

The virus ASFV makes entry via the oro-nasal route, viral attachment to the cells is mediated by structural proteins like p12, p72 and p54 and released inside the cell (Greig 1972; Gaudreault *et al.*, 2020). The virus replicates initially in the tonsils and regional lymph nodes followed by viraemic spread to other target organs through blood or lymph and they undergo cytoplasmic replication in macrophages and monocytes (Colgrove *et al.*, 1969; Salguero *et al.*, 2002; Gomez-Villamandos *et al.*, 2013). The virulence gene involved in pathogenesis is NL genes along with 8-DR protein which has the haemadsorption property (Nogal *et al.*, 2001). After infecting the cells and maturation of the virus, the virus is then released into the blood or lymphatic circulation by budding, further infecting the other organs. The complete ASFV infection cycle (from attachment to maturation and release) occurs within 24hpi (Gaudreault *et al.*, 2020; Munoz-Moreno *et al.*, 2015).

6. Clinical signs and Lesions

Though the ASF is asymptomatic with persistent infection in wild suids and soft ticks (reservoir host) in Africa, most of the ASFV isolates, cause severe infection with acute haemorrhagic fever in domestic pigs and wild boar, resulting in a 100% fatality rate (Blome *et al.*, 2013; Pietschmann *et al.*, 2015). The incubation period for ASF varies from 4-19 days depending on the route of infection. The disease occurs in four forms - peracute, acute, subacute and chronic forms depending on the virulence nature of the virus (Dutta *et al.*, 2020; Yoo *et al.*, 2020). The peracute form of the disease is caused by infection of pigs with highly virulent ASFV isolates leading to the death of the host within 4-10 days after infection without any clinical signs. Some animals may exhibit clinical signs like pyrexia, rapid breathing or hyperemia of the skin with cent percent morbidity and mortality (Sanchez-Vizcaıno *et al.*, 2015; Mebus 1988). The highly virulent and moderately virulent strains of ASFV leads to acute and sub-acute forms of the disease which are most commonly observed. The clinical signs observed in acute forms include anorexia, pyrexia (up to 42˚C), lethargy, epistaxis, vomiting, cyanotic patches/haemorrhagic spots in the leg extremities, ears, abdomen, tail, abortion, diarrhoea, conjunctivitis, mucopurulent discharge from nose and eyes followed by death within 4-9 days of infection (Beltrán-Alcrudo *et al.*, 2017; Gallardo *et al.*, 2015; Salguero 2020). The sub-acute form of ASF shows clinical signs similar to that of acute forms, but the disease severity is less with 30-70% mortality. Animals surviving the infection recovers within 1 month and excrete the virus in its secretion up to 6 weeks (Beltrán-Alcrudo *et al.*, 2017; OIE 2019). The chronic form of the disease is caused by low virulent ASFV isolate and mild signs like emaciation, pneumonia, poor and stunted growth, arthritis, intermittent fever, skin lesions may be observed often resembling Classical swine fever which requires laboratory confirmation (Sanchez-Vizcaıno *et al.*, 2015; Salguero 2020).

The pathological lesions in peracute forms are usually not observed. The lesions associated with the acute form of ASF include splenomegaly, extensive/ petechial haemorrhage of internal organs like lungs, kidneys, and mucous membrane of urinary bladder, larynx. Lymphoid tissue necrosis and multifocal haemorrhagic lymphadenitis are the important lesions observed in post-mortem with the lymph nodes showing marbled appearance due to multifocal haemorrhages. Intense haemorrhages and oedema are the lesions observed in subacute form. The lesions are observed in the chronic form may be due to secondary bacterial infections which include pleuritis and fibrinous pericarditis (Salguero 2020; OIE 2019; Gallardo *et al.*, 2015).

7. Economic importance

ASF is a highly contagious economically important, transboundary disease. In case of a large epidemic, there will be a drastic reduction of the pig population having a severe socioeconomic impact on trade, business and costs involved in the control of disease and obviously result in inflation of pork and pork products. The pig population in India is 9 million with more population in NE India whose staple food is pork. The total pork production during the year 2014-15 was 464.11 thousand metric tonnes as per reports by GOI (dahd.nic.in; USDA 2016). The pig farming sector in India is predominantly unorganized, low input driven and the backyard system of rearing is practiced by small and marginal farmers in which the pigs are usually fed with locally available feed materials like kitchen waste/swill feeding (Kumaresan *et al.*, 2009; Shyam *et al.*, 2016). In the North Eastern states of India, pigs are mostly reared under the scavenging system and those are the places where ASF outbreak has been reported (Talukder *et al.*, 2019; Chauhan *et*

al., 2016). The recent outbreak of ASF in Arunachal Pradesh and Assam shows a report of 11 outbreaks with loss of 3701 pigs which is obviously a huge economical loss to the poor farmers of the NEH region (Patil *et al.* 2020).

8. Diagnosis

As the disease ASF shows clinical signs closely resembling CSF, it is important to undergo laboratory tests for confirmatory diagnosis. The laboratory techniques for diagnosis include isolation and identification of the virus, detection of antigen or antibody from the samples like blood, serum, lymph nodes, kidney, spleen (Yoo *et al.*, 2020). The current laboratory techniques used in the ASF diagnosis has certain limitations like lack of analytical sensitivity and specificity, inability to detect early acute and chronic infections, costly equipments and are time consuming. In spite of limitations, the best method of virus detection is molecular assays like PCR or real time PCR (Gaudreault *et al.* 2019). As no commercial vaccines are available, serological tests are also considered more relevant by detecting the circulating antibodies. There is a need for rapid, accurate diagnosis of ASF at field level in less time without any costly equipments would be highly significant. The list of diagnostic procedures in ASF are mentioned below in the Table 1.

9. Prevention and Control

Prevention and control of ASF outbreaks can be focussed by successful vaccination, early disease diagnosis, restricted movement of susceptible pig population and culling of infected herds. The control measures have to be directed towards understanding the epidemiology of the disease, the geographical distribution of potential disease spreaders namely wild pigs and soft ticks. Adopting integrated measures or development of countermeasures for effective control of disease spread and further epidemic outbreaks. The following are the preventive/control measures that can be adopted for ASF disease:

- Sanitation/ Disinfection of premises: ASF recovered pigs and the reservoir hosts i.e. wild suids can contaminate the environment through their excretions and secretions where the ASFV can remain stable for several days to months. 2-3% chlorine (calcium or sodium hypochlorite), 2% NaOH, iodine compounds, phenol substitutes and detergents can be used to disinfect the animal sheds and surrounding premises which inactivates the virus (FAO 2020; DADF 2020). Small scale or backyard piggery sectors can adopt the sanitation procedures by regularly cleaning and disinfecting the animal sheds, farm utensils, removal of litter and dust particles.
- Strict biosecurity measures like segregation of infected from healthy pigs, restricting the movement of personnel and other populations of pigs or pests inside the farm premises by proper fencing, following the quarantine procedures, proper disposal of the infected carcass by incineration or deep burial (Kouam *et al.*, 2020; Davies *et al.*, 2017)
- In case of an outbreak, the infected zones should be marked, movement of pigs should be restricted, culling or slaughtering the infected herds is vital considering all the biosecurity measures (Dutta *et al.*, 2020)
- Avoid scavenging system of pig rearing (FAO 2010)
- Disease diagnosis and surveillance by early detection, geographical distribution and investigation of soft ticks (biological vector) prevalence in the country (Gervasi *et al.*, 2020).
- Strict trade protocols to be followed for the import of pork and pork products will prevent illegal trade business and also limit the transboundary spread of the disease to vulnerable countries like India (Adkin *et al.* 2004).
- Creating awareness among the farmers about the disease, preventive measures and its management followed by timely reports to the veterinary officials (FAO 2010)
- No prophylactic treatment followed to date. But some antiviral agents targeting the viral replication has been successful in vitro but are validated under field conditions (Dixon *et al.*, 2020; Patil *et al.*, 2020)
- Vaccination: No commercial vaccines are available. Some of the vaccines developed but not in use due to some limitations are mentioned in Table 2.

Table 1. List of methods involved in ASF diagnosis

S.No	Approach	Diagnostics used	Significance and limitations	References
1	**Detection of ASFV**			
	Isolation of ASFV	Primary pig monocyte culture or porcine bone marrow cells	• Gold standard method • Cytopathic effect seen • Time consuming (up to 7 days)	Beltrán-Alcrudo *et al.*, 2017
	Identification of ASFV	Haemadsorption test (HAD) 8DR protein present in the ASFV has HAD property	• Gold standard test for definitive diagnosis • The virus in the macrophages bind with the pig RBC's forming a rosette • Time consuming	OIE 2019
2	Detection of viral antigen	Fluorescent antibody Test (FAT)	• Presumptive diagnostic test application where virus isolation is not possible • Field samples or laboratory obtained viral culture can be used in this assay	Sanchez-Vizcaino *et al.*, 2012b
		Antigen based ELISA	Low sensitivity and specificity	Gallardo *et al.*, 2015
		Lateral flow assays	Low sensitivity and specificity	Gallardo *et al.*, 2015
		Polymerase chain reaction (PCR)	• Detection of ASFV gene (p72) • Best method to detect virus in clinical samples	Agüero *et al.*, 2003
		Real time PCR (TaqMan/ Universal Probe Library (UPL) probes)	• Highly sensitive and specific targeting p72 gene • Confirmatory diagnosis recommended by OIE • Used for screening in field • Less time consuming	King *et al.*, 2003; Fernandez-Pinero *et al.*, 2013
		Linear isothermal amplification assay	Highly specific but not sensitive	Hjertner *et al.*, 2004
		LAMP assay combined lateral flow test	Target gene is viral topoisomerase II gene (P1192R) Highly sensitive	James *et al.*, 2010

		Recombinase polymerase amplification (RPA)	• Rapid and highly sensitive targeting p72 gene • RPA combined with lateral flow dipstick showed robust sensitivity	Wang *et al.*, 2017
3	Detection of antibody (Serological tests)	Indirect ELISA	• Recommended test for international trade • Applicable in endemic areas for detection of circulating antibody • Positive samples should be re-confirmed in IFAT	Gallordo *et al.*, 2019; Pastor *et al.*, 1990
		Indirect FAT and Immunoperoxidase test (IPT)	OIE recommended confirmatory test for the sera from endemic areas which has given inconclusive result in ELISA, sera from the areas free of ASF and that has shown positive in ELISA.	Sánchez-Vizcaíno 1987; Pastor *et al.*, 1989

Table 2. Details of vaccines developed for ASF

S.No	Experimented Vaccines	Limitations	Reference
1	Whole viral antigen inactivated vaccine		Forman *et al.*, 1982
2	Subunit, DNA and vector-based vaccines	Variable results with poor protective nature	Gaudreault and Richt 2019; Sunwoo *et al.*, 2019; Argilaguet et al. 2012
3	Attenuated MLV with gene deletion	Protection only against homologus strain	Borca *et al.*, 2020; Sanchez *et al.*, 2019
4	Live attenuated candidate vaccine	Under field trail	Teklue *et al.*, 2020

10. Conclusion

ASFV is a highly fatal contagious disease having a great impact on the economy to the farmers rearing pigs as there is no vaccine available to date for the disease. The only way of preventing the disease spread is by identifying the positive reactors and the in contact susceptible pig has to be culled which indirectly decelerate the pig population in the country and significant loss to the farmers. Farmers in developing countries like India especially in villages and remote areas are not aware of the biosecurity measures and so are not able to adopt effective preventive strategies to check the economic loss. DIVA strategy of diagnosis may be developed by properly understanding the nature of the virus, its replication, gene functions, disease pathogenesis and the host immune response which will be more rationale in preventing ASF. Thus, early disease diagnosis methods, effective vaccination, strict biosecurity measures, restricted pig movement, control of disease spread among the wild pigs, feral pigs and soft ticks remain to be critical and significantly important to prevent and control ASF in domestic pigs.

11. References

Adkin A, Coburn H, England T, Hall S, Hartnett E, Marooney C, Wooldridge M, Watson E, Cooper J and T Cox (2004) Risk Assessment for the Illegal Import of Contaminated Meat and Meat Products into Great Britain and the Subsequent Exposure of GB Livestock (IIRA): Foot and Mouth Disease (FMD), Classical Swine Fever (CSF), African Swine Fever (ASF), Swine Vesicular Disease (SVD); Veterinary Laboratories Agency: New Haw, UK.

Agüero M, Fernández J, Romero L, Sanchez C, Arias M and JM Sánchez-Vizcaíno (2003) Highly sensitive PCR assay for the routine diagnosis of African swine fever virus in clinical samples. Journal of Clinical Microbiology 41(9): 4431-4434.

Argilaguet JM, Perez-Martin E, Nofrarias M, Gallardo C, Accensi F and A Lacasta (2012) DNA vaccination partially protects against African swine fever virus lethal challenge in the absence of antibodies. PLoS ONE 7: e40942.

Bastos ADS, Penrith ML, Crucière C, Edrich JL, Hutchings G, Roger F, Couacy-Hymann E andGR Thomson (2003) Genotyping field strains of African swine fever virus by partial p72 gene characterisation. Archieves of Virology 148: 693–706.

Beltrán-Alcrudo D, Arias M, Gallardo C, Kramer S and ML Penrith (2017) African Swine Fever: Detection and Diagnosis a Manual for Veterinarians. FAO Animal Production and Health Manual No. 19. Food and Agriculture Organization of the United Nations, Rome. p88.

Biront P, Castryck F and J Leunen (1987) An epizootic of African swine fever in Belgium and its eradication. Veterinary Record 120(18): 432-434.

Blome S, Gabriel C and M Beer (2013) Pathogenesis of African swine fever in domestic pigs and European wild boar. Virus Research 173: 122–30

Blome S, Franzke K and M Beer (2020) African swine fever—A review of current knowledge. Virus Research 287: 198099.

Borca MV, Ramirez-Medina E, Silva E, Vuono E, Rai A and S Pruitt (2020) Development of a highly effective African swine fever virus vaccine by deletion of the I177L gene results in sterile immunity against the current epidemic Eurasia strain. Journal of Virology doi: 10.1128/JVI.02017-19

Chapman DA, Tcherepanov V, Upton C and LK Dixon (2008) Comparison of the genome sequences of non-pathogenic and pathogenic African swine fever virus isolates. Journal of General Virology 89: 397–408.

Chauhan A, Patel BHM, Maurya R, Kumar S, Shukla S and S Kumar (2016) Pig production system as a source of livelihood in Indian scenario: An overview. International Journal of Environmental Science and Technology 5: 2089–2096.

Chenais E, Depner K, Guberti V, Dietze K, Viltrop A and K Stahl (2019) Epidemiological considerations on African swine fever in Europe 2014-2018. Porcine Health Management 5(6): 1-10.

Chenais E, Stahl K, Guberti V and K Depner (2018) Identification of wild boar–habitat epidemiologic cycle in African swine fever epizootic. Emerging Infectious Diseases 24: 810.

Colgrove GS, Haelterman EO and L Coggins (1969) Pathogenesis of African swine fever in young pigs. American Journal of Veterinary Research 30(8): 1343-1359.

Costard S, Mur L, Lubroth J, Sanchez-vizcaino JM and DU Pfeiffer (2013) Epidemiology of African swine fever virus. Virus Research 173: 191–197.

DADF. National Action Plan for Control, Containment and Eradication of African Swine Fever; Ministry of Fisheries, Animal Husbandry and Dairying Department of Animal Husbandry and Dairying Government of India: New Delhi, India, 2020. Available online: http://dadf.gov.in/sites/default/filess/ASF_NAP_Booklet.pdf (accessed on 7 October 2020).

dahd.nic.in. Department of Animal Husbandry, Dairying. Government of India. Ministry of Fisheries, Animal Husbandry and Dairying. Available online: http://dahd.nic.in/sites/default/filess/NAP%20on%20Pig%20.pdf (accessed on 3 September 2020).

Davies K, Goatley LC, Guinat C, Netherton CL, Gubbins S, Dixon LK and AL Reis (2017) Survival of African swine fever virus in excretions from pigs experimentally infected with the Georgia 2007/1 isolate. Transboundary and Emerging Diseases 64: 425–431.

de Carvalho Ferreira HC, Weesendorp E, Quak S, Stegeman JA and WLA Loeffen (2013) Quantification of airborne African swine fever virus after experimental infection. Veterinary Microbiology 165: 243–51

de Carvalho Ferreira HC, Backer JA, Weesendorp E, Klinkenberg D, Stegeman JA and WLA Loeffen (2013) Transmission rate of African swine fever virus under experimental conditions. Veterinary Microbiology 165: 296–304

Dixon LK, Escribano JM, Martins C, Rock DL, Salas ML and PJ Wilkinson (2005) Asfarviridae. In: Fauquet, C.M., Mayo, M.A., Maniloff, J., Desselberger, U. and Ball, L.A., editors. Virus Taxonomy. 8th Report of the International Committee on Taxonomy of Viruses. Elsevier Academic Press, London. p135-143.

Dixon LK, Islam M, Nash R and AL Reis (2019) African swine fever virus evasion of host defenses. Virus Research 266(1): 25-33.

Dixon LK, Chapman DA, Netherton CL and C Upton (2013) African swine fever virus replication and genomics. Virus Research 173: 3–14.

Dutta TK, Roychoudhury P, Vangchhia BL, Ralte RL and PK Subudhi (2019) African Swine Fever: A Potential Threat to Pig Husbandry in India. International Journal of Current Microbiology and Applied Science 8(6): 191-194.

FAO. Food and Agricultural Organization. Manual on Livestock Disease Surveillance and Information Systems. Animal Health Manual No. 8. 1999. Available online: http://www.fao.org/3/Y0510E/Y0510E06.htm (accessed on 1 October 2020).

Fernandez-Pinero J, Gallardo C, Elizalde M, Robles A, Gomez C and R Bishop (2013) Molecular diagnosis of African swine fever by a new real-time PCR using universal probe library. Transboundary and Emerging Diseases 60: 48– 58. doi: 10.1111/j.1865-1682.2012.01317.x

Food and Agriculture Organization. (2010) Good Practices for Biosecurity in the Pig Sector Issues and Options in Developing and Transition Countries. FAO Animal Production and Health Paper No. 169. Food and Agriculture Organization, Rome.

Food and Agriculture Organization. (2018) African swine fever threatens Peoples Republic of China. Animal Health Risk Analysis, Assessment No. 5. Food and Agriculture Organization, Rome, Italy.

Forman AJ, Wardley RC and PJ Wilkinson (1982) The immunological response of pigs and guinea pigs to antigens of African swine fever virus. Archieves of Virology 74: 91–100. doi: 10.1007/BF01314703

Gallardo C, Nieto R, Soler A, Pelayo V, Fernandez-Pinero J and I Markowska- Daniel (2015) Assessment of African swine fever diagnostic techniques as a response to the epidemic outbreaks in eastern European union countries: how to improve surveillance and control programs. Journal of Clinical Microbiology 53: 2555–65. doi: 10.1128/JCM.00857-15

Gallardo C, Fernández-Pinero J and M Arias (2019) African swine fever (ASF) diagnosis, an essential tool in the epidemiological investigation. Virus Research 271(10): 197676.

.

Gallardo C, Soler A, Nieto R, Sánchez MA, Martins C, Pelayo V, Carrascosa A, Revilla Y, Simón A, Briones V, Sánchez-Vizcaíno JM and M Arias (2015) Experimental transmission of African swine fever (ASF) low virulent isolate NH/P68 by surviving pigs. Transboundary and Emerging Diseases 62(6): 612-622.

Gaudreault NN and JA Richt (2019) Subunit vaccine approaches for African swine fever virus. Vaccines 7:E56. doi: 10.3390/vaccines7020056

Gervasi V, Marcon A, Bellini S and V Guberti (2020) Evaluation of the Efficiency of Active and Passive Surveillance in the Detection of African Swine Fever in Wild Boar. Veterinary Sciences 7: 5

Golnar AJ, Martin E, Wormington JD, Kading RC, Teel PD and SA Hamer (2019) Reviewing the potential vectors and hosts of african swine fever virus transmission in the United States. Vector Borne Zoonotic Diseases 19: 512–24.

Gomez-Villamandos JC, Bautista MJ, Sanchez-Cordon PJ and L Carrasco (2013) Pathology of African swine fever: The role of monocyte-macrophage. Virus Research 173(1): 140-149.

Greig A (1972) Pathogenesis of African swine fever in pigs naturally exposed to the disease. Journal of Comparative Pathology 82(1): 73-79.

Guberti V, Khomenko S, Masiulis M and S Kerba (2018) Handbook on African Swine Fever in Wild Boar and Biosecurity during Hunting;World Organization for Animal Health: Paris, France.

Hjertner B, Meehan B, McKillen J, McNeilly F and S Belak (2005) Adaptation of an Invader assay for the detection of African swine fever virus DNA. Journal of Virological Methods 124: 1–10. doi: 10.1016/j.jviromet.2004.10.009

James HE, Ebert K, McGonigle R, Reid SM, Boonham N, Tomlinson JA, Hutchings GH, Denyer M, Oura CAL, Dukes JP and DP King (2010) Detection of African swine fever virus by loop-mediated isothermal amplification. Journal of Virological Methods 164: 68–74. doi: 10.1016/j.jviromet.2009.11.034

King DP, Reid SM, Hutchings GH, Grierson SS, Wilkinson PJ, Dixon LK, Bastos ADS and TW Drew (2003) Development of a TaqMan® PCR assay with internal amplification control for the detection of African swine fever virus. Journal of Virological Methods 107(1): 53-61.

Kouam MK, Jacouba M and JO Moussala (2020) Management and biosecurity practices on pig farms in the Western Highlands of Cameroon (Central Africa). Veterinary Medicine and Science 6(1): 82-91.

Kumaresan A, Bujarbaruah KM, Pathak KA, Das A and RK Bardoloi (2009) Integrated resource driven pig production systems in a mountainous area of Northeast India: Production practices and pig performance. Tropical Animal Health and Production 41: 1187.

Mebus, CA (1988) African swine fever. Adv Virus Research 35: 251–269.

Mellor PS, Kitching RP and PJ Wilkinson (1987) Mechanical transmission of capripox virus and African swine fever virus by Stomoxys calcitrans. Research in Veterinary Science 43: 109–112.

Montgomery R (1921) A form of swine fever occurring in British East Africa (Kenya Colony). Journal of Comparative Pathology 34: 159–91

Bora M, Bora DP, Manu M, Barman NN, Dutta LJ, Kumar PP, Poovathikkal S, Suresh KP and R Nimmanapalli (2020) Assessment of Risk Factors of African Swine Fever in India: Perspectives on Future Outbreaks and Control Strategies. DOI: 10.3390/pathogens9121044

Mulumba-Mfumu LK, Saegerman C, Dixon LK, Madimba KC, Kazadi E, Mukalakata NT, Oura CAL, Chenais E, Masembe C, Ståhl K, Thiry E and ML Penrith (2019) African swine fever: Update on Eastern, Central and Southern Africa. Transboundary and Emerging Diseases 66: 1462–1480.

Munoz-Moreno R, Galindo I, Cuesta-Geijo MA, Barrado-Gil L and C Alonso (2015) Host cell targets for African swine fever virus. Virus Research 209: 118–27. doi: 10.1016/j.virusres.2015.05.026

Nogal ML, de Buitrago GG, Rodriguez C, Cubelos B, Carrascosa AL, Salas ML and Y Revilla (2001) African swine fever virus IAP homologue inhibits caspase activation and promotes cell survival in mammalian cells. Journal of Virology 75(6): 2535-2543.

OIE. African Swine Fever (2019). Available online: https://www.oie.int/fileadmin/Home/eng/Animal_Health_in_the_World/docs/pdf/Disease_cards/AFRICAN_SWINE_FEVER.pdf (accessed on 27 October 2020).

OIE. Global Situation of African Swine Fever; World Organisation for Animal Health: Paris, France, 2020. Available online: http://www.gf-tads.org/

Ozawa Y, Makino S, Park JY, Chang JH, Kim JH and SH An (2006) A review of recent unexpected animal disease events in Japan and Korea and the follow-up action taken. OIE Revue Scientifique et Technique 25: 125–135.

Pastor MJ, Arias M and JM Escribano (1990) Comparison of two antigens for use in an enzyme-linked immunosorbent assay to detect African swine fever antibody. American Journal of Veterinary Research 51(10): 1540-1543.

Pastor MJ, Laviada MD, Vizcaino JMS and JM Escribano (1989) Detection of African swine fever virus antibodies by immunoblotting assay. Canadian Journal of Veterinary Research 53(1): 105-107.

Patil SS, Suresh KP, Vashist V, Prajapati A, Pattnaik B and P Roy (2020) African swine fever: A permanent threat to Indian pigs. Veterinary World 13(10): 2275-2285.

Penrith ML (2020) Current status of African swine fever. CABI Agriculture and Biosciences 1: 1–26.

Penrith ML and W Vosloo (2009) Review of African swine fever: Transmission, spread and control. Journal of South African Veterinary Association 80: 58–62.

Pietschmann J, Guinat C, Beer M, Pronin V, Tauscher K, Petrov A, Keil G and S Blome (2015) Course and transmission characteristics of oral low-dose infection of domestic pigs and European wild boar with a Caucasian African swine fever virus isolate. Archieves of Virology 160: 1657–67.

Plowright W, Thomson GR and JA Neser (1994) African swine fever. In Infectious Diseases of Livestock, with Special Reference to Southern Africa, 1st ed.; Coetzer, J.A.W., Thomson, G.R., Tutsin, R.C., Eds.; Oxford University Press: Cape Town, South Africa, Volume 1, pp. 567–599.

Salguero FJ (2020) Comparative pathology and pathogenesis of African swine fever infection in swine. Frontiers in Veterinary Science 19(7): 282-295.

Salguero FJ, Ruiz-Villamor E, Bautista MJ, Sánchez- Cordón PJ, Carrasco L and JC Gómez-Villamandos (2002) Changes in macrophages in spleen and lymph nodes during acute African swine fever: Expression of cytokines. Veterinary Immunology and Immunopathology 90(1-2): 11-22.

Sanchez EG, Perez-Nunez D and Y Revilla (2019). Development of vaccines against African swine fever virus. Virus Research 265: 150–5. doi: 10.1016/j.virusres.2019.03.022

Sánchez-Vizcaíno JM (1987) African swine fever diagnosis. In: Becker, Y., editor. African Swine Fever. Martinus Veterinary World, EISSN: 2231-0916 2285 Nijhoff, Boston, USA. p63-71.

Sanchez-Vizcaino JM and M Arias (2012b) African swine fever. In: Zimmerman, J.J., Karriker, L.A., Ramirez, A., Schwartz, K.J. and Stevenson, G.W., editors. Disease of Swine. 10th ed. Wiley-Blackwell, Ames, USA. p396-404.

Sanchez-Vizcaino JM, Martinez-Lopez B, Martinez- Aviles M, Martins C, Boinas B, Vial L, Michaud V, Jori F, Etter E, Albina E and F Roger (2009) Scientific Review on African Swine Fever. CFP/EFSA/ AHAW/2007/02, Report. p1-141.

Sanchez-Vizcaino JM, Mur L and B Martinez-Lopez (2012a). African swine fever: An epidemiological update. Transboundary and Emerging Diseases 1(Suppl 59): 27-35.

Sanchez-Vizcaıno JM, Mur L, Gomez-Villamandos JC and L Carrasco (2015) An update on the epidemiology and pathology of African swine fever. Journal of Comparative Pathology 152(1): 9-21.

Shyam J, Tripathi, HE and BL Balaraju (2016) Backyard Pig Rearing Practices among Tribals of Assam. Advanced Life Sciences 5: 2278–3849.

Sunwoo SY, Perez-Nunez D, Morozov I, Sanchez EG, Gaudreault NN, Trujillo JD, Mur L, Nogal M, Madden D, Urbaniak K, Kim JA, Ma W, Revilla Y and JA Richt (2019) DNA-protein vaccination strategy does not protect from challenge with African swine fever virus Armenia 2007 strain. Vaccines 7: 12. doi: 10.3390/vaccines7010012

Swaney LM, Lyburt F, Mebus CA, Buonavoglia C and A Orfei (1987) Genome analysis of African swine fever virus isolated in Italy in 1983. Veterinary Microbiology 14(2): 101-104.

Talukdar P, Talukdar D, Sarma K and K Saikia (2019) Prospects and Potentiality of Improving Pig Farming in North Eastern Hill Region of India: An Overview. International Journal of Livestock Research 9: 1–14.

Teklue T, Sun Y, Abld M, Luo Y and HJ Qiu (2020) Current status and evolving approaches to African swine fever vaccine development. Transboundary and Emerging Diseases 67(2): 529-542.

Terpstra C and G Wensvoort (1986) African swine fever in the Netherlands. Tijdschr Diergeneeskd 111(8): 389-392.

USDA FAS. Global Agricultural Information Network. (2016). Available online: https://www.fas.usda.gov/ data/india-pork-2016 (accessed on 29 September 2020).

Wang J, Wang J, Geng Y and W Yuan (2017) A recombinase polymerase amplification based assay for rapid detection of African swine fever virus. Canadian Journal of Veterinary Research 81: 308–12.

Wilkinson PJ (1984) The persistence of African swine fever in Africa and the Mediterranean. Preventive Veterinary Medicine 2: 71–82.

Wilkinson PJ, Lawman MJ and RS Johnston (1980) African swine fever in Malta, 1978. Veterinary Record 106(5): 94-97.

Yoo D, Kim H, Lee JY and HS Yoo (2020) African swine fever: Etiology, epidemiological status in Korea, and perspective on control. Journal of Veterinary Science 21(2): 38.