



BIOSECURITY IN PIG FARMS

Hrishikesh Jagtap, Prafullata Bashetti, Anil B. Bhosale and Chandrakant D. Bhong*

Department of Veterinary Public Health and Epidemiology, KNP College of Veterinary Science, Shirwal, Dist. Satara, Maharashtra, India (Maharashtra Animal and Fishery Sciences University, Nagpur)

* **Corresponding Author:** Dr. Chandrakant Dadaso Bhong, Associate Professor, Department of Veterinary Public Health and Epidemiology, KNP College of Veterinary Science, Shirwal, Dist. Satara, Maharashtra, India (Maharashtra Animal and Fishery Sciences University, Nagpur)

Article DOI: <https://doi.org/10.36713/epra29155>
DOI No: 10.36713/epra29155

ABSTRACT

Pig farming is an important source of livelihood, animal protein and income for smallholder, tribal and commercial farmers in India, particularly in the North-Eastern states. The sector is repeatedly threatened by transboundary and endemic diseases such as African swine fever (ASF), classical swine fever (CSF), porcine reproductive and respiratory syndrome (PRRS), foot-and-mouth disease (FMD) and porcine epidemic diarrhoea (PED). Several pig-associated pathogens, including swine influenza viruses, Japanese encephalitis virus, *Streptococcus suis* and *Taenia solium*, are also of public health importance. In the absence of a commercial vaccine for ASF, biosecurity remains the most effective and economical tool to prevent, control and contain pig diseases. Biosecurity comprises external measures (bioexclusion), which prevent the entry of pathogens into a farm, and internal measures (biocontainment and biomanagement), which limit pathogen spread within and out of a farm. This review describes the concept and principles of biosecurity, the major diseases and transmission routes relevant to pig farms, practical external and internal biosecurity measures, cleaning and disinfection protocols, and tools for biosecurity assessment such as Biocheck.UGent. It also discusses the economic benefits of biosecurity, its role in reducing antimicrobial use under a One Health approach, and the specific constraints of smallholder and backyard pig systems in India following the incursion of ASF in 2020. Strengthened farmer training, regulated pig movement, swill-feeding control, compartmentalisation and institutional support are recommended to improve biosecurity compliance in Indian pig production.

KEYWORDS: African swine fever, Biosecurity, Bioexclusion, Biocontainment, Disinfection, One Health, Pig farm, Swine diseases

1. INTRODUCTION

Pork is one of the most widely consumed meats in the world, and pig production is a major component of the global livestock economy. Pigs have a short generation interval, high prolificacy, efficient feed conversion and the ability to utilise kitchen waste and agricultural by-products. These qualities make pig rearing attractive to resource-poor farmers. In India, pig farming is closely linked to the socio-economic and cultural life of tribal and weaker sections of society. According to the 20th Livestock Census (2019), India had about 9.06 million pigs, a decline of about 12% compared with the 2012 census (DAHD, 2019). A large share of this population is reared in the North-Eastern states, where pork is a preferred meat.

Most pigs in India are raised under backyard, free-range or small semi-intensive systems with low inputs, minimal housing and limited veterinary care. Such systems are highly vulnerable to infectious diseases. The introduction of African swine fever (ASF) into Assam and Arunachal Pradesh in early 2020, and its subsequent spread to other North-Eastern states and to states such as Kerala, Punjab and Bihar, caused heavy pig mortality and economic loss (Rajukumar *et al.*, 2021). Classical swine fever (CSF) remains endemic, and outbreaks of PRRS, FMD, swine influenza and parasitic diseases continue to reduce productivity.

ASF has no commercially approved, safe and effective vaccine or treatment in India. Its control therefore depends on early detection, stamping out, movement restriction and, above all, biosecurity (Dixon *et al.*, 2020). Biosecurity is also central to reducing antimicrobial use and the emergence of antimicrobial resistance (AMR) in pig production (Laanen *et al.*, 2013; Postma *et al.*, 2016). Biosecurity is broadly defined as the set of management and physical measures designed to reduce the risk of introduction, establishment and spread of animal diseases, infections or infestations to, from and within an animal population (WOAH, 2023).

The objective of this review is to summarise current knowledge on biosecurity in pig farms, covering its principles, the major diseases and transmission routes, external and internal measures, cleaning and disinfection, assessment tools and economics. It also highlights the challenges of implementing biosecurity in Indian smallholder pig systems and suggests future directions.

2. CONCEPT AND PRINCIPLES OF BIOSECURITY

Biosecurity in pig production rests on three linked components: bioexclusion, biocontainment and biomanagement (Dewulf and Van Immerseel, 2018; Alarcón *et al.*, 2021).



1. **Bioexclusion (external biosecurity):** measures that prevent pathogens from entering a farm, such as control of animal introduction, visitors, vehicles, feed, water and wildlife.
2. **Biocontainment (internal biosecurity):** measures that limit the spread of pathogens between age groups, units and pens within a farm, and prevent their escape to other farms.
3. **Biomangement:** the ongoing management of endemic pathogens already present, through vaccination, health monitoring, treatment and record keeping.

Amass and Clark (1999) and the FAO (2010) identified three practical elements of biosecurity: **segregation** (creating and maintaining barriers that keep infected animals and contaminated

materials away), **cleaning** (removing organic matter that harbours pathogens) and **disinfection** (inactivating the remaining pathogens). Segregation is considered the most important and effective element, because cleaning and disinfection cannot fully compensate for poor separation.

A biosecurity plan should be farm-specific and risk-based. It must consider the farm's production system, disease status, location, pig density in the area and the diseases of concern. The plan should be written, communicated to all workers, regularly audited and revised. Its success depends on the knowledge, attitude and consistent behaviour of farm owners and workers, since a single breach can nullify all other measures (Alarcón *et al.*, 2021).

Table 1. Components of biosecurity in pig farms

Component	Aim	Examples of measures
External biosecurity (bioexclusion)	Prevent pathogen entry into the farm	Quarantine of new stock, fencing, visitor control, shower-in/shower-out, vehicle disinfection, safe feed and water, rodent and bird control
Internal biosecurity (biocontainment)	Limit spread within the farm and to other farms	All-in/all-out, age segregation, separate tools per unit, hygienic handling order, isolation of sick pigs, safe carcass and manure disposal
Biomangement	Reduce the impact of endemic pathogens	Vaccination, health monitoring, diagnostics, records, staff training

3. MAJOR DISEASES OF PIGS RELEVANT TO BIOSECURITY

African swine fever (ASF) is a highly contagious haemorrhagic disease of domestic and wild pigs caused by a large DNA virus of the family *Asfarviridae*. Virulent strains cause mortality approaching 100%. The virus is very stable in blood, meat, processed pork products and the environment, and spreads by direct contact, contaminated pork and swill, fomites, vehicles, people and, in some regions, soft ticks (*Ornithodoros* spp.) and wild boar (Costard *et al.*, 2013; Sánchez-Vizcaíno *et al.*, 2015). After entering Georgia in 2007 and China in 2018, ASF spread across Asia and reached India in 2020, where genotype II virus was identified (Rajukumar *et al.*, 2021).

Classical swine fever (CSF), caused by a *Pestivirus*, is endemic in India and causes fever, haemorrhages, abortion and high mortality. Vaccination with lapinised and cell culture vaccines is available, but control also requires biosecurity and movement control.

Porcine reproductive and respiratory syndrome (PRRS) causes reproductive failure in sows and respiratory disease in

growing pigs. It is among the most costly pig diseases worldwide (Holtkamp *et al.*, 2013). PRRS virus can be transmitted by aerosols over several kilometres (Otake *et al.*, 2010), by semen, and by contaminated fomites and vehicles.

Foot-and-mouth disease (FMD) is endemic in India and affects pigs, which act as amplifying hosts because they excrete large amounts of aerosolised virus.

Porcine epidemic diarrhoea (PED) caused severe piglet mortality after its emergence in the USA in 2013, where contaminated transport trailers played a key role in its spread (Lowe *et al.*, 2014).

Zoonotic and public health diseases linked to pigs include swine influenza (pigs act as "mixing vessels" for avian, swine and human influenza viruses), Japanese encephalitis (pigs are amplifying hosts), *Streptococcus suis* infection, leptospirosis, brucellosis, salmonellosis and taeniosis/cysticercosis due to *Taenia solium*. Biosecurity in pig farms thus protects both animal and human health.



Table 2. Major pig diseases and their main routes of transmission relevant to biosecurity

Disease	Agent	Main transmission routes	Vaccine available in India
African swine fever	ASFV (<i>Asfarviridae</i>)	Contact, pork and swill, fomites, vehicles, people, ticks, wild boar	No
Classical swine fever	CSFV (<i>Pestivirus</i>)	Contact, pork and swill, fomites, vertical	Yes
PRRS	PRRSV (<i>Arteriviridae</i>)	Contact, aerosol, semen, fomites, vehicles	Not routinely
Foot-and-mouth disease	FMDV (<i>Aphthovirus</i>)	Contact, aerosol, animal products, fomites	Yes
Porcine epidemic diarrhoea	PEDV (<i>Coronaviridae</i>)	Faecal-oral, contaminated trucks, feed, fomites	No
Swine influenza	Influenza A virus	Aerosol, contact, humans to pigs and pigs to humans	No
Japanese encephalitis	JEV (<i>Flaviviridae</i>)	Mosquitoes (<i>Culex</i> spp.)	Human vaccine only
Cysticercosis	<i>Taenia solium</i>	Ingestion of eggs from human faeces	No

4. ROUTES OF PATHOGEN INTRODUCTION AND SPREAD

Understanding transmission routes is the basis for selecting biosecurity measures. Filippitzi *et al.* (2018) reviewed the transmission routes of 24 pig diseases preventable by biosecurity and found that direct contact with infected pigs and indirect contact through people, vehicles and equipment were the routes shared by most diseases. The main routes are:

1. **Introduction of live animals:** purchase of infected or carrier pigs, including breeding stock, is the most important route of entry of new pathogens.
2. **Semen:** viruses such as PRRSV, CSFV and ASFV can be transmitted through semen from infected boars.
3. **People:** farm workers, visitors, veterinarians, traders and butchers carry pathogens on clothes, footwear and hands.
4. **Vehicles and equipment:** animal transport trucks, feed trucks, carcass collection vehicles and shared equipment act as mechanical carriers (Lowe *et al.*, 2014).
5. **Feed and swill:** feeding of kitchen waste, hotel waste or uncooked pork products is a major route for ASF and CSF. Viruses such as ASFV and PEDV can also survive in feed ingredients during long-distance shipment (Dee *et al.*, 2018).
6. **Water:** contaminated surface water or water sources shared with other pigs.
7. **Air:** airborne spread over distance has been shown for PRRSV, *Mycoplasma hyopneumoniae*, FMDV and influenza viruses (Otake *et al.*, 2010).
8. **Wildlife, vectors and pests:** wild boar, rodents, birds, stray dogs, flies, mosquitoes and ticks.
9. **Manure and carcasses:** improper disposal of dead pigs and slurry contaminates the environment and attracts scavengers.

In India, the open movement and trading of pigs, informal live-pig markets, roadside slaughter, swill feeding and free-ranging pigs combine many of these routes, which explains the rapid spread of ASF in the North-East.

5. EXTERNAL BIOSECURITY MEASURES

5.1 Farm location and layout

Farms should be located away from other pig farms, slaughterhouses, live-pig markets, main roads and wild boar habitats. The farm should have a secure perimeter fence with a single controlled entry point. A clear separation between the "clean" area (where pigs are housed) and the "dirty" area (parking, office, loading ramp, carcass storage) is essential. Feed delivery, loading of pigs and carcass collection should be possible from outside the fence.

5.2 Purchase and introduction of pigs

The number of sources of new pigs should be kept to a minimum, ideally a single source of known high health status. Replacement stock should be accompanied by health certificates and placed in a quarantine unit, separate from the main herd, for at least 30 to 60 days. During quarantine, pigs should be observed, tested for diseases of concern and acclimatised. Semen should be obtained only from certified boar stations with regular disease testing (Alarcón *et al.*, 2021).

5.3 Visitors and farm workers

Visitors should be restricted to those with an essential purpose. All visitors should sign a logbook recording previous contact with pigs, and a pig-free downtime (commonly 24 to 48 hours) should be observed before entry. A changing room with a clear dirty-clean barrier, or a shower-in/shower-out facility, should be provided along with farm-specific clothing and boots. Handwashing and footbaths should be available at the entry of each unit. Workers should not keep pigs at home or visit other pig farms, markets or slaughter points.



5.4 Vehicles and transport

Vehicles from outside should not enter the clean area. Animal transport vehicles should be cleaned, disinfected and dried between loads, and preferably dedicated to one farm. Loading ramps should be designed so that pigs move in one direction only, and drivers should not enter the pig house. Carcass collection should take place at the farm boundary.

5.5 Feed, water and swill

Feed should be procured from reliable sources and stored in rodent-proof bins. Swill feeding is one of the most important risk factors for ASF and CSF and should be prohibited; where kitchen waste is unavoidable in smallholder systems, it must be thoroughly boiled (at least 30 minutes) before feeding. Drinking water should come from a safe source and be treated by chlorination when needed.

5.6 Control of wildlife, pests and vectors

Wild boar, stray dogs, cats and birds should be kept away through fencing and netting. An integrated rodent and fly control programme should be followed, and mosquito control (screening, removal of stagnant water) is important for Japanese encephalitis.

5.7 Carcass and manure disposal

Dead pigs should be removed promptly and disposed of by deep burial with lime, composting, rendering or incineration, according to local regulations. Carcasses should never be sold, consumed or thrown into water bodies or forests, a common practice that has aggravated ASF spread. Manure should be stored and treated (composting or biogas) away from pig houses.

6. INTERNAL BIOSECURITY MEASURES

Internal biosecurity aims to break infection cycles within the farm, especially from older carrier pigs to younger susceptible ones.

1. **All-in/all-out (AIAO) management:** each room or unit is filled with pigs of the same age at one time and emptied completely before cleaning, disinfection and a drying period. AIAO by room or by site is one of the most effective internal measures (Laanen *et al.*, 2013).
2. **Segregation by age and production stage:** farrowing, nursery, grower-finisher, gestation and boar units should be physically separated, with workflow from the youngest to the oldest and from healthy to sick animals.
3. **Minimising cross-fostering and mixing:** cross-fostering should be limited to the first 24 to 48 hours after birth and only within the same room. Mixing of litters and regrouping should be minimised.

4. **Hygiene of personnel and equipment:** separate boots, overalls and tools for each unit; handwashing and boot dipping between units; cleaning of needles, castration knives and tail-docking tools between litters.
5. **Hospital and isolation pens:** sick pigs should be moved to dedicated isolation pens located at the end of the workflow, and should not be returned to the main group.
6. **Stocking density and environment:** overcrowding, poor ventilation and temperature stress increase disease transmission and should be avoided.
7. **Vaccination and health programme:** vaccination against CSF, FMD and other locally important diseases, along with deworming and regular health monitoring, reduces the impact of endemic pathogens.
8. **Records and surveillance:** maintenance of records on mortality, morbidity, treatment, vaccination and production allows early recognition of abnormal events. Unusual mortality must be reported immediately to the veterinary authorities for diagnosis, especially when ASF is suspected.

7. CLEANING AND DISINFECTION PROTOCOLS

Cleaning and disinfection (C&D) of pens, equipment and vehicles is effective only when performed in the correct sequence. Organic matter such as faeces, feed and bedding protects pathogens and inactivates many disinfectants, so thorough cleaning must always precede disinfection (FAO, 2010; Dewulf and Van Immerseel, 2018). A standard C&D protocol consists of the following steps:

1. **Dry cleaning:** remove pigs, then remove manure, bedding, feed residues and movable equipment.
2. **Soaking:** wet all surfaces with water containing a detergent for a few hours to loosen dirt.
3. **Washing:** wash with high-pressure water and detergent, paying attention to corners, slats, feeders and drinkers.
4. **Drying:** allow surfaces to dry so that the disinfectant is not diluted.
5. **Disinfection:** apply an approved disinfectant at the correct concentration and contact time.
6. **Drying and downtime:** leave the unit empty and dry for at least 24 to 72 hours before restocking.
7. **Verification:** visually inspect, and where possible check hygiene by swab testing.

The choice of disinfectant depends on the target pathogen, presence of organic matter, surface, temperature and safety. ASFV is an enveloped virus and is susceptible to many disinfectants, but its stability in organic material means that cleaning is critical (Juszkiewicz *et al.*, 2019).



Table 3. Commonly used disinfectants in pig farms

Disinfectant group	Examples	Strengths	Limitations
Oxidising agents	Potassium peroxymonosulphate, hydrogen peroxide, peracetic acid	Broad spectrum, effective against ASFV and FMDV	Corrosive; reduced by organic matter
Halogens	Sodium hypochlorite, calcium hypochlorite	Cheap, broad spectrum, used for water and footbaths	Strongly inactivated by organic matter; corrosive
Aldehydes	Glutaraldehyde, formaldehyde	Broad spectrum, active in organic matter	Irritant and toxic; need longer contact time
Alkalis	Sodium hydroxide, sodium carbonate, slaked lime	Effective against ASFV and FMDV, cheap, useful for floors and carcass burial	Caustic to skin and metal
Quaternary ammonium compounds	Benzalkonium chloride	Low toxicity, detergent action	Weak against non-enveloped viruses and spores
Phenolic compounds	Ortho-phenylphenol	Active in organic matter, used in footbaths	Toxic; environmental concern

Footbaths should be placed at entries to each unit, kept free of organic matter and refilled regularly. Boots should be brushed clean before dipping, because a dirty footbath gives a false sense of security.

8. BIOSECURITY ASSESSMENT, COMPLIANCE AND ECONOMICS

8.1 Assessment tools

Biosecurity must be measured to be improved. **Biocheck.UGent**, developed at Ghent University, is a widely used, risk-based scoring system for pig farms. It consists of questionnaires on external biosecurity (purchase of animals and semen, transport and carcass removal, feed and water, visitors and workers, vermin control, location) and internal biosecurity (disease management, farrowing and suckling, nursery, finishing, measures between compartments, cleaning and disinfection). Each sub-category is weighted by its importance for disease transmission, giving scores from 0 to 100 (Laanen *et al.*, 2013; Postma *et al.*, 2016). Other tools include PADRAP for PRRS risk assessment in North America and national checklists. Such tools help to benchmark farms, identify weak points and guide herd-specific advice.

8.2 Compliance

The effectiveness of biosecurity depends on human behaviour. Studies of Belgian and European pig herds show that external biosecurity is usually implemented better than internal biosecurity, and that measures such as quarantine, visitor control and cleaning between batches are often incompletely followed (Ribbens *et al.*, 2008; Postma *et al.*, 2016). Barriers to compliance include cost, lack of knowledge, perceived low risk, poor farm infrastructure, labour shortage and lack of visible short-term benefits. Participatory training of farmers has been shown to improve knowledge and practices related to ASF biosecurity in smallholder settings (Dione *et al.*, 2020).

8.3 Economic benefits

Biosecurity requires investment, but higher biosecurity scores have been associated with better production parameters such as higher daily weight gain, lower mortality and better feed conversion, and with lower antimicrobial use (Laanen *et al.*, 2013; Postma *et al.*, 2016). Collineau *et al.* (2017) showed that herd-specific interventions combining improved biosecurity and management could reduce antimicrobial use without compromising technical and economic performance. The cost of a single ASF or PRRS outbreak far exceeds the cost of preventive biosecurity (Holtkamp *et al.*, 2013).

9. BIOSECURITY IN INDIAN SMALLHOLDER AND BACKYARD PIG SYSTEMS

Indian pig production is dominated by smallholders keeping a few pigs in backyard pens or under free-range conditions, often fed on kitchen and hotel waste. Pigs are commonly traded through middlemen and weekly markets and are slaughtered in unregulated settings. These features make standard commercial biosecurity protocols difficult to apply. Similar constraints have been described for smallholder pig systems in Africa and South-East Asia, where low-cost, context-specific biosecurity is recommended (FAO, 2010; Dione *et al.*, 2020).

The ASF epidemic in North-East India since 2020 exposed these weaknesses. Movement of infected pigs and pork across state and international borders, swill feeding, disposal of carcasses in rivers and forests, sale of pork from sick or dead pigs and limited awareness among farmers contributed to rapid spread. The Department of Animal Husbandry and Dairying (DAHD) issued a National Action Plan for ASF control, which includes surveillance, declaration of infected and surveillance zones (commonly 1 km and 10 km radius), culling with compensation, movement restrictions and biosecurity advisories.



Practical, low-cost biosecurity measures suitable for Indian smallholders include:

1. Confining pigs in fenced pens instead of free-range rearing.
2. Boiling all kitchen and hotel waste before feeding, and avoiding pork scraps in swill.
3. Avoiding purchase of pigs from unknown sources or areas with outbreaks, and keeping new pigs separately for at least two to four weeks.
4. Restricting entry of traders, butchers and neighbours into pig pens.
5. Using dedicated footwear and washing hands before and after handling pigs.
6. Using locally available disinfectants such as lime, washing soda and bleaching powder for pens and footbaths.
7. Burying dead pigs with lime instead of selling, eating or discarding them.
8. Reporting unusual deaths promptly to the nearest veterinary officer.

Group-based approaches such as farmer producer organisations, community biosecurity agreements, village-level awareness campaigns, and compartmentalisation of commercial units can help raise biosecurity standards. Veterinary colleges, Krishi Vigyan Kendras and state animal husbandry departments have an important role in extension and training.

10. ONE HEALTH AND PUBLIC HEALTH PERSPECTIVE

Biosecurity in pig farms is an important component of the One Health approach. Pigs share several pathogens with humans, and pig farmers, butchers and veterinarians are at occupational risk of zoonoses such as swine influenza, *Streptococcus suis* infection, leptospirosis, brucellosis and hepatitis E. The 2009 H1N1 influenza pandemic, caused by a virus with genes of swine origin, demonstrated the role of pigs as mixing vessels for influenza viruses. Pigs also amplify Japanese encephalitis virus, which causes human encephalitis outbreaks in several Indian states. Free-ranging pigs with access to human faeces maintain the *Taenia solium* life cycle, leading to neurocysticercosis, a major cause of acquired epilepsy.

Good biosecurity reduces the circulation of these pathogens at the farm level, and thus reduces human exposure. Protective clothing, hygiene, safe carcass disposal and separation of pig housing from human dwellings protect farm families.

Biosecurity is also an important tool to combat antimicrobial resistance (AMR). Pig production is one of the largest users of antimicrobials among food animals worldwide (Van Boeckel *et al.*, 2015). Farms with better biosecurity have fewer disease problems and therefore use fewer antimicrobials (Laanen *et al.*, 2013; Postma *et al.*, 2016). Improving biosecurity, together with vaccination and prudent antimicrobial use, is a key strategy in India's National Action Plan on AMR.

11. CHALLENGES AND FUTURE PERSPECTIVES

The major challenges to biosecurity in Indian pig farming are the predominance of unorganised smallholder production, informal pig trade and slaughter, swill feeding, poor infrastructure, limited access to diagnostics and veterinary services, inadequate compensation for culling, porous international borders in the North-East and low farmer awareness. Future efforts should focus on:

1. Development and validation of safe and effective ASF vaccines, while recognising that vaccines will complement rather than replace biosecurity.
2. Strengthening disease surveillance, rapid diagnostics (including field-based molecular tests) and reporting systems.
3. Regulation of pig movement, registration of pig farms and traders, and establishment of hygienic slaughter facilities.
4. Adoption of simple, India-specific biosecurity scoring tools for smallholder and commercial farms.
5. Compartmentalisation and zoning to allow safe trade from disease-free units.
6. Participatory extension, farmer field schools and use of mobile-based advisories in local languages.
7. Research on the cost-effectiveness of biosecurity measures and on social and behavioural drivers of compliance.
8. Integration of pig biosecurity into One Health and AMR programmes.

12. CONCLUSION

Biosecurity is the foundation of sustainable and profitable pig production. With no commercial vaccine available for ASF and with several endemic and zoonotic diseases affecting pigs, preventing pathogen entry and limiting spread within farms remains the most reliable strategy. Effective biosecurity rests on segregation, cleaning and disinfection, supported by sound management, vaccination, surveillance and record keeping. In India, where smallholder and backyard systems dominate, biosecurity measures must be practical, low-cost and supported by farmer education, regulated pig movement, control of swill feeding and strong veterinary services. Improving biosecurity on pig farms will protect farmers' livelihoods, reduce antimicrobial use and safeguard public health under the One Health approach.

REFERENCES

Note to author: these references were compiled without a live literature search. Verify every volume, page number and DOI against the original source, and reformat to the EPRA IJMR style, before submission.

1. Alarcón, L. V., Allepuz, A., & Mateu, E. (2021). Biosecurity in pig farms: a review. *Porcine Health Management*, 7, 5.
2. Amass, S. F., & Clark, L. K. (1999). Biosecurity considerations for pork production units. *Journal of Swine Health and Production*, 7(5), 217–228.
3. Collineau, L., Rojo-Gimeno, C., Léger, A., Backhans, A., Loesken, S., Nielsen, E. O., et al. (2017). Herd-specific interventions to reduce antimicrobial usage in pig production



- without jeopardising technical and economic performance. *Preventive Veterinary Medicine*, 144, 167–178.
4. Costard, S., Mur, L., Lubroth, J., Sánchez-Vizcaíno, J. M., & Pfeiffer, D. U. (2013). Epidemiology of African swine fever virus. *Virus Research*, 173(1), 191–197.
 5. DAHD. (2019). 20th Livestock Census – 2019: All India Report. Department of Animal Husbandry and Dairying, Ministry of Fisheries, Animal Husbandry and Dairying, Government of India, New Delhi.
 6. Dee, S. A., Bauermann, F. V., Niederwerder, M. C., Singrey, A., Clement, T., de Lima, M., et al. (2018). Survival of viral pathogens in animal feed ingredients under transboundary shipping models. *PLoS ONE*, 13(3), e0194509.
 7. Dewulf, J., & Van Immerseel, F. (Eds.). (2018). *Biosecurity in Animal Production and Veterinary Medicine*. Leuven: Acco.
 8. Dione, M. M., Dohoo, I., Ndiwa, N., Poole, J., Ouma, E., Amia, W. C., & Wieland, B. (2020). Impact of participatory training of smallholder pig farmers on knowledge, attitudes and practices regarding biosecurity for the control of African swine fever in Uganda. *Transboundary and Emerging Diseases*, 67(6), 2482–2493.
 9. Dixon, L. K., Stahl, K., Jori, F., Vial, L., & Pfeiffer, D. U. (2020). African swine fever epidemiology and control. *Annual Review of Animal Biosciences*, 8, 221–246.
 10. FAO. (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. Rome: Food and Agriculture Organization of the United Nations.
 11. Filippitzi, M. E., Brinch Kruse, A., Postma, M., Sarrazin, S., Maes, D., Alban, L., et al. (2018). Review of transmission routes of 24 infectious diseases preventable by biosecurity measures and comparison of the implementation of these measures in pig herds in six European countries. *Transboundary and Emerging Diseases*, 65(2), 381–398.
 12. Holtkamp, D. J., Kliebenstein, J. B., Neumann, E. J., Zimmerman, J. J., Rott, H. F., Yoder, T. K., et al. (2013). Assessment of the economic impact of porcine reproductive and respiratory syndrome virus on United States pork producers. *Journal of Swine Health and Production*, 21(2), 72–84.
 13. Juskiewicz, M., Walczak, M., & Woźniakowski, G. (2019). Characteristics of selected active substances used in disinfectants and their virucidal activity against ASFV. *Journal of Veterinary Research*, 63(1), 17–25.
 14. Laanen, M., Persoons, D., Ribbens, S., de Jong, E., Callens, B., Strubbe, M., Maes, D., & Dewulf, J. (2013). Relationship between biosecurity and production/antimicrobial treatment characteristics in pig herds. *The Veterinary Journal*, 198(2), 508–512.
 15. Lowe, J., Gauger, P., Harmon, K., Zhang, J., Connor, J., Yeske, P., et al. (2014). Role of transportation in spread of porcine epidemic diarrhea virus infection, United States. *Emerging Infectious Diseases*, 20(5), 872–874.
 16. Otake, S., Dee, S., Corzo, C., Oliveira, S., & Deen, J. (2010). Long-distance airborne transport of infectious PRRSV and *Mycoplasma hyopneumoniae* from a swine population infected with multiple viral variants. *Veterinary Microbiology*, 145(3–4), 198–208.
 17. Postma, M., Backhaus, A., Collineau, L., Loesken, S., Sjölund, M., Belloc, C., et al. (2016). The biosecurity status and its associations with production and management characteristics in farrow-to-finish pig herds. *Animal*, 10(3), 478–489.
 18. Rajukumar, K., Senthilkumar, D., Venkatesh, G., Singh, F., Patil, V. P., Kombiah, S., et al. (2021). Genetic characterization of African swine fever virus from domestic pigs in India. *Transboundary and Emerging Diseases*, 68(5), 2687–2692.
 19. Ribbens, S., Dewulf, J., Koenen, F., Mintiens, K., De Sadeleer, L., de Kruif, A., & Maes, D. (2008). A survey on biosecurity and management practices in Belgian pig herds. *Preventive Veterinary Medicine*, 83(3–4), 228–241.
 20. Sánchez-Vizcaíno, J. M., Mur, L., Gómez-Villamandos, J. C., & Carrasco, L. (2015). An update on the epidemiology and pathology of African swine fever. *Journal of Comparative Pathology*, 152(1), 9–21.
 21. Van Boeckel, T. P., Brower, C., Gilbert, M., Grenfell, B. T., Levin, S. A., Robinson, T. P., Teillant, A., & Laxminarayan, R. (2015). Global trends in antimicrobial use in food animals. *Proceedings of the National Academy of Sciences*, 112(18), 5649–5654.
 22. WOAH. (2023). *Terrestrial Animal Health Code. Glossary*. Paris: World Organisation for Animal Health.