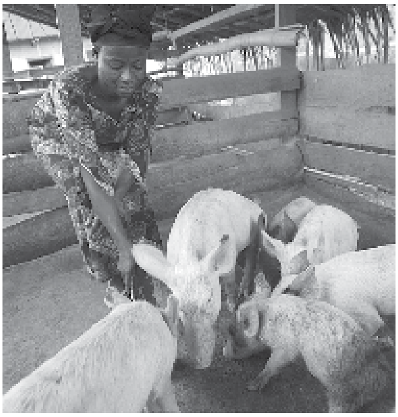
169
ISSN 0254-6019

FAO ANIMAL PRODUCTION AND HEALTH



paper

GOOD PRACTICES FOR BIOSECURITY IN THE PIG SECTOR

Issues and options in developing and transition countries

Cover photographs:

Left: ©FAO/Pius Utomi Ekpei
Center: ©VIKTAR STRALKOUSKI - Fotolia.com
Right: ©FAO/J. Annelli

169

FAO ANIMAL PRODUCTION AND HEALTH
paper

GOOD PRACTICES FOR BIOSECURITY IN THE PIG SECTOR

Issues and options in developing and transition countries

THE FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
THE WORLD ORGANISATION FOR ANIMAL HEALTH
THE WORLD BANK
Rome, 2010

Recommended citation
Food and Agriculture Organization of the United Nations/World Organisation for Animal Health/World Bank. 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, FAO.

FAO ISBN 978-92-5-106507-5
OIE ISBN 978-92-9044-809-9

Contents

Acknowledgements

This report was written on behalf of the Food and Agriculture Organization of the United Nations (FAO), the World Organisation for Animal Health (OIE) and the World Bank, under the overall guidance and responsibility of Dr J. Domenech and his successor Dr J. Lubroth, Chief Veterinary Officers of FAO.

The writers were François Madec, Deputy Director of the French Agency for Food Safety (AFSSA), Veterinary Research Laboratory, Ploufragan (France); Daniel Hurnik, University of Prince Edward Island (Canada); and Vincent Porphyre and Eric Cardinale, veterinarians and researchers in animal husbandry and epidemiology at the International Cooperation Centre of Agricultural Research for Development (CIRAD).

The report was reviewed by a multidisciplinary team from FAO (Philippe Ankers, Nicoline de Haan, Klaas Dietze, Vittorio Guberti, Nick Honhold, Anthony Burnett and Juan Lubroth), OIE (Alain Dehove, Kathleen Glynn, Kazuaki Miyagishima and Alex Thiermann) and the World Bank (Jean Kamanzi, Brian Bedard, Nancy Morgan, Stephane Forman and Jimmy Smith), together with international experts (Sandra Amass of Purdue University, United States; Jordi Casal Fábrega of *Centre de Recerca en Sanitat Animal* [CReSA], Barcelona, Spain; Scott Dee of the University of Minnesota, United States; Dominiek Maes of Ghent University, Belgium; and Keith Campbell and Jane MacDonald of the Canadian Food Inspection Agency [CFIA]).

Grateful appreciation is extended to all of these contributors.

Publication of this document was made possible by financial support from FAO and the World Bank.

Acronyms and abbreviations

AFSSA	French Agency for Food Safety
AI	artificial insemination
ASF	African swine fever
CDC	Centers for Disease Control and Prevention
CFIA	Canadian Food Inspection Agency
CIRAD	International Cooperation Centre of Agricultural Research for Development
CSF	classical swine fever (hog cholera)
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FMD	foot-and-mouth disease
HPAI	highly pathogenic avian influenza
JE	Japanese B encephalitis
MRSA	Methicillin-resistant *Staphylococcus aureus*
NGO	non-governmental organization
OFFLU	OIE-FAO Network of Expertise on Animal Influenza
OIE	World Organisation for Animal Health
PRRS	porcine reproductive and respiratory syndrome
SPF	specific pathogen-free
TAD	transboundary animal disease
TGE	transmissible gastro-enteritis
WHO	World Health Organization
WTO	World Trade Organization

Executive summary

The emergence of pandemic H1N1 2009 (pH1N1) in the spring of 2009 has drawn attention once again to the potential threat of viruses hosted in animals, and is provoking considerable international concern. Humans are affected by the pandemic H1N1 2009 virus. As well as pigs, there are reports of turkeys, ferrets, cats and dogs being infected.

In recent years, viral swine diseases have had a significant impact on human health and people's livelihoods. The introduction of African swine fever to the Caucasus, porcine high fever disease in Asia, and earlier outbreaks of classical swine fever and foot-and-mouth disease in Europe and Taiwan Province of China have all had devastating effects on agricultural economies.

The pandemic H1N1 2009 outbreak and initial uncertainties about the role of pigs in disseminating the virus led the Food and Agricultural Organization of the United Nations (FAO), the World Organisation for Animal Health (OIE) and the World Bank to give the highest priority to developing tools for improving biosecurity in pig production. The biosecurity principles outlined in this paper serve to limit pig-to-pig transmission of disease and reduce the impact of infectious swine diseases, including their economic losses. These principles derive directly from scientific knowledge of the epidemiology and transmission of key swine pathogens.

Routes of disease transmission in pigs

One of the most common routes of transmission for infectious agents is direct pig-to-pig contact: movement of infected pigs in close physical contact with non-infected pigs is decisive in transmitting diseases. Disease transmission through infected semen is well-documented. The role of people in disease transmission has been studied closely over the last decade: they can transport pathogens on footwear, clothing, hands, etc. People can carry viruses on their nasal mucosae (nasal carriers) without being infected. They can also be infected and shed pathogens as healthy or sick carriers. People also determine the movements of domestic animals and products among herds, markets and regions. Economic forces can lead to animals being moved over large distances, which increases the possibility of geographical spread of disease.

Vehicles and equipment can be instrumental in spreading diseases. Airborne transmission is more difficult to document, but has been studied experimentally. As some pathogens can survive in meat waste, specific attention must be paid to the use of food wastes in feeding pigs. Feed, water and bedding can all become contaminated and play a role in maintaining diseases. Faeces from infected pigs can contain large quantities of pathogenic viruses, bacteria or parasites: thus the application of manure to agricultural land may introduce pathogens into the human food chain and ecosystem, if due care is not taken during storage and spreading. Birds, rodents, stray dogs and cats, wildlife and feral pigs, together with arthropods, can all be potential carriers, whether through mechanical transmission or by being infected.

Pig production systems

In most countries, a variety of different pig production systems exist, from the simplest, with minimal investment, to large-scale market-oriented enterprises. This paper groups pig production systems into four categories, based on the size of herds, the production goals and husbandry management:

- Raising *scavenging pigs* is the most basic traditional system of keeping pigs and the one most commonly reported in both urban and rural areas of developing countries. In this free-range system, pigs roam freely around the household and surrounding area, scavenging and feeding in the street, from garbage dumps or from neighbouring land or forests around villages. Few arrangements are made to provide the pigs with housing. Depending on the local situation, pigs may be free-ranging for most of the year and penned during the rainy season. They may be housed at night in a small shelter, to protect them against theft and predators. Keeping scavenging pigs requires minimal inputs and low investment of labour, with no or limited money invested in concentrated feed or vaccines.
- *Small-scale confined pig production* is common in developing and transition countries. Pigs are confined to a shelter, which can range from a simple pen made with local materials to more modern housing. The pigs are completely dependent on their keeper for feed, and receive tree branches, leaves, crop residues, agricultural by-products or prepared feed. Smallholders raise pigs for both subsistence and commercial reasons. Pork is supplied to local markets and to more distant urban markets, through a complex marketing and transport system. Within this system, the financial risks for the producer can be high and there is limited support from organizations and professional bodies for technical inputs or services such as insurance.
- The commercial farms in *large-scale confined pig production* vary in size, but are generally significantly larger than farms in the previously described categories. Because consumers seek to purchase food at the lowest price, but the price of inputs is rising, the profit margin per pig is decreasing. Producers participating in global commodity pork markets must continually reduce the cost of production per pig to be profitable. Production can be on one site only or on several sites that are all part of the same structure. The major cost reduction measures that can be implemented when moving from small-scale to large-scale confined production are through increased farm size, specialization of farming activities, consolidation of the different steps of pig production, and adoption of an "all-in-all-out" production flow at each site, with implementation of some or even extensive biosecurity protocols. Large pig farms may be family-owned, affiliated to companies or corporately owned.
- In *large-scale outdoor pig production*, animals are confined by fencing, but are mainly outdoors; there is therefore less need for investment in bricks and mortar facilities. These farms can brand and sell pork for higher prices, and will often have a larger portfolio of activities, including agro-tourism or hunting for example.

Biosecurity

In this paper, biosecurity is defined as the implementation of measures that reduce the risk of disease agents being introduced and spread. It requires that people adopt a set of attitudes and behaviours to reduce risk in all activities involving domestic, captive/exotic and wild animals and their products. Biosecurity measures should be used to avoid the entry of pathogens into a herd or farm (external biosecurity) and to prevent the spread of disease to uninfected animals within a herd or farm and to other farms, when the pathogen is already present (internal biosecurity). This paper does not present vaccination as a biosecurity measure *per se*.

The following are the three main elements of biosecurity:

1) Segregation	The creation and maintenance of barriers to limit the potential opportunities for infected animals and contaminated materials to enter an uninfected site. When properly applied, this step will prevent most contamination and infection.
2) Cleaning	Materials (e.g., vehicles, equipment) that have to enter (or leave) a site must be thoroughly cleaned to remove visible dirt. This will also remove most of the pathogens that contaminate the materials.
3) Disinfection	When properly applied, disinfection will inactivate any pathogen that is present on materials that have already been thoroughly cleaned.

Within each of these three elements, the measures taken to improve biosecurity depend on the pig production system concerned and the local geographic and socio-economic conditions. Segregation measures include controlling the entry of pigs from outside farms, markets or villages; implementing quarantine for newly purchased animals; limiting the number of sources of replacement stocks; fencing a farm area and controlling access for people, as well as birds, bats, rodents, cats and dogs; maintaining adequate distances between farms; providing footwear and clothing to be worn only on the farm; and using an all-in-all-out management system. Cleaning and disinfection measures may involve the use of high-pressure and low-pressure washers, and will be implemented on not only buildings on the premises, but also vehicles, equipment, clothing and footwear.

The willingness to implement measures depends greatly on the investment capacity and social and economic status of the producers and other stakeholders. For meaningful change to take place in rural communities, those involved must have a clear understanding of the economic importance of pig production for their owners' livelihoods and the resource base that enables appropriate sustainable biosecurity measures to be developed; this depends on having a well-designed communication plan.

Good practices

The implementation of biosecurity measures in *scavenging pig production* systems is constrained by the producers' limited capacity to invest resources and time, and by the nature of scavenging pig production. However, there are simple measures that can be recommended and that are mainly related to segregation: new pigs introduced into a village must be free of disease, and particular attention is required when they are purchased from a market. The use of quarantine is very important. There is also concern over sows and boars that are moved from one location to another for mating. The health status of the boars needs to be known, particularly regarding diseases of concern. It is common practice for poor pig farmers to sell animals for slaughter as soon as disease is suspected. The marketing of sick animals is a serious disease risk, as these incubating or excreting sick pigs disseminate diseases, particularly when they are sold at live-animal markets. This practice should be prevented. The use of untreated pig swill must be avoided, and is often prohibited by national regulations. In the case of unusual pig deaths, veterinary services should be informed, so that immediate actions can be taken to control disease outbreaks; proper disposal of carcasses by burying, composting or burning is also crucial. Cleaning of night shelters and equipment must be emphasized. Disinfection is unlikely to be practicable.

In *small-scale confined pig production*, measures will focus on the three elements of biosecurity. An important difference between small-scale confined and scavenging pig production is that confinement facilitates segregation measures. The measures proposed for scavenging pigs are also valid for small-scale confined pig production. Newly purchased pigs should be kept for a minimum of 30 days in a quarantine pen.

In this system, additional measures can be introduced. The location of the pig farm can be controlled. Age-segregated rearing should be encouraged and buildings designed so that commingling among groups of pigs of different health status can easily be avoided. An all-in-all-out management system is possible. Proper fencing and measures to control contact with birds, rodents, cats and dogs can be promoted. It is important to develop protocols for the farm, to which visitors must strictly adhere; with confined pigs, it is possible to control access for vehicles and people, including drivers and feed providers. Authorized visitors, particularly those dealing with pigs – including other farmers – should be provided with specific clothing and clean footwear by the farm being visited, and should wash their hands on entry. All instruments or equipment that is likely to come into contact with pigs should be assigned to the farm and kept clean. The importance of regular and thorough cleaning of the pig unit is often not fully understood: manure should be removed from the pens every day, unless there are slatted floors or an equivalent. Contact with manure, urine and straw bedding from sick and dead animals should be avoided. After cleaning, the use of disinfectant should be promoted. When a group (batch) of same-aged pigs leaves a building, the room should be thoroughly cleaned and disinfected. Vehicles, especially those used to transport pigs, should be thoroughly cleaned and disinfected before returning to or visiting other farms. A safe pig loading bay will limit movement of vehicles on the farm.

In *large-scale confined production systems* the same principles apply as for the previously discussed systems, but the impact of disease has the potential to be proportionally higher. The physical location of herds should be planned to maintain adequate distances from neighbouring farms and frequently used roads. For aerosol transmission, the same rules apply as for the previous system. For units where significant investment in livestock health has occurred, filtration of incoming air is sometimes employed in an attempt to reduce the risk of airborne infection. Standards should be developed for the purchase of incoming genetic material. When practising artificial insemination (AI), the health status of the AI unit should match that of the recipient herd, and its biosecurity protocols should be adequate. The control of visitors and fomites is a major focus, as both can bring pathogens to the farm. Training and updating of staff by veterinarians and technicians specialized in disease control is necessary. A number of disease control measures and techniques are now available to control relevant pathogens in commercial farms. The biggest challenge is often to ensure proper implementation of good husbandry practices. Progressive eradication of pathogens contributes to regional biosecurity by lowering the regional disease risk. Followed to its logical conclusion, this process can result in eradication of disease from the region or country.

Biosecurity for *large-scale outdoor production* systems needs to focus on the control of feedstuffs, water and pasture contamination, wildlife and human visitors. Other factors such as transportation, fomites and sources of breeding stock also need to be considered, as the risks are the same as in the other production systems.

Intermediaries, service providers and transporters are the key links along pig production and marketing chains. Their potential roles in disease transmission – but also as champions for biosecurity – is important; they must therefore be fully involved in the implementation of biosecurity programmes.

Slaughterhouses are another important element in the marketing chain where all three elements of biosecurity must be implemented, with a major focus on bio-containment.

To maintain a high health status at AI centres, it is essential that the boars purchased are of verified disease-free status. The implementation of a quality assurance scheme in these enterprises should be a priority.

Live-animal markets are obvious mixing points and a potential source of disease spread: bio-containment is crucial at these sites, and contact among animals of different origins must be controlled. To limit the risk of disease spread, animals that have not been sold should not be reintroduced back into the home herd without a quarantine period. Wastewater and slurries need to be managed properly. However, such markets are also a useful location for disseminating and collecting information.

Conclusion

Pigs are susceptible to a wide range of diseases that affect productivity and, *de facto*, the producer's income – whether he/she is a large-scale commercial producer or has only one scavenging pig. The 2009 influenza pandemic, caused by a new strain of swine-origin H1N1, was a timely reminder of the risks for human health related to livestock production – the same livestock, including pigs, that supports the livelihoods and food security of almost a billion people, most of whom are poor.

Among the solutions required to minimize the risk of disease spread, the strengthening of biosecurity is a priority. It does not reduce the need for appropriate preparedness plans and adequate resources to control disease outbreaks once they occur, but it is proactive, has a preventive impact and enables producers to protect their assets.

A thorough knowledge of pig disease epidemiology and the routes of disease transmission has enabled authorities and producers to develop adequate biosecurity measures for the pig sector. Some of these measures are applicable across all production systems, while others are not. Each production system requires specific biosecurity measures, and although decision-makers should not compromise on public health, the measures to strengthen biosecurity in pig production must take into consideration the technical and financial capacity of stakeholders to implement them. The social and economic impacts of closing farms that cannot comply with the required level of biosecurity must also be carefully assessed.

The key to changing behaviours/practices in relation to enhanced biosecurity lies in people's perceptions of risk and the resources available at the production level. For meaningful change to take place in rural communities, a holistic, multi-sectoral approach is required to identify critical risk points for disease spread and to understand the evolution of diseases in specific environments, the impact of disease on people, and the impact that people have or can have on disease. The promotion of appropriate sustainable biosecurity measures goes hand-in-hand with the use of participatory methodologies and a well-designed communication strategy.

Further efforts are required to find the appropriate balance between what the private sector can and will voluntarily implement – based on cost/benefit ratios – and the requirements of regulations. Mutual trust between the public and private sectors is essential. In the case of zoonotic diseases, pre-emptive discussions among public health agencies, agricultural departments, veterinary services and the pig industry should take place to ensure common understanding and good cooperation in the interest of society in general. Strengthened collaboration between public services and the private sector is crucial for better disease control.

Introduction

BACKGROUND AND RATIONALE

In the late 1990s, an epidemic among pigs occurred in Malaysia, along with significant concurrent human mortality. Pig farm workers and others involved in handling pigs were affected: the novel Nipah virus was found in pigs that had contracted the virus from wildlife.

In April 2009, a human influenza epidemic was announced in Mexico, caused by a novel influenza A/H1N1-2009 virus designated pandemic H1N1 2009. The World Health Organization (WHO) declared a human pandemic outbreak as the disease spread rapidly within and among many countries, through sustained human-to-human transmission. At the time of preparing this document, the transmission of the virus in the human population and the virus's ability to cross-infect pigs had become a global concern. The strategy document for surveillance and monitoring of influenzas in animals, developed by the World Organisation for Animal Health and Food and Agriculture Organization of the United Nations (OIE-FAO) Network of Expertise on Animal Influenza (OFFLU) is available in Annex 4.

Other recent swine disease crises of non-zoonotic nature have had a significant impact on animal health and, indirectly, human health. The introduction of African swine fever (ASF) to the Caucasus region and of porcine high fever disease in Asia, along with earlier classical swine fever (CSF) and foot-and-mouth disease (FMD) outbreaks in Europe and Taiwan Province of China have all emphasized the devastating impact that diseases can have on agricultural economies. Pork production plays a major role in the economy and nutrition of many countries.

As part of the response to the H5N1 highly pathogenic avian influenza (HPAI) crisis that began in late 2003/early 2004 in Southeast Asia, FAO, OIE and the World Bank jointly prepared a position paper for advocacy purposes, entitled "The importance of biosecurity in reducing HPAI risk on farms and in markets" (FAO/OIE/World Bank, 2007). This was followed by another joint FAO/OIE/World Bank document, *Biosecurity for highly pathogenic avian influenza: Issues and options* (FAO/OIE/World Bank, 2008), which outlined an approach for developing biosecurity for HPAI.

Apprehension about the pandemic H1N1 2009 crisis and its impact on human health, global trade and food security has led both public health and food production authorities to suggest that actions be taken to minimize the risk of the pandemic H1N1 2009 virus spreading to pigs. FAO, OIE and the World Bank have given high priority to the development of biosecurity protocols for pig production. This document seeks to define biosecurity principles for pig herds, which aim to reduce disease risk for all stakeholders, limit losses and reduce the social and economic impact of infectious swine diseases. It is based on information from available literature and from the individual experiences of an international team of experts in veterinary medicine and pig husbandry. A number of scientific papers were utilized, as well as reports from FAO, OIE, the French Agency for Food Safety (AFSSA), the International Cooperation Centre of Agricultural Research for Development (CIRAD), the University of Prince Edward Island and other organizations. Published and grey literature consulted is listed in Annexes 6 to 9.

In a world where people, animals and goods move globally, the risk of disease spread is increasing. Global markets have brought increased international trade and economic opportunities, making international information and standards on biosecurity essential. OIE defines international standards that are recognized by the World Trade Organization (WTO) under the agreement on the application of sanitary and phytosanitary measures and that aim to enable international trade without compromising animal health.

FAO's mandate is to raise levels of nutrition, improve agricultural productivity, improve the lives of rural populations and contribute to growth of the world economy. Biosecurity is a tool that contributes to achieving these objectives.

TARGET AUDIENCE

FAO, OIE and the World Bank aim to provide applied biosecurity recommendations to all pork production stakeholders in the numerous pig farming systems worldwide, particularly in developing and transition countries. This paper details the specific biosecurity risks within each system. Pig farmers are the main intended beneficiaries of the paper, but it is also of use to veterinary and technical service providers who are in a position to deliver and implement the proposed measures. The authors hope that decision-makers in government and project managers in agricultural development will also find the document useful.

Section 1
Defining biosecurity

In its common usage, biosecurity refers to the protection of health through avoidance of disease. In this publication, biosecurity is defined as: "*The implementation of measures that reduce the risk of the introduction and spread of disease agents; it requires the adoption of a set of attitudes and behaviours by people to reduce risk in all activities involving domestic, captive/exotic and wild animals and their products*" (FAO/OIE/World Bank, 2008).

The foundations of biosecurity derive from the knowledge of disease epidemiology: the duration of pathogen excretion in infected animals; the main routes of excretion; survival in the environment; and routes of infection. Some general biosecurity principles apply to all farming systems and all diseases, but many practical biosecurity actions need to be tailored to the targeted diseases and particularly to the farming systems in which they are to be implemented. It is important to consider the socio-economic aspects of proposed measures, as these will have an impact on compliance.

Disease control is more difficult in countries with significant internal long-distance trade and those with long land borders and substantial movement of pigs across those borders. A national, zonal or compartmental biosecurity plan identifies potential pathways for the introduction and spread of disease in a country, zone or compartment, and describes the measures that are being or will be applied to mitigate the disease risks. The recommendations in OIE's T*errestrial Animal Health Code* (OIE, 2008b) must be taken into account, particularly regarding the spread of diseases among countries and regions. The *Terrestrial Code* defines a biosecurity plan as: "*a plan that identifies potential pathways for the introduction and spread of disease in a zone or compartment, and describes the measures which are being or will be applied to mitigate the disease risks, if applicable, in accordance with the recommendations in the Terrestrial Code*" (OIE, 2008b).

This paper focuses on biosecurity at the farm level: measures should be used to protect a farm from both entry of new pathogens and internal transfer among different areas of the farm. Hence, biosecurity is presented under two components: bio-exclusion (or external biosecurity) combines all activities to preclude the introduction of disease to the farm; and bio-containment (or internal biosecurity) refers to efforts to prevent the spread of a disease within the farm herd and to other farms.

BASIC PRINCIPLES OF BIOSECURITY AT THE FARM LEVEL

The many measures that can be used to improve biosecurity can be categorized in several ways. One way is to classify measures according to three goals: isolation, sanitation and traffic control. Another way is to classify measures into three steps:

1. segregation;
2. cleaning;
3. disinfection.

The latter system will be looked at in more detail.

Segregation is the first and most important element of biosecurity. It involves keeping potentially infected animals and materials away from uninfected animals. Segregation is regarded as the most effective step in achieving the required levels of biosecurity; if a pathogen does not enter a holding, no infection can take place. No animals or materials should enter or leave a pig holding unless absolutely necessary: this includes not only pigs, but also other species (including humans) that may be infected with pathogens and that can also infect pigs.

Segregation involves the creation of barriers and the control of what passes through them. The barriers should be physical and/or temporal where possible, and procedural where not. However, such barriers will only be effective when controlled to exclude potentially contaminated items. This includes such measures as enforcing the changing of footwear and clothing for all people crossing the barrier, and restricting the entry of vehicles.

It is instructive that even, and perhaps particularly, in large-scale production systems, where biosecurity is more critical because of the potential impact of disease in an intensive high-input/high-output/low-margin system, segregation is the basis of most biosecurity measures, from the farm-gate to individual pig sheds.

The next most effective step in biosecurity is *cleaning*. Most pathogen contamination on physical objects is contained in faecal material, urine or secretions that adhere to the surface; cleaning will therefore remove most of the contaminating pathogen. Any materials that must pass through the segregation barrier (in either direction) should be thoroughly cleaned. This means that there should be no visible dirt on the surface of materials. Soap, water and a brush are adequate for small objects, but a high-pressure washer (of 110 to 130 bar) is needed for large vehicles, such as lorries or tractors. The difficulty of properly cleaning such large complex items emphasizes the need for segregation as the first and most effective method of protection.

The final step of biosecurity is *disinfection*. The *Terrestrial Code* defines disinfection as: "*The application, after thorough cleansing, of procedures intended to destroy the infectious or parasitic agents of animal diseases, including zoonoses; this applies to premises, vehicles and different objects which may have been directly or indirectly contaminated*" (OIE, 2008b). Disinfection is important when performed consistently and correctly, but should be regarded as a final "polishing" step in biosecurity, used after effective and comprehensive cleaning. Disinfectants are often not available in village conditions, so any programme that emphasizes their use will invariably be hampered. Even when available, disinfectants are often incorrectly used. The effectiveness of disinfection under ideal controlled conditions differs from its effectiveness in field conditions. Disinfectants will not necessarily penetrate dirt in sufficiently high concentrations, nor will they be present for sufficient time to be effective. In addition, many disinfectants are inactivated by organic materials, such as wood or faecal material. Thus, although important, disinfection can be regarded as the least effective step in biosecurity.

Biosecurity is a cornerstone of herd health maintenance. Management of disease outbreaks and control of endemic diseases are challenges in many pig production systems, but particularly in smallholder pig systems in developing and transition countries, where high mortality and morbidity rates are a major problem.

Section 2
Swine diseases, routes of transmission and implications for biosecurity

MAIN DISEASES AFFECTING SWINE

There are various ways of classifying diseases: the classification used in this paper is based on the impact of the disease.

Infectious diseases with transboundary implications

Most of the major infectious diseases of swine are severe viral diseases affecting animals only. Many are notifiable and/or subject to regulation in many countries, as they represent a major threat to the pig population and, in some cases, other animal species. These viruses show a clear ability to spread and have – in their acute form – a severe impact with high mortality rates in susceptible pigs. For most viruses, diagnostic tests and effective commercial vaccines are available. Many countries have undertaken successful eradication programmes, but the viruses are still present in many parts of the world. These diseases represent a major threat to production and trade and should be regarded as a priority when considering biosecurity in relation to pig health.

Examples: foot-and-mouth disease (FMD), African swine fever (ASF), classical swine fever (CSF) and pseudorabies (Aujeszky's disease). ASF is one of the most serious transboundary animal diseases owing to its high lethality in pigs, potentially devastating socio-economic consequences, propensity for rapid and unanticipated international spread (e.g., through contaminated meat), and the lack of available vaccines.

Other severe infectious diseases

Diseases in this group share several traits with those of the previous group, but even in their acute form are likely to have a less significant economic impact overall (although they may be devastating to the affected premises). These diseases are highly contagious and are consequently widespread around the world; they can occur in epidemics, striking in waves, and some also result in an endemic form, with persistence of viral activity in herds over long periods. Porcine reproductive and respiratory syndrome (PRRS) – and to a lesser extent swine influenza – often show this endemic pattern. On farms with no appropriate control measures, such diseases can have a serious economic impact.

Examples: porcine reproductive and respiratory syndrome (PRRS) and transmissible gastro-enteritis (TGE).

Endemic production diseases

An infectious agent is often involved in endemic production diseases, but the clinical expression of the disease is principally a function of the environment in which pigs are kept on the farm. The pathogens can be transferred without any clear economic impact, if herd management, hygiene and husbandry are adequate. Compared with the two previous groups of diseases, the principal trait of production diseases is that the pathogen is present in many pig populations around the world, but there is wide divergence in the severity of its clinical expression. The disease may have limited consequences or be quite severe and concerning for a producer or production system.

Examples: In the respiratory system, enzootic pneumonia, pleuritis, pleuropneumonia and swine influenza; in the digestive system, enteric disorders occur in suckling piglets and at post-weaning, and ileitis and swine dysentery in growing-finishing pigs; in the reproductive tract, failure to conceive, stillborn pigs; in the skeletal system, arthritis, osteochondrosis; and on the skin, parasites (sarcoptic mange, lice) and bacterial infections (such as *Staphylococcus hyicus*)

Zoonoses

Zoonotic diseases are those in which people are infected with pathogens carried by animals. They can be transmitted directly through animal-to-person contact, or indirectly through consumption of contaminated food. All animals carry potential health hazards, so food animals are an integral part of public health protocols, hence the myriad of food safety legislation found globally. Regarding pigs, classical swine influenza is documented as having been transmitted to people on occasions, as has *Streptococcus suis*, which could be considered an occupational health hazard for those working in the pork industry. Recently, a link was suggested between Methicilin-resistant *Staphylococcus aureus* (MRSA) in pigs and MRSA infection in humans. The domestic pig is known to be susceptible to several other zoonotic diseases: rabies, leptospirosis, brucellosis, erysipelosis, tuberculosis, Japanese B encephalitis (JE), etc. Pig meat from infected pigs, when consumed raw or inadequately prepared, can transmit a number of pathogens, such as *Trichinella* spp., *Cysticercus* spp., *Salmonella* spp. and *Listeria* spp.; for the last two, inadequate hygiene during meat processing or at home can also be a source of contamination.

In many cases, particularly for production diseases, the environment in which animals are kept determines the course and severity of disease expression; a highly contaminated environment for animals with a weakened immune system often tips the balance and makes a disease clinical.

ROUTES OF DISEASE TRANSMISSION AND IMPLICATIONS FOR BIOSECURITY

Direct pig-to-pig contact

Many pathogens are transmitted through direct contact between an infected shedding pig and a susceptible pig. This is the most potent route of transmission for most pig diseases. For pathogen transfer to occur, there must be a sufficient infectious dose of pathogen transmitted to a susceptible animal; swine influenza virus, for example, reproduces in the upper respiratory tract and is shed through the nose, so nose-to-nose contact will spread the virus. Close, prolonged or repeated contact between infectious and susceptible animals, such as in pens or trucks during transport, increases the likelihood of transmission. Pathogen shedding is not constant and is usually highest during the acute phase of a disease.

Some animals that seem to be in good health may also be shedding pathogens at sufficient levels to spread infection; these "silent carriers" can be seen particularly in endemic diseases. Such animals present a clear risk when moved and commingled with susceptible animals. Ancillary testing using serology for previous exposure and molecular techniques may detect carriers when a clinical examination cannot.

Semen

Viral shedding through semen has been well-documented in both experimentally and naturally infected boars. Most systemic viruses can be excreted into the semen, which can be a source of transmission of Aujeszky's disease virus, parvovirus, CSF virus and PRRS virus. Some specific bacterial pathogens, including brucellosis and leptospirosis, are shed in semen, but most bacterial contaminants of semen are from faecal/environmental material. Appropriate hygiene during semen collection and distribution is therefore of primary importance, together with routine screening of boars for infections known to be spread by semen.

Airborne transmission

Airborne transmission is often difficult to document (with some exceptions, such as FMD), but can be studied experimentally. The secure distance between farms varies, depending on farm size, pathogen load, pathogen resistance to desiccation in the air, climatic conditions and local geography. Aerosol transmission of organisms for more than 4.5 km has recently been described for PRRS virus and *Mycoplasma hyopneumoniae*. Under specific climatic conditions, some strains of FMD virus can be carried by wind for up to 20 km (although it is unlikely that pigs would be infected through this route), and pseudorabies virus for up to 9 km. Swine influenza virus is certainly transmissible through aerosol droplets over short distances within premises, but transmission among premises through this route has not been demonstrated to date.

People

The role of people as transmitters of pathogens to pigs has been studied carefully over the last decade; people can transport pathogens on footwear, clothing, hands, etc. People can carry viruses on their nasal mucosae (nasal carriers) without being infected, and can also be infected by and shed pathogens when they are sick or carriers with no clinical signs.

Pig workers must be aware of their own potential role in the spread of disease, as they have physical contact with pigs – including those that are clinically affected – in their daily work. Service providers and intermediaries, such as pig transporters, technicians and veterinarians, may be required to visit several farms on the same day, thereby increasing the risk of disease spread; equally problematic is when farm workers or their households keep pigs of their own.

It should also be remembered that people determine the movements of animals and products among herds, markets and regions. The specific interaction between herds and processors depends largely on the consumer demand and supply of pig products. Large price differentials mean significant – often seasonal – movements of animals, and can therefore spread the disease through increased interaction; economic forces can cause animals to move large distances, increasing the possibility of geographical spread of disease.

Vehicles and other fomites

Equipment used by pig farmers must be considered as potentially contaminated fomites. Moreover, vehicles can transmit swine pathogens, when manure containing disease agents adheres to vehicle tyres or bodywork. There is evidence that ASF, *Actinobacillus pleuropneumoniae*, TGE and *Streptococcus suis* can be spread by contaminated vehicles. Lorries, trailers, vans and even motorbikes used for transporting pigs or carcasses to rendering plants represent a high risk for disease transmission.

Pig feed, including swill feeding, and drinking-water

Feed and water can become contaminated and play a role in maintaining endemic or toxic diseases. As some pathogens can survive in contaminated meat waste, specific attention must be paid to the use of food wastes in feeding pigs (which can include processed pork products, such as dry cured meats, that have not been heated). Fresh pork is a documented risk factor for transmission of a number of pathogens, such as FMD, CSF virus and ASF virus. Recently, investigators have also implicated fresh pork as a potential route of PRRS virus spread. Many countries prohibit the feeding of unrendered meat products to pigs. Unpasteurized milk and milk by-products obtained from cattle infected with tuberculosis, brucellosis, FMD, etc. can also be a source of pathogens.

Influenza virus in pigs is generally restricted to the respiratory tract, and thus is not spread through pork. It does not survive for long outside the host, so feed and water are not thought to be a major source of transmission.

Pig manure and bedding

Manure from infected pigs contains large quantities of viruses, bacteria and/or parasites. Disposal of pig manure must be considered when designing and implementing biosecurity programmes, as manure may contain pathogenic organisms, leading to faecal-oral-transmitted diseases. Contamination from pig manure poses a risk to the health of animals or humans, if the manure is not adequately treated or controlled. The spread of pig slurry on agricultural land may introduce pathogens into the human food chain and ecosystem, if due care is not taken during storage and spreading.

Pig manure may contain *Ascaris*, *Taenia*, *Cryptosporidium*, *Yersinia* and *Salmonella* species, *Campylobacter*, faecal coliforms, faecal Streptococci and other pathogens, such as hepatitis E virus. In areas where tuberculosis occurs in cattle, faeces may also contain viable tubercle bacilli, creating a hazard where pigs and cattle are raised together.

The bedding material provided to pigs can also spread pathogens; for example, sawdust and wood shavings can carry *Mycobacterium avium* bacteria.

Due to the short lifespan of influenza viruses outside the pig, manure is not a significant risk for transmission of influenza. Bedding is also not thought to be a major source of transmission for influenza virus.

The potential for disease transmission by people, vehicles and/or equipment, feed, bedding material or manure will be affected by temperature: cold temperatures enhance the survival of pathogens, whereas exposure to sunlight and drying tends to reduce survival.

In warm weather, swine influenza virus does not survive for long periods once shed, but its survival is enhanced in cold temperatures, so a seasonal pattern to influenza is often seen.

Birds, bats, rodents, feral and wild pigs and stray/domestic animals

Birds and bats are a particular risk for disease spread in open piggeries. Birds (e.g., sparrows, starlings, seagulls and crows) come into close contact with pigs when looking for feed, and may contaminate other herds with droppings and by mechanical transfer.

Birds can transmit *Bordetella* spp., erysipelas and avian tuberculosis. There is also evidence that birds can transmit the viruses that cause CSF, PRRS, influenza and TGE to pigs.

Rodents, particularly rats and mice, commonly live in close contact with pigs and are involved in endemic disease transmission in pig operations. Rodents may roam the countryside looking for new food sources when pig houses are emptied, and return when they are repopulated, when they can re-contaminate incoming pigs. Rodents are able to travel for up to 3 or 4 km from infected areas where pigs are kept, carrying infections. They can carry the agents that cause atrophic rhinitis, *E. coli* diarrhoea, leptospirosis, rotaviral diarrhoea, salmonellosis, swine dysentery, PRRS, *Streptococcus suis* infection and encephalomyocarditis.

Wild animals can harbour brucellosis, leptospirosis, trichinella, pseudorabies and many other pathogens. For example, hares in Denmark and Poland spread *Brucella suis* under some circumstances and have infected outdoor breeding herds.

Wild pigs are undomesticated suidae that remain or that are introduced into regions that did not have an indigenous population of pigs. Feral pigs are domestic pigs that have escaped and established wild populations. They are a major disease threat as they are common in many areas and harbour pathogens that affect domestic pigs.

Among other diseases, feral and wild pigs may transmit CSF, ASF, FMD and pseudorabies. For example, the ASF virus is maintained in Southern and East Africa in an ancient sylvatic cycle between warthogs (*Phacochoerus aethiopicus*) and ticks of the *Ornithodoros moubata* complex. There is also a domestic cycle that involves pigs of local breeds, with or without tick involvement.

At the time of writing, the pandemic H1N1 2009 strain is thought to be transmitted primarily by humans, with pigs being infected through contact with humans. No data exist to show that wild pigs currently carry the pandemic strain of influenza, but as the duration of shedding of the influenza virus is short and requires direct contact with domestic pigs, *wild pigs are unlikely to become a major source of influenza transmission into production systems (except perhaps in those where wild and domestic pigs commingle).*

Stray dogs can spread TGE, swine dysentery and brucellosis pathogens, while cats are a potential transmitter of toxoplasmosis to pigs, through their faeces, and can be mechanical vectors as they seek wandering rodents.

Arthropods

Certain viruses, including those responsible for ASF, JE and PPRS, can be hosted by arthropods, such as ticks or mosquitoes, on which they can replicate, thereby complicating control and eradication programmes. Ticks are unable to travel to pigs, but pigs can be in contact with ticks when they graze or sleep in tick-infested areas. ASF is a good example of a tick-borne virus; its control requires knowledge of both the arthropod and the host's behaviour.

Flies are attracted to organic matter, such as manure and carcasses, and can mechanically spread pathogens such as TGE and *Streptococcus suis* as they fly between farms.

Section 3
Structure of pig production and marketing chains

Pig production systems vary across the world depending on the expectations that people, communities and society at large have of them. Many pig producers are smallholders located in rural areas; depending on the country and patterns of production, pigs can be a source of income, a source of valuable proteins of animal origin for the family or a form of savings.

PIG PRODUCTION SYSTEMS

In most countries, different pig production systems cohabit, from the simplest system with minimal investment, to large-scale market-oriented enterprises. This paper groups pig production systems into four categories, based on the size of herds, the production goals and husbandry management. For each category, the implications of applying biosecurity measures are discussed, together with the general risks of introduction and circulation of pathogens in herds.

Scavenging pigs

Raising scavenging pigs is the most basic traditional system of keeping pigs and the most common in developing countries, in both urban and rural areas.

In this free-range system, pigs roam freely around the household and surrounding area, scavenging and feeding in the street, from garbage dumps, or from neighbouring land or forests around villages. Few arrangements are made to provide the pigs with housing. Depending on the local situation, pigs may be free-ranging for most of the year, and penned during the rainy season. They may be housed at night in a small shelter, to protect them against theft and predators.

Local breeds are commonly used, and although there is often high piglet mortality and a low growth rate, local breeds have the advantage of remaining productive when fed with low-quality feed and in poor sanitary conditions. Scavenging pigs find feed themselves, but they may also receive supplementary feed, such as kitchen waste or agricultural by-products.

The majority of scavenging pigs are owned by subsistence farmers, often women. In most cases, the pigs are not raised to provide meat for the household, nor as a regular source of cash income, but serve as a form of savings or an "insurance policy". These households usually have other sources of income, and pig keeping is a complementary activity. Marketing is usually ad hoc and the animals may be sold for emergency cash needs, such as to buy seeds or fertilizer, at times of illness or family festivity, to pay school fees, or to compensate for a lost harvest. Pigs can also have a social function, being offered as a gift or as food during community events.

Keeping scavenging pigs requires minimal inputs and low investment in labour, with no or limited money invested in concentrated food or vaccines. The financial risk involved for the producer is minimal.

Small-scale confined pig production

Small-scale confined pig production is frequently found in households across the world. Animals are confined in shelters, which range from simple pens made from local materials to more modern housing. The pigs are completely dependent on their keeper for feed, and receive branches, leaves, crop residues, agricultural by-products or prepared feed (although often of poor quality). Smallholders raise pigs for both subsistence and commercial reasons, with an increasing emphasis on the latter. Pork is supplied to local markets and to more distant urban markets, through a complex transport and marketing system. Women often manage these farms, so it is important to understand gender issues in rural and peri-urban areas of developing countries when proposing changes in small-scale confined pig production.

There is a wide diversity of systems in this category. Some of the more representative systems in developing and transition countries are:

1. semi-intensive backyard production;
2. small-scale intensive production;
3. multi-species integrated production.

In the *semi-intensive backyard production system*, pigs are confined in very simple pens built from local materials. This system exists in both rural and urban areas. The herd is usually small (with from 1 to 100 animals raised per year), and activities focus largely on pig fattening. Labour usually comes from the family.

In the *small-scale intensive production system*, pigs are confined in sheds with separate pens for fatteners, boars, gestating sows and sows with their litters. Farmers provide meat or live animals to local or regional markets, and the animals are kept primarily for commercial purposes. These farmers live in areas where there is access to commercial feeds, particularly in peri-urban areas where they are close to markets. These pig farms are family-run, single-site and usually on the same piece of land as the owner's house. The pigs are usually of improved breeds, such as Large White or Landrace and crossbreeds. This system has a number of advantages: the housing design makes it easier to manage the animals; vaccinations and treatments are easy to administer; and the environment can be kept clean. However, in comparison with the semi-intensive backyard system a relatively high level of inputs is required, for housing material, feeds, veterinary products and labour. Pig production is often the sole or a major source of income, and farmers require management skills and financial capacities.

In the *multi-species integrated production system*, pigs are raised in association with other agricultural activities (including those involving cattle, fish, algae, ducks, water hyacinth, vegetables, etc.). The pig manure can fertilize the farmer's fishponds or field crops (or gardens), while dairy by-products, such as whey, can be used in pig feeding. These associations enhance the efficiency of resource use and increase the farm's overall output.

Such mixed systems are often reported in poor rural areas. Multi-species housing of pigs and other farm animals, including poultry, ducks and dairy cows, in the same sheds is often reported.

A continuum among these systems is often observed in developing and transition countries. Rapid changes towards intensification can occur when the demand for pork is growing, but the opposite is also possible in the case of meat overproduction, scarcity of inputs, animal disease or other crisis.

The economic risks within these systems can be high, and there is limited support from organizations and professional bodies for technical inputs or services such as insurance.

Large-scale confined pig production

Despite the term "large scale", commercial farms with confined pigs vary considerably in size, but they are usually larger than those in the systems already described. In a global context, as consumers seek to purchase food at the lowest price, but input prices are rising, the profit margin on each pig has decreased. Producers participating in global commodity pork markets must continually reduce the cost of production per pig to be profitable. In pursuit of lower costs, the following major structural changes have been made in this system:

1. Increased farm size: This helps spread fixed costs and leverage discounts through volume purchasing and marketing (economies of scale).
2. Specialization of farming activities: Traditionally, farmers specialized by raising only one species per premises. More recently, specialization has involved multi-site production systems, with only one production step per premises, most notably one farm for farrowing, another for nurseries, and/or separate farms for finishing. Labour inputs have also become more specialized, and the production cost per pig has declined.
3. Consolidation and integration of ownership: Farms have been consolidated through joint ownership, which may include units for feed milling and pork processing. Common ownership or integrated coordinated production leads to further economies of scale and volume discounts on inputs, while also simplifying decision-making and allowing a more consistent application of production practices.
4. Adoption of the all-in-all-out production system: Animals are kept together in groups according to age and weight, and groups are not mixed during their stay on the farm. When a group moves forward, the facility is completely emptied. This system reduces disease transmission, improves sanitation, allows better environmental control, and improves pig performance and record-keeping. Financial losses from endemic diseases are reduced. Usually, other components of a biosecurity plan are also implemented.

Large-scale confined pig farms can be family-owned, affiliated to companies or corporately owned. Labour can be provided by the owner and her/his family, alone or in combination with hired labour.

The pigs are housed indoors, but the building design can vary, depending on the geographic location. In temperate zones, buildings are closed and often fan-ventilated, while in tropical zones they are open on the sides and naturally ventilated, often with trees planted alongside the buildings to provide shade and cooler temperatures.

There are two major production systems in the large-scale confined production category:

1. *One-site production system*: Farms can be of the farrow-to-finish type, where sows, piglets and fattening pigs coexist at one location. The resulting transport and labour efficiency makes this system amenable to owners/operators who live on the same premises and have close proximity to their livestock.
2. *Multi-site confined system*: To enhance efficiency, farms have specialized their production by site, and move pigs among premises as they are prepared for market. Such systems can run an effective all-in-all-out policy, thereby allowing more disease eradication options. As the scale increases, so does corporate ownership in an integrated system where feed and slaughter may be under common control. Ownership and production can be widespread geographically, while compartmentalization in production is possible, based on varied health status and with sufficient biosecurity to maintain the unique health status in each compartment (Figure 1).

Most pig genetics come from dedicated breeding pyramids with genetic improvement programmes and health surveillance systems. Breeding pyramids are designed around specific pathogen-free (SPF) principles, where genetically improved lines of pigs are issued from pathogen-free nucleus herds and distributed to commercial producers (Figure 2).

FIGURE 1
Multi-site production systems have a larger scale, but also the option of creating separate compartmentalized pig flow

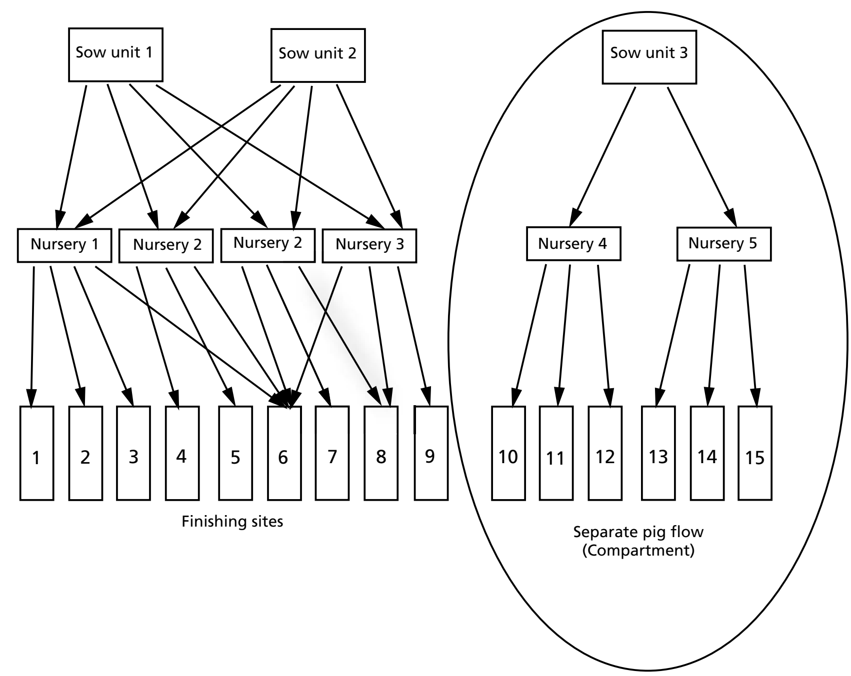
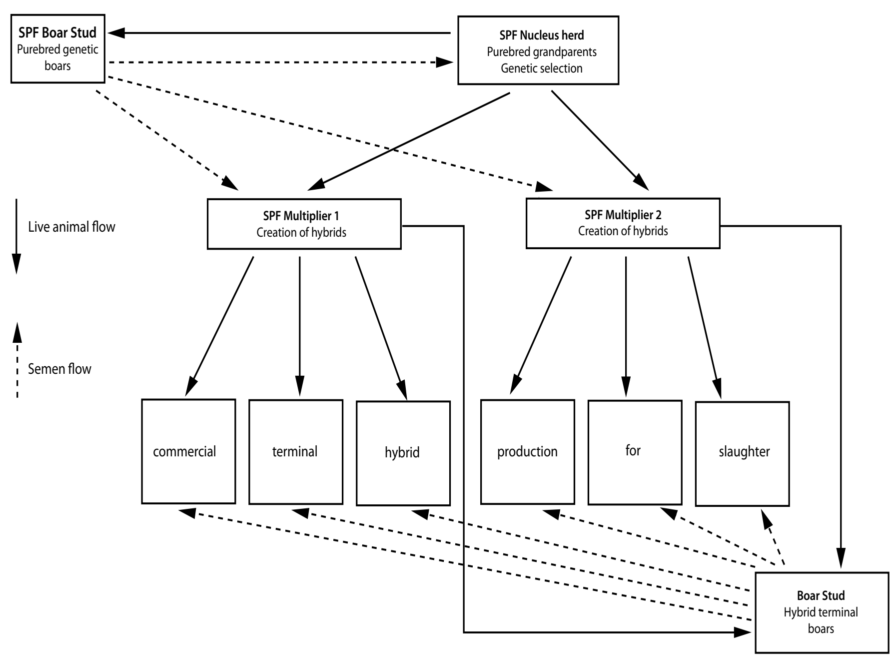


FIGURE 2
An SPF breeding pyramid can provide herds with clean pigs



Large-scale outdoor pig production

An alternative to confined pig production in buildings is the use of outdoor pig units. The animals are confined by fencing, but are mainly outdoors, so there is less need for investment in bricks and mortar facilities. Such farms can brand their products and sell pork at higher prices. Outdoor pig production can only occur in temperate areas with no severe cold seasons.

SERVICE PROVIDERS, SUPPLIERS AND MARKETING CHAINS

The rapid development of commercial and semi-commercial pig production in many countries is being driven by private sector investment, as it seeks to meet increasing consumer demand for pork. A production and marketing network involving many people ensues. The complexity of biosecurity in a multi-stakeholder system has to be understood not only at the farm level, but also throughout the supply and marketing chains.

Artificial insemination centres and boar keepers

Artificial insemination (AI) centres and boar keepers are key elements for reproduction and animal genetic improvement. They provide semen for AI or boars for natural service. Semen is collected from boars, its quality is tested, and it is stored and distributed fresh to neighbouring farmers. Boars for natural mating are raised where smallholder farmers cannot afford to keep a boar in their own herds. A public body often operates AI centres or cooperatives, and the distribution of semen and reproductive animals is their main source of income.

A specialized (or wealthier) farmer may share his/her boar with other farmers, as is frequently the case in developing and transition countries, where collective organization in animal genetics is not effective.

Service providers

Service providers, such as feed manufacturers, veterinarians and technicians, make regular visits to farms, often visiting several farms in a single day. Inadequate decontamination between farms can lead to disease risk.

Marketing chains, live-animal markets and slaughterhouses

In developing and transition countries, formal marketing channels such as cooperatives and large markets are often not accessible to smaller producers. Consequently, pigs are largely traded through a complex series of private auctions and markets, intermediaries, sales barns and butchers. All these stakeholders have an interest in preventing disease outbreaks, as these have an impact on their businesses.

Live pig markets are a key element of the commercial pork trade. The pigs are brought to the marketplace by owners or traders. Animals arrive and leave in a daily two-way stream, allowing pathogens to persist and accumulate over time. Commingling and infection of animals of different origin are inevitable.

Slaughterhouses receive fattening pigs to be killed, and dress the carcasses for processing or retail. The slaughterhouse may belong to a local butcher, public institution, private enterprise or farmers' cooperative. The storage and sale of temperature-controlled pork is growing, but in developing and transition countries, most pig products are still traded through unrefrigerated fresh pork markets and as a variety of ready-to-eat products. Fresh pork that has spoiled or become waste may infect pigs if regulations on swill feeding are not rigorously applied.

Section 4
Biosecurity issues and good practices in the pig sector

ON-FARM RISKS AND RELATED BIOSECURITY MEASURES

The key measures to be implemented to avoid the introduction of new pathogens within a pig unit (bio-exclusion) and to limit the circulation of diseases among a herd and to other farms (bio-containment) are described in the following. The characteristics of selected biosecurity measures are presented in Annex 1, together with their relative efficacies. The potentials for uptake of the selected biosecurity measures in different systems are compared in Annex 2.

Scavenging pig production

In scavenging pig production, health risks are numerous. Contact with other pigs – domestic, feral or wild – wildlife, rodents, birds and other livestock is not controlled, which creates favourable conditions for disease spread.

Owing to its nature, this system is the most problematic. Keepers of scavenging pigs cannot introduce effective biosecurity measures, as pigs roam freely for most of the day. However, there are simple measures that can be recommended, focusing on a minimum burden in terms of costs and time.

Introduction of clean pigs only

The village should be considered as the epidemiologic unit to be secured, because the pigs within a village have usually been born and bred in the village, commingle, and are therefore assumed to have the same health status. New pigs introduced into a village must be free of disease, and particular attention is needed when they are purchased from a market. These pigs should undergo a period of quarantine; a minimum of 30 days is recommended to allow time for clinical signs to develop. During quarantine, the animals should be observed frequently for signs of disease. Quarantine should take place in a separate facility, such as at the periphery of the village, to avoid potential contamination of the entire pig population. It also requires strict observance of clothing and footwear changing or careful cleaning and disinfection, ensuring that quarantined animals are always dealt with last.

There is also concern over sows and boars that are moved from one location to another for mating. The health status of the boars needs to be known, especially regarding diseases of concern. In developing countries, some farmers specialize in boar keeping: it is essential to have at least one mature boar (with a future successor) for each village, to avoid multi-village pig contacts.

Avoiding trade of sick pigs

It is not uncommon for the owners of scavenging pigs to sell animals for slaughter as soon as disease is suspected. The marketing of sick animals is a serious risk, particularly when they are sold at live-animal markets, as these animals can shed infectious agents. It is also a major public health concern, as sick animals may transmit zoonotic diseases to humans, especially children and senior citizens. Despite the financial implications this will have for poor farmers, the sale or consumption of sick animals must be banned and actively discouraged. Potential buyers must be informed that an inexpensive pig for sale is likely to be sick, so will cost more over time.

Avoiding swill feeding

The use of untreated swill must be avoided, and is often prohibited by national regulations. Nonetheless, in developing countries, restaurant waste and kitchen scraps are often used as feed, because they allow rapid fattening of pigs, owing to the high energy and protein contents. If swill is to be fed to pigs it must be heated to a minimum temperature for a sufficient period (e.g., 100° C for at least one hour).

Proper disposal of carcasses

When unusual deaths of animals occur, veterinary services should be informed so that they can take immediate actions to control any outbreak of disease. Following disease or deadly injury, dead animals should be buried, composted or burned. Local authorities must prevent and control the illegal trade of dead animals, which could have a serious impact on consumers' health and confidence in pork products.

Cleaning and disinfection

Prevention measures for bio-containment are not appropriate in an environment where pigs roam without their owner's control. Sustained use of disinfectants is not practicable, but even when pigs spend most of the day roaming, they are usually housed at night, so night shelters should be at least cleaned, and disinfected when possible. The same applies to any equipment used, particularly if it is shared with other pig keepers.

Other pre-emptive measures: vaccination

Because they come into contact with domestic or wild animals, rodents and other potential carriers of diseases, such as ticks, domestic pigs should be vaccinated where possible and when vaccines are available.

Table 1 provides a summary of biosecurity measures that can be implemented in scavenging pig production systems.

A key strategy in achieving biosecurity goals is to engage pig keepers in a participatory approach, in which enhanced understanding of risks and protection measures can be achieved; when community members see that actions are feasible and beneficial, they are more likely to adopt measures within and among villages.

In relation to pandemic H1N1 2009 influenza, the main risk factor is transmission from sick humans to pigs, through direct contact. Education campaigns encouraging community

TABLE 1
Scavenging pig production: summary of biosecurity measures and potential for uptake

Biosecurity measures	Implementable Yes/No	Comments
Segregation		
Avoid introduction of pigs from outside farms, markets or villages	N	As pigs are roaming, their movements cannot be controlled
Limit the number of sources of replacement stocks	Y/N	Purchasing patterns can be influenced by sensitization efforts and access to improved genetics
Use AI instead of moving sows or boars	N	AI infrastructure does not exist nor do the logistics for distribution
Quarantine (isolation) for newly purchased animals	Y	Can be implemented if appropriate incentives are provided
Full fencing around and closed entrance to farm area	N	The nature of the system prevents fencing
Ensure long distances between farms	N	Distances are irrelevant if pigs are free to roam
Install nets against birds	N	Pigs are not confined
Create loading area/bay at farm	N	Pigs are not transported in groups or by truck
Strict control of entrance/exit	N	Pigs are not confined
Specific clothing and footwear for use at the farm	N	Not applicable
Shower with change of clothing and footwear	N	Not applicable
Exclusion of wild pigs and rodents	N	Not applicable
Permanent housing of pigs	N	Not applicable
Ban the keeping of pigs at workers' homes	N	Pigs are not confined
Keep animal species separate	N	Pigs are not confined
Herd management: all-in-all-out system by compartment	N	Not applicable
Fallow period between batches	N	Not applicable
Manure management (composting, spreading)	N	Not applicable
Parasite control (including ticks)	Y/N	Possible only in premises where pigs are housed at night
Avoid non-boiled swill feeding	N	Pigs have access to waste in the field, over which humans have no control
Cleaning		
High-pressure washer	N	Usually not available
Low-pressure washer	Y/N	Water availability can be problematic
Cleaning of vehicles	N	Vehicles are not used
Cleaning of premises	Y	Households can be encouraged to wash pens where pigs spend the night
Footwear cleaning station	N	Specific footwear, such as boots, is normally not used
Disinfection		
Disinfection of vehicles	N	Vehicles are not used
Disinfection of premises	N	
Footwear disinfection	N	Specific footwear, such as boots, is normally not used
Other accompanying pre-emptive measures		
Traceability: knowledge of identity of supplier herd	Y/N	Any purchases can be tracked if incentives are in place to keep records
Transparency: knowledge of health status of supplier herd)	N	Medical knowledge of source animals is unlikely to be available
Vaccination	Y/N	With the proper incentives, when pigs are housed at night
Incentive for change		
Producers in this system may not be aware of all the veterinary and public health risks related to pig production. Activities that can induce change include communication on disease risks and on the benefits related to implementing biosecurity measures; and provision of veterinary services for diagnostics and advice on husbandry practices.		

awareness of the potential for virus transmission between people and pigs are important. People with clinical symptoms of influenza should not be in contact with pigs until at least seven days after the onset of illness. Workers in direct contact with pigs should be prioritized for preventive measures, such as vaccination and the provision of protective clothing, when available. The United States Centers for Disease Control and Prevention (CDC) provide interim guidance on preventing the spread of influenza A viruses, including the H1N1 2009 virus, for people in close contact with pigs in non-commercial settings and for workers employed at commercial swine farms.[1]

Small-scale confined pig production

The higher density of pigs in small-scale confined production systems leads to a higher risk of pathogen circulation among herds. All-in-all-out management, fallow periods and disinfection procedures are often impractical. Segregation of animals of different ages is incomplete. Limiting visitors' access and controlling rodents or stray animals are difficult.

Without a source of clean breeding stock, it is difficult to avoid the transmission of disease through breeding stock. Farmers growing pigs for market usually source their animals from several places, so have a higher risk of disease entering their premises.

Feeding practices still depend on local sources, but some producers use industrial feeds when available. Non-controlled meat, bone- or fishmeal may be fed, including swill from urban restaurants.

As the pig population of a production unit increases, swine effluents become a concern. Pig wastewater and manure are a major source of pollution and faecal contamination. Despite efforts to promote biogas and composts, wastes are usually discharged without control.

Multi-species integrated production systems are a valid strategy for mitigating financial risks and optimizing the use of by-products. However, these systems raise additional concerns for biosecurity and are risk factors for numerous diseases, including FMD, pseudorabies and salmonellosis. Mixing animals of various species on the same farm also increases the risk of novel viruses emerging, particularly influenza viruses that can infect multiple species.

Despite these issues, farmers involved in small-scale confined production are more likely to implement some biosecurity measures than owners of scavenging pigs, if provided with appropriate incentives. For example, farmers often find it difficult to obtain bank loans and credit for this type of production because of the disease-related financial risks involved. Associating good on-farm biosecurity with easier access to credit facilities can be beneficial for both producers and their financial partners.

Segregation, cleaning and disinfection should all be considered, with an emphasis on segregation. The main difference from scavenging pig production is that there is a physical barrier to the outside environment.

---

[1] www.cdc.gov/h1n1flu/guidelines_noncommercial_settings_with_pigs.htm and www.cdc.gov/h1n1flu/guidelines_commerical_settings_with_pigs.htm.

Location and fencing of the pig farm

The location of the pig farm is a critical factor in the risk of pig disease introduction. When a new pig farm is being installed – even a small one – its proximity to other pig farms and public roads must be considered. A minimum distance between neighbouring pig farms and between units within a pig farm is desirable, to limit the risk of aerosol disease spread. The actual distance will vary according to conditions and the environment. On flat land, air streams from a barn can remain in a concentrated plume and are thought to spread pathogens for long distances under certain climatic conditions. This risk is difficult to avoid where land is scarce. Trees and hills that break up airflow can help limit airborne spread, as can the use of a windbreak around the premises.

Farm units or enclosures should be fenced. The fence must be robust enough to prevent the entry of wild animals, including wild boars and feral pigs, and to prevent the escape of domestic pigs. Contact with birds should also be avoided, by using nets on the roof and open sides. The entrance to the farm must be clearly identified, and have controlled access.

Workers and visitors

Workers and visitors must strictly observe farm protocols to minimize the risk of bringing in diseases; the aim is to keep visitors away from pigs as much as possible.

All people entering the farm, including the farmer and salaried workers, should not have been in contact with other pigs recently. Visitors to farms should always be asked whether they have recently been to potentially contaminated places, such as pig farms, slaughterhouses, animal renderers or post-mortem rooms; if they have, they should not be admitted to the farm unless all appropriate protection measures are taken. A visitor log book, in which visitors record their last exposure to pigs, is a useful tool for implementation of this measure. Salaried workers working with the herd should have no contact with other pigs, i.e., they should not keep pigs at their own homes.

Visitors, including other farmers and pig workers, should be provided with specific clothing and clean footwear by the farm being visited, and should wash their hands on entry. Where possible, a dedicated building should be located at the entrance, where workers and visitors can change clothing or put on/take off overalls and boots.

On smaller farms, farmers usually spend limited time in the pig pens and do not clean or change their work clothing or footwear. Extension programmes should recommend the use of clothing and footwear that are worn only in the pig unit (and certainly not during visits to other pig farms).

Another effective option is to have water available to remove all visible organic material, followed by disinfection. Disinfectant mats or buckets will not work if there is manure present on footwear.

In the context of the pandemic H1N1 2009 crisis, infected people can transmit the virus to pigs, so it is critical that people with respiratory illness symptoms are kept away from farms until they have recovered, and any fomite they may have contaminated must be disinfected before entry to farms. Workers and visitors should be encouraged to have regular influenza vaccinations where possible; this recommendation includes the transporters of pigs and others in direct contact with pigs.

Vehicles and equipment

Drivers and their vehicles transporting pigs to the market or slaughterhouse or delivering feed are a major risk for disease transmission. Drivers should strictly adhere to farm protocols and biosecurity principles when handling animals. Feed should be delivered outside the fence. The vehicles, especially those used to transport pigs, should be thoroughly cleaned before returning or visiting other farms.

Pig keepers should also take precautions against contamination from vehicles by establishing a safe pig loading location (possibly with a bay) and by not allowing vehicle drivers into pig buildings. Vehicles need to be cleaned and disinfected after each rotation.

All instruments or equipment that are likely to come into contact with pigs, such as restraint snares, needles and scalpels, should be assigned to the farm and kept clean. They should not be transported from farm to farm; if they have to be, they should be cleaned and disinfected.

Control of pests

Pig farmers should practise regular pest and rodent control, with rodenticides or by keeping the surroundings of the pig unit clean. Rodenticides must not be used where there are risks of pigs eating the bait or the rodent carcasses. Potential refuges for rodents, such as garbage, dumps, bush or wasteland, must be systematically eliminated. Residues of pig feed have to be regularly cleaned and pig feed must be properly stored to prevent access by rodents and larger wild animals and birds.

If used, bedding should come from a pig-free source and not be allowed to become contaminated by birds, rats or mice during storage.

Introduction of clean pigs

It is important to avoid the introduction of pigs from outside farms, other than from breeding, multiplier or other farms that are known to be free of diseases of concern. The proper use of AI can help to introduce new genetics without introducing live pigs to farms. Replacement pigs entering the premises should come from known safe sources and should be quarantined, or at least physically separated. Newly purchased pigs should be kept for a minimum of 30 days in a quarantine pen, isolated from the pig farm. During the first phase of quarantine, the farmer can observe the new pigs and determine whether they are sick or not. After quarantine, the new pigs can be introduced into the herd. Replacement gilts must be allowed to adapt to the local environment before being used for breeding. The second phase of quarantine can therefore be dedicated to acclimatization procedures, to allow replacement pigs to adapt to the microbial flora of the herd, and to feed and management procedures.

Vaccination and deworming programmes should be applied on arrival.

Age segregation

Age-segregated rearing should be encouraged, and buildings should be designed to avoid the commingling of groups of pigs of different health status. Keeping animals in groups according to age and physiological stage is recommended for better productivity, as well as for sanitary reasons.

Homogeneous groups of same-age pigs, such as those born in the same week and in the same room, should preferably be kept together until slaughter, without being mixed with other pigs. The method of "streaming" pigs should be linked to an all-in-all-out hygiene policy, where possible. When a group (batch) of same-age pigs leaves accommodation for a subsequent step, such as from nursery room to grower, the premises should be thoroughly cleaned and disinfected.

Cleaning and disinfection

An important routine for reducing the risk of endemic disease outbreaks is the regular and thorough cleaning of the pig unit, including ensuring that manure is removed from the pens (or drops through the slats) every day, cleaning and disinfecting pig pens regularly, and quickly removing manure, urine and straw bedding where sick and dead animals have been present.

Where possible, farrowing and nursery pens (and small equipment) must be cleaned with detergent. Cleaning is essential for the removal of most organic matter. A sloping, concrete floor facilitates the elimination of wastewaters outside the pen.

Disinfection follows proper cleaning. Only approved disinfectants should be used in the food production chain (e.g., quaternary ammoniums, peroxides, Cresol or monopersulphate of potassium). Disinfectants can be toxic to humans or animals and must be used according to instructions on the label. Mixing disinfectants is inadvisable, as the potency of each may be nullified or a dangerous reaction may be caused, releasing heat or dangerous gases. Allow enough time for drying, as pathogens can survive in pockets of moisture (see Annex 3).

TABLE 2
General properties of common disinfectants

Disinfectant	Bacteria	Virus	Fungi	Spores	Mycobacterium	Human health risk
Alcohol	Cidal	Cidal	Cidal	Inhibitory	Inhibitory	Flammable, strong odour
Formaldehyde	Cidal	Cidal	Cidal	Cidal	Cidal	Irritating, explosive, carcinogen, allergen
Glutaraldehyde	Cidal	Cidal	Cidal	Cidal	Cidal	Allergen
Halogens; chlorine, bromine, iodine	Cidal	Cidal	Cidal	Cidal	Cidal in alcohol	Irritating, reactive with other chemicals
Phenols	Cidal	Cidal	Cidal	Inhibitory	Cidal	Toxic, absorbed though the skin, bio-accumulative
Quaternary ammoniums	Cidal	Cidal Lipophylic		Inhibitory	Inhibitory	
Peroxides	Cidal	Cidal	Cidal	Cidal	Cidal	Explosive, irritating
Acids	Cidal	Cidal	Cidal			Corrosive

Other pre-emptive measures

Where relevant, vaccination programmes should be established. However, vaccines cannot compensate for shortcomings in hygiene and husbandry practices. Pig workers should take notice of the major events related to disease occurrence, for example, by keeping a log book, and should contact a veterinarian or animal health adviser as soon as a problem is identified.

When pigs or pens are moved from one site to another, they should be identified so that if problems occur, they can be traced back to their source. Internally, pig identification also helps herd health monitoring. Periodic herd health inspections (audits) are useful for obtaining an objective view of the situation and instilling trust between the producer and veterinary services.

Table 3 provides a summary of biosecurity measures that can be implemented in small-scale confined production systems.

TABLE 3

Small-scale confined production: summary of biosecurity measures and potential for uptake

Biosecurity measures	Implementable Yes/No	Comments
Segregation		
Avoid introduction of pigs from unknown sources	N	Usually no traceability for movement of pigs from markets and in villages
Limit the number of sources of replacement stocks	Y	Requires good communication on risks related to purchase from multiple sources
Use AI instead of moving sows or boars	Y	AI cooperatives can be financially sustainable in areas were small-scale confined production is practised
Quarantine (isolation) for newly purchased animals	Y	Infrastructure for quarantine periods can be built
Full fencing around and closed entrance to farm area	Y/N	Possible in some farms, but difficult in densely populated villages
Appropriate distances between farms	N	Most pig housing is inside villages with high animal density
Install nets against birds	Y	Pigs are housed, so screens can be built
Create loading area/bay at farm	Y	Dedicated housing can allow for specific loading structures and protocols
Strict control of entrance/exit	Y/N	
Specific clothing and footwear for use at the farm	Y	Separate pig housing allows sanitary protocols to be implemented
Shower with change of clothing and footwear	N	Infrastructure generally does not make showers practical
Exclusion of wild pigs and rodents	Y/N	No contact with wild pigs is possible, but rodents are more difficult to exclude
Permanent housing of pigs	Y	Pigs are indoors where access can be controlled
Ban the keeping of pigs at workers' homes	Y/N	Possible where there is no tradition of pig keeping
Keep animal species separate	Y/N	Possible where there is no mixed farming system
Herd management: all-in-all-out system by compartment	Y/N	Depends on the size of the farm and the cash availability for purchase of pigs in groups
Fallow period between batches	Y/N	Achievable in batch flow systems, but very difficult on breeding farms

(continued)

Biosecurity measures	Implementable Yes/No	Comments
Parasite control (including ticks)	Y	
Manure management (composting, spreading)	Y	With correct incentives, protocols for appropriate manure management can be promoted
Cleaning		
High-pressure washer	N	Usually not available to small-scale farmers
Low-pressure washer	Y	
Cleaning of vehicles	Y	Protocols can be established, but will be a new activity for many farms, and may require incentives and encouragement
Cleaning of premises	Y	
Footwear cleaning station	Y	Easy to set up
Disinfection		
Disinfection of vehicles	Y/N	Protocols can be established, but will be a new activity for many farms, and may require incentives and encouragement
Disinfection of premises	Y/N	
Footwear disinfection	Y	Easy to set up
Other accompanying pre-emptive measures		
Vaccination	Y	
Traceability: knowledge of identity of supplier herd	Y	Incentives for record-keeping can provide data for traceability
Transparency: knowledge of health status of supplier herd	Y/N	Depends on the availability and quality of veterinary services
Incentives for change		
Producers in this system may not be aware of all the veterinary and public health risks related to pig production. Activities that can induce change include communication on disease risks and on the benefits related to implementing biosecurity measures; provision of veterinary services for diagnostics and advice on husbandry practices; easier access to credit facilities for tighter biosecurity measures; and support to the creation of producer associations for knowledge sharing and joint implementation of biosecurity measures.		

Large-scale confined pig production

The highest biosecurity concerns in large-scale confined production regard the nucleus herds and boar studs, as they have the ability to affect many other herds, and a disease outbreak will limit sales.

Feed is manufactured by specialized feed companies or is mixed on the home farm, increasingly within a quality assurance programme. For internal biosecurity, the pigs are often housed in separate rooms (sections) according to age or physiological stage. All-in-all-out management is often scheduled by room, barn or premises, but a continuous flow can also often be found, where a higher throughput can be achieved in the absence of endemic disease challenge. The goal is to adapt the housing and equipment to optimize productivity and health. Major capital investments are needed, particularly in the farrowing section and nurseries. Weaning usually takes place at three to four weeks of age. Vaccination and other cost-effective preventive programmes are usually in place. Animal health varies, depending on the source of the pigs and the disease risk from surrounding communities. Large-scale confined production systems are of increasing importance in regions where investment in new pig production is occurring.

In single-site production systems, the housing of animals of all ages under one roof or in neighbouring barns creates a higher risk of a disease becoming endemic; disease control is more complicated because a wide range of ages and susceptibilities are present on one premises. Depopulation and repopulation of the entire premises is difficult and expensive.

Size and impact: in multi-site production systems, when disease outbreaks occur they can spread rapidly as animals move regularly between sites, so many animals and farms in a wide region can be affected. Furthermore, movement restrictions in the event of a major disease outbreak produce difficulties in pig flow among farms and may create significant welfare problems, particularly in sow units and nurseries.

Compartmentalization: isolation of production systems with common health status and biosecurity can allow for large-scale disease management and differentiated marketing of pork and pigs. This can also provide an alternative to disease-free zoning, if approved by trading partners.

OIE's fundamental requirement for compartmentalization is that the management and biosecurity measures implemented create a functional separation of premises and allow clear differentiation among sub-populations of differing health status.

Decision-making and control actions: disease control can be more effective in a corporate structure, as there are fewer decision-makers and policies can be implemented and monitored more efficiently. Communication of key messages is easier, and response times can be faster. Similarly, biosecurity and preventive strategies can be broadly implemented and technical resources used, as management has an interest in protecting the investment. Labour is specialized in pig production, and complex technical tasks such as depopulation, disinfection and repopulation can be implemented.

Regional disease pressure: large integrated farm systems usually evolve in or create a large population of animals in a region. Regions with large livestock populations have a higher regional disease challenge. Disease risks for farms in such areas tend to be higher than in more sparsely populated regions, particularly for diseases with the potential for aerosol transmission. In pig-dense areas, there is greater need for more specialized biosecurity, with an emphasis on pig movements, aerosols, and the flow of vehicles, insects and people.

In larger-scale production systems, the same principles apply as in the previously discussed systems, but the impact of disease has the potential to be proportionally higher.

The following are key areas for biosecurity:

- Standards for the purchase of incoming genetic material: Before purchasing new reproductive females and males their medical history should be gathered and a veterinary consultation should be obtained on the seller's farm. Before purchase, it is important to test a representative sample of the pigs with serologic or molecular techniques to detect the percentage/level of sub-clinical disease, and to place animals in acclimatization quarantine to identify any incubating diseases.
- Assuring that the health status of the AI unit matches the recipient herd's, and that the unit's biosecurity protocols are sufficient to prevent disease entry and identify an

outbreak as quickly as possible: Molecular diagnostic techniques that are now available can be used on boar studs. There are examples of PRRS virus infection being detected in boar studs before semen transmission to downstream herds occurred.

- The physical location of herds should be planned to maintain sufficient distances from neighbouring farms and frequently used roads: As with small-scale confined pig production, the buffer distance varies according to the size of the farm.
- For aerosol transmission, the same rules apply as for the previous system: For units where significant investment in livestock health has occurred, incoming air is sometimes filtered in an attempt to reduce the risk of airborne infection.

Visitor and fomite control is a major focus, as both can bring pathogens to the farm. The following are the underlying principles:

- Only essential people have access to the farm and animals, and they follow guidelines that recommend changing of clothing and footwear, and hand-washing or showering.
- Farm deliveries are designed to minimize traffic from one farm directly to the next, and deliveries are made in order of health status: feed and equipment deliveries should go first to farms with high health status, then to contaminated facilities later in the week. Nucleus herds and AI units should only receive deliveries and visitors after a weekend of down-time, and always using decontaminated material.
- Decontamination of vehicles is necessary before their entry to the farm and driveways. Parking areas should be designed to prevent cross-contamination of workers and farm vehicles.
- Vehicles that transport pigs among farms are a major source of disease risk, so protocols for the effective disinfection of trailers and trucks are necessary.

The following are the key principles of vehicle decontamination:

1. Clean vehicles as soon as possible to reduce the pathogen load, and put used bedding and manure in an area where it will not re-contaminate cleaned vehicles.
2. Wash trailers with high-pressure water and soap, leaving no organic matter behind; any remaining organic matter may protect pathogens from disinfectants. Vehicle and trailer construction should be such that they can easily be washed.
3. Disinfect vehicles with a product designed for livestock that targets the pathogen being controlled, and ensure that the correct concentration, volume and contact times are fulfilled.
4. Leave vehicles to dry fully before transporting livestock. Cold weather is a significant constraint to vehicle cleaning. Cold temperatures prevent effective washing, preserve pathogens and make drying impossible. In cold climates, an indoor washing facility is essential for cleaning vehicles properly. If there is not enough time to let vehicles dry, forced air fans and heaters can facilitate the process.
5. Vehicle protocols need an appropriate level of inspection to ensure compliance; this can be both a visual and a swab/culture examination to ensure the job is properly completed.

Specialized veterinarians and technicians trained in disease control must continually update staff with information and techniques for preventing or eliminating disease, including on the following:

- Vaccines and strategic hygiene routines, with the help of medications, have eliminated clinical expression of well-known endemic diseases; for example, mange eradication protocols have successfully eliminated the skin parasite from most intensively housed herds.

- Novel diseases do occur, but with strategic research, methods can be introduced relatively quickly to control diseases. Management techniques and new vaccines have effectively brought porcine circovirus-associated diseases under control.
- A number of disease control measures and techniques now available for commercial farms can eliminate many pathogens from clinical relevance. The greatest challenge is often to ensure proper implementation of good husbandry practices.
- Progressive eradication of pathogens contributes to regional biosecurity by lowering the regional disease risk. Followed to its logical conclusion, this process ensures the ability to eradicate disease from the region or country.

These disease mitigation techniques are predicated by four principles:

1. Clean SPF pigs must be available to replace infected herds, hence the priority should be to select clean breeding stock.
2. Uncontaminated premises, either newly build or thoroughly cleaned and disinfected, are readily available.
3. Genetic advances are shared widely – through semen rather than live pigs where possible – hence the need for high biosecurity and enhanced monitoring of boar studs.
4. Cross-contamination of pigs during transport must be avoided. The priority should be to focus on vehicle cleaning.

Table 4 provides a summary of biosecurity measures that can be implemented in large-scale confined production systems.

TABLE 4
Large-scale confined production: summary of biosecurity measures

Biosecurity measures	Implementable Yes/No	Comments
Segregation		
Avoid introduction of pigs from outside farms, markets or villages	Y	Possible, particularly in outbreak situations with an emergency plan
Limit the number of sources of replacement stocks	Y	In place on most farms; encouragement to buy from SPF pyramids is possible
Use AI instead of moving sows or boars	Y	AI is widespread for economic and disease control reasons
Quarantine (isolation) for newly purchased animals	Y	Implementation is not uniform owing to economic constraints; it is more common in pig-dense regions where there is more disease pressure
Full fencing around and closed entrance to farm area	Y	
Ensure long distances between farms	Y	Practical when farms have the ability to plan the location of new buildings; air filtration systems can be implemented where distances cannot be changed
Install nets against birds	Y	Barns are generally enclosed and can keep birds from contact with pigs
Create loading area/bay at farm	Y	Dedicated loading facilities and pig movement protocols are common, for both economic and biosecurity reasons
Strict control of entrance/exit	Y	
Specific clothing and footwear for use at the farm	Y	Normal protocols on most farms

(continued)

Biosecurity measures	Implementable Yes/No	Comments
Shower with change of clothing and footwear	Y	Showers are common in large units; hand-washing facilities available on all farms
Exclusion of wild pigs and rodents	Y	Indoor pigs can be protected from wild pigs and wandering rodents
Permanent housing of pigs	Y	Normal practice
Ban the keeping of pigs at workers' homes	Y	Can be contractually required of employees
Keep animal species separate	Y	Most farms are single-species
Herd management: all-in-all-out system by compartment	Y	
Parasite control (including ticks)	Y	Most farms have programmes for parasite treatment and preventive vaccination
Fallow period between batches	Y	
Manure management (composting, spreading)	Y	Manure spreading is already regulated in most countries
Cleaning and disinfection		
High-pressure washer	Y	Washing/disinfection is part of the normal process on most farms
Low-pressure washer	Y	
Cleaning/disinfection of vehicles	Y	
Cleaning/disinfection of premises	Y	
Footwear cleaning station	Y	
Other accompanying pre-emptive measures		
Vaccination	Y	
Traceability: knowledge of identity of supplier herd	Y	Expertise is usually available to assess the pigs' health status at suppliers' facilities.
Transparency: knowledge of health status of supplier herd	Y	
Incentives for change		
Producers in this production system are aware of the risks of animal and zoonotic diseases, but are usually financially constrained and cannot afford to introduce some of the biosecurity measures required. Change can occur with regular communication of scientific findings on optimal biosecurity practices; if biosecurity practices are tied to farm loans/grants, insurance policies, i.e., grants to help share the costs of biosecurity infrastructure; and if biosecurity has a public good component, so costs should be shared with producers. The marketplace generally rewards low-cost production, so long-term investments are difficult to finance. In critical areas of biosecurity, where widespread adoption of a practice is required (e.g., no swill feeding), government regulation is needed. Resources must be devoted to communicating the need for the change and for enforcing the regulation.		

The pandemic H1N1 2009 outbreak has reinforced the need for biosecurity on confined pig farms. It is known that visitors and workers can introduce this, other influenza viruses and other pathogens to pigs. A protocol to limit visitors, screen those who have influenza symptoms and prevent entry of people until they stop shedding virus is recommended. At the time of writing this paper, CDC suggests that with influenza virus it takes up to seven days from onset of symptoms for shedding to subside in adults. Pig workers should therefore be considered for vaccination and other preventive measures.

Vaccination of pig herds for classical swine influenza has been suggested as a mitigation measure to reduce the clinical impact of the pandemic H1N1 2009 strain, and potentially to *reduce shedding in pigs. Commercial vaccines for other H1N1 viruses of swine are available, and are safe, but as yet their efficacy cannot be assured. If herds are vaccinated, serologically they will become positive for H1N1, unless tests are used to discriminate between pandemic H1N1 2009 and classical swine influenza. Producers should discuss vaccination with their consulting veterinarians, and should consider efficacy data before proceeding.*

Large-scale outdoor pig production

In this system, there is less ability to shelter animals from wildlife vectors and from exposure to soil, wildlife and birds. Where there are wild boars, feral pigs or a combination of both, domestic pigs that escape from large-scale outdoor farms can mingle with the wild population. In regions where there are no wild pigs, outdoor pig production may introduce pigs to the environment, resulting in a self-sustaining feral population. These feral pig populations can act as a reservoir for disease transmission to domestic pigs.

In parts of Sardinia, Italy, where the ASF virus is circulating, pigs are farmed using traditional practices, such as grazing free-range herds on vast communal lands to utilize acorns produced by evergreen oaks. Free-ranging pigs are considered the primary reservoirs of ASF virus in Sardinia, whereas wild boars probably play a secondary role. It is interesting to note that more intensive outdoor raising of local pigs, wild boars (*Sus scrofa*), bush pigs (*Potamochoerus porcus*) or collared peccaries (*Tayassu tajacu*) is reported in Europe (Spain, France, Slovenia, etc.), Africa (Gabon, Cameroon, etc.) and Latin America (Brazil, Venezuela, Peru, etc.).

The advantage of outdoor systems is that the population density of pigs is lower than in confinement housing, so the spread of disease may be slower as there are fewer susceptible animals and they are in less direct contact. However, biosecurity for outdoor systems is more difficult and needs a greater focus on the control of feedstuffs, water and pasture contamination, wildlife and human visitors (the last are thought to have played a role in the CSF and FMD outbreaks in the United Kingdom). Other factors, such as transportation, fomites and sources of breeding stock, still need to be considered, as the risks are the same as in the other production systems. Parasitic diseases, such as Trichuris and Ascariasis, may require pasture rest, rotation and soil management. Trichinosis, which is not normally seen in indoor pigs, may represent a biosecurity challenge in outdoor systems, as may diseases spread by wild pigs and other species. Diseases such as pseudorabies, brucellosis, leptospirosis and CSF may be more difficult to prevent, and require attention to fencing, and visitor and wildlife control. Water sources should not rely on surface water or streams, and should be secured from access by wild animals.

A key component of biosecurity planning for outdoor production is preventing the escape of pigs and the subsequent establishment of self-sustaining pig populations. The introduction of pigs to environments where they have never been before creates a population of an alien species; this can have a negative impact on the environment and maintain disease in a population, which is difficult to control.

Fencing, signs and visitor protocols that limit human access are equally important in outdoor systems (although there is less ability to control public contact). Signs are required to discourage visitors from entering pastures and to indicate that pigs must not be exposed to human food waste.

Table 5 provides a summary of biosecurity measures that can be implemented in large-scale outdoor production systems.

TABLE 5.
Large-scale outdoor production: summary of biosecurity measures and potential for adoption

Biosecurity measures	Implementable Yes/No	Comments
Segregation		
Avoid introduction of pigs from outside farms, markets or villages	Y	Pigs are confined to fields and access can be restricted
Limit the number of sources of replacement stocks	Y	Normal practice for most farms
Use AI instead of moving sows or boars	Y	Available in most regions
Quarantine (isolation) for newly purchased animals	Y	Possible, but enclosed housing may not be possible
Full fencing around and closed entrance to farm area	Y	A requisite for this production system
Ensure long distances between farms	Y	Larger distances may be required than in confined systems owing to the animals being continuously outside
Install nets against birds	N	Not possible, but feed can be sheltered and protected
Create loading area/bay at farm	Y	Designated entrance for loading that can be disinfected
Strict control of entrance/exit	Y/N	As pigs are in the field, visitor access is more difficult to control; signs are essential
Specific clothing and footwear for use at the farm	Y	Direct-access clothing can be controlled
Shower with change of clothing and footwear	Y	Possible, but more difficult if there are no buildings
Exclusion of wild pigs and rodents	N	Requires double fencing for pigs, and rodents cannot be controlled; keeping feed free from contamination is possible
Permanent housing of pigs	N	Housing and complete protection from elements are not possible
Ban the keeping of pigs at workers' homes	Y	Protocols and enforcement are possible
Keep animal species separate	Y/N	Can be achieved only if fencing is maintained
Parasite control (including ticks)	Y	Normal part of management
Herd management: all-in-all-out system by compartment	Y	Animals can be moved in batches; down-time is needed for pens and fields
Fallow period between batches	Y	Normal part of production, sometimes with soil tillage
Manure management (composting, spreading)	Y/N	Manure is self-spreading
Cleaning and disinfection		
High-pressure washer	Y	Available for equipment, but not useful for pens or fields
Low-pressure washer	Y	
Cleaning/disinfection of vehicles	Y	Can be normal part of protocol
Cleaning/disinfection of premises	Y/N	Farrowing hutches are possible, but fields or pens are not
Footwear cleaning station	Y	Easily achieved

(continued)

Biosecurity measures	Implementable Yes/No	Comments
Other accompanying pre-emptive measures		
Vaccination	Y	
Traceability: knowledge of identity of supplier herd	Y	Expertise is usually available to assess the pigs' health status at suppliers' facilities
Transparency: knowledge of health status of supplier herd		
Incentives for change		
Producers in this production system are aware of the risks of animal and zoonotic diseases, but are usually financially constrained and cannot afford some of the biosecurity measures required. Change can occur if biosecurity practices are tied to farm loans/grants and insurance policies, i.e., grants to help share costs of the biosecurity infrastructure; biosecurity has a public good component and so costs should be shared with producers; and in a marketplace for differentiated pork (free range/organic), licensing bodies certify production, as they can require biosecurity in their production criteria and have the means to inspect and certify changes.		

BIOSECURITY MEASURES FOR SERVICE PROVIDERS AND ALONG MARKETING CHAINS

Artificial insemination centres and boar keepers

The main concerns arise when the health status of boars at AI centres and on boar farms is not controlled, and when hygiene of semen collection is neglected. One boar may produce from 20 to more than 50 semen doses per week, so introduction of pathogens through this pathway is of major significance. The number of semen doses produced and the area in which they are distributed make AI centres a major potential source of infection. Practices such as pooling semen from multiple boars exacerbate the health risks to recipient farms.

In cases of natural mating provided by an external boar, animal movements are necessary, for example, sows in heat are moved to the boar's farm (or vice versa). Such movements between farms create significant health risks, and animal quarantine before reintroduction into the herd is usually not feasible.

Maximum efforts must constantly be directed to maintaining a high health status at AI centres through the purchase of boars whose disease-free health status has been verified. The implementation of quality assurance in these enterprises should be a priority. AI centres should be officially controlled, and veterinary services' certification against transmissible diseases (pseudorabies, CSF, ASF, etc.) may be required. Veterinary authorities should plan regular audits of AI facilities and practices. Traceability and quality control of the semen doses must be in place.

Promoting and facilitating farmers' investments in boar studs and training in pig AI may be a viable solution in developing and transition countries. Locally, there would be a biosecurity benefit from the decreased circulation of live animals from farm to farm.

Brokers and transporters

Service providers may understand the risk of disease spread, but may be under pressure to visit multiple farms on a single day, or may take short-cuts on decontamination.

Intermediaries and collectors link the different segments and systems in the pig sector. They are potential transmitters and must implement appropriate biosecurity measures at all times. Brokers and transporters should not transport animals that are showing obvious signs of illness or that come from a farm known to be affected by a disease, unless they follow instructions from the veterinary services and appropriate measures are taken before and after transportation.

Vehicles may transmit pathogens when manure containing disease agents is attached to their bodywork or tyres (although recent studies indicate that tyres are usually decontaminated by heat when the vehicle is driven) or has contaminated the vehicle cab. The driver should be responsible for cleaning and disinfecting the wheels (wheel arches and mudflaps), vehicle bodywork and inside of the cab.

Pig industry service providers should not have to enter pig buildings; if they do so, they must wear specific protective clothing and footwear and follow all visitor protocols. All clothing and footwear must be cleaned and disinfected or be disposable. Commercial incentives must not override biosecurity, and practices such as having visitors document their previous farm visits help to ensure compliance with biosecurity protocols.

Slaughterhouses

Hygiene and biosecurity standards vary widely in slaughtering facilities. In addition, many pigs are slaughtered on-farm, for local consumption and with no meat inspection. Slaughterhouse workers, butchers providing services to individuals, and producers who slaughter their own pigs are all at risk of contracting zoonotic diseases. On premises where pigs are slaughtered, visitors' access and the entry of animals other than those slaughtered must be controlled. By-products from slaughterhouses, such as blood and offal, are sometimes used to feed pigs in the vicinity, thereby creating significant risk of disease transfer. Public investment in environmental protection, urban sanitation, water supply and drainage or hygiene in slaughterhouses is often inadequate, thus increasing the risk of disease transmission.

Slaughterhouses are a risk point for the spread of animal diseases. Animals from different species and of different origins are all concentrated in one location and there is important movement of people and vehicles. All incoming animals must be carefully observed for any signs of disease; many notifiable diseases are first detected at the time of slaughter. Animals with clinical signs of disease, such as a fever, should not enter the food chain.

Slaughterhouse management involves the enforcement of measures for strict hygiene and biosecurity, including:

1. cleaning and disinfecting the entire slaughterhouse premises at the end of each working day to ensure that it is free of manure, hair and other debris that may harbour pathogens;
2. thorough cleaning and disinfection of all vehicles used for transporting live pigs, and of the wheels and undercarriages of all other vehicles before they leave the premises;
3. banning visits to pig farms by operators and their staff;
4. installing a pest management programme;
5. monitoring the health status of all workers.

Application of these basic measures is feasible in all environments.

Live-animal markets and exhibitions

Live-animal markets, particularly those in developing countries, are essential venues for trade. The animals sold are mainly piglets or young replacement breeding stock, such as gilts. Live-animal markets are clear mixing points and a potential source of disease spread. Moreover, as traders are often intermediaries/collectors who collect animals from different locations, pig producers do not have any assurance about the health and sanitary status of the animals. Bio-containment of infection is vital at these sites, and contacts among animals of different origins must be controlled. As far as possible, animals that have been taken to the market but not sold should not be reintroduced into the home herd without a quarantine period. Waste water and slurries must also be managed correctly.

Live-animal markets could play a positive role in the control of pig diseases as places where information can be disseminated and collected. Active surveillance for diseases can also be carried out at the marketplace, but its efficiency depends on having a traceability system with farm or pig identification.

Exhibitions where high-value animals are shown to the public are also key risk points for animal disease transmission; particular attention must be paid to observing an appropriate quarantine period for the exhibited animals before they re-enter the home herd.

CHALLENGES IN THE IMPLEMENTATION OF BIOSECURITY MEASURES

Sections 1 and 2 describe the various routes of contamination and the principles of biosecurity. Farmers' ability to implement on-farm biosecurity measures depends on the characteristics of the production system they operate, their knowledge of technical matters and the availability of cash. Controlling diseases in pig farms is a continuous process, which requires investments. The introduction of new biosecurity measures to a farm may also require important changes in husbandry practices. Global biosecurity issues are relevant to all environments, but may be particularly challenging in developing and transition countries.

Social and economic factors

The pig production systems in a given area are largely determined by the demands that people and society place on them. Knowledge of the diversity of systems and understanding of the people involved in pig production and their motivations for keeping animals will help the development of strategies for implementing sustainable biosecurity measures on-farm and along production and marketing chains. Each of the systems described in the previous sections entails a set of regulations and specific economic and social factors that influence whether people are likely or able to adopt the proposed measures (e.g., the social and cultural acceptability of measures, the costs that people can afford to pay, and the existing regulations, incentives and penalties).

Important issues for producers and other stakeholders involved in pig production are their asset bases, their perceptions of risk, their interactions with the wider community (including their own roles and responsibilities within the community and with the government), and prevalent consumer demands. Tools such as livelihood analysis, value chain mapping and cost/benefit or cost-effectiveness analysis are beneficial in helping to understand these issues. Farmers' motivations and the degree to which pigs contribute to farmers' income portfolios are identified through livelihood analyses; this increases understanding of the resources available and the drivers for or against investment in biosecurity measures. Value chain mapping and institutional analyses provide insight into the people involved in pig production, and therefore into who should be involved in developing biosecurity measures.

When designing and implementing measures at the household level, it is important to undertake a financial evaluation using, for instance, cost-effectiveness or cost/benefit analysis. Cost-effectiveness enables the stakeholder to define the acceptable level of risk and then look for the most economical method of achieving this. This means considering the set-up and recurrent costs for the proposed biosecurity interventions, and the costs of disrupting the production system. When designing interventions, their socio-cultural and religious acceptability should be considered, as should the new measures' impacts on the roles and responsibilities of men and women. Cost/benefit analysis also requires an estimate of the potential benefits to the producer, such as increased production, increased efficiency or decreased risk of losing investment. This process requires producers to have reasonably accurate records of costs and income over a sufficient period.

Understanding the impacts of disease on society and communicating these effectively throughout the production and marketing chains will be essential for improving the uptake of biosecurity measures.

Sharing of responsibilities between the private and public sectors

The maintenance of good health in livestock through appropriate biosecurity measures is important to both the private and public sectors: all the private stakeholders involved in the production and marketing chain, the ministries of health and agriculture, and national/regional trade organizations. When recommending the implementation of biosecurity measures, it is necessary to consider which sector should pay for what and to determine the appropriate balance between incentives for voluntary implementation and regulations.

In recent years, a debate on whether to classify animal health as a public or a private good has emerged. There is now consensus that prevention and control of major diseases, particularly those that are transboundary and those that have an impact on human health, should be totally or partially considered as a public good. For optimal implementation of biosecurity measures, the private and public sectors need to collaborate closely and with mutual trust. Prevention and control programmes should be supported by public funds or by a combination of public and private funds.

The public sector has a strong motive for decreasing the risk of disease introduction and spread, because of the imperative to limit impacts on the national economy. Private animal producers have an equally strong motive for decreasing risk, as they bear the brunt of the impacts (at least initially). Producers also face recurrent losses due to endemic diseases, and this may be the strongest reason for them to apply biosecurity measures.

Positive examples of public-private partnerships are disease eradication programmes; the eradication of pseudorabies in the United States and other countries are recent examples of State-producer partnerships that achieve long-term benefits.

Animal health systems and veterinary services

Developed countries have progressively improved the health status of their national herds through advances in veterinary science and the establishment of appropriate animal health systems comprising public and private veterinary infrastructure and services to the livestock sector. Important livestock diseases have been eradicated at the national level; measures to safeguard against their reintroduction have been initiated. Other endemic diseases are under surveillance or targeted for eradication, where possible. Farmers have access to both public and private veterinary services, while research institutions and public and private extension services foster continuous improvements in livestock industries.

The situation in developing countries varies. The livestock sector is characterized by a large number of small producers, for whom livestock rearing is a major source of livelihood.

There is an absence of influential livestock owners' associations and there is often a need to enhance the capacity and resources of public veterinary services so as to improve the quality and coverage of services provided to livestock owners. Investments in effective control of the animal diseases that can endanger human health are often inadequate. The importance of subsistence livestock production, market failures, the dynamics of contagious diseases, economic constraints and institutional weaknesses all need to be considered and understood when programmes to improve animal health systems are designed.

Education and extension services

The availability of an appropriately trained and skilled workforce is a critical requirement in developing a livestock sector, and education and extension must be undertaken for all stakeholders, after their needs have been identified.

In many regions, animal farming is considered a speculative side-activity, especially in urban and peri-urban areas. Animal owners are often government officers or traders who usually employ salaried workers to look after pig herds; such workers should be specific targets for extension and training programmes on biosecurity. Adapting and disseminating training and extension material is still a challenge for national extension services, but they can be assisted by universities, national research centres, non-governmental organizations (NGOs) or international organizations.

The role and importance of communication in promoting biosecurity

Communication is the process of mediating dialogue among all relevant stakeholders, to identify the attitudes, perceptions and needs of each participant. It involves formulating explanations, recommendations and messages about the policies and activities that best address the collective interest. Communication is also a tool for advocacy, promoting the importance of biosecurity for livestock and livelihoods in key sectors, especially among policy-makers and in farming communities. Communication is essential for the "buy-in" of all parties to biosecurity policies and activities, and for ensuring that these are subsequently adopted and implemented effectively. Communication is also a way of creating an environment or culture that supports activities designed to satisfy the collective interest.

Communication interventions for biosecurity in pig production need to bring together the various stakeholders – including pig keepers, owners and handlers, technical specialists and policy-makers – and to facilitate the sharing of information and opinions on an equal footing among them. It should aim to ensure that policies are not imposed in a top-down fashion, and that those who will be affected by and expected to implement the policies in question have their concerns and needs taken into consideration.

Given the wide range of pig production and marketing systems, and the rapidly expanding and transnational trade in pork products, the core areas that need to be supported by communication, advocacy and social mobilization interventions include:

1. promoting and establishing biosecurity as professional and social rules along the entire production/marketing/consumption chain;
2. promoting community-based surveillance/reporting of disease by producers and service providers, and facilitating active public engagement in control measures in case of outbreaks;
3. advocacy to ensure greater interaction and coordination among national animal and public health systems, and greater engagement between the public and private sectors.

It is critically important to understand that communication cannot replace the provision of services, or overcome structural barriers such as the lack of economic means. Instead, it can use advocacy to influence the provision, availability and uptake of the necessary services, and to encourage the use of subsidies and economic aid to farmers and producers for promoting and improving biosecurity.

The key to changing behaviours and practices lies in people's perceptions of the level of risk. Communication strategies need to build on the way people perceive their own situations and the environment in which they act. Communication cannot be merely prescriptive, imposing rules on which behaviours to practise or avoid; strategies must take into account the complex interplay among perception of risk, response, behavioural intent and message design.

The traffic light system

Although biosecurity measures are part of standard operating procedures in some production systems, it can be difficult to maintain high levels of biosecurity over long periods in less intensive production systems; the greater the intensity of biosecurity measures, the more they impinge on daily routines and the more resources (time and financial) are required. There are periods when their application is mainly relevant to the producer her-/himself, and others when a specific threat emerges (outbreaks of zoonotic diseases or TADs) and biosecurity becomes an issue of public interest.

A useful concept is the traffic light system, which indicates changing biosecurity needs (and therefore practices) as the threat to public interest increases or decreases (Table 6).

To function effectively, this system must be clearly understood, which requires significant work with stakeholders and well-prepared advice on the biosecurity measures

TABLE 6.

The traffic light system for biosecurity measures

Colour	Level of threat	When applicable
Green	Low	Disease not present in the country or neighbouring countries
Amber	Medium	Disease present in neighbouring countries but at low level and not close to border
Red	High	Disease present in neighbouring countries close to border or at high levels

to implement at the various stages. In addition, there must be a well-functioning disease surveillance system and an established method of signalling when the threat increases and to what level. This may be possible in larger commercial systems with good chains of command, but is more difficult to implement in scavenging and small-scale confined production systems, because of the greater difficulty in rapidly transmitting messages about increased risk and the actions to take.

COMPLEMENTARY TOOLS: VACCINATION, TRACEABILITY, COMPARTMENTALIZATION

Infectious disease prevention and control have three major goals, each of which has one or more methods and tools for achieving it:

1. Find infection fast: surveillance.
2. Kill infected animals quickly and humanely: targeted culling and disposal.
3. Stop infection from spreading: biosecurity, vaccination.

Disease prevention and control are most effective and efficient when all three goals are achieved together. Vaccination (under certain circumstances and in conjunction with biosecurity), traceability and compartmentalization are all important tools for achieving these goals.

Vaccination programmes

Vaccines are available for many major infectious diseases, including FMD and CSF, but not ASF. Vaccination reduces the pressure of pathogens, shedding and disease pressure in the region. The use of vaccines must be controlled. Recommended vaccines must have been tested for efficiency, be appropriate to the context and be produced in accordance with existing standards (OIE). Literature on vaccination and vaccination programmes is available in Annexes 8 and 9.

Premises definition and animal identification

Farms should be identified by a standardized definition for use in a database. An example of a definition of premises for traceability purposes is: "A swine premises is a contiguous land location, based on land title records, including all structures housing pig(s) and other livestock."

It may be possible to define premises based on legal deeds that are kept up to date in municipal databases; land title records are normally maintained accurately for tax purposes. However, such records may not be available for many smaller producers, and sometimes even for larger ones.

Some countries and commodities require permanent identification of all animals. This gives the option of linking premises to animal identifications, making it possible to trace each animal to specific premises. Identification without a movement log requires a tag or other identification for each premises. Permanent identification of each individual animal is logical for beef and dairy cattle. In pork production, pigs sometimes need to be identified, but traceability can also be achieved without the identification of each pig.

In many countries, pigs going for slaughter have a permanent tattoo identification, which is read on the slaughter line for payment purposes. This identification method could be used for traceability, if each tattoo is linked to a specific premises. The standardization of tattoos across the country would allow traceability back to the last premises for market pigs.

Compartmentalization

Zoning and compartmentalization are disease management strategies that pursue essentially the same objective: to establish animal populations with distinct health status, based on effective separation of populations of different status and application of biosecurity measures to prevent the introduction of infection. Zoning relies more heavily on geographic factors, such as natural or human-made barriers, while compartmentalization focuses more on management and biosecurity within the establishments comprising the compartment, to ensure the maintenance of health status.

Conclusion

Pigs are susceptible to a wide range of diseases that affect productivity and, *de facto*, the producer's income, whether he/she is a large-scale commercial producer or has just one scavenging pig. The 2009 influenza pandemic caused by a new strain of H1N1, was a timely reminder of the risks for human health related to livestock production – the same livestock, including pigs, that supports the livelihoods and food security of almost a billion people.

Among the solutions required to minimize the risk of disease spread, the strengthening of biosecurity in pig production and marketing chains is a priority. It does not reduce the need for appropriate preparedness plans and adequate resources to control disease outbreaks once they occur, but it is proactive, has a preventive impact and enables producers to protect their assets.

A thorough knowledge of pig disease epidemiology and the routes of disease transmission has enabled specialized institutions, public services and producers themselves to develop biosecurity measures for the pig sector. Some of these measures are applicable across all production systems, while others are not. Each production system requires a specific set of biosecurity measures, and although decision-makers should not compromise on public health, all initiatives taken to strengthen biosecurity in pig production must consider the technical and financial consequences that implementation of these measures will have for individual stakeholders. The social and economic impacts of closing farms that cannot comply with the required level of biosecurity must also be carefully assessed, and appropriate accompaniment measures must be in place.

Further work is required to identify and describe the direct interests of the producers and other stakeholders involved in the production and marketing chain and the interest of society in general.

The private sector can and will implement biosecurity measures when these comply with its own will or interests. Other measures require appropriate regulations, incentives and enforcement capacity. Mutual trust between the public and private sectors is essential. For zoonotic diseases, pre-emptive discussions among public health agencies, agricultural departments, veterinary services and the pig industry should be organized to ensure mutual understanding and cooperation in the interest of society in general. Strengthened collaboration between public services and the private sector is crucial for better disease control.

The key to changing behaviours/practices in relation to enhanced biosecurity lies in people's perceptions of the level of risk and the resources available at the production level. For meaningful change to take place in rural communities, a holistic, multi-sectoral approach is required to identify critical risk points for disease spread and to understand the evolution of diseases in specific environments, the impacts of diseases on people and the impact that people have or can have on diseases. The promotion of appropriate sustainable biosecurity measures in scavenging and small-scale confined production systems requires the use of participatory methodologies and a well-designed communication strategy.

Annexes

Annex 1
Characteristics of selected biosecurity measures

Biosecurity measures	Impact		Time	Costs		Barriers to implementation	
	Potential effect on reducing risk	Persistence of effect	Rapid implementation possible?	Initial cost	Recurrent costs	Disruption of production system	Culturally acceptable?
Segregation measures							
Avoid introduction of pigs from outside farms, markets or villages	+++	+++	Y	$$	$$	- - -	Y/N
Limit the number of sources of replacement stocks	+++	++	Y	$	$	- -	Y
Use AI instead of moving sows or boars	++	++	N	$$	$$	-	Y/N
Quarantine for newly purchased animals	++	++	Y/N	$$	$	-	Y
Full fencing around and closed entrance to farm area	++	+++	Y	$$$	$	-	Y
Ensure long distances between farms	+++	+++	N	$$$	Ø	- - -	Y
Install nets against birds	+	++	Y	$$	$	-	Y
Create loading bay at farm	+	++	Y	$$	Ø	-	Y
Strict control of entrance/exit	+++	+	Y	$	$	- -	Y/N
Specific clothing and footwear for use at the farm	++	++	Y	$	Ø	-	Y/N
Shower with change of clothing and footwear	+++	+	Y	$$	$$	-	Y
Exclusion of wild pigs and rodents	+	+++	Y	$$	$$	-	Y
Permanent housing of pigs	++	++	N	$$$	$$$	-	Y/N
Ban the keeping of pigs at workers' homes	++	+++	N	$	Ø	- -	Y/N
Keep animal species separate	++	++	N	$$	$	- -	Y/N
Parasite control (including ticks)	++	+	Y	$$	$$	-	Y

(continued)

Biosecurity measures	Impact		Time	Costs		Barriers to implementation	
	Potential effect on reducing risk	Persistence of effect	Rapid implementation possible?	Initial cost	Recurrent costs	Disruption of production system	Culturally acceptable?
Herd management: all-in-all-out system by compartment	+++	+	Y/N	$$	$$	-	Y
Fallow period between batches	+++	+	S	Ø	Ø	- -	Y
Manure management (composting, spreading)	+	+	N	$$	$	-	Y/N
Avoid non-boiled swill feeding	++	++	Y	$$$	$$$	-	Y/N
Cleaning and disinfection measures							
High-pressure washer	+++	+	Y	$$$	$$	- -	Y
Low-pressure washer	+	+	Y	$$	$$	- -	Y
Cleaning/disinfection of vehicles	++	+	Y	$$	$$	-	Y
Cleaning/disinfection of premises	+++	+	Y	$$	$$	- -	Y
Footwear cleaning station	++	+	Y	$	$	-	Y
Other accompanying pre-emptive measures							
Vaccination	++	++	Y	$$$	$$$	-	Y
Traceability: knowledge of identity of supplier herd	++	++	Y	?	?	-	Y
Transparency: knowledge of health status of supplier herd	++	++	N	$$$	$$$	-	Y/N

+++ Strong positive effect
++ Moderate positive effect
+ Weak positive effect
- Weak positive effect
- - Moderate negative effect
- - - Strong negative effect
$$$ High cost
$$ Moderate cost
$ Low cost
Ø Minimal cost
? Unknown

Annex 2
Potential for uptake of selected biosecurity measures

Biosecurity measures	Scavenging pig production systems	Small-scale confined production systems	Large-scale confined production systems	Large-scale outdoor production systems	Intermediaries and service providers	AI centres
Segregation measures						
Avoid introduction of pigs from outside farms, markets or villages	N	N	Y	Y	NA	NA
Limit the number of sources of replacement stocks	Y/N	Y	Y	Y	NA	NA
Use AI instead of moving sows or boars	N	Y	Y	Y	NA	Y
Quarantine (isolation) for newly purchased animals	Y/N	Y	Y	Y	NA	Y
Full fencing around and closed entrance to farm area	N	Y/N	Y	Y	NA	Y
Ensure long distances between farms	N	N	Y	Y	NA	Y
Install nets against birds	N	Y	Y	N	NA	Y
Create loading bay at farm	N	Y	Y	Y	NA	Y
Strict control of entrance/ exit	N	Y/N	Y	Y/N	NA	Y
Specific clothing and footwear for use at the farm	N	Y	Y	Y	Y	Y
Shower with change of clothing and footwear	N	N	Y	Y	Y	Y
Exclusion of wild pigs and rodents	N	Y/N	Y	N	NA	Y
Permanent housing of pigs	N	Y	Y	N	NA	Y
Ban the keeping of pigs at workers' homes	N	Y/N	Y	Y	Y	Y
Keep animal species separate	N	Y/N	Y	Y/N	Y	Y
Parasite control (including ticks)	Y/N	Y	Y	Y	NA	Y
Herd management: all-in-all-out system by compartment	N	Y/N	Y	Y	NA	NA

(continued)

Biosecurity measures	**Scavenging pig production systems**	**Small-scale confined production systems**	**Large-scale confined production systems**	**Large-scale outdoor production systems**	**Intermediaries and service providers**	**AI centres**
Fallow period between batches	N	Y/N	Y	Y	NA	NA
Manure management (composting, spreading)	N	Y	Y	Y/N	NA	Y
Avoid non-boiled swill feeding	N	Y	Y	Y	NA	Y
Cleaning measures						
High-pressure washer	N	N	Y	Y	Y/N	Y
Low-pressure washer	Y/N	Y	Y	Y	Y	Y
Cleaning of vehicles	N	Y	Y	Y	Y	Y
Cleaning of premises	Y	Y/N	Y	Y/N	NA	Y
Footwear cleaning station	N	Y	Y	Y	Y	Y
Disinfection measures						
Disinfection of vehicles	N	Y/N	Y	Y	Y	Y
Disinfection of premises	N	Y/N	Y	Y/N	NA	Y
Footwear disinfection	N	Y	Y	Y	Y	Y
Other accompanying pre-emptive measures						
Vaccination	Y/N	Y	Y	Y	NA	Y
Traceability: knowledge of identity of supplier herd	Y/N	Y	Y	Y	NA	Y
Transparency: knowledge of health status of supplier herd	N	Y/N	Y	Y	NA	Y

Y: yes, i.e., implementation of the option (the measure) is possible, even if some efforts are needed.
N: no, i.e., the option is not achievable.
NA: not applicable.

Annex 3
An overview of disinfection procedures

Disinfection should not be considered a stand-alone measure but one step of a more global set of biosecurity procedures. **It should always follow effective and comprehensive cleaning** that has already removed all visible contaminating materials.

How to proceed: Before starting disinfection, the site has to be clean – brush surfaces with water and soap, and let them dry. All organic matter must be removed – which requires thorough washing. Use of a dilute detergent solution can help remove faecal material. Some equipment may need to be displaced to allow proper removal of all dirt. High-pressure washing is advised where possible. Drainage should be controlled, to prevent environmental pollution. After cleaning, spray the disinfectant on the surface and allow it to react.

The selection of the disinfectant should take into account:

- the official approval of the authorities;
- the spectrum of activity;
- the efficacy and practicability under farm conditions: e.g., ease of handling, risk of corrosion of equipment, temperature stability;
- safety: e.g., for operative staff, the environment;
- other points: cost, risk to store, etc.

The conditions for using the disinfectant should be strictly respected (e.g., dilution recommendations, water composition).

After being cleaned and disinfected, materials or vehicles should be allowed to dry before reuse. When re-populating the premises with pigs, a minimum down-time should be applied to ensure sufficient time for drying (e.g., three days).

Commercial desiccants are available to quicken the drying process if necessary. Fans and heaters can also be used.

When an enclosure or paddock is to be disinfected:

- remove equipment that can be displaced, and clean thoroughly;
- if the floor is solid (concrete), it must be washed, while controlling drainage;
- disinfect equipment and the floor as indicated above;

- if the floor is soil, proper disinfection is not possible, but measures to reduce the load of infectious agents can be taken:
  - attempt to clean the floor surface as much as possible (e.g., remove faecal matter);
  - implement surface disinfection: choose a disinfectant that may be effective in the presence of organic matter;
  - leave the pens empty for at least five days before restocking.

When a disease of major concern affects a herd raised outdoors in fields, the animals must be removed from the plots with culling or destruction, depending on the disease. Before the land is reused, ploughing and reseeding are recommended.

Note: Influenza virus is susceptible to many disinfectants and can easily be destroyed. The United States Environmental Protection Agency lists more than 500 disinfectants that are effective against influenza A viruses. The full list can be found at www.epa.gov/oppad001/influenza-a-product-list.pdf.

Annex 4
OFFLU strategy document for surveillance and monitoring of influenzas in animals[2]

BACKGROUND

General

Animal influenza threatens animal health and welfare, agricultural productivity, food security, and the livelihoods of farming communities in some of the world's poorest countries. The emergence of H5N1 highly pathogenic avian influenza (HPAI), the 1918 pandemic influenza, and pandemic H1N1 2009 (pH1N1) highlight the potential for animal influenza viruses to evolve into global public health threats. To ensure that the impact and risks for animals and humans are kept to a minimum it is vital that the animal health sector take the lead in monitoring influenza viruses in animals, in analysing the data, and in sharing this information with the international community particularly with public health partners.

There is a spectrum of influenza viruses circulating in animals that ranges in its ability to affect animal and human health: HPAIs have a severe impact on animal health, and human infections with H5N1 HPAI have severe consequences; other notifiable avian influenzas are a threat to poultry health; equine influenza has a significant impact on equine health and performance; and swine influenza is often a mild disease in pigs.

The objectives and nature of animal influenza surveillance, and the response to positive findings depend on many factors including the significance of the influenza virus for animal and public health; the characteristics of the virus (which may evolve over time); the demographics of the host population; the epidemiology of the infection; geographical factors; involvement of wildlife; the type of control strategy being implemented; whether the disease is OIE-listed (notifiable to the international community); and the capacity of the veterinary services to undertake surveillance and control. The response to disease detection must be proportionate to the risk and the exit strategy should always be considered when introducing any surveillance or control policy.

Timely sharing of virological and epidemiological information between the animal and the human health sectors and other key partners is crucial in developing a better understanding of influenza viruses and their risks, and for providing an early warning to emerging threats. On a global level this is underpinned by the level of reporting of important virological and epidemiological data to the relevant international organizations.

[2] For the latest version of this document see www.Offlu.Net/offlu%20site/offlusurveillanceph1n1_180110.Pdf.

There are horizontal objectives that should apply for all animal influenza surveillance, these include:

- early detection of mutations or reassortments that may alter risks for animal or public health, and inform preparedness and control strategies, e.g., for influenza viruses circulating simultaneously in human and animal populations;
- to gather information to develop a better understanding of influenza viral characteristics, epidemiology, and risk factors, including in virus reservoirs;
- to assess the genetic basis of important viral characteristics such as antiviral resistance, transmissibility, and pathogenicity in different species;
- to monitor the performance of diagnostic tools that aim to detect new influenza viruses.

Owing to the wide range of characteristics and impacts of different influenza viruses in different animal species, the objectives of surveillance for influenza viruses in these species – and the response to positive findings – will vary accordingly.

Some more specific examples of objectives include:

- early detection of animal disease, allowing rapid containment and/or control in affected populations;
- to gather antigenic information and biological material for early preparation of animal vaccines, e.g., for equine, avian, and swine influenzas; to detect antigenic drift or shift; to match vaccine strains with field virus; and to contribute to preparing vaccines against potential emerging human pandemic viruses;
- to assess animal population immune response when vaccination is being implemented for prevention or control in animals;
- to detect infected vaccinated animals in vaccinated populations.

Each module in this document will describe the main objectives of surveillance for influenza in different animal species.

Pandemic H1N1 2009

Currently, pandemic H1N1 2009 (pH1N1) viruses are having a substantial impact on public health globally. Although pH1N1 infections in animals appear to cause varying clinical signs in different species, at this stage evidence does not suggest that infections in animals have a significant impact on public or animal health.

Occurrences of pH1N1 in several species of animals are not surprising given the high prevalence of the virus in human populations, the known susceptibility of some animal species to influenza virus infection, and level of contact between humans and animals. Currently pH1N1 has no significant adverse impact on animal health, it is therefore considered to be primarily a human disease with animals not playing a significant role in the occurrence of human infections. The response to the detection of infections in animals must be proportionate to the risk posed to humans and animals; it is recommended that control measures such as culling are not implemented when the virus is detected in animals. It is also recommended that restrictive trade measures are not taken against countries experiencing outbreaks of pH1N1 in animals.

Surveillance for pH1N1 should be a component of an overall strategy for surveillance of influenza viruses in animals. Surveillance for pH1N1 in susceptible animal species, in particular pigs and turkeys, has been recommended so that any changes in epidemiology or viral characteristics that might alter the risks to animal or human health are detected early.

Main objectives for surveillance of pandemic H1N1 2009 in animals

- Public health – Timely identification of mutations in pH1N1 viruses, or reassortments of pH1N1 with other influenza viruses in pigs and other animals that might be of public health concern. Monitoring of important molecular markers such as for resistance to antiviral drugs or for increased pathogenicity. This knowledge is used to inform preparedness, response, and communication plans.
- Animal health – Detect infections with pH1N1 in animal populations and identify changes in the epidemiology and virulence for pigs and other animals infected with pH1N1 which might have a negative impact on animal health and welfare, productivity, and economics.

Current evidence suggests that the majority of animal infections with pH1N1 are occurring in pigs, and that this species should be the priority when it comes to surveillance for pH1N1 in animals. Depending on the epidemiological situation and current scientific evidence, countries wishing to establish a surveillance system for pH1N1 may also consider including other species at risk and/or that have been demonstrated to be susceptible.

There is a need to balance the short-term and long-term objectives of surveillance for influenza viruses in animals. Surveillance systems for pH1N1 should, where possible, be adaptable to broader influenza surveillance in animal species.

Structure of the document

This document is a dynamic modular document that aims to provide an overview of the objectives and options for surveillance for animal influenza viruses in several different animal species. Contributions for each module are provided generously by experts who contribute to OFFLU, the OIE-FAO joint network of expertise on animal influenza.

The materials in this document are relevant to the disease situation and scientific evidence available at the time of writing. Each module is dated according to the time that it was written. If the disease situation or characteristics of an influenza virus change, the approach to surveillance and recommended response may be modified accordingly.

Modules

1. Surveillance for influenza in pigs
   a. Swine influenza viruses – under development
   b. Pandemic H1N1 2009 (pH1N1) in pigs – available (see below)
   c. Other influenza viruses affecting pigs – under development
2. Surveillance for influenza in birds
   a. Notifiable avian influenza in domestic poultry – under development
   b. Pandemic H1N1 2009 (pH1N1) in poultry – available
   c. Avian influenza in wild birds – under development
   d. Other influenza viruses affecting birds – under development
3. Surveillance for influenza in horses – under development
4. Surveillance for influenza in companion animals – under development
5. Surveillance for influenza in other animal species – under development

Surveillance for pandemic H1N1 2009 in pigs

Pandemic H1N1 2009 (pH1N1) is spreading globally from human to human. Sporadic occurrences of pH1N1 infections in pigs have been reported to the OIE. Experimental studies have also demonstrated that pigs are susceptible to pH1N1 virus isolated from humans and that the virus can be transmitted between pigs. Animal infections most likely result from contact with infective humans.

Main objectives of surveillance for pandemic H1N1 2009 in pigs

- Public health – Timely identification of mutations in pH1N1 viruses, or reassortments of pH1N1 with other influenza viruses in pigs and other animals that might be of public health concern. Monitoring of important molecular markers such as for resistance to antiviral drugs or for increased pathogenicity. This knowledge is used to inform preparedness, response, and communication plans.
- Animal health – Detect infections with pH1N1 in pig populations and identify changes in the epidemiology and virulence for pigs and other animals infected with pH1N1, which might have a negative impact on animal health and welfare, productivity, and economics.

Surveillance approaches

Detection of pH1N1 can be achieved using the following components of general and targeted surveillance. The degree to which each component is implemented is dependent upon the disease and the country situation. However, the combination of some or all of these methods will improve the sensitivity of surveillance.

Note: PH1N1 infections in pigs may lead to inapparent infections or may cause clinical signs that are indistinguishable from other influenza infections known to commonly circulate in pigs.

General surveillance:

Disease detection – Clinical disease - suspicions of influenza-like illness (ILI) - detected by animal owners, producers, veterinarians or other animal health workers; as part of the investigation, consideration should be given to diagnostic testing for pH1N1. In cases where suspicion of pH1N1 is high, including when there is an epidemiological link with ILI in humans or animals the veterinary authorities should be informed.

Targeted surveillance:

Targeted or risk-based surveillance is the preferred approach over statistically based surveys for early detection of pH1N1. By targeting surveillance to high risk groups in the population, greater efficiency and cost effectiveness will be achieved.

Sample targets can include but are not restricted to:

- Laboratory detection – Supplementary testing of samples submitted to laboratories for respiratory syndromes. Laboratory surveillance should focus on virological and molecular detection of pH1N1. All laboratory-confirmed pH1N1 infections should be communicated to animal health authorities for further investigation.
- Slaughterhouse or marketplace surveillance – Testing of animals with signs of respiratory disease consistent with ILI (including at post-mortem in slaughterhouses).

- Animals showing ILI at points of concentrated gathering such as markets, auctions or fairs.
- Farms epidemiologically linked to known infected farms.
- ILI in animals linked to known human cases.
- Pigs in close contact with humans showing ILI.

Categories of data needs

- Basic epidemiological information:
  - location and date;
  - farm type and demographics;
  - date(s) when signs first started and when samples were taken;
  - morbidity, mortality, clinical signs;
  - link to suspected human cases.
- Molecular genome sequencing: Full genome sequencing provides important information about the origins, evolution, and characteristics of the virus including genetic reassortment. Full genome sequencing is preferred, and is important in assessing the genetic basis of antiviral resistance and pathogenicity in different species. If full genome sequencing is not possible, partial genome sequencing can provide some information.
- Antigenic data: Antigenic data will provide important information to ensure that diagnostic reagents are compatible with circulating field viruses and that diagnostic tests are therefore fit for purpose. It is also important to ensure that vaccine efficacy is optimal in terms of matching vaccine antigen to field viruses.

Reporting and response

All relevant findings from pH1N1 surveillance in animals including positive results from laboratory testing should be reported to animal health and public health authorities at the appropriate level. It is recommended that countries share information with other relevant stakeholders including local public health authorities.

Occurrences of pH1N1 and any other influenza viruses not previously reported in animals should be immediately notified to OIE by national veterinary authorities as an emerging disease.

Information about the epidemiological and viral characteristics of pH1N1 in pigs should be shared with the wider scientific community. This includes depositing genetic sequence data from pH1N1 isolated in animals into publicly available databases.

Under the current epidemiological situation, the response to pH1N1 infection in pigs should be proportionate. In particular:

- Culling of infected pigs is not recommended.
- Clinically ill pigs should not be shipped or sent to slaughter.
- Temporary movement restrictions of pigs between enterprises may be implemented.
- Movements of live pigs between holdings of the same enterprise may be allowed under licensing by the veterinary authorities, to alleviate animal welfare concerns.
- Healthy pigs from infected farms can be sent directly to slaughter.
- Vaccination for pH1N1 in pigs is not currently available or recommended.

Risk communication

It is important that veterinary and public health authorities develop a coordinated risk communication strategy following positive surveillance findings. The risk communication strategy should strive to maintain an appropriate level of awareness among key stakeholders and the general public while not creating undue concern.

Outbreak investigation

Further to a positive surveillance finding, an outbreak investigation should aim to gather all relevant and useful epidemiological and virological information, and should be conducted without undue delay.

Role of epidemiological studies and research

It is recognized that valuable information can be gathered through epidemiologic studies and other research to inform the main objectives of surveillance for animal influenza. It is beyond the scope of this strategic document, however, to include all of the options under these categories. A recommendation would be that countries maximize the use of such studies and research to inform their surveillance programmes, for example through building inter-sectoral partnerships with academic and other partners conducting such research.

Annex 5
Glossary of definitions[3]

All-in-all-out A strategy for controlling infectious disease: The building (section, room, etc.) is emptied of all animals, then cleaned and disinfected and left empty for drying before being repopulated. During the down-time, the entire building is empty and clean. (*Definition by the authors*.)

Animal health status The status of a country or zone with respect to an animal disease, according to the criteria listed in the relevant chapter of the *Terrestrial Code* (OIE, 2008b) dealing with the disease.

Animal identification system The inclusion and linking of components such as identification of establishments/owners, the person/people responsible for the animal(s), movements and other records with animal identification.

Animal traceability The ability to follow an animal or group of animals throughout all stages of its/their life/lives.

Artificial insemination centre A facility that is approved by the veterinary authority and meets the conditions set out in the *Terrestrial Code* (OIE, 2008b) for the collection, processing and/or storage of semen.

Biosecurity plan A plan that identifies potential pathways for the introduction and spread of disease in a zone or compartment, and describes the measures that are being or will be applied to mitigate the disease risks in accordance with the recommendations in the *Terrestrial Code* (OIE, 2008b).

Commodity Live animals, products of animal origin, animal genetic material, biological products and pathological material.

[3] Definitions used are those of the *OIE Terrestrial Animal Health Code* unless stated otherwise. http://www.oie.int/eng/normes/mcode/en_glossaire.htm.

Compartment An animal subpopulation contained in one or more establishments under a common biosecurity management system that has a distinct health status with respect to a specific disease or specific diseases for which the surveillance, control and biosecurity measures required for international trade have been applied.

Containment zone A defined zone around and including suspected or infected establishments, based on epidemiological factors and the results of investigations, where control measures to prevent the spread of the infection are applied.

Contamination The presence of an infectious, toxic or otherwise harmful agent on or in the body – also on or in clothes, bedding, buildings, vehicles, etc.

Disinfection The direct application, after thorough cleansing, of chemical or physical agents intended to destroy the infectious or parasitic agents of animal diseases, including zoonoses; is applied to premises, vehicles and objects that may have been directly or indirectly contaminated.

Disinfestation The application of procedures intended to eliminate the arthropods that may cause diseases or that are potential vectors of infectious agents of animal diseases, including zoonoses.

Emerging disease A new infection resulting from the evolution or change of an existing pathogenic agent, a known infection spreading to a new geographic area or population, or a previously unrecognized pathogenic agent or disease diagnosed for the first time and that has a significant impact on animal or public health.

Eradication The elimination of a pathogenic agent from a farm, country or zone.

Fresh meat Meat that has not been subjected to any treatment irreversibly modifying its organoleptic and physico-chemical characteristics. It includes frozen meat, chilled meat, minced meat and mechanically recovered meat.

Hazard A biological, chemical or physical agent in, or a condition of, an animal or animal product that has the potential to cause an adverse health effect.

Herd A number of animals of one kind kept together under human control, or a congregation of gregarious wild animals. For the purposes of the *Terrestrial Code* (OIE, 2008b), a herd is usually regarded as an epidemiological unit.

Incidence The number of new cases or outbreaks of a disease that occur in a population at risk in a particular geographical area within a defined time interval.

Incubation period The period between the introduction of the pathogen into the animal and the occurrence of the first clinical signs of the disease. In OIE definitions, it refers to the longest period between the introduction of the pathogen into the animal and the occurrence of the first clinical signs of the disease.

Infection The entry and development or multiplication of an infectious agent in the body of a human or an animal.

Loading/unloading Loading means the procedure of moving animals on to a vehicle/vessel or into a container for transport purposes; unloading means the procedure of moving animals off a vehicle/vessel or out of a container.

Market A place where animals are assembled for purposes of trade or sale.

Meat products Meat that has been subjected to a treatment irreversibly modifying its organoleptic and physico-chemical characteristics.

Notifiable disease A disease listed by the veterinary authority that must be brought to the attention of that authority as soon as it is detected or suspected, in accordance with national regulations.

Outbreak of disease or infection The occurrence of one or more cases of a disease or an infection in an epidemiological unit.

Premises A swine premises is a contiguous land location, based on land title records, including all structures housing pig(s) and other livestock.

Quarantine Restriction of apparently healthy animals to prevent disease transmission during the maximum possible incubation period of a selected range of infectious diseases

Quarantine station A premises under the control of the veterinary authority where animals are maintained in isolation with no direct or indirect contact with other animals, to prevent the transmission of specified pathogen(s) while the animals are undergoing observation for a specified period and, if appropriate, testing and treatment.

Registration The action by which information on animals (such as identification, animal health, movement, certification, epidemiology, establishments) is collected, recorded, securely stored and made accessible to and usable by the competent authority.

Risk The likelihood that an adverse event or effect will occur and the likely magnitude of the biological and economic consequences of that event or effect for animal or human health.

Sanitary measure A measure, such as those described in various chapters of the *Terrestrial Code* (OIE, 2008b), destined to protect animal or human health or life within the territory of the OIE member country from risks arising from the entry, establishment and spread of a hazard.

Slaughterhouse/ abattoir Premises, including facilities for moving or lairaging animals, used for the slaughter of animals to produce animal products and approved by the veterinary services or other competent authority.

Stamping-out policy Carrying out, under the authority of the veterinary authority and on confirmation of a disease, the killing of the animals that are affected and those suspected of being affected in the herd and, where appropriate, those in other herds that have been exposed to infection by direct animal-to-animal contact or by indirect contact of a kind likely to cause the transmission of the causal pathogen. All susceptible animals – vaccinated or unvaccinated – on an infected premises should be killed, and their carcasses destroyed by burning, burial or any other method that will eliminate the spread of infection through the carcasses or products of the animals killed. This policy should be accompanied by the cleansing and disinfection procedures defined in the *Terrestrial Code* (OIE, 2008b).

Surveillance The systematic ongoing collection, collation and analysis of information related to animal health, and the timely dissemination of information to those who need it so that action can be taken.

Transport The procedures associated with carrying animals for commercial purposes from one location to another by any means.

Vaccination The immunization of susceptible animals through the administration of a vaccine comprising antigens appropriate to the disease to be controlled.

Vehicle/vessel Any means of conveyance, including train, truck, aircraft or ship, used for carrying animal(s).

Veterinarian A person registered or licensed by the relevant veterinary statutory body of a country to practise veterinary medicine/science in that country.

Veterinary para-professional A person who, for the purposes of the *Terrestrial Code* (OIE, 2008b), is authorized by the veterinary statutory body to carry out certain designated tasks (depending on the category of veterinary para-professional) in a territory, which are delegated to them under the responsibility and direction of a veterinarian. The tasks authorized for each category of veterinary para-professional should be defined by the veterinary statutory body, based on qualifications and training and according to need.

Veterinary services The government and non-governmental organizations that implement animal health and welfare measures and other *Terrestrial Code* (OIE, 2008b) standards and recommendations in the territory. The veterinary services are under the overall control and direction of the veterinary authority. Private sector organizations, veterinarians or veterinary para-professionals are normally accredited or approved for delivering functions by the veterinary authority.

Zone/region A clearly defined part of a territory or set of premises containing an animal sub-population with a distinct health status regarding a specific disease for which required surveillance, control and biosecurity measures have been applied for the purpose of international trade.

Zoonosis Any disease or infection that is naturally transmissible from animals to humans.

Annex 6
Reports

Country	Title	Authors	Date	Prepared for
Africa				
Benin, Burkina Faso, Côte d'Ivoire, Ghana, Nigeria, Togo	ROAPPA Réseau Ouest-africain d'épidémiosurveillance de la Peste porcine africaine	Coraline Bouet, Cintli Martinez, Céline Muller, Joseph Savadago	2004	Wellcome Trust
Madagascar	L'élevage porcin dans la région d'Analanjirofo (Tamatave, Madagascar)	Marlène Capochichi	2008	Programme de Promotion des Revenus Ruraux (PPRR). IFAD
Cameroon	The taeniasis-cysticercosis complex in Cameroon	Geerts Stanny	2003	ITG, Antwerpen, Belgium
Caucasus				
Georgia	Proposal for a control plan for ASF in Georgia	Anette Baumer, Kaspar Jörger, Manon Schuppers, Lukas Perler	2007	Swiss Agency for Development and Cooperation (SDC)
Latin America and the Caribbean				
Latin America Caribbean	Porcicultura Urbana y Periurbana en Ciudades de América Latina y el Caribe	Gustavo Castro	2007	IPES Promoción del Desarrollo Sostenible
Jamaica	Assessment of Jamaica's pig/pork industry	Robert Reid	2003	IICA
Asia				
Asia	A review of the industrialisation of pig production worldwide with particular reference to the Asian region	R.D.A. Cameron	2000	FAO
Southeast Asia	Classical swine fever and emerging diseases in Southeast Asia	S. Blachsell	1999	ACIAR
Southeast Asia and the Pacific	Priorities for pig research in Southeast Asia and the Pacific to 2010	Roger Jones (ed.)	2002	ACIAR
Cambodia	Strategic development options for pig production and marketing in Cambodia	T. Barker	2000	World Bank Agricultural Productivity Improvement Project
India	Assam's pig sub-sector: Current status, constraints and opportunities	Rameswar Deka, William Thorpe, M. Lucila Lapar, Anjani Kumar	2008	ILRI
Philippines	Scale and access issues affecting smallholder hog producers in an expanding peri-urban market Southern Luzon, Philippines. Research Report No. 151	Achilles Costales, Christopher Delgado, Maria Angeles Catelo, M. Lucila Lapar, Marites Tiongco, Simeon Ehui, Anne Zillah Bautista	2007	IFPRI
Philippines Thailand Viet Nam	Contract farming of swine in Southeast Asia as a response to changing market demand for quality and safety in pork	Marites Tiongco, Maria Angeles Catelo, M. Lucila Lapar	2008	IFPRI

Annex 7
Manuals

Country	Title	Authors	Date	Prepared for
General	Pig keeping in the tropics (3rd ed.) http://journeytoforever.org/farm_library/AD1.pdf	Dick Muys, Geert Westenbrink, Johan Leinderts	2004	Wageningen University
General	Pigs (2nd ed.)	David H. Holness	2005	CTA
General	Que faire sans vétérinaire?	B. Forse	2002	CIRAD-CTA-Karthala
General	Manual of pig production in the tropics	H. Serres	1992	CABI
General	Recognizing African swine fever – A field manual www.fao.org//DOCREP/004/X8060E/X8060E00.htm	M.M. Rweyemamu (ed.)	2000	FAO
General	Guidelines for the surveillance, prevention and control of taeniasis/cysticercosis	KD. Murrell, P. Dorny, A. Flisser	2005	WHO/FAO/OIE
General	Livestock emergency interventions: a practical guide. FAO Animal Production and Health Manuals Series	FAO	2009	FAO
General	Biosecurity for highly pathogenic avian influenza: issues and options	FAO	2008	FAO/OIE/WB
General	The new tool for the evaluation of performance of veterinary services (PVS Tool) using OIE international standards of quality and evaluation www.oie.int/eng/oie/organisation/ENG_PVS%20TOOL_2009.pdf	OIE	2008	OIE
Africa	Healthy pig, healthy profit http://pigtrop.cirad.fr/resources/library/training_materials/healthy_pig_healthy_profit	Robbie Bain, John Tanner		DFID
Africa	Manual on the preparation of African swine fever contingency plans www.fao.org/DOCREP/004/Y0510E/Y0510E00.htm	William A. Geering, Mary-Louise Penrith, David Nyakahuma	2001	FAO
Asia	Manual on the diagnosis of Nipah virus infection in animals www.fao.org/DOCREP/005/AC449E/AC449E00.htm	Hume Field, Peter Daniels, Ong Bee Lee, Aziz Jamaludin, Mike Bunning	2002	FAO APHCA
Asia	Integrated agriculture-aquaculture: A primer www.fao.org/DOCREP/005/Y1187E/Y1187E00.htm	FAO	2001	FAO/IIRR/World Fish Center
Lao People's Democratic Republic	A manual on improved rural pig production http://pigtrop.cirad.fr/content/download/2489/12879/file/Pig_Eng.pdf	G. Oosterwijk, D. Van Aken, S. Vongthilath	2003	European Union/ Ministry of Agriculture and Forestry
Latin America and the Caribbean	Reconociendo la peste porcina clásica - Manual Ilustrado www.fao.org/docrep/009/y4944s/y4944s00.htm	FAO	2003	FAO

(continued)

Country	Title	Authors	Date	Prepared for
Canada	Biosécurité: un must pour tout le secteur porcin	André Broes, Réal Boutin	2001	Centre de développement du porc du québec
United States	Swine production on a small scale	Kenneth L. Durrance, Cynthia A. Maxson	1999	University of Florida, USA
United States	Biosecurity guide for pork producers	American Association of Swine Veterinarians	2002	National Pork Board
United States	Biosecurity protocols for the prevention of spread of porcine reproductive and respiratory syndrome virus	Andrea Pitkin, Satoshi Otake, Scott De		University of Minnesota

Annex 8
Selected articles

Amass, S.F. & Baysinger, A. 2006. Swine disease transmission and prevention. In B.E. Straw, J.J. Zimmerman, D.J. Taylor and S. D'Allaire, eds. *Diseases of swine*, 9th ed. pp. 1075–1098. Oxford, UK, Blackwell.

Amass, S.F. & Clark L.F. 1999. Biosecurity considerations for pork production units. *Swine Health and Production*, 7: 217–228.

Anderson, E.C., Hutchings, G.H., Mukarati, N. & Wilkinson, P.J. 1998. African swine fever virus infection of the bush pig (*Potamochoerus porcus*) and its significance in the epidemiology of the disease. *Veterinary Microbiology*, 62: 1–15.

Andraud, M., Grasland, B., Durand, B., Cariolet, R., Jestin, A., Madec, F. & Rose, N. 2008. Quantification of porcine circovirus type 2 (PCV 2) within and between-pen transmission in pigs. *Veterinary Research*, 39(5):43.

Awa, D.N., Njoya, A., Ngo Tama, A.C. & Ekue, F.N. 1999. The health status of pigs in North Cameroon. *Revue d Elevage et de Médecine Vétérinaire des Pays Tropicaux*, 52(2): 93–98.

Boqvist, S., Chau, B., Gunnarsson, A., Olsson Engvall, E., Vagsholm, I. & Magnusson, U. 2002. Animal- and herd-level risk factors for leptospiral seropositivity among sows in the Mekong delta, Vietnam. *Preventive Veterinary Medicine*, 53: 233–245.

Buldgen, A., Piraux, M., Dieng, A., Schmit, G. & Compere, R. 1994. Les élevages de porcs traditionnels du bassin arachidier sénégalais. *WAR/RMZ*, 80/81: 63–70.

Cano, J.P., Dee, S.A., Deen, J., Finnegan, C., Murtaugh, M.P. & Pijoan, C. 2007. An exploratory study to evaluate the survival of porcine reproductive and respiratory syndrome virus in non-processed pig meat. *Veterinary Record*, 160: 907–908.

Cardinale, E. 2000. The Senegalese poultry epidemiosurveillance network: Presentation and preliminary results. *Epidémiol. et Santé anim.*, 3: 105–116.

Cardinale, E. 2003. Biosecurity for layers in Senegal. Impact on table eggs quality. In *La Production d'œufs de consommation en climat chaud*, pp. 111 –116. Paris, ITAVI.

Casal, J., De Manuel, A., Mateu, E. & Martin, M. 2007. Biosecurity measures on swine farms in Spain: Perceptions by farmers and their relationship to current on-farm measures. *Preventive Veterinary Medicine*, 82: 138–150.

Cheneau, Y., El Idrissi, A.H. & Ward, D. 2004. An assessment of the strengths and weaknesses of current veterinary systems in the developing world. *Revue Scientifique et Technique de l'Office international des Epizooties*, 23: 351–359

Chiduwa, G., Chimonyo, M., Halimani, T.E., Chisambara, S.R. & Dzama, K. 2008. Herd dynamics and contribution of indigenous pigs to the livelihoods of rural farmers in a semi-arid area of Zimbabwe. *Tropical Animal Health Production*, 40: 125–136.

Costard, S., Porphyre, V., Messad, S., Rakotondrahanta, S., Vidon, H., Roger, F. & Pfeiffer, D.U. in press. Differentiation of management practices of smallholders relevant to disease risk in domestic swine in Madagascar. *Preventive Veterinary Medicine* (in press).

Dargatz, D.A., Garry, F.B. & Traub-Dargatz J.L. 2002. An introduction to biosecurity of cattle operations. *Vet. Clin. North Am. Food Animal Practice*, 18: 1–5.

Dee, S.A, Deen, J., Otake, S. & Pijoan, C. 2004. An experimental model to evaluate the role of transport vehicles as a source of transmission of PRRSV to susceptible pigs. *Canadian Journal of Veterinary Research*, 68: 128–133.

Dee, S.A., Deen, J., Rossow, K.D, Eliason, R., Mahlum, C., Otake, S., Joo, H.S. & Pijoan, C. 2003. Mechanical transmission of porcine reproductive and respiratory syndrome virus throughout a coordinated sequence of events during warm weather. *Canadian Journal of Veterinary Research*, 67: 12–16.

Dee, S.A., Deen, J., Otake, S. & Pijoan, C. 2004. An assessment of transport vehicles as a source of porcine reproductive and respiratory syndrome virus transmission to susceptible pigs. *Canadian Journal of Veterinary Research*, 68: 124–133.

Dee, S.A., Deen, J. & Pijoan, C. 2005. Evaluation of disinfectants for the sanitation of porcine reproductive and respiratory syndrome virus-contaminated transport vehicles at cold temperatures. *Canadian Journal of Veterinary Research*, 69: 64–70.

Dee, S.A., Deen, J. & Pijoan, C. 2006. An evaluation of an industry-based sanitation protocol for full-size PRRSV-contaminated transport vehicles. *Swine Health Prod.*,14: 307–311.

Dijkhuisen, A.A. 1989. Economic aspects of common health and fertility problems for the individual pig producer: an overview. *Veterinary Quarterly*, 11: 116–124.

Donaldson, A.I., Alexandersen, S., Sorensen, J.H. & Mikkelsen, T. 2001. The relative risks of the uncontrollable (airborne) spread of foot-and-mouth disease by different species. *Veterinary Record*, 148: 602–604.

Drouin, P. & Cardinale, E. 1999. Biosecurity and decontamination in broilers production in the tropics. In *Production de poulets de chair en climat chaud*, pp. 94–107. Paris, ITAVI.

Dufour, B. & Audigé, L. 1997. A proposed classification of veterinary epidemio-surveillance networks. *Rev. Sci. Tech. Off. Int. Epiz.*, 16: 746–758.

FAO/OIE/World Bank. 2007. The importance of biosecurity in reducing HPAI risk on farms and in markets. Paper for the international ministerial conference on avian and pandemic influenza. New Delhi, 4–6 Dec. 2007.

FAO/OIE/World Bank. 2008. *Biosecurity for highly pathogenic avian influenza. Issues and options.* Rome. 73 pp.

Gloster, J.H., Hewson, D., Mackay, T., Garland, A., Donaldson, A., Mason, I. & Brown, R. 2001. Spread of foot-and-mouth disease from the burning of animal carcasses on open pyres. *Veterinary Record*, 148: 585–586.

Graham, J.P., Leibler, J.H., Price, L.B., Otte, J.M., Pfeiffer, D.U., Tiensin, T. & Silbergeld, E. 2008. The animal-human interface and infectious diseases in industrial food animal production: rethinking biosecurity and biocontainment. *Public Health Reports*, 123: 282–299.

Guérin, B. & Pozzi, N. 2005. Viruses in boar semen: detection and clinical as well as epidemiological consequences regarding disease transmission by artificial insemination. *Theriogenology*, 63: 556–572.

Harper. A.F., De Rouchey, J.M., Glanville, T.D., Meeker, D.L. & Straw, B.E. 2008. *Swine carcass disposal options for routine and catastrophic mortality*. United States Council for Agricultural Science and Technology, Issue Paper No. 39, July 2008. Ames, Iowa. 16 pp.

Hendrikx, P., Domenech, J., Ouagal, M. & Idriss, A. 1997. Enjeux et contraintes à la mise en place d'un réseau d'épidémiosurveillance national en Afrique: exemple du REPIMAT au Tchad. *Epidémiologie et Santé animale*, 31–32: 1–3.

Hugh-Jones, M. 2006. Biological disasters of animal origin. The role and preparedness of veterinary and public health services. *OIE Sci. and Techn. Reviews*, 25(1): 461 pp.

Huijdens, X.W., Van Dijke, B.J., Spalburg, E., Van Santen-Verheuvel, M.G. & Heck, M.E. 2006. Community-acquired MRSA and pig farming. *Ann. Clin. Microbiol. Antimicrob.*, 5: 26.

Hove, T. & Dubey, J.P. 1999. Prevalence of *Toxoplasma gondii* antibodies in sera of domestic pigs and some wild game species from Zimbabwe. *Journal of Parasitology*, 85: 372–373.

Jensen, T.B., Baadsgaard, N.P., Houe, H., Toft, N. & Ostergaard, S. 2008. The association between disease and profitability in individual finishing boars at a test station. *Livestock Science*, 117: 101–108.

Jori, F., Galvez, H., Mendoza, P., Cespedes, M. & Mayor P. 2009. Monitoring of Leptospirosis seroprevalence in a colony of captive collared peccaries (*Tayassu tajacu*) from the Peruvian Amazon. *Research in Veterinary Science*, 86: 383–387.

Kauffold, J., Beckjunker, J., Scheller, R., Schwarz, B.A., Beynon, N. & Sobiraj, A. 2005. Effects of type of machine and covering on viruses and micro-organisms recovered from dust in ultrasound machines used in German swine production operations. *J. of Swine Health and Production*, 13: 72–80.

Klinkenberg, D., Nielen, M., Mourits, M.C.M. & Jong, M.C.M.D. 2005. The effectiveness of classical swine fever surveillance programmes in the Netherlands. *Preventive Veterinary Medicine*, 67: 19–37.

Last, J.M. 1983. *A dictionary of epidemiology.* New York, Oxford University Press. 144 pp.

Lemke, U., Kaufmann, B., Thuy, L.T., Emrich, K. & Valle Zárate, A. 2006. Evaluation of smallholder pig production systems in North Vietnam: Pig production management and pig performances. *Livestock Science*, 105: 229–243.

Maes, D., Nauwinck, H., Rijsselaere, T., Mateusen, B., Vyt, P., de Kruif, A. & Van Soom, A. 2008. Diseases in swine transmitted by AI: an overview. *Theriogenology*, 70: 1337–1345.

Mannelli, A., Sotgia, S., Patta, C., Sarria, A., Madrau, P., Sanna, L., Firinu, A. & Laddomada, A. 1997. Effect of husbandry methods on seropositivity to African swine fever virus in Sardinian swine herds. *Preventive Veterinary Medecine*, 32: 233–239.

Matlova, L., Dvorska, L., Palecek, K., Mauren, L., Bartos, M. & Pavlik, I. 2004. Impact of sawdust and wood shavings in bedding on pig tuberculous lesions in lymph nodes, and IS1245 RFLP analysis of *Mycobacterium avium* subsp *hominisuis* of serotypes 6 and 8 isolated from pigs and environment. *Veterinary Microbiology*, 102: 227–236.

Missohou, A., Niang, M., Foucher, H. & Dieye P.N. 2001. Les systèmes d'élevage porcin en Basse Casamance (Sénégal). *Cahiers d'études et de recherches francophones/Agricultures*, 10(6): 405–408.

Mopate Logtene, Y. & Koussou, M.O. 2003. L'élevage porcin, un élevage ignoré mais pourtant bien implanté dans les agro-systèmes ruraux et périurbains du Tchad. *In* J.Y. Jamin, L. Seiny Boukar and C. Floret, eds. *Savanes africaines: des espaces en mutation, des acteurs face à de nouveaux défis*. Actes du colloque, mai 2002, Garoua, Cameroun. Prasac, N'Djamena, Tchad. Montpellier, France, CIRAD.

Mopaté, L. Y., Koussou, M.O. & Kaboré-Zoungrana, C.Y. 2006. Consommateurs et consommation de la viande porcine en hors-foyer dans la ville de N'Djaména (Tchad). In L. Parrot, A. Njoya, L. Temple, F. Assogba-Komlan, R. Kahane, M. Ba Diao and M. Havard, eds. *Actes de l'atelier international Agricultures et Développement Urbain en Afrique de l'Ouest et du Centre*. IRAD, INRAB, ISRA et CIRAD, Cameroon. pp. 135 – 141.

Morrow, W.E.M., O'Quinn, P., Barker, J., Erickson, G., Post, K. & McCaw, M. 1995. Composting as a suitable technique for managing swine mortalities. *Swine health and production*, 3: 236–243.

Nsoso, S.J., Monkhei, M. & Tlhwaafalo, B.E. 2004. A survey of traditional small stock farmers in Molelopole North, Kweneng district, Botswana: Demographic parameters, market practices and marketing channels. *Livestock Research for Rural Development,* 16(12).

Oraveerakul, K., Wattanodorn, S., Luengyosluechakul, S. & Boonmar, S. 1998. Seroprevalence of Japanese encephalitis virus in pigs in central and northeastern Thailand. *Thai Journal of Veterinary Medicine*, 28: 91–98.

OIE. 2008a. *OIE quality standard and guidelines for veterinary laboratories: infectious diseases.* Paris.

OIE. 2008b. *Terrestrial Animal Health Code.* 17th ed. Paris. 510 pp.

OIE Animal Production Food Safety Working Group. 2006. Guide to good farming practices for animal production food safety. *Rev. Sci. Tech. Off. Int. Epiz.*, 25: 823–836,

Olsen, C.W., Brown, I.H., Easterday, B.C. & Van Reeth, K. 2006. Swine influenza. *In* B.E. Straw, J.J. Zimmerman, D.J. Taylor and S. D'Allaire, eds. *Diseases of swine*, pp. 469–482. Oxford, UK, Blackwell.

Otake, S., Dee, S.A., Rossow, K.D., Deen, J., Joo, H.S., Molitor, T.W. & Pijoan, C. 2002. Transmission of porcine reproductive and respiratory syndrome virus by fomites (boots and coveralls). *Journal of Swine Health and Production*, 10: 59–65.

Otake, S., Dee, S.A., Rossow, K.D., Moon, R.D., Trincado, C. & Pijoan, C. 2003. Transmission of PRRS virus by houseflies (*Musca domestica*). *Veterinary Record*, 152: 73–76.

Ott, S.L., Hillberg-Seitzinger, A. & Hueston, W.D. 1995. Measuring the national economic benefits of reducing livestock mortality. *Preventive Veterinary Medicine*, 24: 203–221.

Pastoret, P.P., Lombard, M. & Schudel, A. 2007. Animal vaccination. Part 1: Development, production and use of vaccines. Part 2: Scientific, economic, regulatory and socio-ethical aspects. *OIE Sci. and Techn. Reviews*, 26(1) and (2): 400 pp.

Payne, W.J.A. & Wilson, R.T. 1999. *An introduction to animal husbandry in the tropics*. Oxford, UK, Blackwell. 815 pp.

Peters, D. 2005. Rural income generation through improving crop-based pig production systems in Vietnam: Diagnostics and dissemination. *Agriculture and Human Values*, 22: 73–85.

Phillips, N.D., La, T., Adams, P.J., Harland, B.L., Fenwick, S.G. & Hampson, D.J. 2009. Detection of *Brachyspira hyodysenteriae*, *Lawsonia intracellularis* and *Brachyspira pilosicoli* in feral pigs. *Veterinary Microbiology*, 134: 294–299.

Pitkin, A., Deen, J., Otake, S., Moon, R. & Dee, S. 2009. Further assessment of houseflies (*Musca domestica*) as vectors for the mechanical transport and transmission of porcine reproductive and respiratory syndrome virus under field conditions. *Canadian Journal of Veterinary Research*, 73: 91–96.

Pitkin, A.N., Deen, J. & Dee, S.A. 2009. Use of a production region model to assess the airborne spread of porcine reproductive and respiratory syndrome virus. *Vet. Microbiology*, 136: 1–7.

Pinto J., C. & Urcelay, S. V. 2003. Biosecurity practices on intensive pig production systems in Chile. *Preventive Veterinary Medicine*, 59: 139–145.

Pluske, J.R., Le Dividich, J. & Verstegen, M.W.A., 2003. *Weaning the pig: Concepts and consequences*. Wageningen, Netherlands, Wageningen Agricultural University and Enfield. 432 pp.

Porphyre, V., Nguyen Ngoc Son, Ha Minh Tuan, Genewe, S., & Henry, C. 2006. Local epidemio-surveillance in swine diseases in Northern Vietnam: description and preliminary results. *In* E.F. Blouin, B.H. Bokma and T.V. Dung eds. *Impact of emerging zoonotic diseases on animal health: 8th Biennial Conference of the Society for Tropical Veterinary Medicine*, pp. 528-530. Annals of the New-York Academy of Sciences.

Porphyre, V. & Nguyen, Q.C. 2006. *Pig production development, animal-waste management and environment protection: A case study in Thai Binh Province, Northern Vietnam*. PRISE Publications. Viet Nam. 224 pp.

Praet, N., Speybroeck, N., Manzanedo, R., Berkvens, D., Nsame Nforninwe, D., Zoli, A., Quet, F., Preux, P., Carabin, H. & Geerts, S. 2009. The disease burden of *Taenia solium cysticercosis* in Cameroon. *PLoS Negl. Trop. Dis.*, 3: e406.

Radostits, O.M. 2001. *Control of infectious diseases of food-producing animals. Herd health: food animal production medicine*, 3rd ed. Philadelphia, Pennsylvania, USA, WB Saunders.

Roger, F., Ratovonjato, J., Vola, P. & Uilenberg, G. 2001. *Ornithodoros porcinus* ticks, bushpigs, and African swine fever in Madagascar. *Experimental and Applied Acarology*, 25: 263–269.

Román, A.V., Lukešová, D., Novák, P. & Žižlavský, M. 2006. Biosecurity in pig breeding herds. *Agricultura Tropica et Subtropica*, 39: 119–124.

Rougoor, C.W., Dijkhuisen, A.A., Huirne, R.B.M. & Marsh W.E. 1996. Impact of different approaches to calculate the economics of disease in pig farming. *Preventive Veterinary Medicine*, 26: 315–328.

Sander, J.E., Warbington, M.C. & Myers, L.M. 2002. Selected methods of animal carcass disposal. *J. Am. Vet. Medic. Asso.*, 220: 1003–1005.

Sciutto, E., Fragoso, G., Fleury, A., Laclette, J.P., Sotelo, J., Aluja, A., Vargas, L. & Larralde, C. 2000. *Taenia solium* disease in humans and pigs: an ancient parasitosis disease rooted in developing countries and emerging as a major health problem of global dimensions. *Microbes and infections*, 2: 1875–1890.

Stewart, T.B. 2001. Economics of endoparasitism of pigs. *Pig News and Info*., 2: 29N–30N.

Straw, B.E., Zimmerman, J.J., Taylor, D.J. & D'Allaire, S. 2006. *Diseases of swine*. 9th edition. Ames, Iowa, USA, Iowa State University Press. 1153 pp.

Toma, B., Bénet, J.J., Dufour, B., Eloit, M., Moutou, F. & Sanaa, M. 1991. *Glossaire d'épidémiologie animale*. Maison Alfort. Editions du Point Vétérinaire. 365 pp.

Venglovsky, J., Sasakova, N. & Placha, I. in press. Pathogens and antibiotic residues in animal manures and hygienic and ecological risks related to subsequent land application. *Bioresource Technology*, (in press).

Vos, C.J.D., Saatkamp, H.W. & Huirne, R.B.M. 2005. Cost-effectiveness of measures to prevent classical swine fever introduction into the Netherlands. *Preventive Veterinary Medicine*, 70: 235–256.

Wong, J.W.C. & Selvam, A. in press. Reduction of indicator and pathogenic microorganisms in pig manure through fly ash and lime addition during alkaline stabilization. *Journal of Hazardous Materials*, (in press)

Yob, J.M., Field, H., Rashdi, A.M., Morrissy, C., Van Der Heide, B., Rota, P., Bin Adzhar, A., White, J., Daniels, P., Jamaluddin, A. & Ksiazek, T. 2001. Nipah virus infection in bats (order chiroptera) in Peninsular Malaysia. *Emerg. Infect. Dis.*, 7: 439–441.

Annex 9
Selected websites

Food and Agriculture Organization of the United Nations (FAO)
FAO's Animal Production and Health Division
www.fao.org/ag/againfo/home/en/index.htm

World Organisation for Animal Health (OIE)
www.oie.int

The World Bank
www.worldbank.org

La Pagina del Cerdo. News and technical resources for swine production (in Spanish)
www.3tres3.com

PIGtrop website
The CIRAD website dedicated to pig production in the tropics
http://pigtrop.cirad.fr

Pig Disease Information Centre (PDIC)
PDIC empowers farm animal health and welfare decision-makers with high-quality, up-to-date information and skills
www.pighealth.com

The Pigsite
News and technical resources to the global pig industry
www.thepigsite.com

IFIP – L'institut du porc
The French institute for the pig industry (France)
www.itp.asso.fr

Livestock Research for Rural Development (LRRD)
The international journal for research into sustainable developing world agriculture
www.lrrd.org

Electronic Journal of Pig Production – RCPP (Cuba)
A journal that promotes research articles and new methods in tropical pig production in Cuba and Latin America
http://pigtrop.cirad.fr/resources/rcpp_journal

The Global Livestock Production and Health Atlas (GLiPHA)
An interactive electronic atlas that provides a scaleable overview of spatial and temporal variation in quantitative information related to animal production and health.
http://kids.fao.org/glipha/

Porkboard.org
The official website of the United States National Pork Board
www.porkboard.org

Biosecuritycenter.org
The National Biosecurity Resource Center for animal health emergencies
www.biosecuritycenter.org

FAO TECHNICAL PAPERS

FAO ANIMAL PRODUCTION AND HEALTH PAPERS

1 Animal breeding: selected articles from the *World Animal Review*, 1977 (C E F S)
2 Eradication of hog cholera and African swine fever, 1976 (E F S)
3 Insecticides and application equipment for tsetse control, 1977 (E F)
4 New feed resources, 1977 (E/F/S)
5 Bibliography of the criollo cattle of the Americas, 1977 (E/S)
6 Mediterranean cattle and sheep in crossbreeding, 1977 (E F)
7 The environmental impact of tsetse control operations, 1977 (E F)
7 Rev. 1 The environmental impact of tsetse control operations, 1980 (E F)
8 Declining breeds of Mediterranean sheep, 1978 (E F)
9 Slaughterhouse and slaughterslab design and construction, 1978 (E F S)
10 Treating straw for animal feeding, 1978 (C E F S)
11 Packaging, storage and distribution of processed milk, 1978 (E)
12 Ruminant nutrition: selected articles from the *World Animal Review*, 1978 (C E F S)
13 Buffalo reproduction and artificial insemination, 1979 (E*)
14 The African trypanosomiases, 1979 (E F)
15 Establishment of dairy training centres, 1979 (E)
16 Open yard housing for young cattle, 1981 (Ar E F S)
17 Prolific tropical sheep, 1980 (E F S)
18 Feed from animal wastes: state of knowledge, 1980 (C E)
19 East Coast fever and related tick-borne diseases, 1980 (E)
20/1 Trypanotolerant livestock in West and Central Africa – Vol. 1. General study, 1980 (E F)
20/2 Trypanotolerant livestock in West and Central Africa – Vol. 2. Country studies, 1980 (E F)
20/3 Le bétail trypanotolérant en Afrique occidentale et centrale – Vol. 3. Bilan d'une décennie, 1988 (F)
21 Guideline for dairy accounting, 1980 (E)
22 Recursos genéticos animales en América Latina, 1981 (S)
23 Disease control in semen and embryos, 1981 (C E F S)
24 Animal genetic resources – conservation and management, 1981 (C E)
25 Reproductive efficiency in cattle, 1982 (C E F S)
26 Camels and camel milk, 1982 (E)
27 Deer farming, 1982 (E)
28 Feed from animal wastes: feeding manual, 1982 (C E)
29 Echinococcosis/hydatidosis surveillance, prevention and control: FAO/UNEP/WHO guidelines, 1982 (E)
30 Sheep and goat breeds of India, 1982 (E)
31 Hormones in animal production, 1982 (E)
32 Crop residues and agro-industrial by-products in animal feeding, 1982 (E/F)
33 Haemorrhagic septicaemia, 1982 (E F)
34 Breeding plans for ruminant livestock in the tropics, 1982 (E F S)
35 Off-tastes in raw and reconstituted milk, 1983 (Ar E F S)
36 Ticks and tick-borne diseases: selected articles from the *World Animal Review*, 1983 (E F S)

37 African animal trypanosomiasis: selected articles from the *World Animal Review*, 1983 (E F)
38 Diagnosis and vaccination for the control of brucellosis in the Near East, 1982 (Ar E)
39 Solar energy in small-scale milk collection and processing, 1983 (E F)
40 Intensive sheep production in the Near East, 1983 (Ar E)
41 Integrating crops and livestock in West Africa, 1983 (E F)
42 Animal energy in agriculture in Africa and Asia, 1984 (E/F S)
43 Olive by-products for animal feed, 1985 (Ar E F S)
44/1 Animal genetic resources conservation by management, data banks and training, 1984 (E)
44/2 Animal genetic resources: cryogenic storage of germplasm and molecular engineering, 1984 (E)
45 Maintenance systems for the dairy plant, 1984 (E)
46 Livestock breeds of China, 1984 (E F S)
47 Réfrigération du lait à la ferme et organisation des transports, 1985 (F)
48 La fromagerie et les variétés de fromages du bassin méditerranéen, 1985 (F)
49 Manual for the slaughter of small ruminants in developing countries, 1985 (E)
50 Better utilization of crop residues and by-products in animal feeding: research guidelines – 1. State of knowledge, 1985 (E)
50/2 Better utilization of crop residues and by-products in animal feeding: research guidelines – 2. A practical manual for research workers, 1986 (E)
51 Dried salted meats: charque and carne-de-sol, 1985 (E)
52 Small-scale sausage production, 1985 (E)
53 Slaughterhouse cleaning and sanitation, 1985 (E)
54 Small ruminants in the Near East – Vol. I. Selected papers presented for the Expert Consultation on Small Ruminant Research and Development in the Near East (Tunis, 1985), 1987 (E)
55 Small ruminants in the Near East – Vol. II. Selected articles from *World Animal Review* 1972-1986, 1987 (Ar E)
56 Sheep and goats in Pakistan, 1985 (E)
57 The Awassi sheep with special reference to the improved dairy type, 1985 (E)
58 Small ruminant production in the developing countries, 1986 (E)
59/1 Animal genetic resources data banks – 1. Computer systems study for regional data banks, 1986 (E)
59/2 Animal genetic resources data banks – 2. Descriptor lists for cattle, buffalo, pigs, sheep and goats, 1986 (E F S)
59/3 Animal genetic resources data banks – 3. Descriptor lists for poultry, 1986 (E F S)
60 Sheep and goats in Turkey, 1986 (E)
61 The Przewalski horse and restoration to its natural habitat in Mongolia, 1986 (E)
62 Milk and dairy products: production and processing costs, 1988 (E F S)
63 Proceedings of the FAO expert consultation on the substitution of imported concentrate feeds in animal production systems in developing countries, 1987 (C E)
64 Poultry management and diseases in the Near East, 1987 (Ar)
65 Animal genetic resources of the USSR, 1989 (E)
66 Animal genetic resources – strategies for improved use and conservation, 1987 (E)
67/1 Trypanotolerant cattle and livestock development in West and Central Africa – Vol. I, 1987 (E)
67/2 Trypanotolerant cattle and livestock development in West and Central Africa – Vol. II, 1987 (E)
68 Crossbreeding *Bos indicus* and *Bos taurus* for milk production in the tropics, 1987 (E)

69 Village milk processing, 1988 (E F S)
70 Sheep and goat meat production in the humid tropics of West Africa, 1989 (E/F)
71 The development of village-based sheep production in West Africa, 1988 (Ar E F S)
(Published as Training manual for extension workers, M/S5840E)
72 Sugarcane as feed, 1988 (E/S)
73 Standard design for small-scale modular slaughterhouses, 1988 (E)
74 Small ruminants in the Near East – Vol. III. North Africa, 1989 (E)
75 The eradication of ticks, 1989 (E/S)
76 Ex situ cryoconservation of genomes and genes of endangered cattle breeds by means of modern biotechnological methods, 1989 (E)
77 Training manual for embryo transfer in cattle, 1991 (E)
78 Milking, milk production hygiene and udder health, 1989 (E)
79 Manual of simple methods of meat preservation, 1990 (E)
80 Animal genetic resources – a global programme for sustainable development, 1990 (E)
81 Veterinary diagnostic bacteriology – a manual of laboratory procedures of selected diseases of livestock, 1990 (E F)
82 Reproduction in camels – a review, 1990 (E)
83 Training manual on artificial insemination in sheep and goats, 1991 (E F)
84 Training manual for embryo transfer in water buffaloes, 1991 (E)
85 The technology of traditional milk products in developing countries, 1990 (E)
86 Feeding dairy cows in the tropics, 1991 (E)
87 Manual for the production of anthrax and blackleg vaccines, 1991 (E F)
88 Small ruminant production and the small ruminant genetic resource in tropical Africa, 1991 (E)
89 Manual for the production of Marek's disease, Gumboro disease and inactivated Newcastle disease vaccines, 1991 (E F)
90 Application of biotechnology to nutrition of animals in developing countries, 1991 (E F)
91 Guidelines for slaughtering, meat cutting and further processing, 1991 (E F)
92 Manual on meat cold store operation and management, 1991 (E S)
93 Utilization of renewable energy sources and energy-saving technologies by small-scale milk plants and collection centres, 1992 (E)
94 Proceedings of the FAO expert consultation on the genetic aspects of trypanotolerance, 1992 (E)
95 Roots, tubers, plantains and bananas in animal feeding, 1992 (E)
96 Distribution and impact of helminth diseases of livestock in developing countries, 1992 (E)
97 Construction and operation of medium-sized abattoirs in developing countries, 1992 (E)
98 Small-scale poultry processing, 1992 (Ar E)
99 In situ conservation of livestock and poultry, 1992 (E)
100 Programme for the control of African animal trypanosomiasis and related development, 1992 (E)
101 Genetic improvement of hair sheep in the tropics, 1992 (E)
102 Legume trees and other fodder trees as protein sources for livestock, 1992 (E)
103 Improving sheep reproduction in the Near East, 1992 (Ar)
104 The management of global animal genetic resources, 1992 (E)
105 Sustainable livestock production in the mountain agro-ecosystem of Nepal, 1992 (E)
106 Sustainable animal production from small farm systems in South-East Asia, 1993 (E)
107 Strategies for sustainable animal agriculture in developing countries, 1993 (E F)
108 Evaluation of breeds and crosses of domestic animals, 1993 (E)
109 Bovine spongiform encephalopathy, 1993 (Ar E)

110 L'amélioration génétique des bovins en Afrique de l'Ouest, 1993 (F)
111 L'utilización sostenible de hembras F1 en la producción del ganado lechero tropical, 1993 (S)
112 Physiologie de la reproduction des bovins trypanotolérants, 1993 (F)
113 The technology of making cheese from camel milk (*Camelus dromedarius*), 2001 (E F)
114 Food losses due to non-infectious and production diseases in developing countries, 1993 (E)
115 Manuel de formation pratique pour la transplantation embryonnaire chez la brebis et la chèvre, 1993 (F S)
116 Quality control of veterinary vaccines in developing countries, 1993 (E)
117 L'hygiène dans l'industrie alimentaire, 1993 – Les produits et l'aplication de l'hygiène, 1993 (F)
118 Quality control testing of rinderpest cell culture vaccine, 1994 (E)
119 Manual on meat inspection for developing countries, 1994 (E)
120 Manual para la instalación del pequeño matadero modular de la FAO, 1994 (S)
121 A systematic approach to tsetse and trypanosomiasis control, 1994 (E/F)
122 El capibara (*Hydrochoerus hydrochaeris*) – Estado actual de su producción, 1994 (S)
123 Edible by-products of slaughter animals, 1995 (E S)
124 L'approvisionnement des villes africaines en lait et produits laitiers, 1995 (F)
125 Veterinary education, 1995 (E)
126 Tropical animal feeding – A manual for research workers, 1995 (E)
127 World livestock production systems – Current status, issues and trends, 1996 (E)
128 Quality control testing of contagious bovine pleuropneumonia live attenuated vaccine – Standard operating procedures, 1996 (E F)
129 The world without rinderpest, 1996 (E)
130 Manual de prácticas de manejo de alpacas y llamas, 1996 (S)
131 Les perspectives de développement de la filière lait de chèvre dans le bassin méditerranéen, 1996 (F)
132 Feeding pigs in the tropics, 1997 (E)
133 Prevention and control of transboundary animal diseases, 1997 (E)
134 Tratamiento y utilización de residuos de origen animal, pesquero y alimenticio en la alimentación animal, 1997 (S)
135 Roughage utilization in warm climates, 1997 (E F)
136 Proceedings of the first Internet Conference on Salivarian Trypanosomes, 1997 (E)
137 Developing national emergency prevention systems for transboundary animal diseases, 1997 (E)
138 Producción de cuyes (*Cavia porcellus*), 1997 (S)
139 Tree foliage in ruminant nutrition, 1997 (E)
140/1 Analisis de sistemas de producción animal – Tomo 1: Las bases conceptuales, 1997 (S)
140/2 Analisis de sistemas de producción animal – Tomo 2: Las herramientas basicas, 1997 (S)
141 Biological control of gastro-intestinal nematodes of ruminants using predacious fungi, 1998 (E)
142 Village chicken production systems in rural Africa – Household food security and gender issues, 1998 (E)
142 Village chicken production systems in rural Africa – Household food security and gender issues,1998 (E)

143 Agroforestería para la producción animal en América Latina, 1999 (S)
144 Ostrich production systems, 1999 (E)
145 New technologies in the fight against transboundary animal diseases, 1999 (E)
146 El burro como animal de trabajo – Manual de capacitación, 2000 (S)
147 Mulberry for animal production, 2001 (E)
148 Los cerdos locales en los sistemas tradicionales de producción, 2001 (S)
149 Animal production based on crop residues – Chinese experiences, 2001 (C E)
150 Pastoralism in the new millennium, 2001 (E)
151 Livestock keeping in urban areas – A review of traditional technologies based on literature and field experiences, 2001 (E)
152 Mixed crop-livestock farming – A review of traditional technologies based on literature and field experiences, 2001 (E)
153 Improved animal health for poverty reduction and sustainable livelihoods, 2002 (E)
154 Goose production, 2002 (E F)
155 Agroforestería para la producción animal en América Latina – II, 2003 (S)
156 Guidelines for coordinated human and animal brucellosis surveillance, 2003 (E)
157 Resistencia a los antiparasitarios – Estado actual con énfasis en América Latina, 2003 (S)
158 Employment generation through small-scale dairy marketing and processing, 2003 (E)
159 Good practices in planning and management of integrated commercial poultry production in South Asia, 2003 (E)
160 Assessing quality and safety of animal feeds, 2004 (E)
161 FAO technology review: Newcastle disease, 2004 (E)
162 Uso de antimicrobianos en animales de consumo – Incidencia del desarrollo de resistencias en la salud pública, 2004 (S)
163 HIV infections and zoonoses, 2004 (E F)
164 Feed supplementation blocks – Urea-molasses multinutrient blocks: simple and effective feed supplement technology for ruminant agriculture, 2007 (E)
165 Biosecurity for Highly Pathogenic Avian Influenza – Issues and options (E F)
166 Intercambio comercial de aves silvestres vivas (y otros desplazamientos afines) en 33 países de América Latina y El Caribe (S[e])
167 Livestock keepers – guardians of biodiversity (E)
168 Adding value to livestock diversity – Marketing to promote local breeds and improve livelihoods (E)
169 Good practices for biosecurity in the pig sector – Issues and options in developing and transition countries (E)

Availability: April 2010

Ar – Arabic
C – Chinese
E – English
F – French
P – Portuguese
S – Spanish

Multil – Multilingual
* Out of print
** In preparation
[e] E-publication

The *FAO Technical Papers* are available through the authorized FAO Sales Agents or directly from Sales and Marketing Group, FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy.

Animal diseases that are known to spread primarily through human activities can be prevented and controlled through the application of biosecurity measures along the production and marketing chain, together with increased awareness and education. It is this notion that makes biosecurity so critically important in the prevention, control and elimination of transboundary animal diseases (TADs), with the focus on changing the habits and behaviours of people in such a way that the risk of disease transmission is decreased. A key aspect is to work with people to adopt biosecurity measures and to develop with them sets of safe practices in production that are seen as practical, cost-effective and sustainable.

ISBN 978-92-5-106507-5 ISSN 0254-6019

9 789251 065075

I1435E /1/03.10/1900