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BIOSECURITY SURVEY OF PIG FARMS IN THE DISTRICTS OF SOUTHERN BHUTAN IN RELATION TO THE RISK OF AFRICAN SWINE FEVER OUTBREAK

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ABSTRACT: African Swine Fever (ASF) is a viral disease of pigs traditionally localized in African countries but have spread into many continents in recent years. Bhutan experienced two outbreaks since 2021 both of which were effectively controlled by stamping out the susceptible population of pigs. Since there isn't any study conducted to understand the on-farm biosecurity practices of pig farmers in the country, a rapid cross-sectional biosecurity survey among the pig farmers in the six southern districts of the country was carried out. The objectives of this study were to generate baseline information about pig farm characteristics, understand on-farm biosecurity practices and the risk of possible ASF outbreaks in future, and understand the level of pig farmers' knowledge and awareness on ASF. Using a structured questionnaire, a door-to-door survey was conducted among 527 pig farmers of six districts viz. Samtse, Chukha, Tsirang, Dagana, Sarpang and Samdrup Jongkhar in Southern Bhutan from 14 – 30th May 2022. Data was consolidated, cleaned and analyzed using descriptive statistics, Pearson's and Yetes's Chi-squared tests in Microsoft Excel 2016. The study observed that about 67% of the farmers have less than three years of pig farming experience. About 97% of the pigs owned are exotic breeds and their crossbreeds. More than 39% of the farmers do not restrict visitors to their pig farms, and as many as 39% practice swill feeding of which more than 50% feed without boiling. While about 14% share feeds and farm equipment with other farms, only 4% disinfect incoming farm equipment before entering the farm, and as many as 74% do not maintain any records at the farm. Nearly 91% and 81% of the farms do not have perimeter fencing and footbath respectively. Similarly, 58% do not have designated foot wear in the farms. More than 50% of the farmers do not know anything about the ASF, while 26% and 55% are not aware of ASF outbreak at Sampheling and in the North-east India respectively. The level of ASF awareness or biosecurity compliance is directly proportional to the number of pigs the farmers owned. The outcome of the study suggests that there is a low level of ASF awareness and biosecurity compliance amongst pig farmers, especially among the subsistence farmers. There is a clear need for government authorities to educate the pig farmers using appropriate approaches that allow active participation of farmers in the design, planning and implementation of biosecurity practices to enable enhanced adoption. Further, the current situation demands active enforcement of the biosecurity requirements as immediate intervention considering the potential risk of the disease outbreaks.

Keywords: African swine fever; awareness; biosecurity; outbreak; pig farmers

1. INTRODUCTION

African Swine Fever (ASF) was first documented in Kenya in 1921 as a high-mortality illness of domestic pigs that were exposed to wild pigs (Arzt et al. 2010). For a long time, the disease remained localized in African countries with sporadic incursions into Europe or America which were successfully controlled, except for the island of Sardinia, Italy (Costard et al. 2013; Abedin et al. 2020). Following introduction of the disease in Caucasus region of Georgia in 2007, it gradually spread to Europe, Asia and America. Since 2005 and as of 7th July 2022, ASF has been reported in a total of 74 countries (OIE 2022).

ASF virus (ASFV) is a large enveloped double stranded DNA virus of the genus *Asfivirus*, *Asfarviridae* family that affects domestic and wild pigs naturally (Abedin et al. 2020). ASFV can be transmitted through direct contact between infected and susceptible pigs. Other modes of spread include bites by infected ticks (*Ornithodoros spp*.) and by contact with bedding materials, feed, equipment, clothes, footwear and vehicles contaminated with virus-

containing materials such as blood, faeces, urine or saliva from infected pigs. Processing and consumption of the meat from infected pigs can also spread the virus (Abedin et al. 2020). Given the high virulence, resistance to extreme environmental conditions, lack of vaccine, and high loads of the virus shed in the secretions of infected host rendering it highly infectious and contagious, the virus pose a serious threat to pig production worldwide. Besides, ASF is an important transboundary disease of pigs because of the globally distributed tick vectors of the *Ornithodoros* genus combined with availability of sizable naive domestic and wild pig populations in most countries (Arzt et al. 2010).

The outbreaks have had serious economic impact to the affected countries, with thousands of pigs either killed by the disease or mandatorily culled in an effort to limit the spread of the virus (Arzt et al. 2010; Beltran-Alcrudo et al. 2019; Abedin et al. 2020). Although, different countries have implemented various strategies aimed at preventing and mitigating infection with varying degree of success, in some countries the disease has become endemic. One of the main factors responsible for outbreaks and the persistence of the virus in domestic pig populations is the prevalence of widespread backyard small holder piggery where even the basic biosecurity measures are also rarely implemented allowing ASFV to circulate within pig populations resulting in a perpetual virus source to other pig farms (Arzt et al. 2010; Nantima et al. 2016; Beltran-Alcrudo et al. 2019; Abedin et al. 2020).

On-farm biosecurity is one of the most effective forms of protection against ASF and other pig diseases, which is principally the implementation of measures to prevent introduction of infectious agents into the farm or containment measures to prevent infectious agents exiting the farm in the event of outbreaks. Biosecurity entails a regulated movement of stock, people, equipment, feed and products into a clean farm and out of infected premises (Tenzin et al. 2017; Leo and Moses 2020). The pig farming in Bhutan comprise of both commercial and backyard holdings of which, backyard is predominant (Nidup et al. 2011).

Bhutan reported its first ASF outbreak on 16th May 2021 in the scavenging pig population of Phuentsholing town bordering Jaigaon, West Bengal, India, which was effectively controlled by stamping out the susceptible population in the area. The country also saw second outbreak in the backyard pig holdings in Sampheling block of Chukha district in the month of April 2022 where over 1000 pigs were culled (Wangdi 2022). To the knowledge of authors, no studies have been conducted to understand the biosecurity practices of pig holdings in the country. Therefore, it is important to understand the types of pig holdings in the country and on-farm biosecurity practices for better preparedness planning.

In this context, a rapid cross-sectional biosecurity survey among the pig farmers in the six southern districts (Samtse, Chukha, Dagana, Sarpang, Tsirang and Samdrup Jongkhar) of the country was carried out as a part of rapid risk assessment following the outbreak of ASF at Sampheling. The objectives of this study were to (1) generate baseline information about pig farm characteristics, (2) understand on-farm biosecurity practices in the pig farms and the risk of possible ASF outbreaks in future, and (3) understand the level of pig farmers' knowledge and awareness on ASF.

2. MATERIALS AND METHODS

2.1 Study area

The districts of Samtse, Chukha, Dagana, Tsirang, Sarpang and Samdrup Jongkhar are located close to the Indian states of Arunachal, Assam, West Bengal and Sikkim. Except for the West Bengal state, Authorities in India already reported ASF outbreaks in Arunachal, Assam and Sikkim in the recent years (FAO 2022). Following the outbreak of ASF in Sampheling and considering the potential risk of more such outbreaks, a door-to-door survey was conducted among the pig farmers in these districts. These districts were selected for the study considering their geographical locations in relation to the Indian states that have already reported the outbreaks. These districts also have high pig population (NSB 2021).

2.2 Questionnaire design

A set of questionnaires consisting of closed-ended questions was designed to collect information on various aspects of the farm management including farm characteristics, farmers' biosecurity knowledge and practices, and farmers' awareness on ASF as summarized

in Table 1. The questionnaire was pilot tested with two pig farmers of Sarpang district prior to the actual survey and was modified to improve clarity. The questionnaire was written in English and translated into local dialects by the surveyors for the ease and convenience during one-on-one interview at the residence of the farmer respondents with prior verbal consent. The information obtained were noted on the same questionnaire and later on compiled and consolidated.

2.3 Data collection and analysis

Owing to the lack of a proper sampling frame, a purposive sampling was used to identify pig farmers within the six identified districts. A door-to-door survey was conducted using a snowball sampling method in which the first selected household that owned pig provided information about the next household that owned pig in the area. In this way, 527 pig farming households within the six districts were selected and interviewed. One adult person involved in managing pig farm from each household was interviewed face-to face. The selected person was informed about the purpose of the survey with explanation that the data collected will be used for understanding the pig farming practices and to strengthen farm biosecurity. All the identified pig farmers (n = 527) agreed and consented to be interviewed. The survey interview was carried out from 14 to 30th of May 2022. Awareness education on pig farm management, on farm-biosecurity requirements, risk factors for ASF spread, and personal hygiene were provided to the respondents and to the community at the time of survey interview.

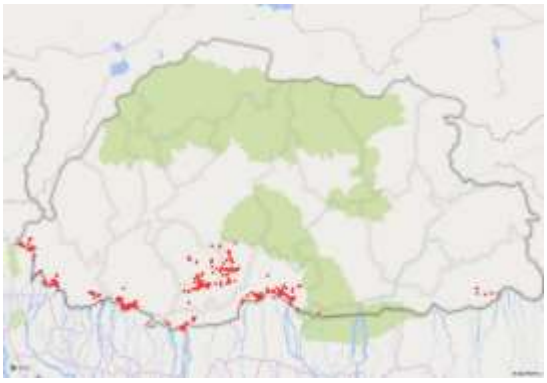

Figure 1: Spatial distribution of survey respondents (red dots)

Data was captured through the questionnaire form developed and later compiled and entered into the database of Microsoft Excel. Data cleaning, management and analyses were carried out using descriptive statistics, Pearson's and Yetes's Chi-squared tests in Microsoft Excel 2016 (Microsoft Corp., Redmond, WA, USA).

3. RESULTS AND DISCUSSION

3.1 Respondent's details

To the knowledge of the authors, this is the first study conducted to understand the biosecurity situations of pig farms especially in the six southern districts of Bhutan and to understand the knowledge and biosecurity practices of farm owners in the study area in relation to the uncontrolled spread of ASF in South Asia. High level of farm biosecurity implementation is considered the most important way out for preventing introduction of diseases on a farm (Tenzin et al. 2017; Bellini et al. 2021;

Table 1: Characteristics of pig farming, biosecurity practices and awareness on ASF of pig farmers addressed by the questionnaire

Particulars	Details
Respondent's details	Name, location address, contact number, GPS coordinates of farms, number of years in pig farming business.
Pig husbandry characteristics	Total number of pigs owned, breed type, age of pigs, farming practices, availability of wild pigs in their locality, type of feeds provided.
On-farm biosecurity knowledge & practices	Pigsty cleaning and disinfection, swill feeding, reporting of sickness and death, carcass disposal, perimeter fence with entrance gate, visitor control, biosecurity notice, vehicle tyre dip, foot dip with disinfection solution, designated foot wear, farm records, bringing farm equipment and feed from other farms, management of farm workers from other farms, isolation of sick, quarantine of new stock.
Awareness on ASF	Awareness on ASF outbreak at Sampheling, awareness on repeated outbreaks of ASF in North-east India, knowledge on ASF

Bedekelabou et al. 2022). The details of the respondents collected included name of the owner, contact number, location address, GPS coordinates of the farms, and the number of years in pig farming. GPS coordinates of the farms were plotted on a Bing Map using the built-in feature of MS Excel to construct a spatial distribution of the farms (Figure 1) surveyed.

Out of 507 farmers who responded to the question related to this information, 33.14% (168/507) had less than one year of experience in pig farming while 34.32% (174/507) had 1 to 3 years' experience (Table 2). Pig farming in Bhutan picked up during the recent COVID-19 pandemic time when the government supported farmers to produce more to bolster national food security reserves through the Big-Ticket Initiative project implemented by the Department of Livestock as a part of the Economic Contingency Plan of the country. This is evident from this study where more than 67% (342/507) of the farmers started pig farming in the last three years.

Table 2: Number of years of pig farming by the farmers

Category	Frequency	Proportion (%)
< 1 year	168	33.14
1 to 3 years	174	34.32
4 to 5 years	53	10.45
> than 5 years	112	22.09

3.2 Pig husbandry characteristics

In the study area, 486 farmers were found rearing 11,148 numbers of improved breeds (exotic and crossbreeds) of pigs while 35 were found rearing 322 local or non-descript breeds of pigs (Table 3). The surveyors have missed the breed information for 6 farmers owning 77 pigs. Improved breeds mainly consist of large black, large white, saddleback, duroc and their crossbreeds. These improved breeds of pigs are made available to the farmers by the National Nucleus Pig Breeding Centre at Yusipang, Thimphu, the National Piggery Research and Development Centre, Gelephu, and the regional pig and Poultry Breeding Centre, Lingmethang of the Department of Livestock. During this survey, the maximum number of pig farmers covered was in Sarpang district (n=170) followed by Dagana (n=116). Tsirang district also has good number of households rearing pigs. However, due to limited numbers of surveyors and time constraint, the households rearing less than five pigs were not included in the study population in this district.

With gradual development of livestock industry in the country, farmers have moved away from traditional scavenging type of pig husbandry towards more intensive husbandry practices. During this study, it was observed that almost all the farmers stall-feed their pigs either in permanent concreted sties (68.70%, 360/524), temporary wooden sties (30.53%, 160/524) or in temporary wire-mesh sties (0.76%, 4/524). The surveyors came across only three farmers (one in Dagana and two in Tsirang) which accounts for <1% who still practice scavenging type of farming as against 13% reported by Nidup et al. (2011). Scavenging pigs have contacts with wild pig population and represents one of the weakest links in the biosecurity chain and the biggest risk factor for ASF introduction into a country or a pig farm (Bellini et al. 2021). Communities mainly in the North-eastern region of India have a culture of pig rearing under scavenging and semi-scavenging systems (Bora et al. 2020). Abedin et al. (2020) strongly believes that the high-density pig population especially in the state of Assam coupled with the extensive scavenging type of husbandry practice could be the main reason why the state is plagued with frequent outbreak of ASF.

Bhutan's 71% landmass under forest cover (DoFPS 2021) provides ideal environment for wild pigs to flourish. About 57% of the farmers surveyed, reported that there are wild pigs in their locality (Table 4). Infected wild boars can mix with scavenging domestic pigs or when farm biosecurity is poorly implemented. Bellini et al. (2021) reported that at times of food scarcity in the wild, wild pigs visit farms resulting in the overlap of habitats of wild and domestic pigs facilitating the spread of the disease. The news articles published by *East Mojo* and *Latestly* on 6th and 15th August 2022 respectively on ASF infecting wild pigs in Mizoram state of India had sounded red alert in Bhutan wherein, forestry officials have been roped in to report any sightings of dead wild pig carcass for testing. Bhutan shares a long stretch of borders especially with the Indian states of Arunachal, Assam, West Bengal and Sikkim most of which reported having outbreaks, and the wild pigs move freely across borders

Table 3: Number of farmers rearing pigs covered during the survey in six districts (May 2022)

Districts	Improved breed		Local breed		Total HH* (No)	Total pigs (No)
	HH (No)	Pigs (No)	HH (No)	Pigs (No)		
Chukha	63	732	11	123	74	855
Dagana	101	2301	15	96	116	2397
S/Jongkhar	9	181	0	0	9	181
Samtse	75	1537	2	34	77	1571
Sarpang	163	3206	7	69	170	3275
Tsirang	75	3191	0	0	75	3191

***HH - households*

Table 4: Pig husbandry characteristics

Variables	**Frequency**	**Proportion (%)**
Pig housing		
Scavenge during day & housed at night	3	0.57
Housed and stall-fed	524	99.43
If house, type of sties		
Permanent concrete sties	360	68.70
Temporary wooden sties	160	30.53
Temporary wire-mesh sties	4	0.76
Are there wild pigs in the locality?		
Yes	298	56.87
No	177	33.78
Not known	49	9.35
Feed type		
Commercial feeds	169	32.31
Commercial feeds & locally available grain mix	329	62.91
Local grains & other non-conventional feeds	25	4.78

between the two countries (personal communication with Dr. Tempa, Program Director, Bhutan Tiger Centre, Motabgor, Panbang). Given this scenario and the fact that interactions between wild and domestic pigs can prolong ASFV circulation, Bhutan is at risk of plaguing with frequent outbreaks of ASF and the disease becoming endemic in the country, if appropriate biosecurity measures are not adopted. While 32% (169/523) of the farmers exclusively feed their pigs with commercially available feeds, about 63% (329/523) use locally available grains and other edible materials to supplement commercial feeds, and the rest, feed only locally available grains and other non-conventional feeds. Locally available grains could include pre-harvest crop damage caused by natural disasters or wild life including wild pigs. A study conducted on ASF in Latvia by Bellini et al. (2021) showed that crops contaminated by wild pigs when used as feed can be a risk factor for ASF occurrence.

3.3 Pig farm management practices in relation to on-farm biosecurity

The summary of pig farm management practices in relation to on-farm biosecurity is presented in Table 5. While majority of the farmers clean their pigsties on a daily basis, less than quarter of them disinfect pigsties after cleaning using bleaching powder or any other detergents available in their locality. A similar finding was observed by Leo and Moses, (2020) among pig farmers at Makurdi, Nigeria. Pigsty disinfection is important as it will help break the cycle of diseases on the farm. The low level of implementation of pigsty disinfection could be because farmers do not understand the importance of it, amongst other reasons. While it is exulting to note that many farmers associate visitors of their farms with biosecurity threats and restrict visitors, 39.07% of them do not know about the threat and allow free access.

Table 5: Pig farm management practices in relation to on-farm biosecurity

Variables	Frequency	Proportion (%)
How often you clean your pigsty?		
Daily	452	86.26
Once in 2-3 days	63	12.02
Weekly	6	1.15
Monthly	3	0.57
Do you disinfect pigsty after cleaning?		
Yes	116	22.22
No	406	77.78
Do you allow visitors to visit pig farm?		
Yes	202	39.07
No	315	60.93
Do you feed kitchen waste to your pigs?		
Yes	202	38.85
No	318	61.15
If yes, do you boil before feeding?		
Yes	99	49.01
No	103	50.99
How do you dispose dead pig carcass?		
Deep burial underground	499	98.62
Dispose in open area or in bushes	3	0.59
Consume the carcass	3	0.59
Sale the carcass	1	0.20
Do you bring pig feed & piggery equipment from other farms?		
Yes	72	13.87
No	447	86.13
Do you disinfect vehicles or equipment entering the farm premises?		
Yes	18	3.95
No	438	96.05
Do you allow workers from other pig farms to visit your farm?		
Yes	131	25.29
No	387	74.71
Do you isolate sick pigs from healthy ones?		
Yes	355	68.14
No	166	31.86
Do you quarantine new pig arrivals before mixing with existing stock?		
Yes	308	60.75
No	199	39.25
Do you maintain records of vaccination, treatment, new stock arrival, feed source etc.?		
Yes	135	26.01
No	384	73.99
Is there a perimeter fence around the farm?		
Yes	46	8.73
No	481	91.27
Is there a biosecurity notice at the farm for visitors?		
Yes	40	7.62
No	485	92.38
Is there a vehicle tyre dip at the entrance of the farm?		
Yes	3	0.62
No	480	99.38
Is there a foot dip at the entry of pigsty?		
Yes	98	18.81
No	423	81.19
Is there a designated foot wear at the farm?		
Yes	214	41.96
No	296	58.04

Vets, para-vets, brokers, meat vendors, piglet buyers etc. can be a potential mechanical carriers of various disease causing agents including the ASFV (Penrith 2009). Hence, they should be following some important biosecurity protocols when visiting farms.

Since pigs are efficient converters of food wastes into valuable proteins, kitchen wastes invariably land up into pig feeding. Feeding of kitchen waste (swill) containing pork is a very high-risk factor for ASF spread (Beltran-Alcrudo et al. 2019). From this study, we learnt that the practice of swill feeding is still prevalent in the country. As many as 38.85% (202/520) said they feed kitchen waste to their pigs, of which 49.01% (99/202) boil before feeding, while 50.99% (103/202) feed without boiling which is a very risky behavior. Almost all the farmers said they dispose dead pig carcass by deep burial. However, three farmers said they dispose in open area or in bushes while the remaining four said they either consume or sell the carcass. Improper disposal of ASF infected pig carcass or processing and consuming those is a high-risk behavior for spread of the virus as it survives in the carcass for relatively longer period compared to other types of viruses. Contaminated fomites or equipment are a potential risk factor for the introduction of ASFV in a farm (Bellini et al. 2021). The risky behavior of sharing feeds and farm equipment between farms is still prevalent. Seventy-two farmers (13.87%) did say that they share feeds and farm equipment with other farms. However, only 18 (3.95%) said they disinfect vehicles and farm equipment when such items are brought into the farm. The practice of farm-to-farm movements by farm workers is one of the most important risk factors for disease transmission between farms and greatly helps in the spread of the disease (Ebwanga et al. 2021). A sizeable number of farmers (25%, 131/518) do not restrict workers from other pig farms visiting their farms which could mean lack of awareness on the risk involved.

Disease can flare up within a farm at any time. So, farmers should practice separation of sick animals to protect the healthy animals. Appreciable proportion (68.14%, 355/521) of the farmers practice isolating of sick animals and 60.75% (308/507) implement quarantine of new arrivals. This might be explained by the fact that majority of the farmers are now aware of the purposes of isolation and quarantine requirements learning from the recent experience of COVID19 pandemic. However, there are still many farmers who do not comply with these requirements. Majority (73.99%, 384/519) of the farmers also do not maintain any records of vaccination, treatment, new stock, feed sources etc. Hence, traceability will be a major concern at times of outbreaks.

A gated perimeter fencing with vehicle tyre dip is one of the basic and most important components of a farm biosecurity measure to prevent access by animals, people and vehicles (Leo and Moses, 2020; Alarcon LV et al. 2021). In the study area, only 8.73% (46/527) of the pig farmers have installed perimeter fence and

Table 6: Awareness of respondents on ASF

Variables	Frequency	Proportion (%)
Are you aware of ASF outbreak at Sampheling, Chukha in recent weeks?		
Yes	390	74.29
No	135	25.71
Are you aware of ASF outbreaks in North-East Indian States?		
Yes	234	44.74
No	289	55.26
Do you know what African Swine Fever is?		
Yes	59	11.28
A little	181	34.61
No	283	54.11
Where do you report if there is sickness or death of pigs in farm?		
Livestock office	508	96.76
Gewog office	13	2.48
BAFRA office	2	0.38
Don't know	2	0.38

Table 7: Awareness on ASF and biosecurity compliances across different categories of farmers

Category	Frequency		Proportion of awareness / biosecurity compliances
	Yes	No	
Aware of ASF outbreak & eradiation at Sampheling, Chukha district? [a]			
Subsistence (<10 pigs)	141	76	65%
Semi-commercial (10-50 pigs)	205	55	79%
Commercial (>50 pigs)	43	4	91%
Aware of ASF outbreaks in North-east India? [b]			
Subsistence (<10 pigs)	90	127	41%
Semi-commercial (10-50 pigs)	113	145	44%
Commercial (>50 pigs)	30	17	64%
Do you feed kitchen waste to your pigs? [c]			
Subsistence (<10 pigs)	99	115	46%
Semi-commercial (10-50 pigs)	93	166	36%
Commercial (>50 pigs)	9	37	20%
Is there perimeter fence around the farm? [d]			
Subsistence (<10 pigs)	15	202	7%
Semi-commercial (10-50 pigs)	23	239	9%
Commercial (>50 pigs)	8	39	17%
Is there foot dip at entrance of pigsties? [e]			
Subsistence (<10 pigs)	26	190	12%
Semi-commercial (10-50 pigs)	50	209	19%
Commercial (>50 pigs)	22	23	49%

a [Yetes's $\chi 2=20.289$, df=2, p value <.05]; b [$\chi 2=7.957$, df=2, p value <.05]; c [$\chi 2=13.105$, df=2, p value <.05]; d [$\chi 2=4.948$, df=2, p value >.05]; e [$\chi 2=33.139$, df=2, p value <.05]

just three farms had vehicle tyre dip facility at the entrance of the farm. The observation of the latter could be explained by the fact that many farms do not have access to motorable roads.

Biosecurity notice at the entrance of the farm is necessary for directing visitors to first contact the farm incharge before entering the farm. Only 7.62% (40/525) of the farms had this biosecurity notice for the visitors. Similarly, footbaths were available in only 18.81% (98/521) of the farms with only 29 farmers using the footbath properly. Footbaths are essential for disinfection of foot wears and the contents changed on a daily basis. Absence of such facility or poor management can increase the risk of disease outbreaks in farm (Leo and Moses 2020). The study also found out that only about 42% (214/510) of the farms had designated footwear in the farms. Having a dedicated footwear is important as it will prevent disease causing agents exiting or entering the farm to or from the places of visits with the footwear on. Farmers' non-compliance with the practice of use of farm specific footwear is very risky as humans can be a potential mechanical carrier of diseases to pigs (Leo and Moses 2020).

3.4 Awareness on African swine fever

Reporting sickness and deaths of pigs to appropriate authorities is of utmost importance as it enables the agencies concerned to take immediate steps to contain the disease. While remarkably high proportion of farmers know whom to report sickness or deaths of pigs (Table 6), quite a sizable number of them (25.71%, 135/525) are not aware of the recent ASF outbreak and eradication operation carried out at Sampheling, and more than 55%

(289/523) of them still do not know that ASF is prevalent in the North-eastern states of India, which are very close to Bhutan borders.

Only 11.28% (59/523) of the farmers know what ASF is all about while more than half of the farmers who participated in this study do not know anything about ASF. This could be explained by the fact that the disease is new in the region and that the farmers did not experience the outbreak before.

Based on the number of pigs owned, MoAF, (2021) classified pig farmers as subsistence (those owning < 10 pigs), semi-commercial (owning 10-50 pigs) and commercial (owning >50 pigs). Level of ASF awareness and biosecurity practices were also assessed across these categories (Table 7) and compared. The results show that the level of ASF awareness or biosecurity compliance is dependent on the number of pigs the farmers owned. More the numbers of pigs owned, better is the awareness and compliance. On testing the findings using Pearson's $\chi 2$ and Yetes's $\chi 2$ tests, except for presence of perimeter fence around the farms ($p > .05$), there exists significant difference ($p < .05$) among different categories of the farms and the level of their awareness and biosecurity compliances. Commercial farms owning large number of pigs are doing better compared to the semi-commercial and subsistence farms with smaller number of pigs. One of the reasons obvious for this observation is because their investment is bigger compared to the other two categories.

4. CONCLUSIONS & RECOMMENDATION

Compliance to on-farm biosecurity requirements is the key to any successful livestock farming. Biosecurity compliance by pig farmers especially in the six southern districts has become the need of the hour as most of the Indian states adjoining southern Bhutan have already reported outbreaks of ASF. This study, found out that the pig farmers' level of awareness on ASF and biosecurity compliance is low and is more pronounced especially among the subsistence farmers. Installing perimeter fencing with secured entrance gate, controlling visitors, avoiding swill feeding, using medicated footbath, having designated footwear, not sharing farm utensils, disinfecting farm machineries and equipment entering farm premises, isolation of sick and quarantining of new arrivals are some of the basic but very important aspects of on-farm biosecurity. Level of implementation of most of these on-farm biosecurity measures are very low in the piggeries in these districts making them highly vulnerable to disease outbreaks especially ASF. The vulnerability of the farmers is exacerbated by the fact that the ASF has now spilled into the domain of wild pigs in North-east India where they roam freely across borders between Bhutan and India. Thus, securing domestic pigs from contacting wild pigs is the most important and urgent intervention required at the moment. As a short-term measure and given the urgency of the requirement, the on-farm biosecurity requirements could be enforced strictly on non-compliant pig farmers by the Bhutan Agriculture & Food Regulatory Authority (BAFRA) and by the livestock extension officials. Officials of BAFRA, Department of Livestock and the Local Government should collaborate to work hand-in-hand with pig farmers to include biosecurity requirements in the inception and design of piggeries. Farmer-centered approach to on-farm biosecurity implementation should be the long-term strategy wherein the farmers should be able to understand the disease transmission pattern and implement necessary on-farm biosecurity measures voluntarily to secure their own farm from disease outbreaks. For this, trainings and awareness programs for the farmers are required which must be included in the plans and programs of agencies responsible for biosecurity implementation and enforcement.

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Conflict of interest

The authors declare that there are no conflict of interest.

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