Assessing the spatial extent of African swine fever spread in Nigeria

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Abstract

African swine fever (ASF) is the most important disease of pigs due to its rapid spread and high mortality. ASF has been enzootic in Nigeria since its introduction in 1997, and understanding the spatial spread of the disease is important for devising effective control measures. Hence, this study assessed the spatial extent of ASF spread in selected States of Nigeria, namely: Adamawa, Benue, Cross-River, Delta, Kaduna, Lagos, Ogun, Plateau, and Taraba States. This assessment was based on three aspects: (i) ASF prevalence using tissue and sera collected from pig farms and abattoirs/slaughter slabs (ii) data collection from veterinary authorities and pig farmers using interviews, and (iii) field observation of farmer practices in relation to ASF spread. The results of tissue samples analyzed by polymerase chain reaction revealed an overall ASF prevalence of 10.21% (100/979), with the highest State-level prevalence recorded in Plateau (32.09%), followed by Cross River (25.47%), Kaduna (6.25%), and lowest in Benue (4.26%) States. Farms under the extensive husbandry system (6.98%) had a higher prevalence compared to farms under intensive husbandry system (2.09%). Abattoir samples had a higher positivity rate (16.70%) compared to pig farm samples (4.58%). Analyzed sera revealed an ASF seroprevalence of 17.03% (87/511), with the highest seroprevalence in Benue (42.9%), followed by Lagos (36.69%), Taraba (34.8%). Plateau (10.25%) and the lowest in Ogun (5.9%) State. Husbandry system-wise, a higher seroprevalence was recorded in extensive husbandry systems (20.74%), compared to intensive systems (14.29%). Data collected from veterinary authorities and farmers revealed mixed results. In some States, ASF was alluded to be major concern, while in others, they stated otherwise. Finally, unregulated pig movement and pigs with clinical signs suggestive of ASF were observed in majority of the States during this study. In conclusion, based on the three aspects of this study, ASF may be widespread in Nigeria.

Introduction

African swine fever (ASF) is a highly lethal haemorrhage disease of domestic and wild pigs caused by ASF virus (ASFV) (Galindo & Alonso, 2017; Montgomery, 1921; Penrith & Kivaria, 2022). ASFV is a complex double-stranded DNA virus and the only member of the family *Asfarviridae* (Galindo & Alonso, 2017). The ASFV has 24 genotypes, all of which are found in Africa, except for genotypes I and II, which are widely distributed and reported in several countries worldwide (Blome et al., 2020, Qu et al., 2022). Originally, ASF was confined to Africa, but the disease has now spread to Europe, Asia, Caribbean, and Oceania, decimating pig populations and a threat to pig production (Guberti, et al., 2022). Transmission of ASFV is either by soft ticks of the genus: *Ornithodoros*, direct contact with infected pigs, or indirect contact with contaminated materials (Penrith & Vosloo, 2009; Bellini et al., 2016; Guinat et al., 2016; Chenais et al., 2018). Clinically, ASF is characterized by febrile syndrome with erythema and cyanosis of the skin, hemorrhagic diarrhoea, anorexia, high morbidity, and mortality (Sánchez-Vizcaíno et al., 2015).

Nigeria has the largest domestic pig population in Africa, and pig farming contributes significantly to the livelihood of rural populaces of pig-rearing communities in the country (Babalobi et al., 2007, Fasina et al., 2011). ASF has been enzootic in Nigeria since 1997, when it was first introduced by trading in live pigs across the international border with the Benin Republic (El-Hicheri, 1998; Odemuyiwa et al., 2001; Fasina et al., 2010). The disease has spread to all pig-producing regions of the country with devastating economic consequences (El-Hicheri, 1998; Odemuyiwa et al., 2005, Fasina et al., 2010; Luka et al., 2017). During outbreaks, selling sick pigs further spread the disease (Adedeji et al., 2022). Additionally, the high demand for live pigs and the unregulated movement of pigs between States and regions for better prices lead to the continuous spread of the disease in the country (Adedeji et al., 2022). Practices by farmers such as sharing of farm equipment, attendants, and breeding boars have also contributed to ASF spread in the country (Fasina et al., 2012). Other risky practices that contribute to ASF spread include locating farms near abattoir/slaughter slabs and poor bio-security measures (Awosanya et al., 2015, Fasina et al., 2010). As a result, it is challenging to get a holistic picture of the ecology of ASF in Nigeria, due to consistent spread/dissemination of the disease The spatial distribution of ASF in Nigeria is dynamic and constantly evolving. Understanding the pattern of disease spread, practices associated with disease spread, and drivers of disease spread are crucial for implementing targeted preventive and control measures. Hence, the aim of this study was to assess the spatial extent of ASF spread in Nigeria, highlighting the affected areas and providing insight into the factors contributing to ASF spread in the country. Moreover, findings from this study will have implications for national preventive and control measures.

Materials and Methods

In this study the spatial distribution of ASF was assessed based on the following three factors: (i) The detection of ASF antigen and antibodies in tissue and sera samples collected from pig farms and abattoirs/slaughter slabs (ii) Data collection from veterinary authorities and pig farmers using interviews, and (iii) field observation of unsafe pig farmer practices that contributes to ASF spread in Nigeria. The study was conducted from March 2019 to October 2019.

Study Area

This study was carried out in Nigeria which shares boundaries with Benin Republic, Niger Republic, Chad, Cameroon, and the Atlantic Ocean. Free movement of livestock across the Nigerian international borders with neighboring countries in both directions has implications for transboundary animal disease spread (Motta et al., 2017; Valerio et al., 2020). Administratively, Nigeria is divided into 36 states and the Federal Capital Territory (FCT), Abuja (Fig. 1), and 774 local government areas (LGAs). Pig production activities are carried out in 30 States of the country. The Nigerian pig husbandry system comprises commercial/backyard-intensive farms and free-roaming extensive pig production systems (Omotosho et al., 2016, Eleazar et al., 2021).

The commercial/backyard-intensive production system is mostly in the southern part of Nigeria and is characterized by small backyard intensive farms and pig farm clusters, also called pig farming estates or settlements (Adesehinwa & Saka, 2009; Eleazar et al., 2021). Pig farm estates or settlements are clusters of many pig farms located near each other, sharing common land, facilities, and other resources. The free-roaming extensive pig production systems are mostly in northern Nigeria with smallholder farmers.

Selection of study sites

Nine States in Nigeria were purposefully selected for this study using these key factors i. major pig production area/high pig destiny ii. pig marketing, and iii. previous report of ASF outbreaks, iv geographical region. The following States and LGAs were selected: Northern region: Adamawa (Mubi, Numan, Yola), Taraba (Jalingo, Zing, Wukari), Benue (Makurdi, Gboko), Plateau (Jos-South, Kanke, Qua Pan, Langtang North, Langtang South Shendam), Kaduna (Zangon Kataf, Zonkwa, Kaduna South). Southern region: Cross River (Akamkpa, Akpabuyo, Ikom, Biase, Ogoja), Delta (Aniocha North, Obiaruku, Ndokwa West, Ughelli, Warri South, Ika South, Ika North-East), Ogun state (Ifo, Yewa North, Odeda), Lagos State (Agege, Ifako/Ijaiye, Ikorodu)(Fig. 1).

Figure 1: Map of Nigeria showing nine pig producing States in Nigeria where samples will be collected.

Determining ASF Prevalence

Sample size and collection

Sera and tissue samples (spleens and lymph nodes) at pig farms and abattoirs/slaughter slabs were collected from nine pig-producing states in Nigeria (Fig. 1). A convenience sampling method was used for sample collection, the sample size was determined using a previously described method by Dohoo et al., (2003). Nigeria has a population of 7 million pigs, the minimum recommended sample size for such a population using a confidence level of 95% and a margin of error of 5% gives a calculated sample size of 495 for both sera and tissue samples each (Dohoo et al., 2009).

Molecular detection of African Swine Fever virus

The tissue samples were weighed and made into 10% homogenates using phosphate-buffered saline. Total genomic DNA was extracted from tissue and blood samples using the QIAamp DNA mini kit (Qiagen, Hilden, Germany) according to the manufacturer’s instructions following the manufacturer's instructions. ASF diagnosis was carried out by detecting the ASFV genome using conventional polymerase chain reaction (PCR) as previously described (Aguero et al., 2003). Amplified PCR products were separated and visualized by gel electrophoresis, with 257 bp being the expected PCR product (Aguero *et al.*, 2003).

Serology

In this study collected sera samples were analyzed using SVANOVIR®ASFV-Ab an indirect enzyme-linked immunosorbent assay (ELISA) kit, according to the manufacturer’s instructions. The ELISA kit uses a recombinant ASFV p30 protein that enables the early detection of ASFV antibodies with high specificity (Perez-Filgueira et al., 2006). The results obtained were summarized in tables.

Data collection

Data was collected through individual interviews with veterinary officials/ authorities, group interviews with pig farmers, and direct observation of activities at the farms and pig slaughter points.

The veterinary authorities were asked about previous history of ASF outbreaks in their States, government plans on ASF control, common pig diseases and government intervention during outbreaks and pig slaughter points. Data collected from pig farmers included questions: i) about previous ASF outbreaks, ii) practices associated with ASF outbreaks, iii) lessons learned from previous ASF outbreaks, iv) sources for restocking their farms, v) marketing channels for their pigs, vi) actions taken during ASF outbreaks, and access to veterinary care.

Ethics approval and consent to participate

This study was approved by the National Veterinary Research Institute Animal Ethics Committee Vom, Nigeria (AEC/03/26/16).

Results

Results of Prevalence study

The overall prevalence of ASF by PCR, was 10.21% (100/979); however, at regional level, a higher prevalence of 13.90% (72/518) was recorded in the northern region in comparison to the southern region (6.06% 28/462) of Nigeria (Table 1). State-level prevalence ranged from 1.56%-32.09%, with ASFV detected in samples collected in Plateau (32.09%, 60/169), Cross River (25.47%), Kaduna (6.25%, 4/64), Benue (4.26%, 4/94), Taraba (3.61%, 3/83), Delta (1.56%, 1/64). and Adamawa (1.11%, 1/90) States (Table 1, Fig 2). However, neither Lagos nor Ogun States had positive samples for ASFV by PCR. ASFV was detected by PCR in 45.86% (18/37) of the LGAs where the samples were collected with prevalence levels ranging from 2.56-100%. Majority of the LGAs with positive ASFV samples were in the northern part, with 61.11% (11/18) in comparison to only 38.89% (7/18) LGAs in the Southern part of Nigeria (Table 1). ASFV was detected in all LGAs sampled in Plateau and Cross River States. Moreover, abattoir/ slaughter slab samples had higher positivity rate of 16.70% (76/455) compared to 4.58% (24/524) pig farm samples. Private slaughter slabs recorded a prevalence of 25.63 % (51/199), compared to 9.77 % (25/256) for government-designed abattoirs/slaughter slabs. Pigs under extensive systems, had a prevalence of 6.98% (15/215), compared to 2.09% (6/287) in pig under intensive systems. ASFV was detected in 3.45% (6/174) of samples collected from intensive pig farms located by themselves, while none in samples collected in pig in farm estates.

Serology results

For this study, the overall seroprevalence was 17.03% (87/511) at the regional level, as result showed that seroprevalence was 21.22% (45/212) and 15.7% (47/299) in the northern and southern region respectively (Table 1). Seroprevalence ranged from 10.3% to 42.9%. across the nine selected states. ASFV antibodies were detected in Benue (42.9%), Taraba (34.8%), Lagos (36.69%), Adamawa (12.9%), Plateau (10.3%), and Ogun (5.9%) (Table 1, Fig 2). No antibodies were detected in samples collected in

Kaduna, Cross River, and Delta States. Additionally, seroprevalence was 3.05-60.0% at the LGA level, and ASFV antibodies were detected in 37.84% (17/38) of LGA where samples were collected. Seroprevalence was higher among pigs reared under extensive husbandry system (20.74%) as compared to intensive husbandry system (14.29%). Seroprevalence was 26.06% (37/142) in pig farms sampled inside pig farming estates compared to 3.52% (5/142) in pig farms standing alone.

Table 1: Polymerase Chain reaction and serology results of samples collected at nine selected pig producing States of Nigeria

State	LGA	No of samples	PCR positive (%)	Sera samples	Sera positive (%)
	Oshimili south	6	0	4	0
	Iseluku	14	0	11	0
	Ika North	15	0	6	0
	Ika South	7	0	3	0
	Ndokwa West	2	0	2	0
	Ughelli	4	0	5	0
	Obiaruku	8	0	7	0
	Warri	8	1 (12.50)	6	0
Delta State	Sub-Total	**64**	1 (1.56)	**44**	**0**
	Odeda	35	0	21	1(4.76)
	Yewa South	23	0	18	0
	Ikenne	30	0	29	4(13.76)
	Ewekoro	35	0	33	1 (3.03)
Ogun State	Total	**123**	**0**	**101**	6(5.94)
	Agege	130	0	96	31 (32.29)
	Ikorodu	39	0	13	9 (69.23)
Lagos State	Sub-Total	**169**	**0**	**109**	40 (36.69%)
	Calabar	34	4 (11.76)	10	0
	Akpabuyo	15	2 (13.33)	10	0
	Akamkpa	21	7(33.33)	9	0
	Biase	2	2 (100)	0	0
	Ikom	27	12 (44.44)	11	0
	Yala	7	0	5	0
Cross River State	Sub-Total	**106**	27 (25.47)	**45**	0 (0.00)
Southern Region		**462**	**28 (6.06%)**	**299**	**47 (15.7%)**
	Jos South	34	11 (32.35)	2	0
	Qua Pan	17	1 (5.88)	10	1 (10)

	Kanke	66	20 (30.30	8	1(12.5)
	Langtang North	50	23 (46.0)	8	0
	Langtang South	13	2 (15.38)	2	0
	Shendam	7	3 (42.86)	10	2(20.0)
Plateau State	Sub-Total	**187**	60(32.09)	**39**	4 (10.26)
	Makurdi	36	3 (8.33)	5	3 (60.0)
	Gboko	58	1(1.77)	16	6(37.50)
Benue State	Sub-Total	**94**	4(4.26)	**21**	9 (42.86)
	Jalingo	22	1 (4.55)	22	5 (22.73)
	Wukari	26	2(7.69)	16	7 (43.75)
	Zing	35	0	28	11 (39.29)
Taraba State	Sub-Total	**83**	3 (3.61)	**66**	23 (34.85)
	Numan	37	1 (2.70)	22	6 (27.27)
	MubiNorth	30	0	26	0 (0.00)
	Gerei	23	0	20	3(15.00)
Adamawa State	Sub-Total	**90**	1 (1.11)	**68**	9(13.24)
	Zonkwa	10	0	4	0
	Zagon Kataf	40	4 (10.00)	11	0
	Kaduna South	14	0	3	0
Kaduna State	Sub-Total	**64**	4 (6.25)	**18**	**0**
Northern region		**518**	**72(13.90)**	**212**	**45(21.22%)**
Grand Total		**979**	100 (10.26%)	**511**	87 (17.03)

Fig 2: Map of Nigeria showing spatial spread of African swine fever based laboratory results of samples collected and analyzed by polymerase chain reaction and enzyme-linked immunosorbent assay

Feedback from Veterinary authorities

Information collected from veterinary authorities in Adamawa Plateau, Benue, Taraba, Ogun, Delta, and Kaduna States, revealed that ASF is a major challenge in those states. While reports from Lagos and Cross River States indicated ASF outbreaks had not been reported in the last three years. Veterinary officials in the nine States surveyed said that there was no government backed ASF control plan. The governments of Lagos, Benue, and Plateau States provided disinfectants to pig farmers for decontaminating pig pens in order to prevent ASF transmission. Other information obtained from the Veterinary authority in Ogun state, suggested the involvement of farmers in cross-border trading of pigs with Benin Republic. In Cross River State, around 69,000 live pigs were brought into the State in 2018, primarily from Abia, Enugu, Adamawa, Benue, Plateau, and Kaduna States. While in Benue State, pigs were brought from Plateau, Kaduna, and Nasarawa States. Also, information gathered from the veterinary authorities revealed there were no government-designed abattoirs or slaughter slabs for pigs in Ogun, Adamawa, Taraba, and Delta States. While Kaduna, Plateau and Lagos States had government-designated abattoirs or slaughter slabs. ASF, erysipelas, bacterial gastroenteritis, tuberculosis, food poisoning, and cysticercosis were the most common pig diseases reported by veterinary authorities.

Data collected from farmers

A total of 12 pig farmer group interviews were carried out in seven of the nine selected States as follows: Benue (2), Cross River (1), Delta (1), Plateau (3), Lagos (3), Ogun (1), and Taraba (2). Pig farmers in the nine selected States reported that ASF occurs frequently. however, they seldom report due to lack of financial compensation. Hence, farmers indicated that sick pigs were sold off during suspected ASF outbreaks. In all the states surveyed, pig farmers expressed dissatisfaction with veterinary authorities due to lack of support. Specifically, the Oke-Aro pig farmers in Lagos reported that ASF caused significant losses, including the deaths of some farmers due to the trauma of losing their sources of likelihood notably between 2005 and 2006. In Plateau State, farmers reported that ASF outbreaks devastated their pigs in 2018 and 2019. Feedback from farmers in all states surveyed indicated that the following practices may lead to the introduction of ASFV into pig farms; buying fresh pork from external sources and bringing it to farms, sharing breeding boars, restocking from live pig markets and neighbours and the activities of butchers. Other risky practices include poor traffic control, non-resident-, and poorly trained farm attendants /workers.

On the other hand, pig farmers suggested the following preventive measures to protect their pigs from ASF, namely: boiling water to disinfect pens and good traffic control. Other preventive measures include avoiding stagnant water, proper burial of dead pigs, improved sanitation, isolation of sick animals, use of disinfectants, foot dips, fumigation, resident farm workers, and prohibiting consumption of pork from external sources. Also, as an incentive, resident farm workers were given pork from pigs slaughtered on the farm to prevent the consumption of pork from external sources. As a coping strategy to mitigate losses due to ASF, farmers in Langtang North and Langtang South in the southern part of Plateau State claimed the use of various “curative agents” for the treatment of ASF such as cannabis, anti-retroviral drugs, petrol, salt, detergent, and "insect powder". Additionally, some farmers in Lagos State mentioned using anointing oil, prayers, and charms to treat and prevent ASF. Farmers in Ogun State source pigs from within the State, Osun State, South Africa, and Europe, but sell their pigs within the State, and to Delta State, Lagos State and Benin Republic.

Description of husbandry system in the nine pig producing states of Nigeria

The husbandry systems observed in the nine pig producing states were extensive, semi-intensive, and intensive systems. The intensive farms are further classified into backyard, commercial and pig farming estates. The extensive, semi-intensive, and intensive husbandry systems were practiced in Plateau, Benue, Adamawa, and Kaduna, while intensive systems exclusively were practiced in Cross-river, Delta, Lagos, and Ogun States. Pig farming estates were observed in Lagos, Ogun and Delta States. The Lagos pig farming estate visited were the Oke-Aro, Ikorodu and Gberigbe pig farm settlements/estates. Oke-Aro pig settlement/estate consist of two sites, namely, the old and new sites. The new site is about 11 hectares with 750 pig pens, while the Old Site occupies 22 hectares with 1500 pig pens. Both sites were reported to sell about 650 pigs a week. Gberigbe pig farm settlement is the second pig farm estate/cluster visited in Lagos, it is situated on about 40 hectares, and the farmers' population is about 1,000. Gberigbe pig farm settlement is reported to sell 500 pigs weekly, they all practice intensive husbandry. The common breeds observed in the nine States surveyed were Large White, Camborough, Landrace, Duroc, and Hampshire.

Activities of abattoir/slaughter slabs in nine pig-producing states of Nigeria

Data collected from Abattoir/slaughter slabs revealed that private individuals were in charge of the abattoirs /slaughter slabs in Cross River (4/5), Lagos (2/3), Taraba (1/1), Ogun (2/2), and Delta (5/5), Benue (20/28), Plateau (4/5). Abattoirs/slaughter slabs in Cross River (5/5), Lagos (3/3), Taraba (1/1), Ogun (3/3), Plateau (4/5), and Delta (3/3) were regulated, while no regulation of slaughter slabs was reported in Adamawa State (0/2). Clinical signs of ASF were observed in pigs from many of the private slaughter slabs visited. In Cross River and Delta States, pig slaughter slabs were located close to major rivers, one of the rivers is part of a National Park with a documented population of wild pigs. A similar scenario has been observed in Kaduna and Benue States with slaughter slab water draining into public drainage systems. Private pig slaughter slabs were accessible to roaming pigs in Adamawa, Benue, Plateau, and Cross River (Fig 3A, 2B).

Practices by direct observation in states visited

Swill feeding of pigs in Cross River, Plateau, and Benue State was observed during data collection. In Lagos State, specifically in Gberigbe, it was observed that one attendant was managing up to four pig farms. Improper disposal of dead piglets was observed in Lagos and Plateau States (Fig 3D). It was also noticed that feed materials were centrally stored for all the farms in one of the pig farming estates. Furthermore, we observed that cattle egrets were commonly seen at the abattoirs, refuse sites, and farms in Oke-Aro and Gberigbe pig estates. Another important observation was farmers are involved in the self-treatment of their sick pigs without consulting veterinarians or animal health workers. In Plateau State, we observed traders visiting multiple pig farms on the same day to purchase pigs for slaughter. In Cross River, Ogun, and Lagos State, mixed rearing of pigs and poultry was observed. Another interesting practice observed was the slaughtering of pigs on farms or at home in Adamawa, Benue, Plateau, and Ogun States (Fig 3C).

Fig 3A: Free roaming pig at private slaughter slab North Central Nigeria. **3B:** Free roaming pig at a pig butcher's table in Gboko, Benue State, Nigeria. **3C:** Slaughtering of pigs at a pig farm Southwest Nigeria. **3D:** Improperly disposed piglet carcass in Shendam, Southern Plateau State, Nigeria.

Discussion

Our study reconfirmed that ASF is widespread and enzootic in Nigeria, ASFV antibodies and or antigen were detected in the nine selected States in Nigeria (Table 1, Fig 2). PCR results revealed Plateau, Cross River Benue, and Taraba State had high prevalence rates by PCR. Higher ASF prevalence was recorded for samples analyzed by PCR in States practicing extensive husbandry systems such as Plateau, Benue, and Taraba States compared to States with intensive systems in Lagos, Ogun, and Delta State. The seroprevalence of 17.03% in this study was higher than the 9.0% national seroprevalence reported by Fasina et al. (2010), although the sample size in this study was smaller than the previous study. Nevertheless, our finding suggested that ASF is widespread disease in all the regions, State and LGA in Nigeria. Seropositivity is evidence of ASFV still circulating in the pig population, and survivor pigs from previous outbreaks. Higher ASF seroprevalence was recorded in the northern region and high-density pig populated States such as Plateau, Benue, Taraba, and Lagos States. According to previous reports, extensive husbandry is associated with high seropositivity and outbreaks of ASF (Mannelli et al., 1997; Penrith & Vosloo, 2009). Private slaughter slabs recorded a higher prevalence of ASF compared to government-designed abattoir/slab, which is not surprising, as pigs showing clinical signs suggestive of ASF were noticed during visits for sample collection. Furthermore, free-roaming pigs had easy access to private slabs and butcher's tables (Fig 3A, 3B), this is inimical to ASF control measures. In four States surveyed, water from slaughter slabs drained into rivers or public drainage systems raising concerns about the potential transmission of ASF through wastewater. Contaminated water from rivers and streams has been suggested to play a role in ASF outbreaks in some countries (Cheng & Ward, 2022; Fasina et al., 2020). The lack of government-designated pig slaughter slabs in Adamawa, Delta, Taraba, and Ogun State creates room for unregulated slaughter slabs and slaughtering at the household/farm level (Table 1). Authorities must address this issue and ensure that pig slaughter points are regulated to prevent the spread of diseases. In all selected States surveyed, a state-level ASF control plan was absent, indicating a lack of commitment to controlling the disease. This is exacerbated by a weak disease surveillance system and poor relationships between veterinary authorities and pig farmers.

Farmers reported that ASF occurs frequently on their farms but they seldom report it due to a lack of financial compensation. When ASF outbreaks occur, farmers suffer significant economic and social losses. Despite these losses, there is a perceived lack of support from relevant authorities, discouraging farmers from reporting outbreaks. This is similar to previous studies in Nigeria that highlighted these challenges resulting in underreporting of suspected ASF cases in the country (Awosanya et al., 2015; Fasina et al., 2012). The impact of ASF on pig farming cannot be understated. Not only does it lead to the loss of valuable livestock, but it also inflicts severe emotional and financial hardships on the farmers. The devastating effects of ASF in Nigeria were demonstrated by significant losses and deaths of some pig farmers in 2005/2006 and 2020 (Ambagala et al., 2023). Several practices outlined by farmers and observed in this study are detrimental to biosecurity measures. To prevent the introduction of ASF into pig farms, raising awareness among farmers regarding practices such as purchasing pork from external sources is crucial. ASFV-contaminated pork is an important route of ASF transmission in various pig production systems (Sánchez-Vizcaíno et al., 2012; Li & Tian, 2018; Wang et al., 2019; Hu et al., 2021). Sharing breeding boars also poses a potential risk for the spread of ASF which can be mitigated by promoting the use of artificial insemination techniques instead of sharing/borrowing boars (Lichoti et al., 2016; Galli et al., 2022). Restocking from live pig markets and neighboring farms can contribute to the introduction and spread of ASF if proper precautions are not taken (Fasina et al., 2012; Adedeji et al., 2022). Farmers need to ensure that the pigs they purchase for restocking are free from diseases, including ASF. The activities of farm attendants play a significant role to the spread of ASF. Sharing of farm attendants is a known practice in Nigeria, particularly in smallholder pig farming clusters (Fasina et al., 2012; Omowon et al., 2019). Training farm attendants on proper biosecurity protocols, regular monitoring, and reinforcing these protocols will enhance farm biosecurity. Having resident farm attendant/workers living on-site were suggested by farmers to helps limit their activities, such as working in other pig farms which can result in the introduction of ASFV. During our data collection process in Cross River, Plateau, and Benue States, we observed the practice of feeding pigs with swill. Swill feeding is a cost-effective way of feeding pigs, but it can also pose a major risk factor for introducing ASFV into farms and new areas (Fasina et al., 2012; Gao et al., 2021; Cheng & Ward, 2022). To mitigate the risk of ASFV transmission via swill feeding, farmers can heat treat the swill before feeding it to pigs (Zu Ermgassen et al., 2016; Nuanualsuwan et al., 2022; Penrith et al., 2023). To mitigate their losses, farmers in the southern part of Plateau State claimed to use several unconventional substances as curative agents for ASF treatment. Using cannabis, anti-retroviral drugs, and petrol as curative agents raises public health concerns. Farmers in Lagos believe in the use of anointing oil, prayers, and charms for ASF cure. This shows the desperation of pig farmers and their willingness to experiment with these substances to save their pigs. There are claims by farmers on the efficacy of plants for curative treatment of ASF in Nigeria and West Africa, these claims were investigated but not substantiated (Fasina et al., 2013). In this study, another risky practice observed was traders visiting multiple pig farms on the same day to purchase pigs, which is an important route for the spread of ASF in Nigeria and other countries (Atherstone et al., 2019; Aliro et al., 2022; Adedeji et al., 2022)

Conclusion

This study highlights the spatial spread of ASF in all the nine States surveyed and majority LGA based on the prevalence results and data collected from veterinary authorities and pig farmers. The spatial spread was evident in Plateau, Benue, Taraba, and Lagos States with antibodies and or antigen detected in nearly all the LGA in the States. ASF was also widespread in the husbandry systems and abattoirs/slaughter slab. As a result, veterinary authorities in Nigeria should enact a workable ASF strategic control program to mitigate the continue spread of the disease.

Declarations

Authors' contributions

AJA, PDL, CM, VBM conceived and designed the study, AJA, IVI, NDC, RW, ARJ, HOO, NAM, AW, TAO, TO carried out field data and sample collection, AJA, VII, ARJ, HOO, PDL,GM analysed the data and samples. AJA, RW, PLD drafted the manuscript. Critical revision was done by PDL, CM and VBM. All authors have read and approved the final manuscript.

Availability of data and materials

The main findings are presented in this article. However, further inquiries should be directed to the corresponding author.

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Data availability: Data available request to corresponding author.

Ethics approval and consent to participate

This study was approved by the National Veterinary Research Institute Animal Ethics Committee Vom, Nigeria (AEC/03/26/16).

Consent for publication

Not applicable.

Competing interests

The authors declare no conflict of interest.

References

1. Adedeji, A. J., Atai, R. B., Gyang, H. E., Gambo, P., Habib, M. A., Weka, R., Muwanika, V. B., Masembe, C., & Luka, P. D. (2022). Live pig markets are hotspots for spread of African swine fever virus in Nigeria. *Transboundary and emerging diseases*, *69*(5), e1526–e1540. https://doi.org/10.1111/tbed.14483
2. Adesehinwa, A. O. K., & Saka, J. O. (2009, April). Incidence of African swine fever and its socio-economic implications on pig production in Lagos state, Nigeria. In *Proceedings of the British Society of Animal Science* (Vol. 2009, pp. 37-37). Cambridge University Press. DOI: 10.1017/s1752756200028763
3. Agüero, M., Fernández, J., Romero, L., Sánchez Mascaraque, C., Arias, M., & Sánchez-Vizcaíno, J. M. (2003). Highly sensitive PCR assay for routine diagnosis of African swine fever virus in clinical samples. *Journal of clinical microbiology*, *41*(9), 4431–4434. https://doi.org/10.1128/JCM.41.9.4431-4434.2003
4. Aliro, T., Chenais, E., Odongo, W., Okello, D., Masembe, C., & Ståhl, K. (2022). Prevention and control of African swine fever in the smallholder pig value chain in northern Uganda: Thematic analysis of stakeholders' perceptions. *Frontiers in veterinary science*, *8*, 707819. 10.3389/fvets.2021.707819
5. Ambagala, A., Goonewardene, K., Lamboo, L., Goolia, M., Erdelyan, C., Fisher, M., Handel, K., Lung, O., Blome, S., King, J., Forth, J. H., Calvelage, S., Spinard, E., Gladue, D. P., Masembe, C., Adedeji, A. J., Olubade, T., Maurice, N. A., Ularamu, H. G., & Luka, P. D. (2023). Characterization of a Novel African Swine Fever Virus p72 Genotype II from Nigeria. *Viruses*, *15*(4), 915. https://doi.org/10.3390/v15040915
6. Atherstone, C., Galiwango, R. G., Grace, D., Alonso, S., Dhand, N. K., Ward, M. P., & Mor, S. M. (2019). Analysis of pig trading networks and practices in Uganda. *Tropical animal health and production*, *51*(1), 137–147. https://doi.org/10.1007/s11250-018-1668-6
7. Babalobi, O. O., Olugasa, B. O., Oluwayelu, D. O., Ijagbone, I. F., Ayoade, G. O., & Agbede, S. A. (2007). Analysis and evaluation of mortality losses of the 2001 African swine fever outbreak, Ibadan, Nigeria. *Tropical animal health and production*, *39*(7), 533–542. https://doi.org/10.1007/s11250-007-9038-9
8. Bellini, S., Rutili, D., & Guberti, V. (2016). Preventive measures aimed at minimizing the risk of African swine fever virus spread in pig farming systems. *Acta veterinaria Scandinavica*, *58*(1), 82. https://doi.org/10.1186/s13028-016-0264-x
9. Blome, S., Franzke, K., & Beer, M. (2020). African swine fever - A review of current knowledge. *Virus research*, *287*, 198099. https://doi.org/10.1016/j.virusres.2020.198099
10. Chenais, E., Ståhl, K., Guberti, V., & Depner, K. (2018). Identification of Wild Boar-Habitat Epidemiologic Cycle in African Swine Fever Epizootic. *Emerging infectious diseases*, *24*(4), 810–812. https://doi.org/10.3201/eid2404.172127
11. Dohoo, I., Martin, W., & Stryhn, H. (2003). Veterinary Epidemiologic Research, Atlantic Veterinary College, Charlottetown, PE, Canada, 2003., Vol. 68, Issues 2–4, 2005, Pages 289–292, https://doi.org/10.1016/j.prevetmed.2004.11.001.

12. El-Hicheri, K. (1998). *Report of the FAO Consultancy Mission to Nigeria*.
13. Eleazar, A., Sonibare, A., Ojo, O., Awoyomi, O., & Otesile, E. (2021). A Survey of Neonatal Piglet Mortality in Commercial Pig Farms in Lagos State, Southwest Nigeria. *Nigerian Veterinary Journal*, *42*(3), 238-251.
14. Fasina, F. O., Shamaki, D., Makinde, A. A., Lombin, L. H., Lazarus, D. D., Rufai, S. A., Adamu, S. S., Agom, D., Pelayo, V., Soler, A., Simón, A., Adedeji, A. J., Yakubu, M. B., Mantip, S., Benshak, A. J., Okeke, I., Anagor, P., Mandeng, D. C., Akanbi, B. O., Ajibade, A. A., … Gallardo, C. (2010). Surveillance for African swine fever in Nigeria, 2006-2009. *Transboundary and emerging diseases*, *57*(4), 244–253. https://doi.org/10.1111/j.1865-1682.2010.01142.x
15. Fasina, F. O., Agbaje, M., Ajani, F. L., Talabi, O. A., Lazarus, D. D., Gallardo, C., Thompson, P. N., & Bastos, A. D. (2012). Risk factors for farm-level African swine fever infection in major pig-producing areas in Nigeria, 1997-2011. *Preventive veterinary medicine*, *107*(1-2), 65–75. https://doi.org/10.1016/j.prevetmed.2012.05.011
16. Fasina, F. O., Kissinga, H., Mlowe, F., Mshang'a, S., Matogo, B., Mrema, A., Mhagama, A., Makungu, S., Mtui-Malamsha, N., Sallu, R., Misinzo, G., Magidanga, B., Kivaria, F., Bebay, C., Nong'ona, S., Kafeero, F., & Nonga, H. (2020). Drivers, Risk Factors and Dynamics of African Swine Fever Outbreaks, Southern Highlands, Tanzania. *Pathogens (Basel, Switzerland)*, *9*(3), 155. https://doi.org/10.3390/pathogens9030155
17. Fasina, F. O., Olaokun, O. O., Oladipo, O. O., Fasina, M. M., Makinde, A. A., Heath, L., & Bastos, A. D. (2013). Phytochemical analysis and in-vitro anti-African swine fever virus activity of extracts and fractions of Ancistrocladus uncinatus, Hutch and Dalziel (Ancistrocladaceae). *BMC veterinary research*, *9*, 120. https://doi.org/10.1186/1746-6148-9-120
18. Galindo, I., & Alonso, C. (2017). African Swine Fever Virus: A Review. *Viruses*, *9*(5), 103. https://doi.org/10.3390/v9050103
19. Galli, F., Friker, B., Bearth, A., & Dürr, S. (2022). Direct and indirect pathways for the spread of African swine fever and other porcine infectious diseases: An application of the mental models approach. *Transboundary and emerging diseases*, *69*(5), e2602–e2616. https://doi.org/10.1111/tbed.14605
20. Gao, L., Sun, X., Yang, H., Xu, Q., Li, J., Kang, J., Liu, P., Zhang, Y., Wang, Y., & Huang, B. (2021). Epidemic situation and control measures of African Swine Fever Outbreaks in China 2018-2020. *Transboundary and emerging diseases*, *68*(5), 2676–2686. https://doi.org/10.1111/tbed.13968
21. Guberti, V., Khomenko, S., Masiulis, M., & Kerba, S. (2022). *African swine fever in wild boar: ecology and biosecurity* (Vol. 28). Food & Agriculture Org..
22. Guinat, C., Gogin, A., Blome, S., Keil, G., Pollin, R., Pfeiffer, D. U., & Dixon, L. (2016). Transmission routes of African swine fever virus to domestic pigs: current knowledge and future research directions. *The Veterinary record*, *178*(11), 262–267. https://doi.org/10.1136/vr.103593
23. Hu, J.-H., Pei, X., Sun, G.-Q., & Jin, Z. (2021). Risk analysis of the transmission route for the African swine fever virus in Mainland China. *Frontiers in Physics*, *9*, 785885.

24. Li, X., & Tian, K. (2018). African swine fever in China. *The Veterinary record*, *183*(9), 300–301. https://doi.org/10.1136/vr.k3774
25. Lichoti, J. K., Davies, J., Kitala, P. M., Githigia, S. M., Okoth, E., Maru, Y., Bukachi, S. A., & Bishop, R. P. (2016). Social network analysis provides insights into African swine fever epidemiology. *Preventive veterinary medicine*, *126*, 1–10. https://doi.org/10.1016/j.prevetmed.2016.01.019
26. Luka, P. D., Achenbach, J. E., Mwiine, F. N., Lamien, C. E., Shamaki, D., Unger, H., & Erume, J. (2017). Genetic Characterization of Circulating African Swine Fever Viruses in Nigeria (2007-2015). *Transboundary and emerging diseases*, *64*(5), 1598–1609. https://doi.org/10.1111/tbed.12553
27. 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 medicine*, *32*(3-4), 235–241. https://doi.org/10.1016/s0167-5877(97)00026-3
28. Montgomery, R. E. (1921). On a form of swine fever occurring in British East Africa (Kenya Colony). *Journal of comparative pathology and therapeutics*, *34*, 159-191.
29. Motta, P., Porphyre, T., Handel, I., Hamman, S. M., Ngu Ngwa, V., Tanya, V., Morgan, K., Christley, R., & Bronsvoort, B. M. (2017). Implications of the cattle trade network in Cameroon for regional disease prevention and control. *Scientific reports*, *7*, 43932. https://doi.org/10.1038/srep43932
30. Nuanualsuwan, S., Songkasupa, T., Boonpornprasert, P., Suwankitwat, N., Lohlamoh, W., & Nuengjamnong, C. (2022). Thermal Inactivation of African Swine Fever Virus in Swill. *Frontiers in veterinary science*, *9*, 906064. https://doi.org/10.3389/fvets.2022.906064
31. Odemuyiwa, E., Odaibo, S. A. A. O. G., & Adetosoye, O. O. A. (2005). Field and experimental investigations of an outbreak of African swine fever in Nigeria. *Revue Élev. Méd. vét. Pays trop*, *58*(1-2), 21-26.
32. Odemuyiwa, S. O., Adebayo, I. A., Ammerlaan, W., Ajuwape, A. T., Alaka, O. O., Oyedele, O. I., Soyelu, K. O., Olaleye, D. O., Otesile, E. B., & Muller, C. P. (2000). An outbreak of African Swine Fever in Nigeria: virus isolation and molecular characterization of the VP72 gene of a first isolate from West Africa. *Virus genes*, *20*(2), 139–142. https://doi.org/10.1023/a:1008118531316
33. Omowon, A., Daodu, O., Omowon, A., & Bello, I. (2019). Knowledge, attitude and practices of pig farmers post African swine fever outbreaks in Ogun and Oyo states of Nigeria. *Sokoto Journal of Veterinary Sciences*, *17*(4), 14-24.\DOI: 10.4314/sokjvs.v17i4.3
34. Penrith, M. L., van Heerden, J., Pfeiffer, D. U., Oļševskis, E., Depner, K., & Chenais, E. (2023). Innovative Research Offers New Hope for Managing African Swine Fever Better in Resource-Limited Smallholder Farming Settings: A Timely Update. *Pathogens (Basel, Switzerland)*, *12*(2), 355. https://doi.org/10.3390/pathogens12020355
35. Penrith, M. L., & Vosloo, W. (2009). Review of African swine fever: transmission, spread and control. *Journal of the South African Veterinary Association*, *80*(2), 58–62. https://doi.org/10.4102/jsava.v80i2.172
36. Penrith, M. L., & Kivaria, F. M. (2022). One hundred years of African swine fever in Africa: Where have we been, where are we now, where are we going?. *Transboundary and emerging diseases*, *69*(5),

e1179–e1200. https://doi.org/10.1111/tbed.14466

37. Pérez-Filgueira, D. M., González-Camacho, F., Gallardo, C., Resino-Talaván, P., Blanco, E., Gómez-Casado, E., Alonso, C., & Escribano, J. M. (2006). Optimization and validation of recombinant serological tests for African Swine Fever diagnosis based on detection of the p30 protein produced in Trichoplusia ni larvae. *Journal of clinical microbiology*, *44*(9), 3114–3121. https://doi.org/10.1128/JCM.00406-06
38. Qu, H., Ge, S., Zhang, Y., Wu, X., & Wang, Z. (2022). A systematic review of genotypes and serogroups of African swine fever virus. *Virus genes*, *58*(2), 77–87. https://doi.org/10.1007/s11262-021-01879-0
39. Sánchez-Vizcaíno, J. M., Mur, L., & Martínez-López, B. (2012). African swine fever: an epidemiological update. *Transboundary and emerging diseases*, *59 Suppl 1*, 27–35. https://doi.org/10.1111/j.1865-1682.2011.01293.x
40. Sánchez-Vizcaíno, J. M., Mur, L., Gomez-Villamandos, J. C., & Carrasco, L. (2015). An update on the epidemiology and pathology of African swine fever. *Journal of comparative pathology*, *152*(1), 9–21. https://doi.org/10.1016/j.jcpa.2014.09.003
41. Valerio, V. C., Walther, O. J., Eilittä, M., Cissé, B., Muneepeerakul, R., & Kiker, G. A. (2020). Network analysis of regional livestock trade in West Africa. *PloS one*, *15*(5), e0232681. https://doi.org/10.1371/journal.pone.0232681
42. Wang, W. H., Lin, C. Y., Chang Ishcol, M. R., Urbina, A. N., Assavalapsakul, W., Thitithanyanont, A., Lu, P. L., Chen, Y. H., & Wang, S. F. (2019). Detection of African swine fever virus in pork products brought to Taiwan by travellers. *Emerging microbes & infections*, *8*(1), 1000–1002. https://doi.org/10.1080/22221751.2019.1636615
43. Zu Ermgassen, E. K., Phalan, B., Green, R. E., & Balmford, A. (2016). Reducing the land use of EU pork production: where there's swill, there's a way. *Food policy*, *58*, 35–48. https://doi.org/10.1016/j.foodpol.2015.11.001

Figures

Figure 1

Map of Nigeria showing nine pig producing States in Nigeria where samples will be collected.

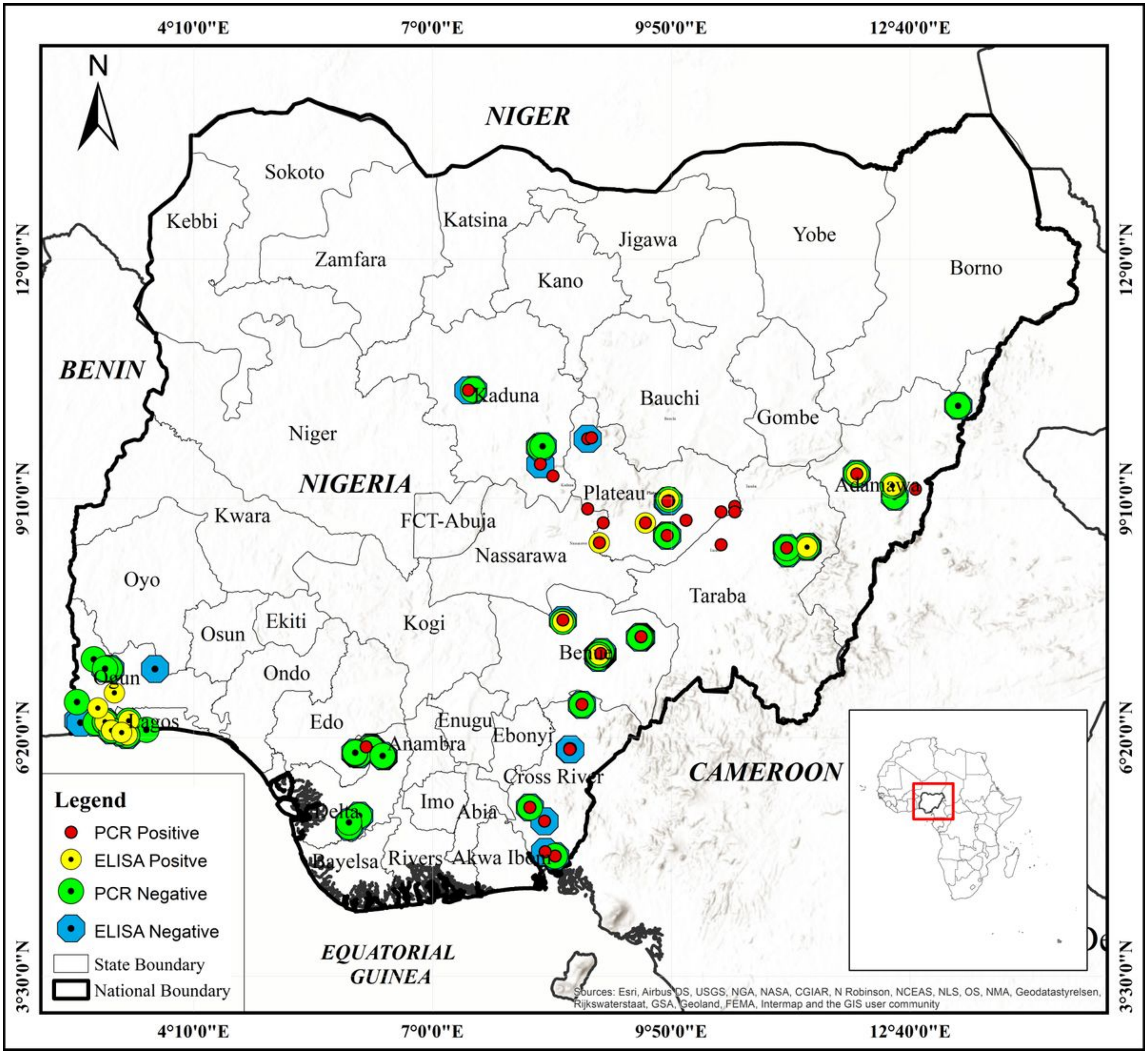

Figure 2

Map of Nigeria showing spatial spread of African swine fever based laboratory results of samples collected and analyzed by polymerase chain reaction and enzyme-linked immunosorbent assay.

Figure 3

A: Free roaming pig at private slaughter slab North Central Nigeria. **B:** Free roaming pig at a pig butcher's table in Gboko, Benue State, Nigeria. **C:** Slaughtering of pigs at a pig farm Southwest Nigeria. **D:** Improperly disposed piglet carcass in Shendam, Southern Plateau State, Nigeria