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ORIGINAL ARTICLE

HUSBANDRY PRACTICES, BIOSECURITY MEASURES OF PIG FARMERS AND THEIR AWARENESS OF TRANSMISSIBLE GASTROENTERITIS IN KWARA AND OYO STATES, NIGERIA

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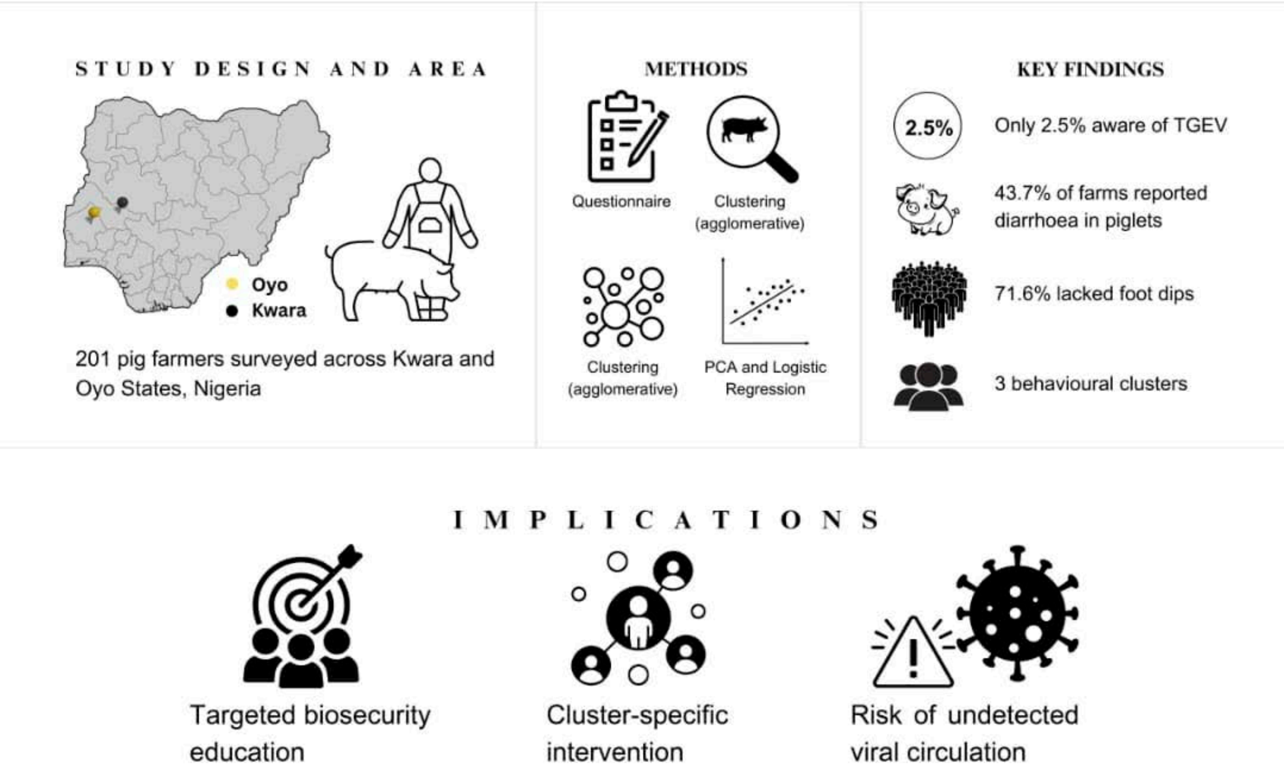
Ethical considerations: When reporting experiments on animals Observation of the ARRIVE guidelines 2.0: Updated guidelines for reporting animal research, published on July 14, 2020 (DOI: 10.1371/journal.pbio.3000410), is applied. The authors ensure that all procedures were performed in compliance with the guidelines for animal care of their institutions or with national/international guidelines.

ABSTRACT

Transmissible gastroenteritis (TGE) is a highly contagious enteric viral disease of swine with serious implications for pig health and productivity. However, data on its occurrence and impact in Nigeria remain scarce. This study assessed pig farmers' awareness of TGE, alongside husbandry and biosecurity practices, across 201 farms in Kwara and Oyo States. Structured questionnaires and on-site observations were analyzed using descriptive statistics, agglomerative hierarchical clustering, principal component analysis (PCA), and logistic regression. Awareness was strikingly low—only 2.5% of respondents had heard of TGE, and 12.9% understood biosecurity. Essential infrastructure was lacking: 71.6% of farms had no foot dips, and 73.1% lacked staff access control. Although just 5.5% of pigs reportedly showed diarrhoea alone, 57.7% presented diarrhoea with other symptoms, and 43.7% of farmers observed signs in piglets aged 0–3 months, suggesting underreporting and possible silent circulation. Cluster analysis defined three farm profiles: Cluster 1 (13.9%) with strong compliance, Cluster 0 (73.1%) with basic hygiene but no personnel control, and Cluster 2 (12.9%) with minimal adherence. PCA reinforced these divisions, highlighting foot dips, staff access, and segregation as key drivers. Findings expose critical gaps in biosecurity and awareness, emphasizing the need for targeted education, veterinary outreach, and surveillance to strengthen Nigeria's pig sector.

Keywords: clustering analysis; husbandry practices; Nigeria; PCA; pig farming; targeted biosecurity; TGE awareness; transmissible gastroenteritis (TGE)

GRAPHICAL ABSTRACT



INTRODUCTION

Transmissible gastroenteritis (TGE) is an acute, rapidly spreading viral disease of pigs of all ages characterised by profuse watery diarrhoea, vomiting, dehydration, and high mortality in piglets less than two weeks old. It is caused by the TGE virus (TGEV), which is a member of the family *Coronaviridae*, genus *Alphacoronavirus,* and species *Alphacoronavirus-1*, and constitutes a threat to the pork industry worldwide [1–3]. In addition to pigs, infections have been documented in foxes, dogs, and cats [4]. As an enteric pathogen, TGEV predominantly targets and affects the villous epithelial cells of the small intestine, disrupting normal absorption mechanisms and causing severe diarrhoea and dehydration in infected pigs [5]. Infection has been reported to occur through faecal-oral, respiratory (aerosol), and vertical transmission via milk from infected sows, with these three routes of spread for TGEV [2, 6]. Apart from direct contact with infected pigs, TGEV is also spread via contaminated fomites such as feeding equipment, clothing, or vehicles, and mechanical vectors, including farm personnel, rodents, and birds [7].

Due to the multiple transmission pathways, biosecurity remains the fundamental element in the prevention and control of Transmissible Gastroenteritis Virus (TGEV). The implementation of rigorous biosecurity measures, such as restricting access to the farm, disinfecting equipment, isolating new or ill animals, and upholding high standards of sanitation, effectively reduces the introduction and dissemination of viruses, thereby protecting both animal and public health [8–10]. Additionally, robust farm biosecurity fortifies the resilience of livestock systems against emerging and re-emerging diseases and promotes sustainable pig production [11]. In Africa, the epidemiology and impacts of TGE remain poorly defined and less well understood [8]. Apart from reports of its identification based on clinical history, post-mortem pathology, virus isolation and/or serology (neutralization test, enzyme-linked immunosorbent assay) in Kenya [9, 10], Uganda [11], South Africa [12], Central African Republic, Rwanda and Togo [13], and Nigeria [14], there is limited information on its occurrence in Africa. In regions with intensive pig production, particularly in Western and Southern Africa [15], the potential for TGE outbreaks is higher due to increased close contact among pigs on farms.

Prior to the report of Aiki-Raji et al. [15], there was no information on the prevalence and impact of TGE in Nigeria. In a study conducted on pigs sampled from livestock farms and abattoirs in Ogun and Oyo States, southwest Nigeria, these researchers found a higher TGE seroprevalence in abattoir pigs (33.3%) than in farm pigs (27.7%). Since pigs are not vaccinated against TGEV in Nigeria, the detection of TGEV antibodies in pig sera could be attributed to natural exposure to the virus. This study was therefore carried out to evaluate the husbandry practices and biosecurity measures of pig farmers, as well as their knowledge of TGE in Kwara and Oyo States of Nigeria. It is anticipated that the findings will offer valuable insights into the current understanding and preventative practices regarding TGE in these two states and will serve as a foundation for developing strategies for effective disease control.

MATERIAL AND METHODS

Study design

A cross-sectional study was conducted between April 22 and June 9, 2024, in Kwara and Oyo States, two of the largest pig-producing states in Nigeria [15]. These states were purposively selected due to their significant pig farming activity, contrasting agro-ecological zones, high pig population density, and strategic economic importance in the swine value chain.

Participant selection and sampling criteria

Participants were adult pig farmers (≥ 20 years) engaged in continuous commercial pig farming. Eligible farms were purposively selected based on the following criteria:

(i) a minimum herd size of 50 pigs,
(ii) ongoing commercial operation,
(iii) willingness to grant access for field assessment, and
(iv) logistical accessibility.

Although being in pig farming for a minimum of 5 years was originally intended as a criterion, actual respondent profiles varied, and this was retained during analysis to reflect real-world situations.

Survey instrument, reliability assessment, and questionnaire design

A semi-structured questionnaire was administered via both Google Forms and in-person interviews. It included four sections:

(i) Demographics: location, gender, age, years of experience in pig farming, level of education, herd size, staff employed, and management type, amongst others.
(ii) Husbandry practices: age and source of pigs and type of feed used.
(iii) Biosecurity measures.
(iv) Knowledge of TGE.

The questionnaire was reviewed by three independent experts (a veterinarian, a research scientist, and an extension officer) to ensure content validity. A pilot test with 20 farmers (excluded from the main study) refined question clarity. Cronbach's alpha ($\alpha = 0.80$) confirmed acceptable internal reliability for biosecurity and TGE knowledge items, which depict the awareness scale items primarily based on binary and Likert-type responses. This indicates an adequate level of internal reliability and is considered sufficient for exploratory public health research, particularly in field-based cross-sectional studies involving behavioural and awareness constructs [16]. The final version of the questionnaire is available as a supplementary file and through the following link:

https://docs.google.com/forms/d/e/1FAIpQLSeYuWyx8GMzo92gH-AVZ7x0VltotxVj7-Ibgn740xHthbO9Hg/viewform

Data analysis

Descriptive statistics (frequencies, percentages, central tendencies) were used to summarise demographic and practice-related data using Microsoft Excel and the IBM® SPSS® v17 software package for statistical analysis (Pennsylvania, USA). This descriptive methodology was adopted, as previously reported [17], to assess the knowledge of TGE, farmers' perceptions of the disease, their husbandry and management practices, understanding of routine biosecurity measures, and common TGE symptoms. To identify latent patterns in farm behaviour, unsupervised machine learning (agglomerative clustering with $k = 3$) was applied to biosecurity behaviour patterns among respondents. The optimal cluster count was determined using the silhouette score compared with K-means. Clusters were profiled to reflect varying levels of awareness and implementation. Chi-square testing was conducted to assess associations between cluster membership and geographic location. Finally, logistic regression models were built using Python (statsmodels v0.14.4) to assess predictors of (a) absence of foot dips (proxy for poor biosecurity) and (b) TGE awareness. Results were reported as odds ratios (ORs), 95% confidence intervals (CIs), and p-values < 0.05.

RESULTS

Socio-demography

A total of 201 pig farmers (Kwara, n = 100; Oyo, n = 101) out of 120 contacted in each state participated, yielding an approximately 83% response rate per state. Most (71.6%, n = 144) were males aged 50–60 years (31.8%). Most (58.7%, n = 118) had secondary education, while 20.4% (n = 41) had no formal education. Despite a criterion of ≥ 5 years' experience, 74.1% had less than 5 years in pig farming (Table 1).

Husbandry practices

Most farms (68.2%) used intensive management, and 81.6% categorised pigs by age. Herd sizes varied; 34.2% had fewer than 20 pigs, while 25.4% had over 80. Nearly half (49.3%) used self-compounded feeds; others relied on local industry feeds like brewery wastes and kitchen scraps. Although 65.7% kept records, these were mostly basic, noting animal purchases or treatments (Table 2).

Biosecurity awareness and practices

Only 12.9% (n = 26) knew the term "biosecurity," but many practised cleaning (100%) and disinfection (84.3%). Structural biosecurity was weak: 71.6% lacked foot dips, 73.1% had no staff entry protocols, and 84.4% allowed visitors without strict controls. Only 14% enforced full protocols, and 34.8% routinely segregated animals (Table 3).

Clustering of biosecurity behaviours

Agglomerative hierarchical clustering was applied to seven standardized binary biosecurity indicators: foot dip, staff and visitor protocols, segregation, cleaning, disinfection, and hygiene measures. A three-cluster solution (k = 3) was selected based on silhouette scores (agglomerative = 0.53; K-means = 0.42), showing better cohesion and separation with the agglomerative method. The resulting clusters represented distinct profiles of biosecurity awareness and implementation:

Cluster 1 (13.9%): High-compliance farms implementing comprehensive protocols, including foot dips (92.9%), visitor control (85.7%), and staff routines (89.3%).

Cluster 0 (73.1%): Practised core hygiene (100% cleaning; 84.3% disinfection) but lacked staff (11.6%) and visitor controls (15.6%).

Table 1. Demographics of respondents

Variable	Category	Frequency (n)	Percentage (%)
Age group (years)	20–30	45	22.4
	31–40	23	11.4
	41–50	45	22.4
	51–60	64	31.8
	≥61	24	11.9
Gender	Male	144	71.6
	Female	57	28.4
Location	Oyo	101	50.2
	Kwara	100	49.8
Academic status (level of education)	No formal education	41	20.4
	Primary/Secondary education	118	58.7
	Tertiary education	42	20.9
Years of experience as a pig farmer (years)	1–3	76	37.8
	4–6	73	36.3
	7–9	23	11.4
	10–12	3	1.5
	13–15	11	5.5
	>15	15	7.5

Table 2. Husbandry practices associated with pig farming in Kwara and Oyo States

Variable	Category	Frequency (n)	Percentage (%)
Flock size (n = 196)	1–20	67	34.2
	21–40	22	11.2
	41–60	24	12.2
	61–80	33	16.8
	81–100	31	15.8
	101–120	10	5.1
	121–140	3	1.5
	141–160	0	0.0
	161–180	4	2.0
	181–200	2	1.0
Sectioning of pigs based on groups (n = 201)	Yes	164	81.6
	No	37	18.6
Record keeping (n = 201)	Yes	132	65.7
	No	69	34.3
Management practice (n = 201)	Intensive	137	68.2
	Semi-intensive	14	7.0
	Extensive	50	24.9
Source of pigs (n = 201)	Nigeria	198	98.5
	Imported	3	1.5
Age range (months) (n = 200)	Above 12 only	8	4.0
	6–12 only	34	17.0
	0–6, Above 12	12	6.0
	0–6, 6–12, Above 12	103	51.5
	0–6, 6–12	12	6.0
	0–6 only	31	15.5
Type of feed (n = 201)	Self-compounded, Local, Kitchen waste	31	15.4
	Self-compounded, Local	1	0.5
	Self-compounded only	99	49.3
	Others	1	0.5
	Local only	63	31.3
	Kitchen waste only	3	1.5
	Imported only	3	1.5

Cluster 2 (12.9%): Minimal adoption of recommended practices with poor foot dip use (3.8%) and complete absence of staff protocols.

A Principal Component Analysis (PCA) was performed on the standardised indicators to verify the cluster structure. The first two components (PC1 and PC2) explained 58.4% of the total variance. Clusters were distinguished in the PCA scatterplot (Fig. 1). A PCA loading heatmap (Fig. 2) indicated that foot dip, staff and visitor protocols, and segregation were the main contributors to PC1. A summary heatmap (Fig. 3) illustrates the proportion of farmers in each cluster who have adopted key biosecurity practices, while Table 4 presents the distribution of farmers across clusters by state.

Awareness of TGE and clinical observations

Awareness of TGE among surveyed pig farmers was remarkably low, with only 5 respondents (2.5%) recognizing clinical signs of the disease and correctly identifying it as a cause of diarrhoea in piglets. Despite this, clinical signs consistent with TGE were often reported. Specifically, 43.7% (n = 86) of farmers observed diarrhoea in piglets aged 0–3 months, the most vulnerable age group for severe disease, while 57.7% reported diarrhoea along with other

Table 3. Biosecurity practices associated with pig farming in Kwara and Oyo States

Variable	Category	Frequency (n)	Percentage (%)
Biosecurity awareness (n = 201)	Yes	26	12.9
	No	175	87.1
Presence of foot dip on farms (n = 201)	Yes	57	28.4
	No	144	71.6
Awareness of biosecurity protocols (n = 201)	Cleaning only	94	46.8
	Cleaning and disinfection only	16	8.0
	Disinfection only	57	28.4
	Segregation only	1	0.5
	Segregation, cleaning, disinfection	33	16.4
Biosecurity protocols practiced (n = 201)	Cleaning only	82	40.8
	Cleaning and disinfection only	39	19.4
	Disinfection only	48	23.9
	None	1	0.5
	Segregation cleaning only	1	0.5
	Segregation, cleaning, disinfection	30	14.9
Protocol for staff (n = 201)	Yes	54	26.9
	No	147	73.1

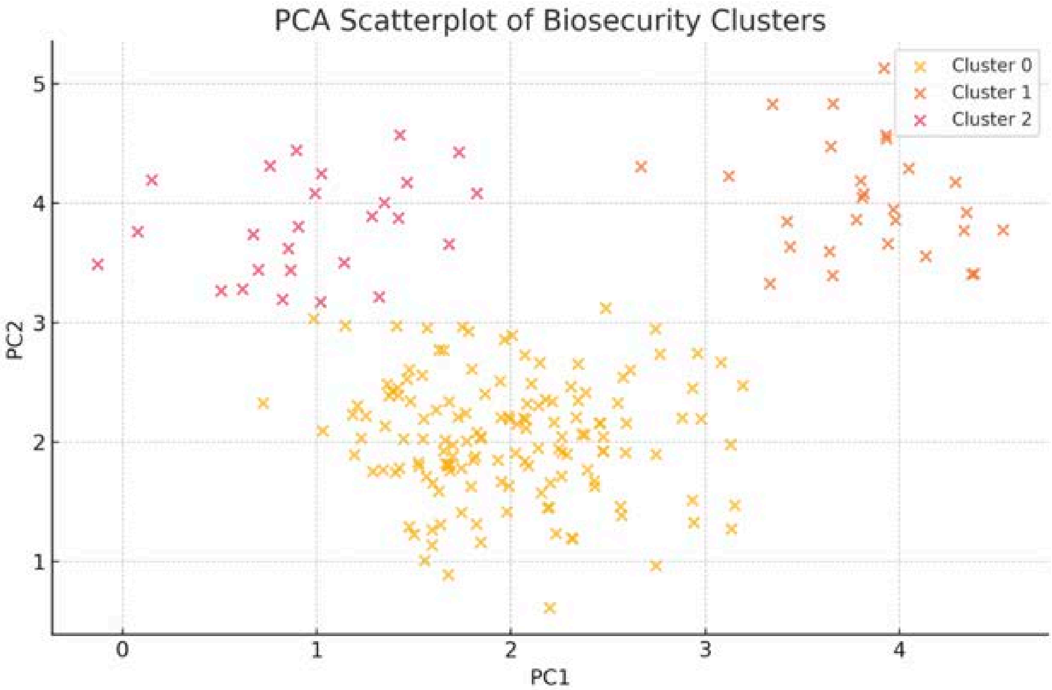


Fig. 1. Principal Component Analysis (PCA) scatterplot showing separation of farmers (n = 201) based on standardized biosecurity indicators. Each point represents a farmer and is colored by cluster membership (k = 3), illustrating clear cluster separation along the first two principal components (PC1 and PC2).

symptoms, and only 5.5% observed diarrhoea as an isolated sign. Logistic regression analysis showed that TGE awareness did not vary significantly based on age, gender, education level, location, or years of farming experience ($p > 0.3$ for all variables). Although awareness was marginally higher among farmers with primary or secondary education compared to those with no formal or tertiary education, this association was not statistically significant (OR: 1.43; 95% CI: 0.13–72.55). Similarly, male respondents had higher odds of being aware of TGE than females

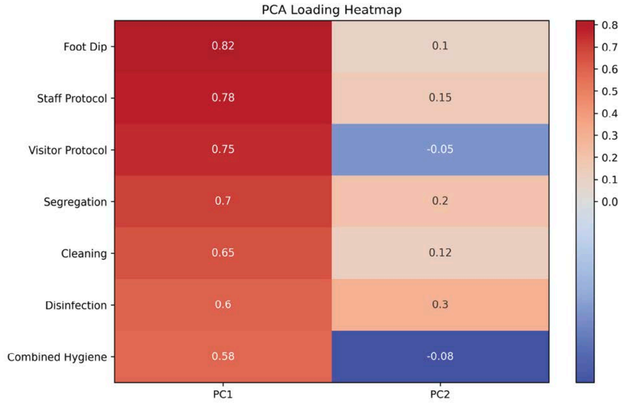


Fig. 2. PCA loading heatmap displaying the contribution of each biosecurity indicator to the first two principal components. Darker shades indicate higher loading values; foot dip, staff and visitor protocol, and segregation contributing most strongly to PC1.

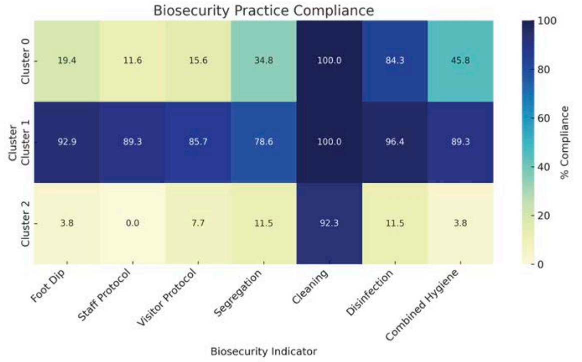


Fig. 3. Heatmap illustrating the proportion (%) of pig farmers within each biosecurity cluster demonstrating positive implementation of key biosecurity practices. Cluster 1 shows the highest compliance across all indicators; Cluster 2 exhibits minimal adherence.

Table 4. Distribution of pig farmers by biosecurity cluster and states

Cluster	Kwara State (n, %)	Oyo State (n, %)	Total (n, %)
0	77 (52.4)	70 (47.6)	147 (73.1)
1	11 (39.3)	17 (60.7)	28 (13.9)
2	11 (42.3)	15 (57.7)	26 (12.9)
Total	99 (49.3)	102 (50.7)	201 (100.0)

(OR: 1.60; 95% CI: 0.15–80.18), but this difference was also not significant (Table 5).

Regression analysis

Logistic regression identified predictors of poor biosecurity, defined as no foot dips. Significant factors were farm location, education, and farming experience. Farms in Kwara State had higher odds of lacking foot dips than those in Oyo (OR = 98.9; $p < 0.001$). Farmers with secondary education showed better compliance than those with less or more education. Longer farming experience (≥ 10 years) was linked to poor biosecurity, with such farmers being 7.53 times more likely to lack foot dips than those with ≤ 6years (OR = 7.53; $p = 0.026$) (Table 6).

DISCUSSION

In the present study, we assessed the husbandry practices and biosecurity measures of pig farmers as well as their knowledge of TGE in Kwara and Oyo States of Nigeria. The results provided several important insights into the current state of pig production in these states, highlighting significant gaps in husbandry and biosecurity practices, as well as knowledge of the disease.

The study population primarily consisted of male farmers (71.6%) aged 51–60 years, with most (58.7%) having only secondary education, while just 20.9% attended tertiary institutions. This demographic profile aligns with findings from other studies on small-scale pig farming in developing countries, which often show a prevalence of middle-aged to older male farmers with limited formal education [18, 19]. Our findings regarding these demographic characteristics (age group, gender, and years of experience and expertise) support those of other studies in Nigeria [20, 21] and Zambia [22]. The relatively low education level of these farmers may impact their ability to adopt modern animal husbandry practices and disease control measures, highlighting the importance of continuous education and training, as experience alone does not ensure compliance with evolving biosecurity standards.

Most farmers in this study had limited experience, with the majority having only 1–3 years of pig farming experience. This indicates potential recent growth in the pig farming sector in these regions, possibly driven by factors such as increased demand for pork, low start-up costs for pig farming, and government initiatives to promote livestock production. However, the limited experience of many farmers also points to a need for targeted training and support programs to enhance their farming practices and disease management skills. The study further shows that the majority (68.2%) of farmers practised the intensive production system, aligning with global trends [23]. While intensification can boost productivity and improve disease control, it presents various challenges in developing countries, especially regarding biosecurity and disease management, due to higher animal densities, frequent an-

Table 5. Awareness of TGE

Variable	Category	Frequency (n)	Percentage (%)
Awareness of TGEV (n = 201)	Yes	5	2.5
	No	196	97.5
Age range of diarrheal observed	0–3 months	86	43.7
	0–3 months, 4–6 months	20	10.2
	0–3 months, 4–6 months, 6 months and above	12	6.1
	0–3 months, 6 months and above	2	1.0
	4–6 months	50	25.4
	4–6 months, 6 months and above	11	5.6
	6 months and above	13	6.6
	Unknown	3	1.5
Awareness of TGEV as agent of diarrhoea	Yes	5	2.5
	No	196	97.5
Other common pig diseases noticed	Anthrax	1	2.9
	ASF only	12	35.3
	ASF and Foot Rot	11	32.4
	Cough	1	2.9
	Foot Rot only	3	8.8
	Undisclosed	6	17.6
Carcass disposal method	Burning	3	1.5
	Burying	117	58.2
	Burning, Burying	1	0.5
	Burying, Open dumping	4	2.0
	Incineration	22	10.9
	Open dumping	47	23.4
	Undisclosed	7	3.5

ASF = African Swine Fever virus

Table 6. Binary logistic regression for predictors of poor biosecurity (foot dip absence)

Predictor	Comparison	Odds Ratio (95% CI)	p-value
State	Kwara vs Oyo	98.9 (8.7–1126.0)	< 0.001**
Gender	Male vs. Female	1.28 (0.44–3.71)	0.655
Age group (years)	30–40 vs ≤ 30	1.83 (0.45–7.48)	0.400
	40–50 vs ≤ 30	1.34 (0.31–5.79)	0.695
	50–60 vs ≤ 30	2.52 (0.35–18.03)	0.357
	≥ 60 vs ≤ 30	1.76 (0.10–31.15)	0.701
Education level	Secondary education vs. No formal	0.22 (0.06–0.73)	0.013*
	Secondary education vs. Tertiary	0.24 (0.06–0.90)	0.035*
Farming experience (years)	7–9 vs ≤ 6	2.55 (0.54–11.99)	0.235
	≥ 10 vs ≤ 6	7.53 (1.28–44.36)	0.026*

*Significant at p < 0.05; **Highly significant at p < 0.01.

imal and human movement, and reliance on shared equipment [24, 25]. Our findings, which show that over 68% of farms were intensive but 73.1% lacked staff control protocols, highlight this contradiction — intensification is not accompanied by adequate biosecurity.

One of the most striking findings from this study is the poor knowledge of biosecurity among pig farmers, with only 12.9% (n = 26) being familiar with the term. These gaps were further explored through unsupervised clustering, which revealed three distinct farmer profiles based on biosecurity awareness and implementation. Cluster 1 represented farmers with strong biosecurity knowledge and consistent practice, reflecting high compliance with recommended protocols. In contrast, Cluster 2 included those with minimal awareness and weak implementation, highlighting the highest-risk group. Cluster 0 encompassed farmers who engaged in moderate practices, such as cleaning and disinfection, but lacked comprehensive protocols, including visitor and staff controls. The absence of a clear regional pattern across clusters suggests that these biosecurity gaps are widespread rather than state-specific. Importantly, the presence of farmers who engaged in good practices without formal awareness highlights a disconnect between conceptual understanding and routine behaviour. This emphasises the need for training interventions that prioritise practical application over terminology, given the pivotal role of biosecurity in swine disease prevention and control [26, 27]. The lack of foot dips and protocols for staff in 71.6% and 73.1% of farms, respectively, underscores the significant gaps in biosecurity practices on those farms. These results are consistent with those of other workers who reported suboptimal biosecurity measures on small-scale pig farms in developing countries [25, 28].

Perhaps the most important finding of this study is the extremely low level (2.5%) of knowledge of TGE among the respondents. Our findings show that the majority of the sampled population (57.7%) observed diarrhoea and other related symptoms of TGE on their farms. However, the extremely low level of knowledge of TGE among the respondents, the presence of clinical signs consistent with the disease, and the low level of biosecurity suggest that the disease may be present but remains unrecognised; these patterns indicate that TGEV, or other enteric pathogens with similar presentations, may be circulating undetected on many farms. This aligns with studies in Kenya and Uganda, where a similar phenomenon was reported for enteric viral infections [19]. This low awareness level is worrisome, as TGE causes significant morbidity, mortality, and economic losses, particularly in piglets [29]. Further, it is consistent with the findings of other studies conducted in Nigeria and elsewhere [30–32] and highlights the need for increased education and awareness creation regarding TGE. The disease is endemic in the tropics, and biosecurity practices are the best way to ensure its spread is controlled, while unvaccinated piglets are protected from infection with the virus. With 87.1% of respondents being unaware of the concept of biosecurity, the likelihood of TGEV spreading in southwest Nigeria is very high. The persistence of diarrhoea across multiple age groups, especially in young pigs, is a warning sign that needs further investigation. Although various pathogens can cause diarrhoea, the age distribution and clinical signs observed in this study are consistent with TGEV infection [33, 34].

LIMITATIONS

Since this study was conducted in only two states of Nigeria, the results may not be a true reflection of the situation in other parts of the country. However, considering that these are two of the largest pig-producing states in Nigeria [15], further research involving other states is recommended to provide a more comprehensive picture of TGE knowledge and pig farming practices across the country. Furthermore, laboratory confirmation of TGE occurrence in farms reporting clinical symptoms suggestive of the disease would provide valuable epidemiological data that can influence the development of effective prevention and control strategies against the disease.

RECOMMENDATIONS AND CONCLUSIONS

The results of this study highlight the urgent need for education and awareness programmes that focus on TGE among pig farmers in Kwara and Oyo States of Nigeria. The observed gap between the low-level awareness of TGE and the reported clinical symptoms associated with the disease suggests that TGE may be underdiagnosed/misdiagnosed and possibly endemic in these states. Furthermore, there is a clear need to improve biosecurity practices on the studied pig farms. While some farmers had introduced basic biosecurity measures, comprehensive and standardized protocols remain lacking.

Recommended biosecurity measures include:

1. Installation and regular use of foot dips/baths at entrances to pig pens.
2. Provision of aprons or protective gear for farm visitors.
3. Implementation of compulsory showers before entry into animal production facilities.
4. Establishment of formalized, consistent biosecurity protocols across farms.

5. Educational initiatives should emphasize not only best practices but also how to translate them into routine, enforceable procedures.
6. Tailored biosecurity programmes should be developed based on the farmer profiles identified via the clustering analysis:

- Cluster 1 (Informed and Compliant Farmers): Sustain momentum through periodic refresher trainings and updated biosecurity guidelines. These farmers can be engaged as peer educators or local biosecurity champions. Innovative tools such as mobile-based disease reporting systems and standard operating procedure (SOP) checklists should be piloted within this group to strengthen monitoring and compliance.
- Cluster 0 (Cautious but Under-informed Farmers): Implement targeted awareness campaigns that build on existing practices, such as routine cleaning. Practical training sessions and simplified SOP templates should be introduced to help formalize and expand current hygiene behaviors into full biosecurity protocols.
- Cluster 2 (High-Risk and Unaware Farmers): Prioritize basic biosecurity education using grassroots strategies, including local language radio messages, religious institutions, and farmer cooperatives. Provide starter hygiene kits (e.g., foot dips, protective wear), integrate training with feed and input delivery systems, and assign trained extension officers for direct field engagement.

7. The use of machine learning techniques in this study shows promise for targeted extension interventions and data-driven swine health planning.
8. The dominance of local pig sourcing highlights the importance of establishing robust national disease surveillance and control programmes.
9. Collaboration between pig farmers, state veterinary services, and the Federal Ministry of Agriculture and Food Security will be crucial for the successful implementation of any surveillance and control initiatives.
10. Effective TGE prevention and control will require the development and enforcement of standard protocols aimed at preventing the introduction and spread of the disease at the farm level.
11. Given that TGEV is an RNA virus prone to genetic recombination, resulting in both high- and low-pathogenicity field strains [35–37], active surveillance will be essential to determine the disease's endemicity and the nature of circulating strains.
12. This surveillance will inform the establishment of effective biosecurity guidelines, especially among breeders and high-risk farms.
13. As supported by MacLachlan & Dubovi [38], TGE control protocols should include depopulation of affected herds during severe outbreaks, isolation of diseased animals to prevent transmission, routine cleaning and disinfection of facilities and equipment, strict enforcement of biosecurity measures across all pig farming operations, and vaccination, which remains the most effective preventive strategy for TGE [39]. The availability and usage of vaccination should be prioritized within national control frameworks.

Data Availability Statement

Repository name: Mendeley Data
Direct URL to data: doi: 10.17632/t8fv4bgcxn.1

Ethical Statement

Ethical clearance was obtained from the Kwara State Ministry of Agriculture and Rural Development (Approval number: ERC/MARD/2024/09/001) and the Oyo State Ministry of Agriculture (Approval number: VD 922/29). Informed consent was secured from all participants in accordance with the World Medical Association Declaration of Helsinki Ethical Principles (WMA, 2015) and the National Health Research Ethics Committee, Nigeria (NHREC, 2014).

Conflict of Interest

The authors have no conflict of interest to declare.

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Authors' Contributions

Conceptualization: BIO, HOT, JOA, DOO; Methodology: BIO, JOA, AOA; Field data and Sampling: BIO, IDO, OBT, TJA, AJT; Data analysis: BIO, IDO, AH; Resources and Supervision: BIO, JOA, DOO; Writing-original draft preparation: BIO, AOA, IDO, AH, OJI, FAA, MAA, OBT; Writing-review and Editing: BIO, AOA, AH, HKA; Final Edit: BIO, HKA, DOO.

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Appendix

Supplementary materials.

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