P-ISSN: 2304-3075; E-ISSN: 2305-4360
International Journal of Veterinary Science
www.ijvets.com; editor@ijvets.com

Research Article https://doi.org/10.47278/journal.ijvs/2026.027

Risk Factor-Based Epidemiological Analysis of African swine fever in East Nusa Tenggara, Indonesia

Imron Rosyadi [1]*, Christoffel Madha [2], Ewaldus Wera [3], Aris Haryanto [4], Argamjav Bayanzul [5] and Heru Susetya [6]*,

[1]Department of Veterinary Public Health, Faculty of Veterinary Medicine, Universitas Gadjah Mada, Fauna No. 2, Karangmalang, Yogyakarta, Indonesia 55281
[2]Livestock Service of Ngada Regency, East Nusa Tenggara
[3]Kupang State Agricultural Polytechnic (Politeknik Pertanian Negeri Kupang), Kupang, West Timor, Indonesia
[4]Department of Biochemistry, Faculty of Veterinary Medicine, Universitas Gadjah Mada, Fauna No. 2, Karangmalang, Yogyakarta, Indonesia 55281
[5]School of Veterinary Medicine, Mongolian University of Life Sciences, Ulaanbaatar, Mongolia, 17024
[6]Department of Veterinary Clinical Pathology, Faculty of Veterinary Medicine, Universitas Gadjah Mada, Fauna No. 2, Karangmalang, Yogyakarta, Indonesia 55281
***Corresponding authors:** imron.rosyadi@ugm.ac.id (IR); herususetya@ugm.ac.id (HS)

Article History: 25-136 Received: 21-May-25 Revised: 21-Jul-25 Accepted: 06-Aug-25 Online First: 28-Feb-26

ABSTRACT

African swine fever (ASF) is a highly virulent and economically devastating transboundary animal disease, characterized by up to 100% mortality in affected pig populations. Since its initial outbreak in 2020, ASF has continued to sporadically affect pig farms in Ngada Regency, East Nusa Tenggara, Indonesia, posing a persistent threat to smallholder livelihoods and food security. This study aimed to elucidate the epidemiological dynamics of ASF by assessing the association between outbreak incidence and multiple risk factors, including demographic, biosecurity, socio-cultural, economic, and pig movement variables. A cross-sectional design was employed, utilizing both primary data from structured farmer interviews (n=325) across 33 villages in six sub-districts, and secondary data on confirmed ASF cases, pig mortality, and population statistics. Stratified sampling ensured broad regional representation. Data were analyzed using chi-square tests, binary logistic regression, and odds ratio estimation (SPSS v26). Significant associations were identified between ASF incidence and farmer demographic profiles, economic vulnerability, pig husbandry practices, awareness of ASF, and animal movement patterns ($P<0.05$). The principal novelty of this study lies in its integrative approach, explicitly incorporating socio-cultural and economic determinants, particularly traditional pig exchange systems and ethnically embedded practices, into ASF risk modeling. The findings highlight the urgent need for context-sensitive control strategies that combine enhanced biosecurity, culturally adapted outreach, and targeted regulation of animal movement to mitigate ASF spread in smallholder-dominated settings.

Key words: African swine fever, Risk factors, Socio-cultural, Pig, Smallholder farming.

INTRODUCTION

African swine fever (ASF) is an acute, highly contagious, and often fatal viral disease affecting domestic pigs (*Sus scrofa domesticus*) and wild suids. Since its initial identification in Kenya in 1921, ASF has evolved from a regional concern to a pressing global threat, disrupting pig production systems and national economies across continents (Danzetta et al. 2020). The causative agent, African swine fever virus (ASFV), is a large, enveloped, double-stranded DNA virus classified under the Asfarviridae family. ASFV induces a severe haemorrhagic disease in pigs, with clinical outcomes ranging from peracute death to subclinical infections, depending on the virus strain, host immunity, and epidemiological context. The virus is notorious for its exceptionally high mortality rates, frequently approaching 100% in naive pig populations, and its ability to persist in the environment and in pork products, further complicating eradication efforts (Álvarez et al. 2019; Danzetta et al. 2020; Penrith et al. 2021).

Cite This Article as: Rosyadi I, Madha C, Wera E, Haryanto A, Bayanzul A and Susetya H, 2026. Risk factor-based epidemiological analysis of African swine fever in East Nusa Tenggara, Indonesia. International Journal of Veterinary Science 15(3): 949-957. https://doi.org/10.47278/journal.ijvs/2026.027

Unlike many other transboundary animal diseases, there is currently no commercially available vaccine or specific antiviral treatment for ASF. Control efforts therefore rely exclusively on early detection, culling of infected animals, strict quarantine, and biosecurity measures (Álvarez et al. 2019; Gallardo et al. 2021). ASF's unique epidemiological characteristics—such as its stability in carcasses, feed, and fomites, its ability to infect both domestic and wild suids, and the potential role of soft ticks (*Ornithodoros* spp.) in virus maintenance—contribute to its persistence and re-emergence. These features, compounded by socio-economic and logistical barriers in low-and middle-income countries, render ASF one of the most complex and devastating swine diseases globally (Penrith et al. 2021; Chenais et al. 2022).

The recent global expansion of ASF has been unprecedented in scale and speed. Since the early 2000s, outbreaks have intensified in Eastern Europe, eventually spreading into the Russian Federation and subsequently into China in 2018—the world's largest pork-producing country. The introduction of ASFV into China marked a turning point in the global pig industry, with massive culling campaigns, trade disruptions and long-term supply chain consequences (Danzetta et al. 2020; Assavacheep et al. 2022). From China, ASF rapidly disseminated across Southeast Asia, with confirmed outbreaks in Vietnam, the Philippines, Cambodia, Myanmar, Laos and Indonesia within a short time frame. This trajectory has elevated ASF to the forefront of veterinary public health, food security, and international trade discussions (Costard et al. 2009; Hsu et al. 2023).

Indonesia officially reported its first ASF outbreak in 2019, initially confirmed in North Sumatra, where thousands of pigs died in a short span (Ha and RD 2023). Ngada Regency represents a microcosm of Indonesia's broader challenges in managing ASF. Pig farming in this region is not merely a commercial enterprise but a deeply embedded socio-cultural tradition. Pigs are integral to local identity, customary laws, and community rituals, including weddings, funerals, and ancestral offerings. Ownership of pigs symbolizes social status, familial wealth, and kinship ties. Consequently, ASF outbreaks are not only economic setbacks but also cultural and emotional crises for the affected communities (Sawford et al. 2015; Ha and RD 2023).

The complexity of ASF transmission in Ngada is further exacerbated by several systemic factors. Smallholder pig farming is the dominant production system in this region, characterized by low-input, low-output backyard operations. These farms often lack basic biosecurity infrastructure such as pig pens with restricted access, disinfection routines, or controlled feed sources. Pigs are frequently raised in close proximity to human dwellings or allowed to scavenge, creating numerous points of exposure to contaminated materials or infected animals (Aliro et al. 2022). In addition, informal pig trading networks are widespread, with live pigs or pork products transported without regulatory oversight, health certification, or movement restrictions (Costard et al. 2009; Álvarez et al. 2019).

This informal nature of pig production and trade creates a highly permissive environment for ASFV transmission. The disease can be introduced into naïve villages through infected pigs purchased from markets, shared boars for breeding, communal slaughtering practices, or even the return of leftover swill from ceremonies (Chenais et al. 2019; Saragih et al. 2021). Moreover, the human behavioural component of ASF epidemiology remains underexplored. Farmers' perceptions of ASF, trust in veterinary authorities, and willingness to report suspected cases directly influence disease surveillance and control success (Sánchez-Vizcaíno et al. 2015; Jean-Pierre et al. 2022). In some cases, fear of mandatory culling without compensation may prompt farmers to hide cases or resort to emergency sales, which inadvertently fuels disease dissemination. Cultural resistance to biosecurity recommendations—such as limiting visitor access or changing traditional feeding practices—may also hinder intervention efforts. As such, any ASF control strategy in Ngada must be grounded in a deep understanding of local customs, beliefs, and economic realities (Chenais et al. 2022; Hsu et al. 2023).

The endemicity of ASF in parts of Indonesia raises critical questions about its long-term epidemiological behavior. In Ngada, the virus appears to persist in cycles of acute outbreaks followed by apparent lulls, suggesting possible cryptic maintenance mechanisms. These could include subclinical infections, virus survival in the environment or meat products, and repeated reintroductions through animal movement (Danzetta et al. 2020; Assavacheep et al. 2022).

Given these multifaceted challenges, there is an urgent need to comprehensively investigate the drivers of ASF spread in Ngada Regency. Understanding the demographic, environmental, socio-economic, and behavioral risk factors that shape disease dynamics is critical for designing effective interventions. Previous studies have demonstrated that risk mapping and epidemiological profiling at the community level can guide targeted control strategies and optimize resource allocation. In particular, identifying the most vulnerable farmer groups, high-risk movement corridors, and key cultural practices that contribute to ASF transmission can support the development of locally appropriate and culturally sensitive disease management plans (Costard et al. 2009; Álvarez et al. 2019).

This study, therefore, aims to analyze the epidemiological patterns of ASF outbreaks in Ngada Regency, East Nusa Tenggara, by examining a wide range of contributory factors. These include demographic profiles of pig farmers, farming practices, biosecurity behaviors, pig movement patterns, and socio-cultural determinants of disease exposure. The data generated by this study will serve as a foundation for co-creating risk communication strategies, designing culturally acceptable biosecurity measures, and advocating for integrated surveillance systems. In the longer term, such efforts can strengthen the resilience of smallholder pig farming systems in Ngada and serve as a model for other ASF-affected regions in Southeast Asia.

MATERIALS AND METHODS

Study area and period

This study was conducted in Ngada Regency, East Nusa Tenggara, Indonesia (Fig. 1), covering six sub-districts: Aimere, Jerebuu, Bajawa, Golewa, Soa, and

Riung. The study was carried out over a three-month period, from October to December 2023, during which data collection and field assessments were conducted.

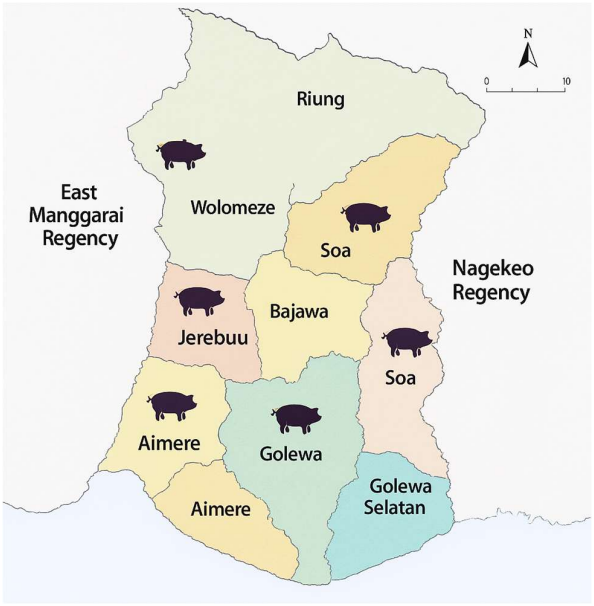

Fig. 1: Map of pig farms in Ngada Regency, East Nusa Tenggara, Indonesia.

Study design and sampling

A cross-sectional study assessed the association between ASF outbreaks and various risk factors. The study utilized a stratified random sampling approach to ensure proportional representation of pig farming communities across different ethnic groups (Bajawa, Soa, and Riung). The sample size was determined using a statistical formula for cross-sectional studies, ensuring a 95% confidence level and an estimated ASF prevalence of 22.8% (Álvarez et al. 2019; Kivumbi et al. 2021). A total of 325 farmers were surveyed and selected based on their involvement in pig farming and willingness to participate in the study. The sample size is based on the cross-sectional research formula (Bech-Nielsen 1989).

$n = 4PQ/L^2$

Where,

n = Number of samples

P = Approximate level

Q = 1 – P

L = Error

Data collection

Primary and secondary data were collected to understand ASF transmission dynamics comprehensively. Primary data: Structured interviews and questionnaires were administered to pig farmers, traders, quarantine officers, and veterinary personnel to collect information on farm management practices, biosecurity measures, pig movement, socio-economic factors, and farmer knowledge regarding ASF. Secondary data: Official reports from government veterinary services were reviewed, including ASF case records, pig mortality statistics (2020–2023) and pig population data. Additional epidemiological records were obtained from local livestock agencies and relevant scientific literature.

Variables and measurements

The study focused on multiple independent variables to assess their association with ASF outbreaks:

- Demographic factors: Age, gender, occupation, and education level of pig farmers.
- Economic factors: Monthly income, pig farming as a primary or secondary source of livelihood and market dependency.
- Farm management: Feeding practices, housing conditions and farm biosecurity measures.
- Socio-cultural factors: Traditional pig trade practices, religious ceremonies involving pigs, and local perceptions of ASF.
- Pig movement patterns: Frequency of pig transportation, sources of pig acquisition, and quarantine measures.

Statistical Analysis

Data were analyzed using SPSS version 26.0. Descriptive statistics were used to summarize demographic and economic characteristics. The chi-square test was employed to determine the associations between risk factors and ASF outbreaks. Logistic regression analysis was conducted to estimate odds ratios (OR) and assess the strength of the association between independent variables and ASF mortality. The final multivariate logistic regression model included variables with a ($P<0.25$) in univariate analysis.

RESULTS

Demographic characteristics of pig farmers

The study population consisted mainly of male farmers (66.8%), with 70.2% engaged in agriculture as their primary occupation. The majority (58.5%) had a monthly income below IDR 1,000,000. Nearly half (48%) had more than six years of pig farming experience (Table 1).

ASF epidemiology in Ngada

Over 52% of respondents reported pig deaths between 2020 and 2023. The primary clinical signs included loss of appetite (49.12%), sudden death (21.64%), and paralysis (17.54%). The high mortality rate suggests the presence of highly virulent ASFV strains (Table 2).

Risk factors associated with ASF outbreaks

Chi-square analysis revealed significant associations between ASF incidence and economic factors (P=0.000, V=0.537), farm management (P=0.036, V=0.297), socio-cultural practices (P=0.035, V=0.238), and pig movement (P=0.001, V=0.326). The uncontrolled movement of pigs between villages contributed significantly to disease transmission (Table 3).

The results of the chi-square test indicated that there was a significant association between the economic value of pig farming and pig mortality ($\chi^2(21) = 131,389$, P=0.000 and V=0.537). Pig farming management also showed a statistically significant association with pig death ($\chi^2(19)=31.471$, P=0.036 and V=0.297), indicating a moderate relationship. Similarly, sociocultural factors were significantly associated with pig death ($\chi^2(10)=19.448$, P=0.035 and V=0.238), reflecting a weak to moderate association. Furthermore, pig movement with pig death due

Table 1: Description of characteristics of pig farmers in Ngada Regency

No.	Description	Category	Frequency (%)
1.	Age	20 – 24 y.o.	0.6
		25 – 29 y.o.	7.4
		30 – 34 y.o.	8.0
		35 – 39 y.o.	9.8
		40 – 44 y.o.	16.3
		45 – 49 y.o.	17.8
		50 – 54 y.o.	14.5
		55 – 59 y.o.	11.4
		60 – 65 y.o.	6.8
		66 – 69 y.o.	5.5
		70 – 74 y.o.	1.5
		75 – 79 y.o.	0.3
2.	Gender	Man	66.8
		Woman	33.4
3.	Main Jobs	Farmer	70.2
		Civil servant/Army/Police	14.8
		Self employed	7.4
		Private employees or contract workers	7.4
		Driver (4 wheels) and motorcycle taxi	0.9
4.	Income	<Rp 1.000.000*	58.5
		Rp 1.000.000 – 2.000.000	20.9
		>Rp 2.000.000 – 4.000.000	13.5
		>Rp 4.000.000 – 6.000.000	5.8
		> Rp 6.000.000	1.2
5.	Breeding Experience	<3 years	20.6
		3–6 years	21.5
		>6– 9 years	9.8
		> 9 years	48

Note: * Rp = Indonesian Rupiah/IDR

Table 2: Clinical presentation, mortality patterns, and management practices associated with African swine fever outbreaks in smallholder pig farms of Ngada Regency, Indonesia

No.	Description	Category	Frequency (%)
1.	Pig death	Dead pigs suspected of ASF (171 farmers)	52.7
		Pigs do not die (154 breeders)	47.4
2.	Clinical symptoms	Abortion in pregnant females before death	2.34
		Cough	0.58
		Fever, lethargy, not wanting to eat	1.17
		Sudden death	21.64
		Reduced appetite, red spots on the skin and odor	0.58
		Heat, snoring, fever	1.17
		Redness and red patches on the skin	5.26
		Unable to get up	17.54
		Unable to wake up, redness of the abdomen	0.58
		Not willing to eat for a few days until death	49.12
2.	The period when pigs begin to show symptoms sick to death	< 3 days	19.7
		> 12 days	2.2
		4 - 7 days	28.9
		8 - 11 days	4.6
3.	Mortality rate after the introduction of new pigs into the pen	Farmers who bring in new pigs	79.7
		Farmers who do not include new pigs	20.3
4.	Purpose of stuffing pigs	Population increases and seedling improvement	8.6
		Derived from pig livestock received in traditional activities	7.1
		Purchased for fattening	4.6
5.	Source of origin of pigs	Outside the village/sub-district	6.8
		Outside the sub-district	5.5
		Outside Ngada Regency in Flores Island	4.0
		One village/sub-district	3.7
		Outside NTT Province	0.3
6.	Treatment of pig carcasses	Dumped in the river	1.75
		Sold to merchants	0.58
		Buried in the ground	95.92
		Cut and split	1.75

to ASF disease $\chi^2(15)=38.670$, P=0.001 and V=0.326. The pig trade is related to economic activities because of the demand for pigs in socio-cultural activities. The results of the chi-square test indicated that there was no significant association with pig mortality due to ASF, P>0.05.

Table 3: Statistical associations between African swine fever outbreaks and risk factors in smallholder pig farms of Ngada Regency, Indonesia

No	Variables	X^2	*V*	db	P-Value
1	Demography	18.209	0.230	14	0.197
2.	Pig farming economy	131.389	0.537	21	0.000*
3.	Pig breeding management	31.471	0.297	19	0.036*
4.	Breeder knowledge about ASFV	6.481	0.140	4	0.166
5.	Biosecurity	24.511	0.265	18	0.139
6.	Socio-Cultural	19.448	0.238	10	0.035*
7.	Pig Movement	38.670	0.326	15	0.001*

*P<0.05 indicates statistically significant

Table 4: Logistic regression analysis of risk factors influencing African swine fever mortality in smallholder pig farms of Ngada Regency, Indonesia

No	Variables	Coefficient B	Std. Error	Significance	Exp.(B)/Odd ratio
1.	Demography	0.109	0.055	0.048*	1.001
2.	Pig farming economy	-0.372	0.046	0.000*	0.630
3.	Pig breeding management	-0.091	0.041	0.026*	0.842
4.	Breeder knowledge about ASFV	-0.383	0.177	0.031*	0.482
5.	Biosecurity	0.068	0.044	0.121	0.982
6.	Socio-Cultural	0.007	0.067	0.919	0.883
7.	Pig Movement	-0.129	0.060	0.030*	0.782

*P<0.05 indicates statistically significant

Logistic regression analysis

Modeling is an important instrument in analyzing the epidemiological characteristics of infectious diseases (Skrip and Townsend 2019). The association between independent and dependent variables with a P<0.25 is calculated by logistic regression analysis. The logistic regression analysis results between the dependent variable (ASF pig death) and the independent variables (demographics, pig farming economic activities, pig farm management, farmers' knowledge about ASF, biosecurity, *s*ocio-culture, and pig movement) are presented in Table 4.

The analysis found five risk factors had a statistically significant relationship (P<0.05) in pig mortality due to ASF in Ngada Regency. These variables are demographics, pig farming economics, pig farming management, farmers' knowledge about ASFV and pig movements. Biosecurity and sociocultural variables were the moderator variables, indicating that the two variables strengthened the chance of pig mortality due to ASF disease, but together, the effects were not significant. The results of this analysis show that the risk of pig mortality due to African swine fever (ASF) in Ngada Regency increases when farmers have lower demographic status, such as limited education, low income, or unstable occupations. The risk is further heightened by larger herd sizes, poor pig-rearing practices, limited farmer knowledge of ASFV and weak enforcement of pig movement control.

The results of this study revealed that demographic factors had the most dominant influence on pig mortality due to African swine fever (ASF), with an odds ratio (OR) of 1.001 and a statistically significant P<0.048, indicating a positive association between demographic characteristics and the likelihood of ASF-related pig deaths. Pig farming management practices demonstrated the strongest protective association, with an OR of 0.842 and a P<0.026, suggesting that improved management reduces the risk of mortality. Similarly, economic factors related to pig farming showed a significant association with pig mortality, with an OR of 0.630 and a highly significant P<0.001, implying that better financial capacity and resource allocation can mitigate losses due to ASF. Additionally, knowledge of ASFV was significantly associated with reduced mortality risk, with an OR of 0.482 and a P<0.031, highlighting the critical role of farmer awareness and understanding of disease prevention.

The logistic regression equation can be seen in Appendix 16 based on calculating the variables in the equations. Logistics equations with Koef (B) values of demographics (X1=1.106), economics (X2=-0.364), management (X3=-0.085), pig movement (X4=-0.115), and constants (5,879). The regression equation is as follows:

$Y = 5.879 + 0.106\ X1 - 0.364\ X2 - 0.085\ X3 - 0.115X4$

The results of the Exp(X1) value analysis show that if the demographic status increases by one level, the pig farmer family is 1.112 times more likely not to die due to ASF. An increase in the economy of farmers' households by 1 time increases the probability that pigs do not die due to ASF by 0.695 times.

DISCUSSION

This study provides critical insights into the epidemiological dynamics of African swine fever (ASF) in Ngada Regency, East Nusa Tenggara, Indonesia. By examining multiple risk domains—demographics, pig farming economics, management practices, farmer knowledge, pig movement, biosecurity, and socio-cultural factors—the research confirms that ASF outbreaks are shaped by an intricate interplay of biological, behavioral, economic, and social determinants. These findings emphasize the importance of adopting a multifactorial risk-based framework for understanding ASF transmission and for formulating tailored, region-specific disease control strategies.

A key finding of the study is the significant association between demographic characteristics of pig farmers and the likelihood of ASF-related pig mortality. Logistic regression analysis identified demographic variables—particularly education level, income, and occupational status—as dominant predictors of mortality risk (OR = 1.001, P = 0.048). Farmers with limited education and low

income were more likely to experience ASF-related losses. These results corroborate earlier studies in sub-Saharan Africa and Southeast Asia, where lower socio-economic status was associated with reduced access to disease information, inadequate preparedness, and limited capacity to implement control measures (Mutua and Dione 2021; Aliro et al. 2022; Requier et al. 2024).

In Ngada, where more than half of the surveyed farmers earn less than one million rupiah monthly and rely primarily on agriculture, low household income limits the ability to invest in protective infrastructure such as fencing, feed troughs, or proper waste disposal systems. This economic vulnerability increases disease exposure and impedes recovery following outbreaks. The association between demographic status and pig mortality is further exacerbated by age-related factors: older farmers, who make up a substantial proportion of respondents, often maintain traditional husbandry practices with minimal adoption of modern biosecurity principles (Sawford et al. 2015; Penrith et al. 2023).

Closely linked to demographics is the influence of economic factors in pig farming, which were also found to be significantly associated with ASF mortality (OR=0.630, P=0.000). Households with stronger economic capacity—such as those treating pig farming as a primary rather than secondary activity—were more likely to adopt improved husbandry and reporting practices. This association is consistent with observations from other ASF-affected countries, including the Philippines and Uganda, where farmers with stable income sources were better able to respond to outbreaks, restock animals, and implement containment measures (Aliro et al. 2022; Cooper et al. 2022). In Ngada, however, many pig farmers operate within a subsistence economy, where pig production serves both commercial and cultural functions. Economic losses due to ASF not only affect immediate income but also reduce farmers' capacity to maintain social obligations, such as providing pigs for ceremonies or community events (Bernardes et al. 2020; Ha and RD 2023).

The role of pig farming management practices was another significant protective factor in this study (OR=0.842, P=0.026). Farmers who adhered to better management standards—such as regular pen cleaning, controlled feeding, and isolation of sick or newly introduced pigs—reported lower rates of mortality. These findings mirror results from several countries in Southeast Asia and Africa, where improved husbandry was associated with decreased ASF risk (Dharmawan et al. 2021; Penrith et al. 2021). In Ngada, pig rearing is often conducted in open or semi-confined systems, which increases contact with potentially infected materials, scavenging pigs, and contaminated environments. Management-related factors such as feeding leftover food waste (swill), allowing pigs to roam freely, and neglecting to isolate new or sick animals are known to facilitate ASFV transmission (Xu et al. 2021; Chenais et al. 2022).

However, transitioning to improved management requires financial investment, technical knowledge, and changes in long-standing practices. Many smallholder farmers lack formal training in pig husbandry or access to veterinary consultation, which hinders their ability to implement optimal management protocols. Moreover, even when farmers are aware of recommended practices, the cost of construction materials, water access, and secure feed storage can be prohibitive without external support (Busch et al. 2021; Cochran et al. 2023).

Farmer knowledge and awareness of ASFV were also significantly associated with mortality outcomes (OR=0.482, P=0.031). Farmers with a better understanding of disease transmission routes, clinical symptoms and preventive measures were less likely to experience ASF-related deaths. This is consistent with findings from other endemic regions, where farmer knowledge has been shown to be a key determinant of outbreak detection, early reporting and biosecurity compliance (Muñoz-Gómez et al. 2021; Penrith et al. 2021; Jean-Pierre et al. 2022). In Ngada, the results indicate a critical need for targeted communication strategies that go beyond awareness to promote behavior change.

Notably, knowledge alone may not be sufficient to change practices. Even informed farmers may continue high-risk behaviors—such as participating in informal pig trading or swill feeding—due to economic necessity, social expectations, or lack of infrastructure. Therefore, extension programs should incorporate practical, low-cost solutions and leverage local community leaders or customary institutions to enhance message acceptance (Chenais et al. 2022). For example, integrating ASF education into religious gatherings or village meetings could increase coverage and credibility.

The influence of pig movement on ASF transmission was strongly supported by both chi-square and logistic regression analyses (OR=0.782, P=0.030). The introduction of pigs from outside the local area—especially those acquired through markets or traditional exchanges—was frequently associated with outbreaks. This pattern is consistent with previous studies showing that unregulated pig movement is one of the most significant risk factors for ASF dissemination (Costard et al. 2009; Puspitarani et al. 2023). In Ngada, pigs are often traded or shared without health certification, and quarantine practices are inconsistently applied, if at all.

The role of movement in ASF transmission is magnified by the region's geography and cultural practices. Ngada is composed of remote villages with variable road access, and veterinary oversight is limited by logistical constraints. Moreover, pigs are commonly used in social exchanges, including dowries and conflict resolution ceremonies, with animals often moved across sub-districts in the absence of formal inspection (Anugrah Lase et al. 2021; Ha and RD 2023). Restricting pig movement without addressing these socio-cultural dynamics may result in non-compliance or concealment of cases. Therefore, policies aimed at regulating movement must be context-sensitive and include provisions for culturally appropriate animal sourcing alternatives (Jean-Pierre et al. 2022; Penrith et al. 2023).

Although biosecurity and socio-cultural factors did not emerge as statistically significant in the final regression model, their interactional and moderating effects are important. Many farmers reported partial implementation of biosecurity measures, such as occasionally cleaning pens or using designated feeding tools. However, full compliance was rare due to resource limitations. Prior studies have emphasized that while biosecurity is effective in theory, its real-world adoption is uneven, especially in

smallholder contexts (Cochran et al. 2023; Di Francesco et al. 2025). In Eastern Indonesia, traditional beliefs about animal health and disease causation—such as spiritual or ancestral factors—may also shape farmer behavior in ways that diverge from scientific recommendations (Sawford et al. 2015; Assavacheep et al. 2022).

The socio-cultural role of pigs in Ngada cannot be understated. As noted in the literature, pigs serve not only as livestock but also as symbols of wealth, status and kinship (Leslie et al. 2015; Sawford et al. 2015). Their use in marriage ceremonies, funerals, and community events makes them integral to cultural identity. The impact of ASF is therefore felt not only in terms of lost income, but also in the disruption of traditional customs and social harmony. In some cases, families have been unable to host ceremonies or fulfill ritual obligations due to pig shortages, leading to social exclusion or delayed life events (Ha and RD 2023; Puspitarani et al. 2023). These cultural dimensions must be incorporated into ASF control programs through community dialogue, co-created solutions, and culturally resonant messaging.

Comparisons with international ASF experiences underscore the importance of integrated approaches. In countries such as Belgium and Estonia, early detection, wildlife surveillance, and strict movement controls helped contain outbreaks (Moskalenko et al. 2022; Licoppe et al. 2023). In contrast, countries like the Philippines and Vietnam struggled with prolonged outbreaks due to informal trade, insufficient coordination, and delayed responses (Cooper et al. 2022; Hsu et al. 2023). In China, ASF management evolved through centralized control, technological investments, and farmer compensation schemes, which significantly reduced disease spread over time (Chenais et al. 2022). While these systems differ in resources and infrastructure, their emphasis on a multi-sectoral response is instructive for settings like Ngada.

Applying such lessons to Ngada requires adaptation. While centralized surveillance and compensation may be logistically challenging, certain components—such as village-based disease reporting, mobile veterinary clinics, and participatory monitoring—are both feasible and potentially impactful. The integration of risk mapping tools, farmer registries, and community animal health workers could also improve response capacity and data flow (Skrip and Townsend 2019; Penrith et al. 2021). Moreover, establishing trust between veterinary authorities and local populations is essential to ensuring cooperation in outbreak response and compliance with control measures (Busch et al. 2021; Jean-Pierre et al. 2022).

This study's strengths lie in its large, ethnically stratified sample and its use of both quantitative and qualitative variables, offering a holistic view of ASF epidemiology in a culturally unique setting. However, some limitations should be acknowledged. First, the reliance on self-reported data may introduce recall bias or underreporting. Second, molecular confirmation of ASFV was based on secondary data, and the possibility of other co-infections cannot be excluded. Third, while logistic regression provided robust associations, future studies may benefit from spatial modeling or longitudinal surveillance to capture disease dynamics over time (Danzetta et al. 2020; Gallardo et al. 2021).

Conclusion

This study highlights the complex interplay of factors contributing to African swine fever (ASF) outbreaks in Ngada Regency, East Nusa Tenggara, Indonesia. Key risk factors identified include farmer demographic status, economic conditions, husbandry practices, knowledge of ASFV, and pig movement. Demographic and economic vulnerabilities were most strongly associated with increased pig mortality, emphasizing the need to support low-income smallholders through targeted interventions. Improved farm management and enhanced farmer knowledge significantly reduced ASF risk, underscoring the importance of education and extension services. Unregulated pig movement was a major contributor to disease transmission, calling for community-based strategies to improve biosecurity and enforce culturally appropriate movement controls. While biosecurity and socio-cultural practices were not statistically significant, their moderating influence remains relevant, especially given the socio-cultural role of pigs in Ngada's traditional ceremonies. Effective ASF control requires an integrated, context-specific approach that balances disease mitigation with the economic and cultural realities of smallholder farmers in eastern Indonesia.

DECLARATIONS

Funding: This research was funded by UGM through Academic Excellent B scheme.

Acknowledgement: We acknowledge support from the Gadjah Mada University Grant, especially through the Academic Excellence B Grant, as well as from local veterinary officers, farmers, and government agencies for providing data and assistance during this study.

Conflict of Interest: There is no conflict of interest.

Data Availability: All data supporting the findings of this study are included within the content of this article. No additional supporting datasets were generated or analyzed.

Ethics Statement: This research has received ethical approval from the Faculty of Veterinary Medicine, Gadjah Mada University, Indonesia, with no 114/EC-FKH/Int./2023.

Author's Contribution: HS, CM, and AH designed the experiment. CM and EW conducted the research. IR performed statistical analyses. CM, EW, and IR wrote the manuscript. HS, IR, and AH reviewed the final manuscript. All authors approved the final submission of the manuscript.

Generative AI Statement: The authors declare that no Gen AI/DeepSeek was used in the writing/creation of this manuscript.

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