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PROOF
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An Assessment of the Impacts of Biosecurity Measures on Mortality of Fish from Fish Farms

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Abstract

Fish mortality has a significant impact on fish production by lowering fish productivity, causing an economic loss to the farmers, and also has a cost in terms of reduced fish health, thereby limiting the growth of the enterprise. A cross-sectional study was carried out to determine the impact of biosecurity measures and risk factors on the mortality of fish from fish farms. A structured questionnaire that focused on socioeconomic information, management practice, health, disease, and biosecurity measures was administered to fish farmers. A total of eighty fish farmers were involved in this study. Most of the fish farmers were male (70.00%), had tertiary education qualifications (60.00%), and were between the ages of 41 and 50 (37.50%). They had been engaged in fish farming for about 1-3 years (48.75%) and they combined it with poultry production. Varying mortality rates were recorded on the farm and the recorded mortality was associated with management practices, disease, health, and biosecurity measures and they differed significantly at P≤0.05. Fish farmers' practices were generally not in accordance with biosecurity principles. Therefore, it is crucial to create and implement biosecurity measures to prevent, manage, and eliminate the mortality of fish in fish farms.

Introduction

In many countries around the world, aquaculture is critical for food security, livelihood, nutrition, and socioeconomic well-being. Fish production through aquaculture provides a safe and reliable source of fish for human consumption (Adah *et al*., 2022; Kaleem & Abudou-Fadel, 2021; Muringai *et al*., 2022). As a result, fish production has increased to match the surging population's protein demand and is linked to the intensification of fish farming operations, such as increased stocking density and a rise in water quality concerns, which make disease outbreaks more likely (Henriksson et al., 2018).

Outbreaks of diseases are one of the most important limitations in fish production systems, causing a decline in productivity and lowering feed conversion efficiency, resulting in decreased growth and overall increasing morbidities and mortalities in farms, as well as increased cost of production, reduced incomes, and food insecurity (Adeleke et al., 2021; Maulu et al., 2021).

Fish mortality has caused massive production losses of up to 50% in developing nations, prompting many farmers to abandon fish farming (Tavares-Dias & Martins, 2017; Assefa & Abunna, 2018; Ali et al., 2020). Mortality is the outcome of a bad health condition brought on by a combination of pathogens, host and environmental factors, and a lack of biosecurity measures. Consequently, this has led to the use of antibiotics as a growth promoter for prophylactic and therapeutic purposes which has led to the spread of antibiotics resistance in aquaculture ultimately decreasing the choice and efficacy of antimicrobial agents used for treatment of fish diseases (Manyi-Loh et al., 2018; Zhao et al., 2021).

One of the most essential components of aquaculture development and management is the maintenance of health through biosecurity measures to prevent and reduce the spread of disease-causing agents, thereby controlling disease outbreaks and mortality (George & Akinrotimi, 2021; Ngueguim et al., 2020). Biosecurity refers to the systematic measures, procedures, policies, and regulations taken to keep disease away from a farm and to prevent disease transfer from one farm to another (Ali et al., 2020; Scarfe & Palić, 2020). It is also regarded as one of the most critical factors of long-term output in the aquaculture business. This application protects aquaculture from high mortality and low growth rates caused by pathogenic microorganisms and reduces the spread of the pathogenic agent within and between different holding facilities in a location (Ali et al., 2020; Omitoyin & Osakuade, 2021).

Implementing a biosecurity plan is undeniably one of the most efficient and cost-effective approaches to reduce the entry of etiological agents of disease, and minimizing stress on the fish that will predispose them to high mortality on a farm (Admasu & Wakjira, 2021; Mzula et al., 2021; Scarfe & Palić, 2020). To prevent morbidity and mortalities of fish and decrease the impact of disease and economic losses in fish farms, appropriate biosecurity measures are required. As part of the farm's fish health management, the etiology and risk factors associated with mortality must be investigated. Therefore, the aim of this study was to assess the impact of biosecurity measures and risk factors of mortality on fish farms.

Materials and Methods

Study Location

The study was conducted in Kaduna State, where four Local Government Areas (LGAs), including Sabo-Gari, Kaduna-South, Kaduna North, and Zaria LGAs, were chosen by random sampling. Kaduna State is situated in the North-Central region of Nigeria (with Kaduna town as its capital) and shares common borders with Zamfara, Katsina, Niger, Kano, Bauchi, and the Plateau States, to the South-West, the Federal Capital Territory, and Abuja. The state's coordinates are 10°20′N, 7°45′E, 10.333°N. The State occupies an area of approximately 48,473.2 square kilometers and has a population of more than 6 million people (Adah et al., 2020).

Study Design and Selection of the Fish Farms

A questionnaire-based survey was carried out, with samples for the study drawn using a multi-stage random sampling technique. In the first stage, two LGAs each out of the seven LGAs from Kaduna North and Kaduna Central districts of Kaduna state respectively were purposively selected based on the presence of fish farming activities in the area. A simple random sample technique was employed in the second stage to select twenty fish farms each from four LGAs, totaling eighty catfish farmers. The twenty fish farmers were selected purposively from the different communities in the LGAs based on the presence and accessibility of the fish farms in the areas, the farmer's willingness to participate in the interview and fill out the questionnaire, and the mortality observed on the farm at the time of sampling.

Questionnaire Design and Data Collection

To facilitate data processing, reduce variation, and enhance response, a well-structured questionnaire was created with the questions being closed-ended. The questionnaire was divided into three sections. The first section consisted of the socio-economic characteristics of the farmers (age, sex, education, farming, and experience, Local Government Area). The second part was about the general management of the fish farms (such as holding systems, number of ponds, water source, management system, production system, species of fish, farm record, and pond preparation). The third section was on the biosecurity measures (which included isolation, traffic control, and sanitation) and mortality on the farms (Scarfe and Palić, 2020). Face-to-face interviews and on-farm inspections were used to complete a total of 40 questions on the questionnaire. Prior to the commencement of the study, the questionnaire was pretested, and the questions were modified accordingly.

Data Management and Statistical Analysis

Before analyzing the data, it was checked for quality and where ever possible, it was regrouped to create biologically significant groupings and eliminate small groups in categorical data (less than ten entries). The mortality rate from the fish farms was calculated based on the counted deaths and less than 20% was categorized as low, while a mortality rate greater than 21% was categorized as high (Ellis, et al., 2012). To determine knowledge of biosecurity measures on the fish farms, a scoring system was used by the addition of scores from the variables relating to the biosecurity practices. A reliability test of 0.783 was obtained for the questionnaire and on an item scale, knowledge regarding biosecurity measures on fish farms was scored and rated. A right response received a score of 1, while a wrong response received a score of 0 (Kone et al., 2012). The mean knowledge of biosecurity score was computed, in which adequate knowledge or good biosecurity practices were then categorized using mean as the cutoff. Respondents who had scores above the mean were categorized as high, while those having little or no knowledge of biosecurity practice scores were those with scores below mean were categorized as low.

Current study's data were first summarized in Microsoft Excel 2016 before being analyzed with Open-Source Epidemiologic Statistics for Public Health (OpenEpi), version 3.03a (Dean et al., 2013). For each variable, descriptive statistics were computed and presented as frequencies and proportions. The Chi-square test was used to determine bivariate associations between variables and mortality of the fish in the fish farms. The variables were later subjected to univariate analysis using Chi-square tests. Values of $P \leq 0.05$ were considered significant.

Results

Socio-economic Characteristics of the Fish Farmers

A total of eighty fish farmers were involved in this study. Most of the fish farmers were male (70.00%), had tertiary education qualifications (60.00%), and were between the ages of 41 and 50 (37.50 %). They had been engaged in fish farming for about 1-3 years (48.75%). However, fifty percent of the fish farms were between four and six years. The majority of the fish farmers were civil servants (42.5%), and they combined both fish farming and poultry farming (52.5%) (Table 1).

Management Factors

The majority of the farms sampled (77.50%) practiced multi-age production. Earthen ponds were the most prevalent holding facilities (43.75%), with the farms having between 4-6 ponds (42.50%). The majority of the farms (58.75%) were intensively managed, involved in grow-out production (88.75%), and obtained their water from boreholes (56.25%). The bulk of the fish farmers were engaged in monoculture, and 68.75% of the fish stocked by the farmers was *Clarias gariepinus.* But for 60% of the fish farms that were sampled, there were no records of mortality kept (Table 2).

Mortality Records

All of the fish farms studied from various Local Government Areas had varying levels of mortality, with approximately 65 percent of the fish farms having significantly high mortality on their farms (Table 2).

Table 1. Socio-economic characteristics of the fish farmers sampled.

Variable	N (%)
Age	
21-30	10 (12.50)
31-40	15 (18.75)
41-50	30 (37.50)
51-60	19 (23.75)
> 60	6 (7.50)
Gender	
Male	56 (70.00)
Female	24 (30.00)
Level of Education	
No formal Education	2 (2.50)
Primary	8 (10.00)
Secondary	22 (27.50)
Tertiary	48 (60.00)
Experience (years)	
1-3	39 (48.75)
4-6	38 (47.50)
>6	3 (7.75)
Occupation	
Civil servant	34 (42.50)
Business	32 (40.00)
Teacher	14 (17.50)
Local Government Area	
Sabon Gari	20 (25.00)
Kaduna North	20 (25.00)
Kaduna South	20 (25.00)
Zaria	20 (25.00)
Age of the farm	
1-3	36 (45.00)
4-6	40 (50.00)
>6	4 (5.00)
Farm type	
Fish farming only	20 (25.00)
Fish / poultry farming	42 (52.50)
Fish with other animal	18 (22.50)

The univariate association between management practices and mortality of fish from fish farms is presented in Table 3. There was a higher likelihood of mortality occurring in solely fish-raising farms compared with the multispecies farms. Fish reared in earthen ponds were 1.88 times more prone to mortality compared with the other holding facilities. Farms with 1-3 ponds and sourced their water from the dam/ stream were 1.67 and 2 times more prone to mortality respectively. *Clarias gariepinus* raised and stocked on the farms were 1.78 times more likely to experience mortality when compared with *Heteroclarias* species. When compared to intensively managed farms, semi-intensively managed farms were prone to mortality, and this difference was significant (P≤0.05). Farms that practiced multi-age production were 5.75 times more likely to experience mortality when compared with farms that practiced all-in and all-out, and this difference was significant (P≤0.05).

Component-specific Biosecurity Measures

Univariate associations between biosecurity measures (isolation and traffic control) and mortality rate of fish on fish farms were significantly different at P≤0.05 for fencing of farms, presence of other farms, vehicular entry, allowing visitors, frequency of visits, and contact of visitors with the holding facilities (Table 4). Nothing about vehicle decontamination upon entry was reported by any of the farms sampled. Farms without fences were more likely to experience mortality compared with those with fences. More so, the presence of other farms around the fish farms made them 2.89 times more prone to mortality. Mortality of fish increased with the frequency of visits and contact of visitors with the holding facilities (Table 4).

Health Management of the Fish

Compared to farms where fish disease diagnosis is performed, farms without such diagnostics had a higher risk of mortality. In the majority of the fish farms that were sampled, the services of veterinarians were not relied upon in making diagnoses. The mortality of the fish decreased with the frequency of treatment and increased in fish farms with the consumption of dead fish by fish. Farms without a water quality analysis were 5.15 times more likely to experience mortality than farms with a water quality analysis. In farms without foot baths, specific footwear, or specific clothes for farm employees, there was an observably higher mortality. Fish diagnosis, who does the diagnosis, dead fish management, treatment frequency, foot baths, specific footwear, and clothes for an employee all showed a significant difference (P≤0.05) (Table 5).

Table 2. Management practice of the fish farms sampled.

Variable	N (%)
Holding System	
Concrete tank	30 (37.50)
Earthen Ponds	35 (43.75)
Plastic Tank	15(18.75)
No of ponds	
1-3	27 (33.75)
4-6	34 (42.50)
>6	19 (23.75)
Water source	
Borehole	45 (56.25)
Dam /stream	35 (43.75)
Management System	
Intensive System	47 (58.75)
Semi-intensive system	33 (41.25)
Production type System	
Grow –out	71 (88.75)
Brood stocks	6 (7.50)
Fish seed	3 (3.75)
Species of fish cultured	
Clarias gariepinus	55 (68.75)
Heteroclarias	25 (31.25)
Farm practice	
All in all out	18 (22.50)
Multi-age farm	62 (77.50)
Farm record	
No	48 (60.00)
Yes	32 (40.00)
Pond preparation	
Yes	53 (66.25)
No	27 (33.75)
Mortality of fish	
Low	28 (35.00)
High	52(65.00)

Sanitation and Knowledge of Biosecurity

Mortality was higher in farms where hand washing was not practiced (75%), farm tools and equipment were exchanged often (80.8%), and where there was no disinfection on the farm or its equipment (86.5%). However, none of the farms reported disinfecting the vehicles at the entrance in any way. The overall knowledge of biosecurity was low, and farms with low knowledge of biosecurity experienced higher mortality. The sanitation component of the biosecurity measures all differed significantly at P≤0.05 (Table 6).

Discussion

In this study, key contributors to the mortality of fish from fish farms were identified and measured. The socio-economic characteristics of the farmers revealed that they were dominated by males, and this could be associated with the growing demands of families on men, forcing their search for additional sources of income to meet domestic demands. These findings are like the reports of Omitoyin and Osakuade (2021) and Ngueguim et al. (2020). Nwabueze and Ofuoku (2020) and Ali et al. (2020) stated that males are predominantly involved in fish farming. The fish farmers from this study were educated, and education is required to make farmers aware of their duties on the farm and regard mortality as a hindrance to productivity and profitability (Omitoyin & Osakuade, 2021). The result also showed that the farmers were in their prime economic years, and they combined fish farming and other businesses. Our findings also revealed that fish farming is relatively young compared to other animal production in this part of the world (George & Akinrotimi, 2021; Ngueguim et al., 2020; Nwabueze & Ofuoku, 2020).

The earthen pond is the most common holding facility in this study, and the farms had between 4–6 different holding facilities. Most fish farms produce fish of different ages. The earthen ponds had the highest risk of high mortality as observed in this study, and this is like the reports of Mulei et al. (2021), where one hundred percent mortality was observed in some earthen ponds. The necessity for multiple-age production is to satisfy the rising demand for fish and ensure all-year-round availability of fish caused by the fact that fish farming is often practiced at the smallholder level in many African countries, with ponds of limited size and number (Ngueguim et al., 2020; Adeosun et al., 2019). This finding is different from the reports of Ali et al. (2020), who only recorded all-in and all-out production; this difference may be due to the farm's exclusive commercial status. However, multiple age production systems represent a potential risk factor for high mortality as seen in this study.

Table 3. Univariate association of management practices and mortality rate of fish from fish farms.

Variable	Mortality (%)		OR (95% CI)	X^2	*P*-value
	High	Low			
Farm type					
Fish farming only	15(28.8)	5(17.9)	1.88 (0.46;8.12)	1.18	0.36
Fish and Poultry farming	26(50.0)	16(57.1)	1.03 (0.32; 3.27)		0.94
Fish with other animal¥	11(21.2)	7(25.0)	1.00		
Holding System					
Concrete tank	20(38.5)	10(35.7)	1.73(0.47; 6.38)	0.57	0.39
Earthen Ponds	24(46.2)	11(39.3)	1.88 (0.53; 6.76)		0.31
Plastic Tank¥	8(10)	7(8.8)	1.00		
No of ponds					
1-3	20(38.5)	7(25.0)	1.67(0.47; 5.93)	0.46	0.45
4-6	20(38.5)	14(50)	0.83(0.26; 2.65)		0.76
>6¥	12(23.1)	7(25.0)	1.00		
Water source					
Dam /Stream	25 (48.1)	10 (35.7)	1.67(0.65; 4.29)	1.13	0.30
Borehole	27 (51.9)	18 (64.3)	1.00		
Management System					
Intensive System	26(50.0)	21 (75.0)	0.33 (0.12; 0.92)	4.7	0.01*
Semi-intensive system¥	26(50.0)	7 (25.0)	1.00		
Production System					
Grow –out	46 (88.5)	25 (89.3)	0.92 (0.08;10.65)	0.01	0.98
Brood stocks	4 (7.7)	2 (7.1)	1.00 (0.05; 18.91)		0.99
Fish seed¥	2 (3.8)	1 (3.6)	1.00		
Species of fish cultured					
Clarias gariepinus	38(73.1)	17 (60.7)	1.76 (0.66; 4.66)	1.3	0.27
Heteroclarias¥	14(26.9)	11 (29.3)	1.00		
Farm practice					
Multi-age farm	46(88.5)	16(57.1)	5.75(1.85;17.85)	10.24	< 0.01*
All in all out	6(11.5)	12(42.9)	1		
Farm record					
No	33 (63.5)	15(53.6)	1.51(0.59; 3.83)	0.74	0.40
Yes ¥	19 (36.5)	13(46.4)	1		
Pond preparation					
Yes	36 (69.2)	17 (60.7)	1.46 (0.56;3.80)	0.59	0.45
No¥	16 (30.8)	11 (39.3)	1		

¥ Reference category, OR = odds ratio, CI = confidence interval, X^2 = chi square, * significant at P<0.05

Fish mortality is a common occurrence in all fish farms and is associated with the varying management practices used by fish farmers from the various locations sampled and is a significant factor in mortality (Nilsen et al., 2020; Mulei et al., 2021). Even though most farmers were concerned about mortality, none of them kept any kind of record relating to mortality; instead, they relied on memory recall (Ali et al., 2020). One of the most crucial sources of information on a farm is mortality records, and maintaining records is essential to the effectiveness of any biosecurity program.

According to our findings, the absence of fencing, the existence of neighboring farms, vehicular access, allowing visitors, frequency of visits, and visitor contact with holding facilities are significant contributing factors that result in farm mortality. These findings are in collaboration with Faye et al. (2020). These interactions expose the fish farms to the risk of the introduction, emergence, and spread of disease-causing agents, and these exchanges lead to biosecurity gaps.

The majority of the fish farms do not carry out fish diagnosis and rely more on extension workers and

Table 4. Univariate association of Biosecurity measures (Isolation and traffic control) on farm and mortality rate of fish from fish farms.

Variable	Mortality (%)		OR (95% CI)	X^2	*P*-value
	High	Low			
Is farm fenced					
Yes	30 (57.7)	23 (82.1)	0.30 (0.10; 0.90)	4.9	0.03*
No¥	22 (42.3)	5 (17.2)	1.00		
Presence of other farms					
Yes	40 (76.9)	15 (53.6)	2.89 (1.08; 7.73)	4.6	0.04*
No¥	12 (23.1)	13 (46.4)	1.00		
Are visitors allowed in					
Yes	50 (96.2)	18 (64.3)	13.89 (2.77; 69.54)	14.5	< 0.01*
No¥	2 (3.8)	10 (35.7)	1.00		
Frequency of visit					
Always	37(71.2)	10 (35.7)	18.5 (3.48; 98.4)	2.7	< 0.01*
Sometimes	13 (25.0)	7 (25.0)	9.29 (1.56; 54.76)		0.01*
Not at all¥	2 (3.8)	11 (39.3)	1.00		
Visitor contact with holding facility					
Yes	50 (96.2)	18 (64.3)	13.8(2.77; 69.54)	14.5	< 0.01*
No¥	2 (3.8)	10 (35.7)	1.00		
Vehicle entry					
Yes	38 (73.1)	14 (50.0)	2.71(1.04;7.1)	4.26	0.04*
No¥	14 (26.9)	14 (50.0)	1		

¥ Reference category, OR = odds ratio, CI = confidence interval, X^2 = chi square, * significant at P<0.05

Table 5. Univariate association of Biosecurity measures (fish health management and isolation) on farm and mortality rate of fish from fish farms.

Variable	Mortality (%)		OR (95% CI)	X^2	*P*-value
	High	Low			
Fish diagnosis					
Yes	15 (28.8)	18 (64.3)	0.23(0.8; 0.60)	9.43	< 0.01*
No¥	37 (71.2)	10 (35.7)	1		
Dead fish management					
Feeding of fish	48 (92.3)	13 (46.4)	13.85 (3.92; 48.89)	21.15	< 0.01*
Disposed off¥	4 (7.7)	15(53.6)	1		
Who diagnose disease					
Extension worker	31 (59.6)	12 (42.9)	5.16 (1.30; 20.39)	6.09	0.02 *
Fellow fish farmers	17 (32.7)	8 (28.6)	4.25(0.98; 18.93)	3.97	0.06
Veterinarian¥	4 (7.7)	8 (28.6)	1		
Frequency of treatment					
Weekly	17 (32.7)	16 (57.1)	0.21 (0.52; 0.87)	5.50	0.03*
Fortnight	20 (38.5)	9 (32.1)	0.44 (0.10;1.92)		0.30
Monthly¥	15 (28.8)	3 (10.7)	1		
Water quality analysis					
No	40 (76.9)	11 (39.3)	5.15 (1.90;13.94)	11.16	< 0.01*
Yes ¥	12 (23.1)	17 (60.7)	1		
Specific farm clothing					
No	45(86.5)	17(60.7)	4.16 (1.39;12.49)	6.96	0.01*
Yes¥	7(13.5)	11(39.3)	1		
Specific foot boot					
No	46 (88.5)	18 (64.3)	4.26 (1.35; 13.44)	6.65	0.01*
Yes ¥	6 (11.5)	10 (35.7)	1		
Provision of footbath					
No	46 (88.5)	10 (35.7)	13.8(4.37; 43.56)	24.11	< 0.01*
Yes ¥	6 (11.5)	18 (64.3)	1		

¥ Reference category, OR = odds ratio, CI = confidence interval, X^2 = chi square, * significant at P<0.05

fellow fish farms for diagnosis than veterinarians. This was also reported by Ali et al. (2020). Fish disease diagnosis is one of the most important components of biosecurity as disease identification and control of actual disease is key to reducing mortality in fish. For effective fish production, it is necessary to have a good knowledge of health issues and the factors that contribute to mortality (Persson et al., 2022). In this study, only a few veterinarians have been trained to be involved in aquaculture.

Furthermore, farmers in this study typically don't employ the best practices for disposing of their dead fish. Such practice clearly has the potential to spread diseases again, as the dead fish being fed to the fish serves as a reservoir of disease pathogens, which contributed considerably to an increase in mortality on the farm (Muniesa et al., 2022).

Interestingly, the risk factor for increased mortality in farms from this study was water for fish production without water quality analysis. This was the leading cause of mortality as this risk affects all of the components of aquaculture and exposes all aspects of the production to the introduction and spread of disease within the farm. As the most significant limiting factor in fish farming is water quality, which has a direct impact on feed efficiency, growth rate, the health of the fish, and survival, its analysis is key (Ngueguim et al., 2020; Wanja et al., 2020).

Our study also revealed a low level of mortality in fish farms where there is an increase in the frequency of medication. This result agrees with other studies showing that medication reduces mortality on farms (Okocha et al., 2018). Low effective use of farm clothing, boots, and provision of functional foot baths was observed in this study and was significantly associated with fish mortality as it poses a higher risk of transmission of possible disease-causing agents. This is like the reports of Ngueguim et al. (2020).

Given that hand washing practices, equipment exchange, and a lack of disinfection on farms can introduce and transmit a number of infectious agents that cause mortality, it is reasonable to assume that the higher mortality level was observed on farms without any sanitation or disinfection plan as documented in this study.

The poor knowledge and compliance with biosecurity measures occasioned by the general practice on the farm have led to the high mortality observed on the farm (Jia et al., 2017). Fish welfare and health are compromised because of mortality during the production cycle, which results in economic loss for the farmers. Given that mortality is a crucial factor in determining the profitability of any farming enterprise (Oliveira et al., 2021; Persson et al., 2022). By implementing biosecurity measures, it is possible to avoid, limit, or erase dangers to health and life, as well as lessen the financial burden of the disease. Nigeria is one of Africa's top producers of aquaculture. However, due to the country's poor policy on aquatic animal health, significant production losses due to disease have occurred (World Fish, 2021).

Conclusion

This study revealed the contributing factors to mortalities in fish farms, with most of the fish farmers not complying with biosecurity measures. Overall, we found that management practices, health, and biosecurity measures were factors associated with mortality and that, rather than having just one cause, the occurrence of mortality is influenced by a number of interrelated factors.

Ethical Statement

Not applicable.

Funding Information

The authors did not receive any funds for this project.

Table 6. Univariate association of Biosecurity measures (Sanitation) on farm and mortality rate of fish from fish farms.

Variable	Mortality (%)		OR (95% CI)	X^2	*P*-value
	High	Low			
Farm disinfection					
Yes	29 (55.8)	22 (78.6)	0.34(0.12; 0.10)	4.10	0.04*
No ¥	23(44.2)	6(21.4)	1		
Exchange of farm tools					
Yes	42 (80.8)	10 (35.7)	7.56 (2.68; 21.3)	16.24	<0.01*
No¥	10 (19.2)	18 (64.3)	1		
Disinfection of farms equipment					
No	45 (86.5)	8 (28.6)	16.07 (5.13;50.4)	27.35	<0.01*
Yes¥	7 (13.5)	20 (71.4)	1		
Hand wash practice					
No	39 (75.0)	12 (28.6)	4 (1.51;10.62)	8.14	0.01*
Yes¥	13 (25.0)	16 (71.4)	1		
Knowledge about biosecurity					
Low	40 (76.9)	15 (53.6)	2.89 (1.08; 7.73)	4.62	0.03*
High ¥	12 (23.1)	13 (46.4)	1.00		

¥ Reference category, OR = odds ratio, CI = confidence interval, X^2 = chi square, * significant at P<0.05

Author Contribution

Conceptualization: AAD. Investigation: AAD and AAS. Methodology: AAD. Formal analysis: AAD and AAS Supervision: LS and SJO, Writing - original draft: AAD. Writing - review and editing: LS, SJO and AAS.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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