ANTIBIOTICS USE AND AWARENESS OF RISKS ASSOCIATED WITH ANTIMICROBIAL RESISTANCE AMONG FISH FARMERS IN KATSINA STATE, NIGERIA †

[USO DE ANTIBIÓTICOS Y CONOCIMIENTO DE LOS RIESGOS ASOCIADOS CON LA RESISTENCIA A LOS ANTIMICROBIANOS ENTRE LOS PISCICULTORES DEL ESTADO DE KATSINA, NIGERIA]

Akeem Babatunde Dauda[1*], Abdulsalam Sani Nababa[1], Justina Omolegho Oshoke[1], Hauwau Abubakar Salele[1], Ismail Ayoade Odetokun[2], Ibraheem Ghali-Mohammed[2], Oluwasesan M. Bello[3] and Awawu Dasuki[1]

[1]Department of Fisheries and Aquaculture, Federal University Dutsin-Ma, PMB 5001, Dutsin-Ma, Katsina State, Nigeria. Email: tdabak@gmail.com; +2348062085120
[2]Department of Veterinary Public Health and Preventive Medicine, University of Ilorin, Ilorin, Nigeria
[3]Department of Chemistry, Federal University Dutsin-Ma, PMB 5001, Dutsin-Ma, Katsina State, Nigeria
**Corresponding author*

SUMMARY

Background. Disease outbreaks are considered to be a significant drawback in aquaculture development globally which leads aquaculturists to indiscriminate use of antibiotics. **Objective**. To assess the status of antibiotics use, farmers' knowledge of risks associated with antimicrobial resistance (AMR), and disease occurrence in fish farms in Katsina state, Nigeria. **Methodology** Semi-structured questionnaires were administered to the active and accessible fish farms in the state, The data collected were presented and analyzed using descriptive statistics and binary logistic regression. **Results**: Most of the respondents were male (87.5%), aged 31 to 40 years and average of 7 years in operation. The majority (78.1%) use antibiotics for curative purposes, and the dominant usage frequency was occasional (28.1%). Majority (75%) of the respondents noted that antibiotics are readily available and moderately priced (46.9%) while the method of addition to water (37.5%) was the most frequently. Fish cure™ (37%), Aquaceryl plus™ (26%) and Oxytetracycline (10%) were the most commonly used antibiotics in the state. Most of the respondents (65.6%) are aware of the risks associated with AMR for fish but many of them (56.2%) are not aware of possible risks associated with consuming fish with antibiotic residue. Disease occurrence is very high (78.1%) among the farms in the state, with the majority (59.3%) having experienced outbreaks between one and three times. Despite the small scale of fish farming in the state, the mean economic loss due to disease outbreaks stood at ₦594, 605.3±0.21 (USD 371.63). The logistic regression model revealed that years in operation is the major factor influencing the use of antibiotics (P=0.072) and the occurrence of fish diseases (P=0.055) in fish farms in the state. **Implication**: Antibiotics is highly used in fish farms in the state without prescription by the veterinary experts and the majority of the farmers are not aware of risk associated with consuming fish with antibiotic residue. **Conclusion**.The study collectively provide a foundation for informed decision-making, targeted interventions, and future research directions in the realm of sustainable and responsible aquaculture practices in Katsina state.
Key words: Antibiotics; antimicrobial resistance; diseases; economic loss; fish farms; Katsina state.

RESUMEN

Antecedentes. Los brotes de enfermedades se consideran un inconveniente importante en el desarrollo de la acuicultura a nivel mundial, lo que lleva a los acuicultores al uso indiscriminado de antibióticos. **Objetivo.** Evaluar el estado del uso de antibióticos, el conocimiento de los agricultores sobre los riesgos asociados con la resistencia a los antimicrobianos (RAM) y la aparición de enfermedades en las piscifactorías del estado de

† *Submitted December 6, 2024 – Accepted December 18, 2024. http://doi.org/10.56369/tsaes.6065*

ISSN: 1870-0462.
ORCID = A.B. Dauda: https://orcid.org/0000-0002-0051-1148**; A. S. Nababa:** https://orcid.org/0000-0002-0871-4898**; J. O. Oshoke:** https://orcid.org/0000-0002-8915-8984**; H. A. Salele:** https://orcid.org/0000-0002-6277-4998**; I. A. Odetokun:** https://orcid.org/0000-0002-5171-1895**; I. Ghali-Mohammed:** https://orcid.org/0000-0003-1877-2335**; O. M. Bello:** https://orcid.org/0000-0003-1431-7319**; A. Dasuki:** https://orcid.org/0000-0001-7056-4184

Katsina, Nigeria. **Metodología** Se administraron cuestionarios semiestructurados a las piscifactorías activas y accesibles del estado. Los datos recopilados se presentaron y analizaron mediante estadística descriptiva y regresión logística binaria. **Resultados:** La mayoría de los encuestados fueron del sexo masculino (87.5%), con edad de 31 a 40 años y promedio de 7 años de funcionamiento. La mayoría (78.1%) utiliza antibióticos con fines curativos y la frecuencia de uso dominante fue ocasional (2.,1%). La mayoría (75%) de los encuestados señaló que los antibióticos están fácilmente disponibles y tienen un precio moderado (46.9%), mientras que el método de adición al agua (37.5%) fue el más utilizado. Fish cure$^{(MR)}$ (37%), Aquaceryl plus$^{(MR)}$ (26%) y Oxitetraciclina (10%) fueron los antibióticos más utilizados en el estado. La mayoría de los encuestados (65.6%) son conscientes de los riesgos asociados a la RAM para el pescado, pero muchos de ellos (56.2%) no son conscientes de los posibles riesgos asociados al consumo de pescado con residuos de antibióticos. La incidencia de enfermedades es muy alta (78.1%) entre las granjas del estado, y la mayoría (59.3%) ha experimentado brotes entre una y tres veces. A pesar de la pequeña escala de la piscicultura en el estado, la pérdida económica media debido a los brotes de enfermedades fue de ₦ 594,605.3 ± 0.21 (USD 371.63). El modelo de regresión logística reveló que los años de operación son el principal factor que influye en el uso de antibióticos (P=0.072) y la aparición de enfermedades de peces (P=0.055) en las piscifactorías del estado. **Implicación**: Los expertos veterinarios utilizan mucho los antibióticos en las piscifactorías del estado sin receta médica y la mayoría de los piscicultores no son conscientes del riesgo asociado con el consumo de pescado con residuos de antibióticos. **Conclusión.** El estudio en conjunto proporciona una base para la toma de decisiones informadas, intervenciones específicas y futuras direcciones de investigación en el ámbito de las prácticas de acuicultura sostenible y responsable en el estado de Katsina.
Palabras clave: antibióticos, resistencia a los antimicrobianos, enfermedades, pérdidas económicas, piscifactorías, estado de Katsina.

INTRODUCTION

Disease outbreaks have been globally identified as one of the major impediments to sustainable aquaculture development (Abdelrahman *et al.*, 2023; Naylor *et al.*, 2021). It leads to substantial economic loss through the loss of stocked fish, an increase in operation costs due to treatment, and a reduction in growth rate as diseased fish hardly grow at the normal rate even after treatment (Mukaila *et al.*, 2023; Dauda and Ibrahim, 2015). Researchers over the years have attempted several sustainable means to reduce disease outbreaks in fish farms; these include vaccination, inclusion of probiotics in the feed, feeding with materials that can enhance fish immune response, practicing biosecurity systems, and developing an improved fish culture system, among others (Kyule-Muendo *et al.*, 2022; Dauda, 2020; Ajadi *et al.*, 2018; Adeshina *et al.*, 2018). Nonetheless, the use of antibiotics and many other chemicals to prevent stocked fish mortality and economic loss is still being practiced (Ajadi *et al.*, 2016), especially in developing countries where weak or limited policies on on antibiotic use exist.

Antibiotics are used both as prophylaxis and curative, unfortunately, their usage is being abused without following any strict regulations. For instance, previous research in Katsina State, Nigeria, about a decade ago, reported that 84.2% of fish farmers were using antibiotics, with the majority of them using them without a prescription from veterinary experts (Dauda and Ibrahim, 2015). Generally, antibiotics in fish farms are administered either through direct addition to the culture water or mixing with fish feed, with the latter being more practiced. According to Olatoye and Basiru (2013), when antibiotics are mixed with fish feeds, their residue may be deposited in the meat and inadvertently consumed by human beings. Consumption of such fish with antibiotic residues may lead to changes in the microbial flora of the consumers, and this comes with many associated risks, including development of bacterial resistance, toxicity to consumers and might lead to morbidity or death (Okocha *et al.*, 2018; Cabello, 2006). It is not impossible that farmers' also have a poor understanding of antimicrobial resistance (AMR) considering a previous research that documented knowledge of AMR among veterinary students in Nigeria with over 60% having lower-than-average knowledge (Odetokun *et al.*, 2019). It is therefore important to intensify research on the use of antibiotics and farmers' understanding of the risks associated with AMR and the public health implications of consuming fish with antimicrobial drug residues.

Katsina State is located in the topmost part of the Northwestern region of the country, with much of the effect of climate change due to desertification, rainfall variability and drought which stands to increase pressure on the fish culture due to fluctuation in temperature and other weather vagaries. Although disease infestation was regarded as a minor constraint as of 2015 (Dauda *et al.*, 2015), the use of antibiotics was relatively high at 84.2% (Dauda and Ibrahim, 2015). This appears dangerous because most were using antibiotics without a prescription from veterinary experts. It is uncertain whether the use of antibiotics in the state has changed in the last decade, and there is a lack of information on the farmers' knowledge of the

risks associated with indiscriminate usage, AMR, and the dangers of consuming fish with antimicrobial drug residues.

Therefore, this research was carried out to examine the status of antibiotic use, farmers' knowledge of risks associated with antimicrobial resistance and disease prevalence in fish farms in the state.

MATERIALS AND METHODS

Study area

The research was carried out in Katsina state, North-western part of Nigeria. The State lies between latitude 11° to 13°N and longitude 7° to 8° 30' E and shares borders with the Niger Republic, Kastina state is the 3rd most populated state in the country, with an estimated population of 9,300,382 as of 2019 (NBS, 2020) and the 17th largest in territorial extension. It is also reported to have about 40 man-made reservoirs (Dauda *et al.,* 2017). According to Adekunle *et al.* (2005), the State has the Northern Guinea savannah agroecological zone in the south, the Sudan savannah in the central, and the Sahel savannah in the north. The state is reputed for farming crops like millet, sorghum, cowpea, and cotton, and rearing animals like cattle, sheep, and goats. Fish farming is relatively new to the state, as only seven fish farms were reported in the state two decades ago by AIFP (2004), this was reported to have increased to over thirty-five in 2014 (Dauda *et al.,* 2015).

The data collection was targeted at all known active fish farms in the state, estimated to be a little above 50 based on the information from the farmers' association. However, the protracting insecurity in the State limited the areas that can be visited and only 32 fish farms that were active and accessible were sampled.

Questionnaire, pre-test, consent, and data collection

In this survey, a semi-structured questionnaire was used, which was designed with input from experts and informed by relevant literature. The questionnaire mainly featured closed-ended questions, a strategic choice aimed at improving data organization and precision in responses (Thrusfield, 2009). The questionnaire contains sections on the socio-demographic characteristics of the respondents, knowledge of antibiotics, farmers' knowledge of AMR, and fish disease. Before questionnaire administration, the survey tool was pre-tested among five fish farmers. Responses received were used to improve the quality and delivery of the questionnaire during administration. Data was collected with the questionnaire administered face-to-face by experienced scientists from the research team who visited all the accessible farms in all the parts of the state. Data were gathered during both the pre-testing and the main survey phases. Farmers were briefed on the study objectives, and data collection relied on verbal consent. Participation was voluntary, and confidential, and respondents could withdraw from the study at any stage without facing bias (Alhaji *et al.*, 2023).

Data analysis

The data collected was analyzed and presented using simple descriptive statistics frequency, percentage, and mean. Binary logistic regression was used to assess the influence of the demographic characteristics of the respondent's farm on the use of antibiotics, awareness of the risk associated with AMR and fish disease experience on the farm. All analyses were carried out using IBM SPSS version 22 for MAC.

The implicit model of the regression is $Y = f(X_1, X_2, X_3, X_4, X_5, e)$

Where:
Y = Use of antibiotic drugs or awareness of risk associated with anti-microbial resistance or experience of fish disease on the farm
X_1 = Years in operation of the farm
X_2 = Size of farm
X_3 = Number of ponds/tanks
X_4 = Smallest pond/tank size
X_5 = Largest pond/tank size
e = error term

RESULTS

Demographic characteristics of the respondents and respondents' farms

The majority of the respondents were male (87.5%) (Figure 1) and the age group of 31 to 40 years with 34% representing the dominant age group (Figure 2). The demographic characteristics of the respondents' farms are shown in Table 1. 50% of the farms have been in operation for only 1 to 5 years while a minority of 6.3% have been in operation for over 15 years, the mean years in operation is approximately seven years. The mean farm size of the respondents was 1.77±0.62 ha with the majority (40.6%) of the respondents owning between 0.01-0.50 ha. The mean number of ponds on the respondents' farms stood at approximately 11 while 53.1% of the farmers have 1 to 5 ponds. The mean smallest pond/tank size used by the respondents was 21.25±3.93 m^2, and the largest group, 43.8%, used between 1 to 10m^2. The mean largest pond size used by the respondents was 58.84±8.78 m^2 while 50% had their largest pond size between 1 and 40 m^2.

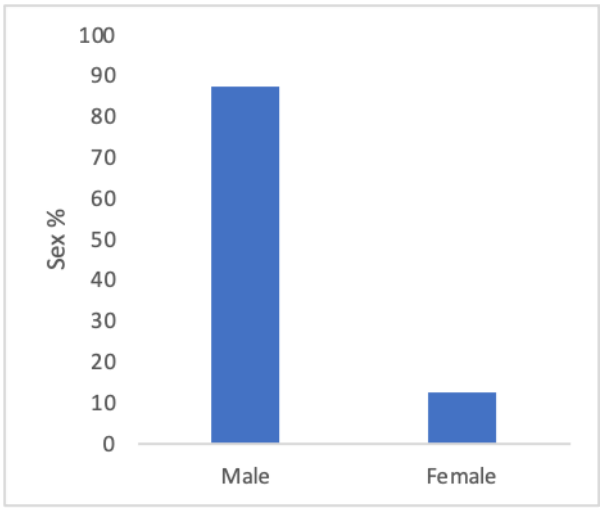

Figure 1. Sex distribution of the respondents.

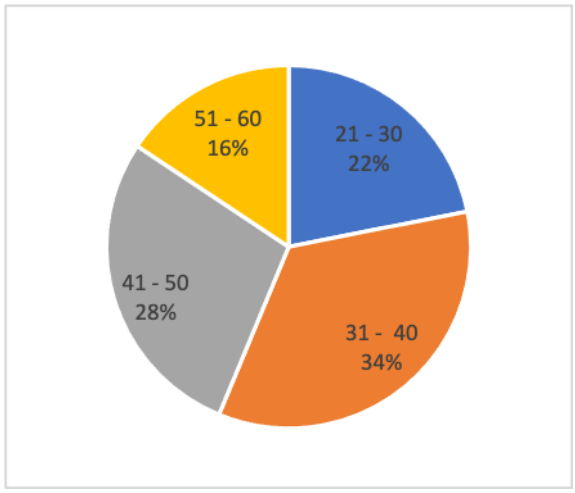

Figure 2. Age distribution of the respondents.

Table 1. Demographic characteristics of the respondents' farm.

Variables	Parameters	Frequency	%	Mean± S.E
Years in operation	1 - 5	16	50	6.97±1.00
	6 - 10	10	31.3	
	11 - 15	3	9.3	
	16 - 20	2	6.3	
	>20	1	3.1	
Size of the farm (ha)	0.01 – 0.50	13	40.6	1.77±0.62
	0.51 – 1.0	5	15.8	
	1.1 – 1.5	4	12.5	
	1.6 – 2.0	3	9.3	
	2.1 – 2.5	3	9.3	
	>2.5	4	12.5	
Number of ponds/tanks	1 - 5	17	53.1	10.91±2.61
	6 – 10	6	18.8	
	11 - 15	1	3.1	
	16 - 20	2	6.2	
	>20	6	18.8	
Smallest pond/tank size (m^2)	1 – 10	14	43.8	21.25±3.93
	11 - 20	7	21.8	
	21 - 30	2	6.3	
	31 - 40	3	9.3	
	41 – 50	4	12.5	
	>50	2	6.3	
Largest pond/tank size (m^2)	1 – 20	9	28.1	58.84±8.78
	21 - 40	7	21.9	
	41 - 60	3	9.4	
	61 – 80	3	9.4	
	81 - 100	6	18.7	
	>100	4	12.5	

Antibiotics use in fish farms

The results revealed that the majority, 78.1% of the respondents use antibiotics, and the dominant purpose of use representing 71.8% was for curative purposes. The frequency of use varies considerably, with occasional usage leading at 28.1% followed by rare and routine with 25% each. A larger percentage, 43.8% of the respondents relied on veterinary consultants for and how to use, while

40.6% did self-medication. Of most respondents, 75% noted that antibiotics are readily available and the mode of administration were, mixing with feed only was 18.8%, added to water only was 37.5% while 28.1% of the respondents practiced a combination of the two methods. The majority of the respondents, 46.9%, opined that the price of antibiotics was moderate, while 25% categorized it as expensive (Table 2). Figure 3 shows that; Fish cure, 37% and Aquaceryl plus, 26% are the two most commonly used antibiotics in the state.

Table 2. Antibiotics use in fish farms in Katsina State.

Variables	Parameters	Frequency	%
%Do use antibiotics	Yes	25	78.1
	No	7	21.9
Purpose of use	Curative	23	71.8
	Prophylaxis	3	9.4
	Growth promoter	3	9.4
	Not applicable	3	9.4
Frequency of use	Often	4	12.5
	Routine	8	25
	Rare	8	25
	Occasionally	9	28.1
	Not applicable	3	9.4
Who determines when and how to use	Self	13	40.6
	Veterinary consultants	14	43.8
	Advice from other farmers	2	6.3
	Not applicable	3	9.4
Antibiotics are readily available	Yes	24	75
	No	8	25
Mode of administration	Mixed with feed	6	18.8
	Added to water	12	37.5
	Both	9	28.1
	Not applicable	5	15.6
How affordable are antibiotics	Very expensive	8	25
	Moderate price	15	46.9
	Cheap	3	9.4
	Not sure	6	18.8

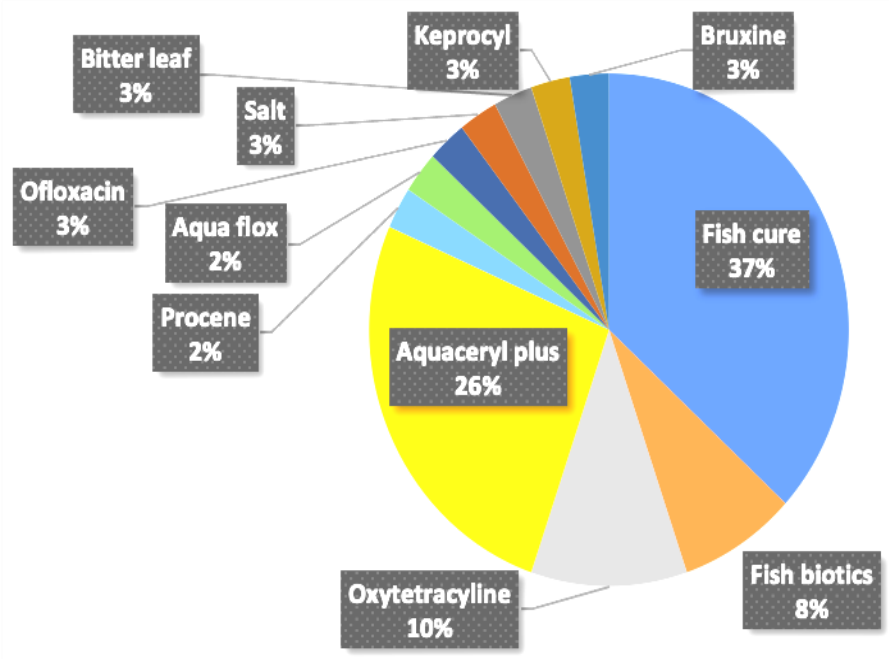

Figure 3. Types of antibiotics used in fish farms in Katsina State.

Respondent's knowledge and perception of risk associated with antimicrobial resistance (AMR)

The results of knowledge and farmers' perception of risk associated with AMR are shown in Table 3. Awareness of AMR risk appears popular with 65.6% being aware as against 34.4% not. A larger percentage, 43.7% of the respondents have observed a reduction in the effectiveness of previously used drugs, while 53.1% have had to increase the dosage of the drugs they used for effectiveness. On the contrary, only 21.9% were aware of possible risks associated with consuming fish with antibiotic residue while the majority, 56.2% were not aware.

Occurrence of fish disease in fish farms in Katsina State

The results showed that 78.1% of the respondents had experienced fish diseases in their farms while 59.3 had experienced diseases between one and three times. The respondents revealed that 59.4% were able to trace the source of the diseases and bacteria diseases were the dominant with 40.6%. The majority (62.4%) reported one to three ponds as the largest group of ponds affected. The economic loss to diseases was led by the group that lost ₦10000 (USD 6.25) to ₦ 50000 (USD 31.25) representing 28.1% and the group that lost over ₦200,000 (USD 125) to diseases representing 37.4%. Of most respondents, 62.4% treated the diseases by themselves, 71.9% reported that the disease was treated successfully. Antibiotics were used by 43.8% to treat the disease and were the most commonly used drugs (Table 4).

Relationship between demographic characteristics and antibiotics use, awareness of AMR risk and disease occurrence

The results of the logistic regression to examine the influence of the demographic characteristics of the farms on the use of antibiotics in fish farms in the state are shown in Table 5. The regression model was statistically significant X^2 (DF=5) =12.832 (P<0.05). The model explained 50.8% (NagelKerke R^2) of the variance in antibiotics use and correctly classified 84.4% of the antibiotics use. The output revealed that only Years of operation of the respondent significantly influenced the use of antibiotics and the odd shows a 1.422 likely chance of using antibiotics with an increase in years of operation. The following important variables, though not significant, are the number of ponds/tanks and the correspondent's farm's smallest pond/tank size.

The logistic regression model was not significant in terms of the influence of demographic characteristics on farmers' awareness of the risk associated with AMR X^2 (DF =6) = 3.711 P>0.05 (Table 6).

The results of the influence of demographic characteristics on the occurrence of fish diseases are shown in Table 7. The logistic regression model was significant X^2 (DF =5) = 10.985 P<0.05. The model explained 44.7% (NagelKerke R^2) of the variance and correctly classified 84.4% of the disease occurrence. Only years of operation showed a significant difference at a 10% confidence level (P<0.1) and the probability of disease occurrence with an increase in years of operation was 1.636 times.

DISCUSSION

The demographic profile of the respondents provides a foundation for contextualizing the study results. The predominance of male respondents (87.5%) and the most represented age group being 31 to 40 years (34%) suggest a specific demographic engaged in fish farming in Katsina State. This is similar to some earlier findings where more male fish farmers are observed (Umunna *et al.*, 2020; Alfred *et al.*, 2020; Nwabueze, 2010) and probably showing some limitations to the aquacultural activities of women in the area (Ayeloja *et al*., 2022). Understanding the demographics is crucial for tailoring interventions and support programs to the specific needs of this group.

Table 3. Respondent's knowledge and perception of risk associated with Anti-microbial resistance (AMR).

Variables	Parameters	Frequency	%
Awareness of AMR risk	Yes	21	65.6
	No	11	34.4
Observation of less effectiveness of previously used antibiotics	Yes	14	43.7
	No	7	21.9
	Not sure	11	34.4
Increment in dosage of antibiotics for effectiveness	Yes	17	53.1
	No	10	31.3
	Not sure	5	15.6
Awareness of the risk of consuming fish with antibiotic residue	Yes	7	21.9
	No	18	56.2
	Not sure	7	21.9

Table 4. Occurrence of fish diseases in fish farms.

Variables	Parameters	Frequency	%
Have you ever experienced fish disease	Yes	25	78.1
	No	7	21.9
Number of times disease was experienced	Nil	2	6.3
	1 - 3	19	59.3
	4 - 6	8	25
	7 - 9	1	3.1
	10 - 12	2	6.3
Were you able to trace the source of the disease	Yes	19	59.4
	No	13	40.6
Types of disease experienced	Fungi	5	15.6
	Viral	1	3.1
	Bacteria	13	40.6
	Nutritional	1	3.1
	Unknown	6	18.8
	others	6	18.8
Number of ponds affected	Nil	1	3.1
	1 - 3	20	62.4
	4 - 6	5	15.7
	7 - 9	3	9.4
	10 - 12	3	9.4
Estimated loss to disease (₦)	Nil	3	9.4
	10000 - 50000	9	28.1
	51000 - 100000	4	12.5
	101000 -150000	2	6.3
	151000 - 200000	2	6.3
	>200000	12	37.4
Was the disease treated successfully	Yes	23	71.9
	No	3	9.4
	Not applicable	6	18.8
Who treated the disease	Self	20	62.4
	Consultant	6	18.8
	Not applicable	6	18.8
What was used in treating the disease	Antibiotics	14	43.8
	Probiotics	2	6.3
	Salt	3	9.4
	Others	6	18.8
	N/A	7	21.9

Table 5. Relationship between respondent's farm demographics and antibiotics use in fish farms.

Variable	Estimate (B)	Wald (Z-score)	P-value	Odds
Years in operation	0.352	3.247	0.072*	1.422
Size of farm	0.129	1.332	0.248	1.138
Number of ponds/tanks	-0.101	2.341	0.126	0.904
Smallest pond/tank size	-0.081	2.635	0.105	0.923
Largest pond/tank size	-0.012	1.223	0.269	0.988
Constant	2.683	3.502	0.061	14.635
Model				
Chi-square value	12.832			
Df	5			
P	0.025			
NagelKerke R square	0.508			
Correct classification	84.4%			

*significant at 10% (P<0.1)

Table 6. Relationship between respondent's farm demographics and awareness of Awareness of risks due to Antimicrobial resistance (AMR)

Variable	Estimate (B)	Z-score	P-value	Odds
Years in operation	0.053	0.482	0.488	1.055
Size of farm	0.008	0.007	0.935	1.008
Number of ponds/tanks	0.021	0.172	0.679	1.021
Smallest pond/tank size	-0.034	1.253	0.263	0.967
Largest pond/tank size	0.016	1.142	0.285	1.016
Constant	-0.093	0.012	0.912	0.911
Model				
Chi-square value	3.711			
Df	5			
P	0.592			
NagelKerke R square	0.151			
Correct classification	68.8			

Table 7. Relationship between respondent's farm demographics and Occurrence of fish diseases.

Variable	Estimate (B)	Z-score	P-value	Odds
Years in operation	0.492	3.684	0.055*	1.636
Size of farm	-0.044	0.094	0.759	0.957
Number of ponds/tanks	0.010	0.019	0.890	1.010
Smallest pond/tank size	0.004	0.023	0.881	1.004
Largest pond/tank size	-0.015	1.064	0.302	0.985
Constant	-0.107	0.010	0.920	0.898
Model				
Chi-square value	10.985			
Df	5			
P	0.052			
NagelKerke R square	0.447			
Correct classification	84.4			

*significant at 10% (P<0.1)

Fifty percent (50%) of the farms in the study have operated for 1 to 5 years, with a minority of 6.3% having been in operation for over 15 years, the mean years in operation is approximately 7 years. This is consistent with previous research by Dauda *et al.* (2015) and Dauda and Ibrahim (2015), indicating that fish farming and aquaculture businesses in the state are typically managed by individuals with less than five years of experience, suggesting that they are still in the learning process. The prevailing farm sizes of 0.01 to 0.50 ha and pond numbers between 1 to 5 indicate predominantly small-scale fish farms, which is consistent with the observations of Dauda *et al.* (2015) about a decade ago. Unfortunately, this trend suggests limited improvement in aquaculture production in Katsina state, which is not unique as it reflects similar patterns seen in other regions of the country, such as in the southern part of Edo state (Emefe *et al.*, 2020) and Lagos state (Okunade *et al.*, 2023; Adeogun *et al.*, 2007), where smaller production facilities dominate.

On the farms surveyed, antibiotics are employed to prevent or treat bacterial disease outbreaks in cultured fish species, and in certain instances, they serve as growth promoters. A substantial majority (71.8%) reported using antibiotics, primarily for curative purposes. This information underscores the importance of veterinary support, with 43.8% seeking advice from veterinary consultants. This is similar to the findings of Ndahi *et al.* (2023). However, no fish farmers in Southwest Nigeria retained veterinary services for antibiotic use in their farms (Adelowo and Okunlola, 2019), while in North Central Nigeria, over 90% of fish farmers engage in self-administration of antibiotics (Alhaji *et al.*, 2021). Our result indicates an alarming use of antibiotics by farmers in Katsina State compared to other locations in Nigeria. For instance, in a survey of 50 farms in Southwest Nigeria, 25 (50%) indulged in antibiotic use mainly on their farms (Adelowo and Okunlola, 2019). Comparably with the occasional usage (28.1% frequency) of antibiotics by the surveyed Katsina farms, Olatoye and Basiru (2013) reported that more than 90% of fish farmers in Ibadan, routinely utilized antimicrobial drugs to control and prevent diseases in their ponds. This situation is relatively positive for the state, particularly if the observed reduction in usage is attributed to an enhanced understanding of the consequences of antibiotic use and the adoption of improved aquaculture practices. This study, as well as other previous studies in Nigeria,

indicates the use of varying methods of antibiotic administration such as mixing with feed, water, or a combination of both methods (Adelowo and Okunlola, 2019; Usman *et al.,* 2022). The diverse methods of antibiotic administration, coupled with varying perceptions of their affordability, present avenues for targeted education and intervention programs to promote responsible use.

Findings from this study revealed Fish cure (37%), Aquaceryl plus (26%), and Oxytetracycline (10%) are the most commonly used antibiotics in the state. A further check on the component of the Fish cure and Aquaceryl plus revealed that oxytetracycline is the dominant active component. These findings of oxytetracycline as the dominant antibiotic either as the active ingredient in other products or directly in pure form are in line with previous studies that documented oxytetracycline as the most commonly used antibiotic in fish farms (Alhaji et al., 2021; Okocha et al., 2021; Adelowo and Okunola, 2019). Yet, employing fish-specific drugs like Fish cure and Aquaceryl plus could be advantageous for the industry, as these drugs tailored for fish may have fewer adverse effects compared to their non-specific pure forms. This study revealed that 43.7% of the respondents have observed a reduction in the effectiveness of previously used drugs while 53.1% have had to increase the dosage of the drugs they used for effectiveness. The use of antibiotics in food animals is associated with antibiotic resistance, a global public health concern. In this study area, only 21.9% are aware of the possible risks related with consuming fish with antibiotics residue while a majority, 56.2% are not aware. Findings from this study are similar to those by Adelowo and Okunlola (2019) in Southwestern Nigeria, who reported that most fish farmers are unaware of any risk associated with antibiotics use in their ponds.

The majority of respondents in Katsina State have experienced fish diseases between one and three times over the years of operation by most of them with bacterial diseases as the dominating one. This is in line with the reports from Dauda *et al.* (2015) who stated that most fish farms in Katsina state have experienced disease outbreaks, and most of them have happened more than once, though fewer than half of the farms have experienced disease outbreaks frequently. The economic loss to diseases was led by the group that lost ₦10000 (USD 6.25) to ₦ 50000 (USD 31.2) representing 28.1% and the group that lost over ₦200,000 (USD125) to diseases representing 37.4%. These findings are also similar to those by Dauda and Ibrahim (2015) that revealed significant amount of money is lost when ponds larger than ten are infected, particularly in a state where small-scale farmers still mostly practice fish farming, and, also agree with Mukaila *et al.* (2023) who stated that the economic performance of the small-scale catfish farms reduced as the disease outbreak increased. The majority of the respondents reported that the disease was successfully treated and they were self-treated as only a few relied on consultants for drug administration. Antibiotics were used by 43.8% to treat the disease and it represented the major material used. This indicates that most of the disease infestation in the state is caused by bacterial infections and coincides with the observations of Ajadi *et al.* (2016) who reported the continual utilization of antibiotics and many other chemicals to prevent mortality in fish culture to prevent economic loss especially in the developing countries.

The study also sheds light on respondents' awareness and perception of AMR risks. While a considerable portion (65.6%) are aware of AMR risks, there remains a gap in understanding, especially concerning the risk of consuming fish with antibiotic residues (21.9%). Despite the farmers' report of easy access to antibiotics (Oyebanji and Oyebisi, 2018) and an increase in the dosages of antibiotics applied to fish, they failed to relate this to the associated risk of AMR arising from this practice. On the contrary, 60% of farmers are unaware of the risk involved in the indiscriminate use of antibiotics in fish farms in Nigeria (Oyebanji and Oyebisi. 2018; Adelowo and Okunlola, 2019). In a study by Alhaji et al. (2021), most farmers hold a significant perception that the consumption of contaminated fish (87.3%) and fish products (74.6%) poses a low risk for the spread of AMR and residues to humans. This underscores the need for educational campaigns to bridge this knowledge gap and promote responsible antibiotic use, considering the potential implications for public health.

The National Action Plan for Antimicrobial Resistance (NAP-AMR) should prioritize increasing the awareness of proper antibiotic use among Nigerian fish farmers. The lack of quantitative data on antibiotic use in aquaculture, a common issue in many countries (Chuah *et al.,* 2016), complicates the assessment of associated risks, especially with AMR. This challenge is exacerbated by the rapid expansion of the aquaculture industry in Nigeria (Adelowo and Okunlola, 2019). A successful AMR surveillance program in aquaculture necessitating farmers to adopt good practices for antimicrobial stewardship is encouraged (Alhaji *et al.,* 2021). However, this depends on the awareness and compliance behaviors of farmers regarding guidelines for antibiotic use.

As analyzed through logistic regression, the relationship between demographic characteristics and study parameters, offers nuanced view: for

instance, years in operation significantly influence both antibiotic use and disease occurrence, and there is a trend towards an increase in the use of antibiotics and the occurrence of diseases as the number of years of operation increases. This underscores the importance of experience in shaping farming practices. Comparably, Alhaji *et al.* (2021) identified several socio-cultural factors capable of driving antimicrobial misuse and overuse in fish farms in Northcentral Nigeria. These associated factors include the weak economic status of farmers, intensive management systems, poor biosecurity measures, poor sanitation and hygiene, and the non-expertise of farmers. Antibiotic use may persist as long as diseases occur frequently (Ajadi *et al.*, 2016). To address this, measures must be taken to enhance fish immunity or decrease fish pathogens, ultimately reducing disease outbreaks. (Kyule-Muendo *et al.*, 2022; Dauda, 2020; Adeshina *et al.*, 2018). Abdelrahman *et al.* (2023) emphasized that disease outbreaks in fish farms significantly hinder aquaculture development. Consequently, farmers must implement effective strategies to prevent or minimize disease-related economic losses.

CONCLUSION

While small-scale farms dominate fish farming in the state, the use of antibiotics is high, especially for those using it for curative purposes. The most commonly used antibiotics are the fish cure, aquaceryl plus, and oxytetracycline. Though the state's fish farmers are aware of antimicrobial resistance risk, most of them are unaware of the risk due to the consumption of fish with antibiotics residue. Fish diseases have been experienced by the majority of the fish farms in the state and those who have experienced them between one and three times are the dominant group. This constitutes a huge economic loss to fish farming and is perhaps responsible for the high usage of antibiotics in fish farms. Years in operation are the major factor influencing antibiotics use and the occurrence of fish diseases in fish farms.

The results of the study, taken together, provide a basis for informed decision making, targeted interventions and future research directions in the area of sustainable and responsible aquaculture practices in Katsina State.

Acknowledgements
The authors appreciate TETFund, the management of Federal University Dutsin-Ma, and the Directorate of Research and Development of the University for their support.

Funding. This study was funded by the Tertiary Education Trust Fund (TETFund) through the Institutional Based Research Award of Federal University Dutsin-Ma (FUDMA/VC/R&D/IBR/PS383/VOL.1/1).

Conflicts of Interest. The authors declare no conflict of Interest

N.B. The manuscript has been previously uploaded as a pre-print and it can be found online with the link and DOI as cited below:
Dauda, Akeem Babatunde and Nababa, Abdulsalam Sani and Oshoke, Justina Omolegho and Salele, Hauwau Abubakar and Odetokun, Ismail A. and Bello, Oluwasesan Micheal and Dasuki, Awawu, Antibiotics Use and Awareness of Risks Associated with Antimicrobial Resistance Among Fish Farmers in Katsina State, Nigeria. Available at SSRN: https://ssrn.com/abstract=4767228 or http://dx.doi.org/10.2139/ssrn.4767228

Compliance with ethical standard. The research was carried out in compliance with local ethical standard as approved by the ethical committee of Federal University Dutsin-Ma, Katsina State, Nigeria.

Data availability. Data is available with the corresponding author and it will be made available on request.

CRediT authorship contribution's statement. A.B. Dauda – Conceptualization, Data curation Formal analysis, Funding acquisition, Investigation, Methodology, Administration, Validation, Visualization, Original draft writing, Review and editing**. A.S. Nababa** – Conceptualization, Funding acquisition, Investigation, Methodology, Administration. **J.O. Oshoke** – Conceptualization, Funding acquisition, Investigation, Methodology, Administration. **H.A. Salele –** Validation, Visualization, Original draft writing, Review and editing**. I.A. Odetokun –** Formal analysis, Methodology, Validation, Visualization, Original draft writing, Review and editing**. I. Ghali-Mohammed** - Data curation, Methodology, Visualization, Review and editing**. O.M. Bello** - Conceptualization, Data curation, Funding acquisition, Methodology, Review and editing**. A.Dasuki** - Conceptualization, Funding acquisition, Investigation, Methodology.

REFERENCES

Abdelrahman, H. A., Hemstreet, W.G., Roy, L.A., Hanson, T.R., Beck, B.H. and Kelly, A.M., 2023. Epidemiology and economic impact of disease-related losses on commercial catfish farms: A seven-year case study from Alabama, USA. *Aquaculture*, 566, p.739206

https://doi.org/10.1016/j.aquaculture.2022.739206.

Adekunle, A. A., Olowu, T. A. and Ladele, A. A., 2005. Bridging the communication gap Between scientists and farmers in Katsina State of Nigeria. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. pp. 26.

Adelowo, O.O. and Okunlola, I., 2019. Field assessment of antibiotic use in fish farms in Southwestern Nigeria. *Revue d'élevage et de Médecine Vétérinaire des Pays Tropicaux*, 72 (4), pp 187-191. http://doi.org/10.19182/remvt.31472

Adeogun, O. A., Ogunbadejo, H. K., Ayinla, O. A., Oresegun, A., Oguntade, O. R., Tanko, A. and Williams, S. B., 2007. Urban aquaculture: producer perceptions and practices in Lagos State, Nigeria. *Middle-East Journal of Scientific Research 2*(1), pp. 21- 27.

Adeshina, I., Emikpe, B. O. Jenyo-Oni, A. Ajani, E. K. and Abdel-Tawwab, M., 2018. Stimulatory effect of dietary clove, *Eugenia caryophyllata* bud extract on growth performance, nutrient utilization, antioxidant capacity, and tolerance of African catfish, *Clarias gariepinus* to *Aeromonas hydrophila*. *Journal of the World Aquaculture Society*, 49 (6), pp.1–16. https://doi.org/10.1111/jwas.12565

AIFP, Aquaculture and Inland Fisheries Project, 2004. Inventory of Fish Farms, Lakes and Feed Producers in Nigeria. pp. 24

Ajadi, A., Sabri, M.Y., Dauda, A.B**.,** Ina-Salwany M.Y. and Hasliza A.H., 2016. Immunoprophylaxis: A Better Alternative Protective Measure against Shrimp Vibriosis – A Review. *Pertanika Journal of Scholarly Research Reviews*, 2(2), pp. 58-69. http://www.pjsrr.upm.edu.my

Ajadi, A., Sabri, M. Y., Dauda, A. B., Ina-Salwany, M. Y. and Hasliza, A. H., 2018. Growth enhancement and protective potential of feed-based outer membrane proteins against vibriosis in *Macrobrachium rosenbergii*. *Aquaculture International*, 26, pp. 673-684. http://doi.org/10.1007/s10499-018-0244-4

Alfred, O., Shaahu, A., Amon, T. E., Msaakpa, T. S., Orban, D. A. and Egwenomhe, M., 2020. Aquaculture Operations and Feeding Practice of Fish Farmers in Bida Local Government, Niger State, Nigeria. *International Journal of Research and Innovation in Applied Science*, 5 (12), pp. 109-114.

Alhaji, N. B., Maikai, B. V. and Kwaga, J. K., 2021. Antimicrobial use, residue and resistance dissemination in freshwater fish farms of North-central Nigeria: One health implications. *Food Control*, 130, p.108238. https://doi.org/10.1016/j.foodcont.2021.108238

Alhaji, N.B., Aliyu, M.B., Adamu, A.M., Adeiza, A.M., Nafarnda, W.D., Usman, A.H., Odetokun, I.A., Hassan, A., Lawan, M.K. and Fasina, F.O., 2023. Assessment of Abattoir Workers' Knowledge, Perceptions and Preventive Preparedness during COVID-19 Pandemic in North-central Nigeria: The Health Belief Mode. *Sahel Journal of Veterinary Sciences* 20(1), pp. 13-21. http://dx.doi.org/10.54058/saheljvs.v20i1.308

Ayeloja, A. A., Jimoh, W. A., Adebisi, G. L. and Amusat, M. A. 2022. Gender Differentia Among Fish Farmers Within Ilorin Metropolis, Kwara State, Nigeria. *Momona Ethiopian Journal of Science*, 14(2), pp. 127-138. http://dx.doi.org/10.4314/mejs.v14i2.2

Cabello, F.C., 2006. Heavy use of prophylactic antibiotics in aquaculture: a growing problem for human and animal health and for the environment. *Environmental Microbiology*, 8, pp.1137-1144. https://doi.org/10.1111/j.1462-2920.2006.01054.x

Chuah L., Effarizah M.E., Goni A.M. and Rusul G., 2016. Antibiotic application and emergence of multiple antibiotic resistance (MAR) in global catfish aquaculture. *Current Environmental Health Reports*, 3, pp. 118–127. http://doi.org/10.1007/s40572-016- 0091-2

Dauda, A.B., 2020. Biofloc technology: a review on the microbial interactions, operational parameters and implications to disease and health management of cultured aquatic animals. *Reviews in Aquaculture*, 12, pp. 1193-1210 https://doi.org/10.1111/raq.12379

Dauda, A.B. and Ibrahim H.I., 2015. Prevalence of Fish Diseases in Fish Farms in Katsina State, Nigeria. *Bulletin of Animal Health and Production in Africa*, 63, pp. 495-503.

Dauda, A. B., Dasuki, A. and Bichi, A. H., 2015. Analysis of constraints to aquaculture development in Sudano-Sahelian region of Nigeria. *Tropical and Subtropical Agroecosystems*, 18(2), pp. 189-193. http://dx.doi.org/10.56369/tsaes.2074

Dauda, A. B., Ibrahim, H. I., Bichi, A. H. and Tola-Fabunmi, A. S., 2017. Assessment of fish farming practices, operations, water resource management and profitability in Katsina state, Nigeria. *Journal of Northeast Agricultural University* (English Edition), 24(4), pp. 89-96.

Emefe, O., Egwenomhe, M. and Ugbotor, E. 2020. A survey of fish culture facilities used by farmers in Edo South, Nigeria. *Journal of Agriculture and Environment*. 16, pp. 63-72. http://doi.org/10.13140/RG.2.2.20186.88003

Kyule-Muendo, D., Otachi, E., Awour, F., Ogello, E., Obiero, K., Abwao, J., Muthoni, C., and Munguti, J., 2022. Status of fish health management and biosecurity measures in fish farms, cages and hatcheries in Western Kenya. *CABI Agriculture and Bioscience* 3, 18. https://doi.org/10.1186/s43170-022-00086-7

Mukaila, R. Ukwuaba, I.C., and Umaru, I.I., 2023. Economic impact of disease on small Scale catfish farms in Nigeria, *Aquaculture*, 575, p.739773. https://doi.org/10.1016/j.aquaculture.2023.739773.

Naylor, R. L., Hardy, R. W., Buschmann, A. H., Bush, S. R., Cao, L., Klinger, D. H.,Little, D.C., Lubchencho, J., Shumway, S.E. and Troell, M., 2021. A 20-year retrospective review of global aquaculture. *Nature*, 591(7851), pp. 551-563. https://doi.org/10.1038/s41586-021-03308-6

NBS, 2020. National Bureau of Statisitics, Demographic Statistics Bulletin. pp 12.

Ndahi, M.D., Hendriksen, R., Helwigh, B., Card, R.M., Fagbamila, I.O., Abiodun-Adewusi, O.O., Ekeng, E., Adetunji, V.O., Adebiyi, I., and Andersen, J.K., 2023. Determination of antimicrobial use in commercial poultry farms in Plateau and Oyo States, Nigeria. *Antimicrobial Resistance & Infection Control*, *12*(1), pp. 1-9.

Nwabueze, A. A., 2010. The role of women in sustainable aquacultural development in Delta State. *Journal of Sustainable Development in Africa*, 12, pp. 284-293.

Odetokun, I. A., Akpabio, U., Alhaji, N. B., Biobaku, K. T., Oloso, N. O., Ghali-Mohammed, I., Biobaku A.J., Adetunji, V.O., Fasina, F. O. 2019. Knowledge of antimicrobial resistance among veterinary students and their personal antibiotic use practices: A national cross-sectional survey. *Antibiotics*, 8(4), p. 243. https://doi.org/10.3390/antibiotics8040243

Okocha, R.C., Olatoye, I.O. and Adedeji, O.B., 2018. Food safety impacts of antimicrobial use and their residues in aquaculture. *Public Health Reviews*, 39, 21. https://doi.org/10.1186/s40985-018-0099-2

Okocha, R. C., Olatoye, I. O., Alabi, P. I., Ogunnoiki, M. G. and Adedeji, O. B., 2021. Aquaculture management practices associated with antimicrobial residues in Southwestern Nigeria. *Aquaculture*, 533, p.736195. https://doi.org/10.1016/j.aquaculture.2020.736195

Okunade, O. A., Oladosu, G. A., Adeogun, O. A., Ajani, E. K., Adejinmi, J. O. and Akintayo, I. A., 2023. Status of Fish Farming Practices: A Case Study of Selected Fish Farms in Lagos State, *Nigeria. Nigerian Journal of Fisheries*, 20(1), pp. 2539 – 2558.

Olatoye, I. O. and Basiru, A., 2013. Antibiotic usage and oxytetracycline residue in African catfish (*Clarias gariepinus*) in Ibadan, Nigeria. *World Journal of Fish and Marine Sciences*, 5(3), pp. 302-309.

Oyebanji, B.O. and Oyebisi, M. O., 2018. Use of Antibiotics and Knowledge of Antibiotics Resistance by Selected Farmers in Oyo Town, Nigeria. *Uganda Journal of Agricultural Sciences*, 18 (1), pp. 43 – 56. DOI: http://dx.doi.org/10.4314/ujas.v18i1.4

Thrusfield, M., 2009. Veterinary Epidemiology, third ed. Blackwell Science Ltd, a

Blackwell Publishing company, 9600 Garsington Road, Oxford OX42DQ,

Umunna, M.O., Adebayo, O.A., Adelakun, K.M., Ibrahim, A.O., Sodiya, O.M. and Ige, O., 2020. Analysis of Gender Participation in Fish Farming in Borgu Local Government Area, Niger State, Nigeria. *KIU Journal of Social Sciences*, 6(4), pp. 133–140.

Usman, M.D., Wakawa, A.M., Musa, A., Talba, A.M., Ahmad, K.H., Muazu, T.A., Musa, A.Z. and Atabo, S.M., 2022. Occurrence of haemolytic *Escherichia coli*, antimicrobials residue in cultured *Clarias gariepinus* and assessment of antimicrobial use among catfish farmers in Kano metropolis, Nigeria. *Journal of Sustainable Veterinary and Allied Sciences*,2(2), pp. 105-113. http://doi.org/10.54328/covm.josvas.2022.068