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Use and abuse of antibiotics in Eriwe farms in Ijebu Ode, Ogun State, Nigeria: A case report

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ABSTRACT: Antibiotic use is rampant across freshwater and brackish-water farms. It is routinely used by farmers for disease treatment, prevention and control to maintain high productivity in farms. Antibiotic use and abuse in fish farms have raised concerns regarding public health, environmental sustainability, and the emergence of antibiotic resistance. This study surveyed 60 farms (Grow-out and hatchery ponds) in Ijebu Ode Local Government of Ogun State, Nigeria. The study specifically evaluated the use/abuse of antibiotics among fish farmers, the different forms and types of antibiotics used by farmers, the mode of administration and the withdrawal periods of antibiotics used; using a well-structured questionnaire. In almost 50% of farms surveyed, different antibiotics were lavishly used for routine management. Evidence of antibiotic type and use was found on-site. The on-site production system is 100% earthen ponds. Antibiotics found included those not permitted, not labelled for use in aquaculture or mainly for use in humans; these are Oxytetracycline, Tetracycline, Chloramphenicol, Gentamycin, Doxycycline, Ampicillin, and Streptomycin; with the usage frequencies of 28.4, 23.4, 8.3 and 3.3% respectively. Antibiotics found to be used in Eriwe Fish Farms with most forms of antibiotics being powdered and administration is through feed and/or water at incorrect measurement resulting in entire fish stocks exposure to antibiotics, including uninfected fish. About 58.4% of the farmers use antibiotics once a week, 16.6% use antibiotics twice a month, 25% use antibiotics once a month and 45% of the respondents sell infected fish even while being treated. At the same time, 25.5% of the respondents do not observe antibiotic withdrawal period. Several issues including poor technical knowledge such as misuse and overuse were evident. Developing sustainable fish farming practices that reduce antibiotic dependence, protect public health, and preserve the effectiveness of antibiotics in aquaculture is important. It is important to promote responsible antibiotic use, raise awareness and implement appropriate regulations to safeguard public health, environmental well-being and a viable production of antibiotics in aquaculture.

Keywords: Antibiotics use, antibiotics abuse, fish farms, fish farmers.

INTRODUCTION

Globally aquaculture contributes 8% of animal protein intake to the human diet, and per capita consumption is increasing faster than meat and dairy consumption. Reports have documented antimicrobial use in the rapidly expanding aquaculture industry, which may contribute to the rise of antimicrobial resistance, carrying potential consequences for animal, human, and ecosystem health (Schar *et al.,* 2020). Aquaculture continues to be the fastest-growing animal food-producing sector accounting for about 46% of the total food fish supply to meet the protein needs of the increasing world population and because of this increasing demand, intensification of aquaculture activities is also on the increase (FAO, 2011). Aquaculture is becoming increasingly important at the global level (Garlock *et al.,* 2020). It plays a vibrant role in providing food and means of subsistence for the growing population of the world (Golden *et al.,* 2021). China contributes more than 60% of the global aquaculture production and also administers large amounts of antibiotics to ensure adequate aquaculture productivity and disease management (Mo *et al*., 2017). The use of antimicrobials in fish farming is a reflection of the rapid aquaculture development worldwide. The intensification of aquaculture to achieve market demands could lead to an increase in infectious diseases by pathogenic bacteria (Schar *et al.,* 2020). Consequently, antimicrobials act as controls for emerging infectious diseases, but their use must follow the rules and regulations of the country where the activity is performed. Although the regulations impose limits to the use of antimicrobials in fish farming, many studies show that resistant bacteria are isolated from this system (de Souza Gazal *et al.,* 2020). The growth of aquaculture has led to the promotion of conditions that favour the development of infection and disease-related problems and bio-fouling. Antibiotics have not always been used responsibly in aquaculture, control levels and compliance have not also provided proper assurance on human food safety concerns (FAO/WHO, 2003). The practices of unregulated use of antibiotics in cultured fish and shrimps pose human health and food safety concerns that remain largely unaddressed in most developing nations globally (Biswas *et al.,* 2016). Intensive fish farming has contributed to the spread of various bacterial infections, which in turn has led to increased use of antimicrobials. High rates of antibiotic-resistant bacteria persisting in sediments and in the farm environment can pose a hazard to fish farms as they can be a source of antibiotic resistance genes for fish diseases in fish farms (Yadava *et al.,* 2023). Drug residues, even in very low concentrations are found in edible tissues of the treated animals. In aquaculture products, there could be the development of bacterial resistance and toxicity to consumers that can lead to morbidity and/or mortality. Toxic effects like immuno-pathological effects and carcinogenicity by sulphamethazine, oxytetracycline, and furazolidone; mutagenicity and nephropathy by gentamicin; and allergy by penicillin are issues of great concern (European Commission, 2017). Fish raised in aquaculture are subjected to common procedures globally, some of which are very stressful to the species of culture compromising the fish immune system leading to bacterial and other infections (Cabello, 2017). The use of prophylactic antibiotics to avoid the emergence and rapid spread of infection is therefore a widespread practice, especially in those countries where no other preventive measures are adopted (de Souza Gazal *et al.,* 2020). In aquaculture, antimicrobial agents are usually administered to entire populations containing sick, healthy, and carrier individuals, by a process known as metaphylaxis. The consequences of this practice could be worrisome because drugs contained in fish can persist in the aquatic environment for a long time and can rapidly spread via excretion throughout water systems, exerting undue pressure in many ecosystems (Yadava *et al.,* 2023). Fish generally, do not effectively metabolize antibiotics so the active substance largely passes into the environment in the faeces, with approximately 70–80% of the antibiotics applied in aquaculture being dispersed into water systems (O'Neill, 2015). The determination of antimicrobial residues in fish products can provide relevant information on the type and quantity of these drugs that are being used in aquaculture production because antibiotic residues remain in fish tissues for prolonged periods of time (Yadava *et al.,* 2023). Non-adherence to recommended directions or dosage, non observance of recommended withdrawal periods; administration of too large a volume at a single injection site; use of antibiotic contaminated equipment or failure to properly clean equipment used to mix or administer drugs. Also, unintentional feeding with spilled chemicals or medicated feeds; animal effects, such as age, congenital illness and allergies; chemical interactions between drugs; variations in water temperature for aquatic species have been found to be contributory factors to human health safety issues (Canadian Food Inspection Agency) (CFIA, 2014). The injudicious and/or incorrect use of anti-microbial agents against diseases of farmed aquatic species poses a considerable threat to the development and growth of a successful and sustainable aquaculture industry. An increase in antimicrobial resistance (AMR) is an important consequence, resulting in difficulty in treating common bacterial diseases in populations of aquatic organisms, combined with the presence of antibiotic residues in food fish and their products, leading to import refusals and negative impacts on international trade (Bondad-Reantaso *et al.,* 2023). Another area of concern is the use of antibiotics as growth promoters in fish farming. Misuse or abuse of antibiotics could result in the deposition of drug residues in the muscles and other parts of fish further exposing the consumers to the challenge of antibiotic resistance (Ladan *et al.,* 2021; Barde *et al.,* 2022).

The African contribution to world aquaculture production is still insignificant (~2.7%) (Hanson, 2020) albeit significantly increasing with larger-scale investments in Egypt, Nigeria, Uganda and Ghana producing substantial quantities of fish (Chai and Bong*,* 2022). Application of different types of antimicrobial agents because of the low technical knowledge leading to the use and abuse of such chemical agents which are detrimental to human health is a common practice among naïve fish farmers (Satya, 2018). According to the World Health Organization (WHO), AMR has already reached alarming levels in many parts of the world (FAO/WHO, 2003). Resistant bacteria are responsible for infections that are more difficult to treat, requiring less available, more expensive, and usually more toxic drugs. In some cases, resistant bacteria have become resistant to all known antibiotics for the treatment of simple infections (ECDC, 2017). The indiscriminate and abusive use of antibiotics can result in higher concentrations of antibiotics in the environment termed antibiotic pollution. The sources via which antibiotics can be released into the environment are diverse, including the human waste streams, and wastes from veterinary use and livestock farming fronts (Miranda, 2013). Antibiotics used for prophylaxis or therapy in humans contaminate the human waste streams, likewise, the antibiotics used in animals for growth promotion, prevention, and treatment equally contaminate the animals' waste streams. Others are the continuous dispersal of medicated feed and accidental spill of microbial products are considered prime sources of antibiotic release and discharges into the environment (Chee-Sanford *et al.,* 2015).

In developed countries, the use of antibiotics in aquaculture is highly controlled. The FDA, FAO's Codex Alimentarius Commission (Codex), the European Medicines Agency (EMA) and the European Union (EU) EC have been very influential in setting up Maximum Residue Levels (MRLs) permitted in or on food commodities and animal feeds of antibiotics in food (European Commission, 2017). The existing regulatory environment, specifically from the EU, Norway and the USA, has helped to shape the use of antibiotics in global aquaculture production. In the USA, the FDA phased out indiscriminate use of antibiotics in food animal production (FDA, 2013), and collects data on the amount of antimicrobial active ingredients in drugs sold or distributed for use in animal production systems (FDA, 2015). Farmers were found to use veterinary antibiotics labelled for use in poultry or livestock, but not specifically fish. These include enrofloxacin, cephalexin, oxytetracycline and tetracycline (FDA, 2015). There was limited awareness about the required dosage, which could vary depending on the body mass of the animal or fish. Administered antibiotic dosage therefore varied among different farms and was based on farmer experience and word of mouth. Since the antibiotics used were not labelled for fish, there was no information on the withdrawal period. In such a scenario, there is no question of withdrawal periods being followed (Biswas *et al.,* 2016).

The use of antibiotics in aquaculture depends on the local regulations, which vary widely between different countries. The emerging view that antibiotics should be used with more care has prompted more strict regulations on the use of antibiotics in aquaculture and on the presence of antibiotic residues in aquaculture products. In some countries, regulations on the use of antibiotics are strict, and only a few antibiotics are licensed for use in aquaculture (Kelly *et al.,* 2020). However, a large proportion of global aquaculture production takes place in countries that have permissive regulations. The public health risk associated with antimicrobial residues depends on the quantity of the antimicrobial encountered or consumed. Antimicrobial-resistant bacteria in aquaculture present a risk to public health. The appearance of acquired resistance in fish pathogens and other aquatic bacteria means that such resistant bacteria can act as a reservoir of resistance genes from which genes can be further disseminated and may ultimately end up in human pathogens. The use of anti-microbial compounds in aquaculture to prevent or treat fish diseases is not unusual and sometimes necessary (Kelly *et al.,* 2020). Recognition of the risks associated with the direct and indirect effects on human health of both active and passive consumption of antibiotics has led to bans on the use of certain antibiotics in animal food production and the establishment of Maximum Residue Limits (MRLs) for those with known risks (He *et al.,* 2016; Mensah *et al.,* 2019). Despite all efforts and resources channelled towards the fight against Antimicrobial Resistance (AMR), it manages to remain one of the top public health challenges of the 21st century. It is almost as if the problem itself has developed resistance. Numerous researches have been conducted to unravel its persistence and seek ways to reduce or eradicate AMR (Pepi and Focardo, 2021; Golden *et al.,* 2021; Chai and Bong, 2022). This has increased awareness and emphasized the urgency to which effective measures have to be taken to alleviate AMR (Chai and Bong, 2022). Among the factors discovered to contribute to this menace is the use of antibiotics in livestock/animal rearing. It has come to light that most antibiotics used in animal rearing are done with little or no expert consultation and some of these antimicrobials are available over the counter in many countries. Lack of awareness, unavailability of agricultural extension services, inadequate instructions supplied by manufacturers, and the need for profit by animal rearers culminate in the irrational use of antibiotics (Martins *et al.,* 2022). Prudent use of antibiotics in aquaculture under veterinary supervision is critical in ensuring the safety of aquaculture products. Good animal husbandry practices as well as the use of alternatives to antibiotics such as vaccination are recommended panaceas to reducing the use of antimicrobial residues in aquaculture and consequent food safety. Associated public health concerns are on the increase and this concern has become a global health issue leading to multidisciplinary action and teamwork resulting in the formation of the global one health action (FAO/WHO, 2003).

Antimicrobial resistance is a global public health concern, with extensive associated health and economic implications. Actions to slow and contain the development of resistance are imperative. Despite the fact that overuse and misuse of antibiotics are highlighted as major contributing factors to this resistance, no sufficiently validated measures aiming to investigate the drivers behind consumer behaviour amongst the general population of fish farmers are available. Once triggered,

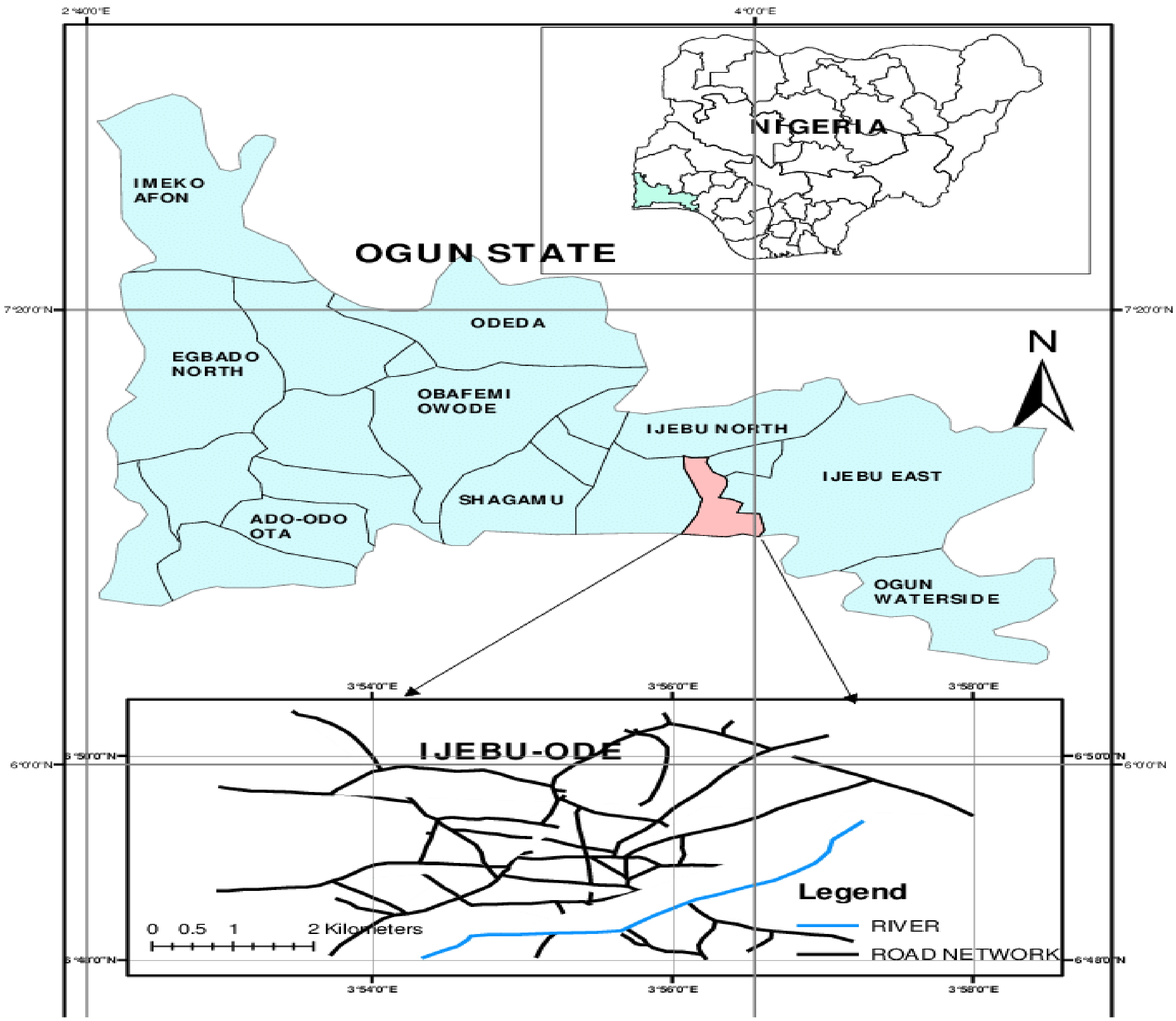

Figure 1. Map of Ijebu Ode showing the location of the Eriwe fish farm.

antibiotic resistance easily spreads among aquatic microbial communities and, from there, can reach human pathogenic bacteria, making vain the use of antibiotics for human health (Pepi and Focardi, 2021). Regardless of the fact that antibiotics are often used in aquaculture in Nigeria, there is currently very limited information available on the impact of antibiotic usage on the environment. Most reports include information on antibiotic usage and residues in aquaculture products (Ladan *et al.,* 2021). This study surveyed 60 farms (Grow-out and hatchery ponds) in Ijebu Ode Local Government of Ogun State, Nigeria. The study specifically evaluated the use/abuse of antibiotics among fish farmers, the different forms and types of antibiotics used by farmers, the mode of administration and the withdrawal periods of antibiotics used; using a well-structured questionnaire.

METHODOLOGY

The study was carried out on Eriwe Fish Farm Estate, Ijebu-Ode, a town in Ogun State, South-West of Nigeria (Figure 1). The duration of the study was three (3) weeks in June 2022. Eriwe fish farm village has majorly earthen grow-out systems, where fishes are raised from fingerlings to table size. The farm Estate is located on a 156 acres farm village under the auspices of the Ijebu Development Initiative on Poverty Reduction (IDIPR) in 2001.

In all, sixty (60) questionnaires were randomly administered. A well-structured questionnaire was pretested before it was randomly distributed to the respondents to collect the primary data. Observation technique was used to collate information for analysis which gave more understanding to study. Descriptive statistics was used to

Table 1. Type of antibiotics used in Ijebu Ode fish farms.

Type of antibiotic	Frequency	Percentage (%)
Tetracycline (Livestock)	14	23.4
Oxytetracycline (Livestock)	17	28.4
Chloramphenicol (Livestock)	5	8.4
Ampicillin (Human)	2	3.3
NCO-MIX (gentamycin and doxycycline) (Poultry)	5	8.3
Penicillin (Human)	12	20
Streptomycin Sulphate (Livestock)	2	3.3
Calcium	2	3.3
Livestock vitamins	1	1.6
Total	60	100

Table 2. Frequencycy of antibiotic use by fish farmers.

How frequent do you use antibiotic in a cycle?	Frequency	Percentage
Once a week	35	58.4
Twice in a month	10	16.6
Once a month	15	25
Total	60	100

analyze data collected from individual farmers and focused group interviews examining the profile of the respondents, antibiotics type and use. The focused group interview was also used for capturing experiences shared in a group setting and recording the perceptions of participants in their natural farm environment and comparing with what was captured in the questionnaire. Data were presented using tables and charts. The prevalence data were tested using Chi-square statistic. Graphpad prism version 4.0 for Windows was used for the analyses and values of $p < 0.05$ were considered significant.

RESULTS AND DISCUSSION

Farmers in the study area were found to use veterinary-grade antibiotics labeled for use in poultry or livestock, and not specific for aquaculture production. These included Oxytetracycline, Tetracycline, Chloramphenicol, Gentamycin, Doxycycline, Ampicillin, and Streptomycin; with usage frequencies of 28.4, 23.4, 8.4 and 3.3%, respectively (Table 1). This is in agreement with Ladan *et al.* (2021) who reported that tetracycline is the most frequently used antibiotic in fish. Also, Schar *et al.* (2020) reported that globally, the most commonly used classes of antimicrobials were, by frequency of use, quinolones (27%), tetracyclines (20%), chloramphenicols (18%), and sulfonamides (14%). These global trends in antimicrobial use in aquaculture are heavily influenced by the expansion of the aquaculture industry in many countries of the world including Nigeria. Table 2 shows that 58.4% of the farmers use antibiotics once a week, 16.6% use antibiotics twice a month and 25% use antibiotics once a month. It has come to light that most antibiotics used in aquaculture rearing are done with little or no expert consultation and some of these antimicrobials are available over the counter in many countries. Lack of awareness, unavailability of agricultural extension services, inadequate instructions supplied by manufacturers, and the need for profit by animal rearers culminate in the irrational use of antibiotics (Zincic, 2020; Martins *et al.,* 2022). Figure 2 showed that 45% of the respondents sold infected fish even while being treated; while Figure 3 showed that 25.5% of the respondents did not observe antibiotic withdrawal period. This concurs with the report of Ladan *et al.* (2021) that the majority of fish farmers did not observe antibiotic withdrawal periods before sales of fish to consumers in a study carried out in Kaduna State Nigeria. Since the antibiotics used were not labelled for fish, the withdrawal period was hardly observed. 25.5% of the fish farmers did not know what the withdrawal period was all about and had no information on the withdrawal period. A similar study of non-observance of drug withdrawal period happened in Ibadan where the majority (95%) of the respondents frequently administered drugs (in feed and water) without veterinary prescription and not observe antibiotics withdrawal period (Olatoye and Afisu, 2013). Figure 4 shows that 46.7% of the respondents use a prescription on the leaflets to measure, 43.3% of the respondents measure antibiotics based on assumption, 6.7% of the respondents measure antibiotics per the average weight of the fish stocked in a pond and 3.3% of the respondents measure antibiotic as told by their fellow fish farmers. Figure 5 shows that 53.3% of the respondents mix antibiotics with feed before administering.

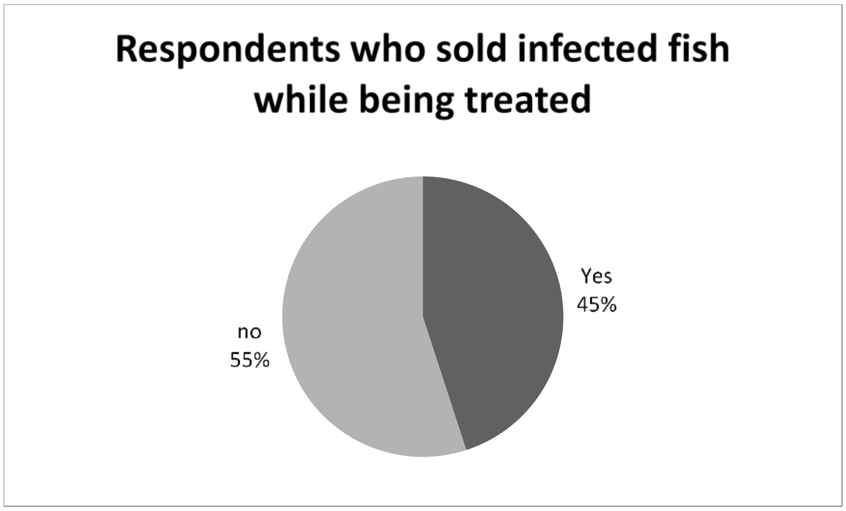

Figure 2. Respondents who sold infected fish while being treated.

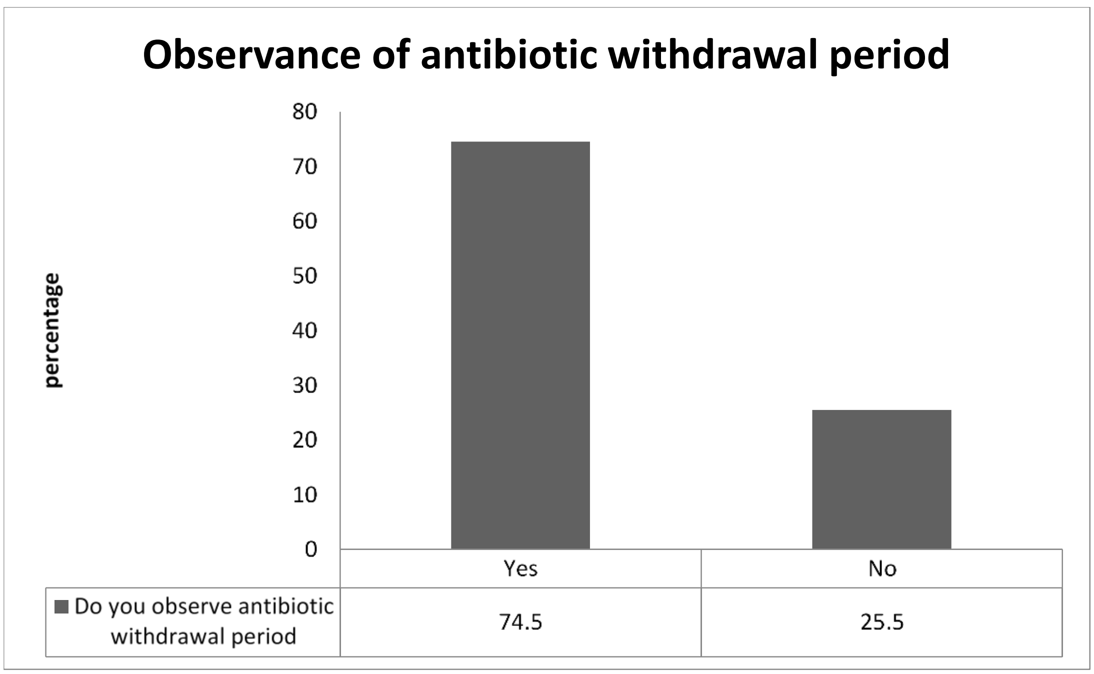

Figure 3. Observance of antibiotic withdrawal period in fish ponds by respondents.

40% of the respondents mix antibiotics with water before pouring it into the pond 3.3% of the respondents inject infected fishes while 3.3% of the respondents use all methods of administration. This is similar to the findings of Yadava *et al.* (2023) who reported that antimicrobial agents are usually added to the feed and then put into the water for raising fish. In some cases, the antimicrobial agent can be added directly to the water sometimes without precise measurements. This could be due to limited awareness about the required dosage, which could vary depending on the body mass of the animal or fish. Administered antibiotic dosage varied among different farms and was based on farmer experience and word of mouth from other farmers. The absence of drugs approved specifically for fish production was clearly identified in this study. It seemed like farmers had no fore knowledge of where to obtain the required drugs specific for aquaculture production. Farmers believed that if an antibiotic works for

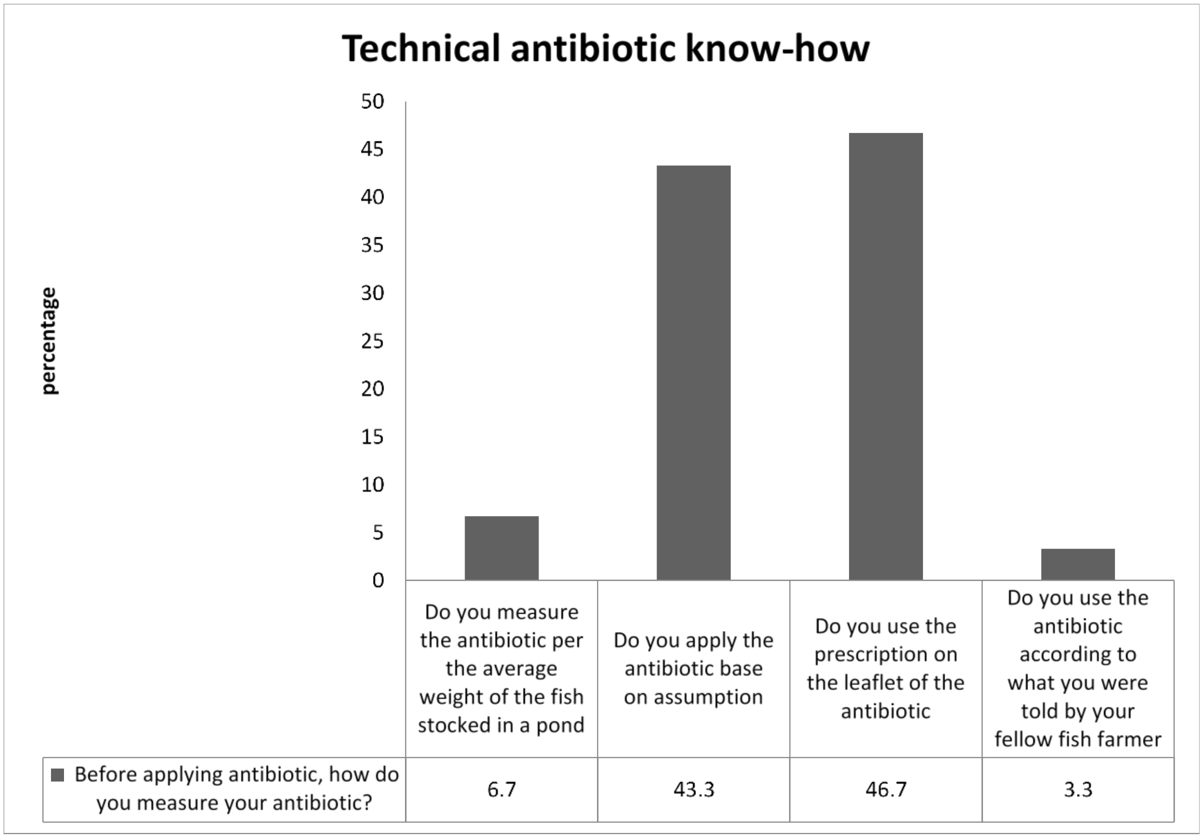

Figure 4. Technical antibiotic know-how by respondents.

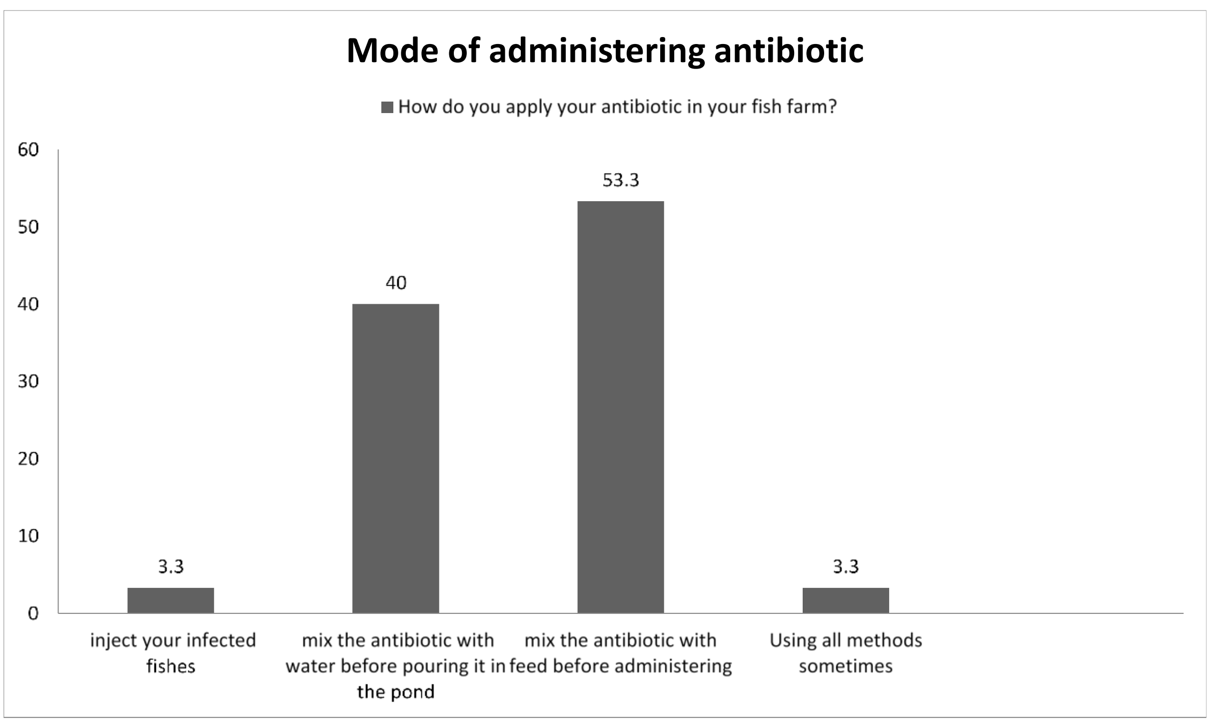

Figure 5. Mode of administering antibiotic in fish ponds by respondents.

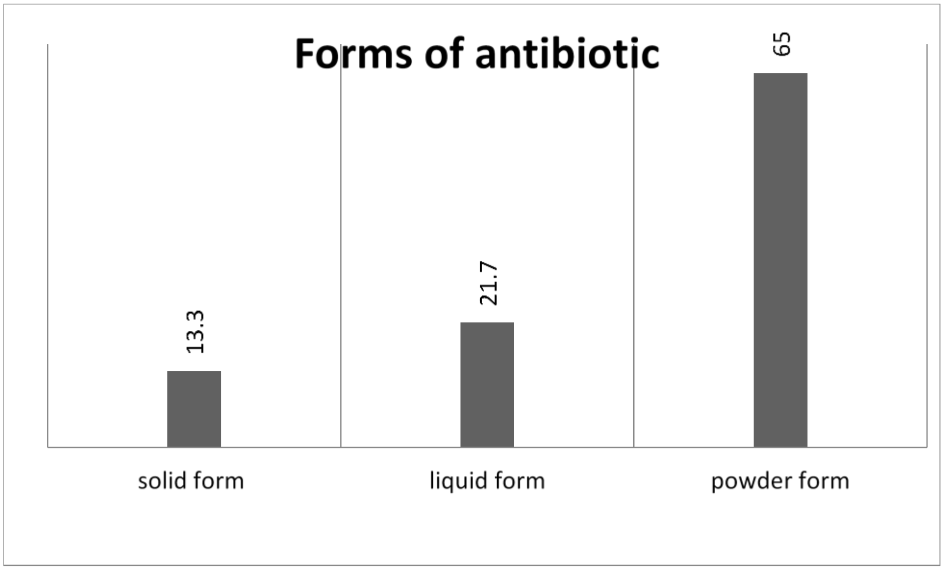

Figure 6. Form of antibiotic used in fish ponds by respondents.

humans, it will work for fish and that such use has been fruitful in the past. Farmers rely largely on peers, quacks, company representatives and on self-discretion. Fish farmers use antibiotics for fish irrespective of whether the infection is viral, bacterial or parasitic. They rely largely on inputs from bigger farmers, peers, quacks or company technologists who visit farms to sell their products. They also exercise self-discretion. If a farmer seeks guidance from a fishery officer, it may not always be available because of additional administrative costs and responsibilities on the fish's health. Figure 6 shows that 65% of the respondents use the powder form of antibiotic, 21.7% of the respondents use the liquid form of antibiotic and 13.3% of the respondents use the solid form of antibiotic. This agrees with Martins *et al.* (2022) who reported that antimicrobial agents used in aquaculture could be in powder, liquid or tablet forms.

Conclusion

Farmers in the study area were found to use veterinary grade antibiotics labelled for use in poultry or livestock, and not specific for aquaculture production, which included Oxytetracycline, Tetracycline, Chloramphenicol, Gentamycin, Doxycycline, Ampicillin, and Streptomycin. 58.4% of the farmers use antibiotics once a week, 16.6% use antibiotics twice a month and 25% use antibiotics once a month. While 45% of the fish farmers sell infected fish even while being treated and 25.5% of the farmers do not observe the antibiotic withdrawal period. About 46.7% of the farmers use prescriptions on the leaflets to measure, 43.3% of them measure antibiotics based on assumption, 6.7% measure antibiotics per the average weight of the fish stocked in a pond and 3.3% of them measure antibiotics as told by their fellow fish farmers. 53.3% of the fish farmers mixed antibiotics with feed before administering, 40% of them mixed antibiotics with water before pouring it into the pond, 3.3% of them injected infected fishes while 3.3% of them used all methods of administration. 65% of the respondents use a powder form of antibiotic, 21.7% of them use the liquid form of antibiotic and 13.3% of them use the solid form of antibiotic. Knowledge contributing to comprehensive guidelines and educational materials must be developed to promote responsible antibiotic use. Targeting fish farm operators, workers, and stakeholders is the key campaign to emphasize disease prevention, proper management practices, and alternative methods are necessary. Collaboration between regulatory bodies, fish farmer associations, and stakeholders is advocated to enforce the responsible use of antibiotics. Continuous monitoring and evaluation of frameworks will assess intervention effectiveness, including data on antibiotic usage, resistance patterns, and farmers' adherence. Developing sustainable fish farming practices that reduce antibiotic dependence, protect public health, and preserve the effectiveness of antibiotics in aquaculture is important. It is important to promote responsible antibiotic use, raise awareness and implement appropriate regulations to safeguard public health, environmental well-being and a viable production of antibiotics in aquaculture.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

Barde, I. J., Bot R. B., Ishaku, L. E., Leo, S. N., Isa, S., Abubakar, S. A., Shekaro, A., Lot, L. E., Ugbe, A. D., Barde, D. J., Ladan, A. A., Ngulukun, S. S., Anjili, I. W., Arinze, S., & Chabiri, L. A. (2022). Histopathology, coprology and bacteriological survey of tilapia fish in Jos Plateau State, Nigeria. *Acta Scientific Veterinary Sciences, 4*(6), 12-17.

Bondad-Reantaso, M. G., MacKinnon, B., Karunasagar, I., Fridman, S., Alday-Sanz, V., Brun, E., Le Groumellec, M., Li, A., Surachetpong, W., Karunasagar, I., & Caputo, A. (2023). Review of alternatives to antibiotic use in aquaculture. *Reviews in Aquaculture*, *15*(4), 1421-1451.

de Souza Gazal, L. E., de Brito K. C. T., Kobayashi, R. K. T., Nakazato, G., Cavalli, L. S., Otutumi, L. K., & de Brito, B. G. (2020). Antimicrobials and resistant bacteria in global fish farming and the possible risk for public health. *Arquivos do Instituto Biológico*, *87*, e0362019.

Cabello, F. C., Godfrey, H. P., Tomova, A., Ivanova, L., Dölz, H., Millanao, A., & Buschmann, A. H. (2013). Antimicrobial use in aquaculture re-examined: its relevance to antimicrobial resistance and to animal and human health. *Environmental Microbiology*, *15*(7), 1917-1942.

Canadian Food Inspection Agency (CFIA) (2014). Tags approved under the national livestock identification and traceability program. Canadian Food Inspection Agency. Retrieved May 5 2014 from http://www.inspection.gc.ca/animals/terrestrial-animals/traceability/tags/eng/1331582406844/1331582476216.

Chai, C., & Bong, C. W. J. S. M. (2022). Tetracycline resistance and prevalence of tetracycline resistance genes in bacteria from marine aquaculture farms in Peninsular Malaysia, *51*(2), 345-357.

Biswas, P. C., Sultana, S., Kabiraj, M., & Hossain, S. S. (2019). Role of probiotics in aquaculture practice of Satkhira region of Bangladesh. *International Journal of Fisheries and Aquatic Studies*, *7*(5), 174-181.

Chee-Sanford, J. C., Mackie, R. I., Koike, S., Krapac, I. G., Lin, Y. F., Yannarell, A. C., Maxwell, S., & Aminov, R. I. (2015). Fate and transport of antibiotic residues and antibiotic resistance genes following land application of manure waste. *Journal of Environmental Quality*, *38*(3), 1086-1108

Schar, D., Klein, E. Y., Laxminarayan, R., Gilbert, M., & Van Boeckel, T. P. (2020). Global trends in antimicrobial use in aquaculture. *Scientific Reports*, *10*, Article number 21878.

European Centre for Disease Prevention and Control (ECDC) (2016). Surveillance of antimicrobial resistance in Europe. Annual Report of the European Antimicrobial Resistance Surveillance Network (EARS-Net) ECDC; Stockholm, Sweden. Pp. 1-14.

European Commission (2017). Guidelines for the prudent use of antimicrobials in veterinary medicine. Retrieved from https://ec.europa.eu/health/sites/default/files/antimicrobial_resistance/docs/2017_prudent_use_guidelines_en.pdf16.

Zrnčić, S. (2020). European union's action plan on antimicrobial resistance and implications for trading partners with example of national action plan for Croatia. *Asian Fisheries Science*, *33*(S1), 75-82.

FAO (2011). The state of world fisheries and aquaculture. Edited by FAO Fisheries and Aquaculture Department. Rome, Italy: FAO. Pp. 1-209.

FAO/WHO (2003). Code of practice for fish and fishery products. Codex Alimentarius Commission. FAO, Rome: CAC/RCP. Pp. 229-238.

Food and Drug Administration (FDA) (2013). Antimicrobials sold or distributed for use in food-producing animals. Reports. Pp.1-57

Food and Drug Administration (FDA) (2015). FDA's Strategy on Antimicrobial Resistance - Questions and Answers. Regulatory Information. Pp.1-5

Garlock, T., Asche, F., Anderson, J., Bjørndal, T., Kumar, G., Lorenzen, K., Ropicki, A., Smith, M. D., & Tveterås, R. (2020). A global blue revolution: aquaculture growth across regions, species, and countries. *Reviews in Fisheries Science & Aquaculture*, *28*(1), 107-116.

Golden, C. D., Koehn, J. Z., Shepon, A., Passarelli, S., Free, C. M., Viana, D. F., Matthey, H., Eurich, J. G., Gephart, J. A., Fluet-Chouinard, E., & Thilsted, S. H. (2021). Aquatic foods to nourish nations. *Nature*, *598*(7880), 315-320.

He, X., Deng, M., Wang, Q., Yang, Y., Yang, Y., & Nie, X. (2016). Residues and health risk assessment of quinolones and sulfonamides in cultured fish from Pearl River Delta, China. *Aquaculture*, *458*, 38-46.

Hanson, L. A. (2020). Practical management of bacterial diseases in finfish aquaculture to minimise antimicrobial resistance. *Asian Fisheries Science*, *33*(11), 55-61.

Kelly, T., Verner-Jeffreys, D., Hinchliffe, S., Rahman, M. M., Bass, D., & Tyler, C. R. (2020). Evaluating antimicrobial resistance in the global shrimp industry. *Reviews in Aquaculture*, *12*(2), 966-986.

Ladan, A. A., Okolocha, E. C., Kabir, J., Bolorunduro, P. I. O., & Barde, I. J. (2021). Assessment of antimicrobial drugs use and their residue in the farmed fish of Kaduna, Nigeria. *Global Journal of Fisheries Science*, *3*(3), 15-26.

Martins, O. E., Oloye, S., Bubakari, M., & Adeyeye. M., (2022). Use of antibiotics in livestock in Nigeria: Curbing antimicrobial resistance and developing a national regulatory guideline towards monitoring antibiotic use in animal and animal foods. *International Research Journal of Public and Environmental Health, 9*(2), 55-66.

Mensah, S. E., Dakpogan, H., Abléto, M., Adjahoutonon, K. Y. K., & Sanders, P. (2019). Occurrence of antibiotic residues in raw fish *Clarias gariepinus* and *Oreochromis niloticus* from intensive rearing system in Benin. *Veterinaria*, *68*(2), 91-94.

Miranda, C. D., Tello, A., & Keen, P. L. (2013). Mechanisms of antimicrobial resistance in finfish aquaculture environments. *Frontiers in Microbiology*, *4*, 233.

Mo, W. Y., Chen, Z., Leung, H. M., & Leung, A. O. W. (2017). Application of veterinary antibiotics in China's aquaculture industry and their potential human health risks. *Environmental Science and Pollution Research*, *24*, 8978-8989.

O' Neill, J. (2015). Antimicrobial resistance: tackling a crisis for the health and wealth of nations. The review on antibiotic resistance. Retrieved from https://wellcomecollection.org/works/rdpck35v.

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

Pepi, M., & Focardi, S. (2021). Antibiotic-resistant bacteria in aquaculture and climate change: A challenge for health in the Mediterranean area. *International Journal of Environmental Research and Public Health*, *18*(11), 5723.

Satya, S. (2018). Antibiotic use in food animals: Indonesia

Overview. Centres for Disease Control and Prevention. Antibiotic Resistance, Food and Food-producing Animals. Pp. 1-35. Retrieved from https://www.cdc.gov/features/ antibiotic-resistance-food/index.html.

Yadava, K. K., Kumari, P., Ediga, A. G., & Bhandari, P. (2023). Antibiotics Deployment in Aquaculture and Approaches for Prevention. *Vigyan Varta*, *4*(2), 146-150.