Antimicrobial use and practice in aquaculture production systems in Nairobi, Kenya.

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DECLARATION

I, Elvis Madara hereby declare that this report is based on research duly conducted in Nairobi County, Kenya towards my Fleming Fellowship programme. This work has neither been previously published by any other person, nor has the material been presented for the award of any certificate in any other institution. All published work from which references were taken have been duly acknowledged to the best of my knowledge.

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EXECUTIVE SUMMARY

Inappropriate use of antibiotics contributes significantly to development of antimicrobial resistance. Limited studies have been conducted on antibiotic use in low- and middle-income countries (LMICs) and particularly in aquaculture farming. This study was conducted to assess the Knowledge, Attitudes and Practices surrounding safety and use of antimicrobials amongst aquaculture farmers within Nairobi County, Kenya. Chemical analysis of antibiotic residues was performed to determine levels of antibiotics accumulation that enters the aquatic food distribution chain. This study provides baseline data that can inform better policies for greater societal impact.

This study revealed that there are only 21 aquaculture farmers within Nairobi County, Kenya; fewer than expected, considering its vast land size and population. A cross-sectional questionnaire was conducted with only 18 aquaculture farmers. Electronic semi-structured questionnaires were developed in Open Data Kit (ODK) and administered electronically.

Contrary to the global literature on ABU/C in aquaculture, this study suggests low usage of antibiotics in aquaculture farming within Nairobi County in Kenya, with only 11% of farmers reporting using antibiotics in their farms during the time of this study. Tetracyclines (5.56%) and colistin (5.56%), as a combination, were the only antibiotics found to be used in aquaculture farming. Generally, farmers reported adequate knowledge, and favourable attitude and practices around antibiotic usage. However, farmers lack a clear knowledge of fish diseases; something that might have highly influenced low rates of antimicrobial usage.

Results also found the most commonly farmed fish species are African Nile Tilapia and African catfish, *Oreochromis niloticus* and *Clarias guriepinus* respectively. The level of household income from fish farming was relatively low, reflecting 25-50% of economic activity for a large proportion of aquaculture farmers (44.4%). This is suggestive of aquaculture being not

the sole, and rarely the primary source of income for households that participated in this study. The study also indicated that the majority of the farmers use borehole water (55.6%) for aquaculture farming, which is not treated by most aquaculture farmers (83.3%). The wastewater from the aquatic sites is usually not treated and most frequently used for crop farming (94.4%), as integrated farming systems are frequently practiced.

This study explores the pathways between the aquaculture industry and environmental transmission of AMR determinants in Nairobi, Kenya. Although few farmers reported using antibiotics, different practices show higher underlying risk of pathogens (earthen pond structure, water naturally sourced from rivers in some cases), combined with variable drainage times, and poor knowledge of fish diseases and treatment options. Importantly, this is teamed with disposal practices that further affect the food system and surrounding ecosystem: 17(94.44%) of farmers used pond water for crop and vegetable farming, whilst seven (38.89%) released wastewater into the open environment. We therefore call for better regulation of aquaculture, including fish management, appropriate use of antibiotics and biosafety measures.

ABBREVIATIONS

AB: Antibiotic

ABU: Antibiotic use

ABR: Antibiotic resistance

ARB: Antibiotic resistance bacteria

ARGs: Antibiotic resistance genes

AHSP: Animal health service provider

AM: Antimicrobial

AMR: Antimicrobial resistance

BACUC: Biosafety Animal Care and Use Committee

CIA: Critically important antibiotics

FAO: Food and Agriculture organisation

GDP: Gross Domestic Product

LMIC: Low-middle-income countries

LSHTM: London school of Hygiene and Tropical Medicine

NACOSTI: National Commission for Science Technology & Innovation

ODK: Open Data Kit

OIE: World Health Organisation for Food animals

SDGs: Sustainable Development Goals

UK: United Kingdom

WHO: World Health Organisation

USAID: United State Agency for International Development

GAP: Good Agricultural Practice

MOH: Ministry of Health

MOALF: Ministry of Agriculture, Livestock and Fisheries

KNBS: Kenya National Bureau of Statistics

STATA:

FAOLEX:

OR: Odds Ratio

CI: Confidence Interval

VMD: Veterinary Medicines Directorate

DVS: Directorate of Veterinary Services

NOAA: National Oceanic and Atmospheric Administration

ESP-FFEPP: Economic Stimulus Programme-Fish Farming Enterprise Productivity program

NOFP: National Oceans and Fisheries Policy

CRSP: Collaborative Research Support Program.

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INTRODUCTION

1.1 REVIEW OF THE LITERATURE

GLOBAL DEMAND FOR AQUACULTURE

Aquaculture is a controlled production of aquatic plants such as algae and aquatic animals such as fish, shellfish and crustaceans (NOAA, 2021). It is regarded as the fastest growing food production system globally (Iwu, C et al., 2020; Ström GH et al., 2019; FAO, 2020). Approximately, 20% of animal protein for human consumption is from fish and shellfish, amongst 56% of the global population (Lulijwa et al., 2020). Global demand for fish products has increased in the past decade; in 2018, global fish production reached 179million tons, representing a 122% increase of fish consumption over the past 30 years. (Żaczek, M et al., 2020). The rise in demand for fish protein has been ascribed to its critical nutritional benefits, obtained from its omega-3-fatty acids and other essential minerals, important in prevention and control of common chronic cardiovascular diseases, foetal neuronal, immune and retinal development and Alzheimer's disease management (Żaczek, M et al., 2020; FAO, 2016). Increase in fish consumption is also as a result of urbanization and improved distribution channels for fish products (FAO, 2016).

ANTIMICROBIAL USE IN AQUACULTURE

Intensification of aquaculture production, characterized by economically efficient high stocking densities, can render aquaculture systems vulnerable to disease outbreaks (Subasinghe, R. P et al., 2019; Pham, D et al., 2015; Jia, Beibei et al., 2017). Consequently, full biosecurity and practices such as prophylactic use of antimicrobials to reduce risks of disease outbreaks and economic losses are employed globally in this sector (Subasinghe, R. P et al., 2019; Schar, D et al., 2020). A progressive management pathway for improving aquaculture biosecurity (PMP/AB) has been outlined by FAO, 2018 and puts into consideration aquatic host, pathogen and environment/people management to achieve an appropriate biosecurity and long-term risk management. Aquatic host management involves obtaining and maintaining healthy stocks (specific pathogen free, specific pathogen tolerant and specific pathogen resistant) stocks in the farm, providing high quality nutrition and tracking brooding stocks' lineage to avoid inbreeding in order to increase host immunity and quarantine practices.

More research and innovations are encouraged to enable development of more sensitive and rapid diagnostic tools so that routine observations and disease surveillance within aquaculture can be achieved at early stages to permit early interventions in ceasing transboundary spread of pathogens. Moreover, management of pathogens also requires use of vaccines, sanitation and disinfection with appropriate disinfectants in their right concentrations and contact times (FAO, 2018; Claire Erlacher and Reid, 2012). People management involves assigning staff to specific areas of work, use of footbaths, handwashing stations and order of handling hosts for instance handling healthy fish or young ones first, then old ones and lastly dead, sick and quarantined ones (Claire Erlacher and Reid, 2012).

Global increase in demand for the animal protein, and diseases in animals for human consumption, has led to an increased use of antimicrobial agents for purposes of growth promotion, treatment and prophylaxis (Iwu, C et al., 2020). In the United states of America (USA), antimicrobials used in food animals accounts for 80% of national annual antimicrobial consumption (Thomas P, 2014; Lulijwa, R et al., 2020). It's estimated that by 2030, global antimicrobial consumption in aquaculture will reach 13,600 tonnes (Schar, D et al., 2020). Multiple countries globally have reported on quantitative use of antimicrobials in aquaculture production. However, patterns of antimicrobial use are not largely documented, thereby limiting administration of antimicrobial stewardship interventions and policies in the aquaculture sector (Schar, D et al., 2020). Regulatory policies are independent for each and every country thereby posing variability in use of antimicrobials globally (Watts, J et al., 2017; Okocha, R. C et al., 2018). For instance, 13 antibiotics have been authorised for use in aquaculture farming in China and only 5 antibiotics permitted for use in the United Kingdom (Liu, X. et al., 2017; Topp, E et al., 2017). Some of the approved antibiotics for use in aquaculture system in Europe include sulfonamide (sulfadiazine-trimethoprim), florfenicol, oxytetracycline and erythromycin (Iwu, C et al., 2020). In the USA, florfenicol, sulfadimethoxine-ormethoprim combination, and oxytetracycline are approved for aquaculture use. In China, 13 antibiotics are authorized for use and include doxycycline, enrofloxacin, florfenicol, flumequine, neomycin, norfloxacin, oxolinic acid, sulfadiazine, sulfamethazine, sulfamethoxazole, sulfamonomethoxime, thiamphenicol an trimethoprim.

In some LMICs, over the counter sales of antibiotics in community pharmacies have been strongly correlated to occurrence of antibiotic resistance bacteria (ARB) and antibiotic resistance genes (ARGs) in aquatic animals and human (Abia, A. L. K., & Lanza, G. R. 2020). ARB and ARGs that cause diseases in human are of major concern and are projected to be the leading global cause of death by 2050 (O'Neill, 2016). Weak, or lack of, drug regulation and a lack of veterinarian supervision during antibiotic administration in some LMICs, results in the indiscriminate use of antibiotics for therapeutic or growth promotion purposes, in aquaculture, livestock and agriculture (Abia, A. L. K., & Lanza, G. R. 2020; Okocha, R. C et al., 2018).

Stringent hygienic practices and vaccinations can reduce tremendously use of antimicrobials in aquaculture farming as has been observed in Norway where a ton of Salmon fish is produced using 0.0008kg compared to 1.4kg of antibiotics in Chile (Topp, E et al., 2017). In Vietnam, every ton of aquatic production utilizes up to 3.3kg of antibiotics (Pham, D et al., 2019). Some of the vaccines that have been developed among many others include bacterial vaccines against Francisellosis disease, streptococcosis, pseudomonas and aeromonas infections in Nile tilapia (R. Hoare et al., 2021; Ingunn. S et al., 2005; Osman, K.M. et al., 2009). An enteric septiceamia vaccine has also been developed for use in catfish species (Ingunn. S et al., 2005).

A global survey on aquaculture-allied professionals reported tetracyclines as the most used antimicrobial in aquaculture farms, followed by sulphonamides, penicillins and phenicols (Tuševljak N et al., 2013). These findings slightly contrast a study by Tuševljak N et al., 2013 that reported quinolones as the most widely used antibiotic globally.

KNOWLEDGE, ATTITUDES AND PRACTICE AMONGST AQUACULTURE FARMERS, GLOBALLY

In China, a study by Jia, Beibei et al., 2017 revealed that 88% of yellow catfish farmers in Guangdong and Zhejiang provinces had good knowledge of fish pathogens. However, about 50% of them had limited knowledge of transmission of the fish pathogens in disease outbreaks. The farmers (64%) had a fair attitude towards the significance of biosecurity measures in fish health management. Majority agreed to the idea that water quality, pond disinfection and medication through feeds were important strategies in disease control and aquaculture health. Despite antibiotic use in fish diseases treatment among these farmers, over 30% of them preferred use of probiotics and Chinese traditional medicines in the early stages of disease outbreaks in the aquaculture farms to antibiotics. Monitoring stock densities was not considered by the majority of these Chinese farmers as a predisposing factor to vulnerability of aquaculture production to a compromised fish health (Jia, Beibei et al., 2017). This study by Jia, Beibei et al., 2017 also indicated that 52% of the interviewed farmers had poor practice in regards to adherence to biosecurity measures. Almost all of these farmers shared harvesting/disinfection equipment with neighbouring farms with more than 87% never disinfecting their farm equipment. More than two-thirds never observed isolation and disinfection of new fingerlings introduced into the farms. These were believed to have contributed to disease outbreak and hence use of antibiotics for treatment (Jia, Beibei et al., 2017).

A survey study in Vietnam found that all the surveyed farms used at least one antibiotic at one point throughout the production cycle (Pham, D et al., 2019). The commonly reported used antibiotics from this study were tetracyclines, sulfamethoxazole and trimethoprim. This study also revealed that 30.8% of antimicrobials used in aquaculture farms in Vietman were listed by WHO as critically important antimicrobials for human medicine and they included colistin, fluoroquinolones, Beta-lactams, aminoglycosides and macrolide (erythromycin) (Pham, D et al., 2019; Hedberg, N et al., 2018; OIE, 2018). Some aquaculture farms in Northern Vietnam use human antibiotics in aquaculture farms (Lulijwa, R et al., 2020; (Cabello, F.C et al., 2016). Despite the ban of fluoroquinolones in aquaculture in Vietnam, fluoroquinolones, especially enrofloxacin, have been highly used because of its stability in water (Binh, V. N et al., 2018). In Vietnam, the majority of the aquaculture farmers use antimicrobials based on biased information obtained from sellers, drug manufacturers and by financial incentives (Pham, D et al., 2019). This unregulated use of antimicrobials especially antibiotics poses public health risks concerns from antibiotic residues deposition in aquatic products through dispensation of excess dosages, failure to observe recommended antibiotic withdrawal periods, wrong medications, adverse drug reactions from non-compatibility drug combinations and contribution to ecological pollution from poor disposal of unused drugs and their container closure systems (Ibrahim, M et al., 2020; Okocha, R. C et al., 2018). These farmers have been reported to have limited knowledge on purpose of antibiotic as more than half agreeing to the idea of prophylactic use of antibiotics, practice poor storage of antibiotics by hanging them on the roofs of farm houses in plastic bags and failing to keep records of antibiotics used in their farms (Pham, D et al., 2015). Lack of regulation in Vietnam has resulted in little information on antibiotic use in the aquaculture industry. Majority of the farmers practice intensive and integrated agriculture-aquaculture farming in which both livestock and human wastes are added to the aquatic system to sustain fertility (Pham, D et al., 2015). This is linked to transmission of human and livestock antimicrobial resistant genes from human and other animals into aquaculture (Cabello, F.C et al., 2020).

In Africa, the majority of countries are characterized as LMICs, coupled with inappropriate prescription, self-medication and Over the Counter sales of antibiotics (Okocha, R. C et al., 2018; Abia, A. L. K., & Lanza, G. R.2020). Usage of antibiotics in aquaculture in Africa has been understudied but the available literatures report minimal use (Abia, A. L. K., & Lanza, G. R. 2020). However, contamination of aquaculture production systems is common, due to use of fertilisers from the organic waste of livestock, previously treated with antibiotics (Okocha, R. C et al., 2018; Abia, A. L. K., & Lanza, G. R. 2020). Growing demand for aquatic food has led approximately 10% of the African population to venture into fisheries and aquaculture (FAO, 2018). The commonly produced aquatic species in Africa are the African catfish (*Clarias guriepinus*) and the Nile tilapia (*Oreochromis niloticus)* contributing to about 17-18% of fish production in Africa (Abia, A. L. K., & Lanza, G. R. 2020; FAO, 2018).
The most frequently used antimicrobial classes in aquaculture industry globally are quinolones (27%), tetracyclines (20%), amphenicols (18%) and sulphonamides (14%) (Schar, D et al., 2020).

THE REGULATORY AND POLITICAL LANDSCAPE IN KENYA

In Kenya, policies legislating for aquaculture practices are available. The policies and programmes stipulated by the government have shown its commitment to the sustainable development of the fisheries and aquaculture sectors within the country. The Government of

Kenya responded to a national decline in fish consumption, between 1990 and 2000, by designing an enabling policy landscape for aquaculture sector growth, encouraging both production and demand for fish consumption.

In 2008, the Kenya Ministry of Fisheries Development was established and published the 2008 National Oceans and Fisheries Policy. This was developed to address the vast challenges that affected the fisheries sector at that moment in time which included unprioritized aquaculture development approaches, low investment and inadequate funding of fisheries research projects, over-exploitation of water bodies (the riverine, lakes, coastal waters and oceans), underutilization of fisheries resources, poor market access for aquatic products and poor sectors coordination among the research institutions, fisheries sector management and other public and private stakeholders (NOFP, 2008). The policies guidelines were focussed to be challenge specific and were as follows; research development, resource management, aquaculture development, fish quality assurance and value addition, monitoring, control and surveillance based on the national laws, regional and international agreements and cooperation, legislative and institutional framework, investments, trade and commerce, infrastructure and human resource development and public awareness and participation. Detailed strategies and implementation framework were outlined with an aim to provide a sustainable fisheries sector development to enhance both national and global economy (NOFP, 2008).

In 2009, the Aquaculture directorate under the Kenya Ministry of Fisheries Development was established. During this time, the directorate through collaborative research support programme by the United State Agency for International Development (USAID) promoted establishment of small scale ponds, hatcheries across the entire Kenyan Republic and also managed expansion of technical training, improved aquaculture seed and feed production to promote freshwater aquaculture sector in Kenya (James. B et al., 2010).

In mid 2009, Economic Stimulus programme - Fish Farming Enterprise Productivity Program (ESP-FFEPP) was set up in Kenya and it targeted areas with high unemployment rates. It was designed to increase national fish production by 10% annually and increase per capita fish consumption from 4.75 to 10 kg/capita/year, by 2030 (Safina. M et al., 2012; Opiyo, M et al., 2018). It also sought to increase employment opportunities in the fisheries and aquaculture sectors from 80,000 to approximately 2.0 million by 2030. The approach was to construct 48,000 fish ponds and to supply fingerlings and feed supplies to fish farmers. Alongside these resources, the Gov of Kenya sought to build capacity through training and to strengthen coordination with fish farming institutions.. Impact assessment for the programme was done in Western Kenya and it reported an increment of stocking of ponds with Nile tilapia from 4% between 2003 and early 2009 to 92% in 2010 just one year after the commencement of the programme (Safina. M et al., 2012). Within the same one year, over 27,000 ponds were dug within the selected 160 constituencies across the country (Safina. M et al., 2012). This study by Safina. M et al., 2012 showed how the programme propelled growth of aquaculture in the country. The programme resulted in participation of private sectors in fish feeds and fingerlings production as the number of the farmers grew from 4,700 in 2007 to 12,000 in 2010. Through the programme, 48,000 fish ponds were constructed across the 160 constituencies within the country (Safina. M et al., 2012). There were challenges and critiques to this approach, including barriers to access of affordable inputs and high start-up costs, poor extension services and support and non-inclusionary practices, with low female participation (Safina. M et al., 2012).

In 2011, the Ministry of Fisheries Development published the National Aquaculture Policy. It was aimed at ensuring full utilization of aquaculture resources in a sustainable development and coordinated manner to optimize benefits. The policy also addresses the Good Aquaculture Practices (GAP) including appropriate use of veterinary medicines for food safety concerns from aquaculture production (National aquaculture policy, 2011).

In 2016, Fisheries Management and Development Act, No.35 was enacted. It addresses various issues in regards to fisheries and aquaculture management and conservation, fish processing and market access (FAO & FAOLEX, 2016). The aims of this act were to utilize, protect, manage the existing aquatic resources and develop new ones in accordance to conservation of the ecological system, optimize fisheries output among the fishing communities and introduce aquaculture to other non-fishing communities in order to improve their livelihoods and overall, to enhance food security (FAO & FAOLEX, 2016). The act also outlined implementation strategies for commitments within the international laws concerning fisheries. This act also paved the way for a review of The National Aquaculture Policy (2011), National Aquaculture Strategy and Development Plan (2010-2015) and Aquaculture Communication Strategy (2012) (Laws of Kenya, 2016).

In 2017, the Ministry of Health (MOH) in collaboration with the Ministry of Agriculture, Livestock and Fisheries (MOALF) published the National Policy on prevention and containment of AMR through which the National Action Plan on prevention and containment of AMR was developed. This outlined coherent policy frameworks and priority actions that were to be applied in containing development and spread of AMR through to 2022 (MOH/MOALF, 2017). This was in response to global public-health threats posed by AMR from both human and animal health including aquaculture.

Kenya has no registered antimicrobial formulations specific for use in aquaculture farms and therefore those formulations used in livestock and even human medicine are possibly used in aquaculture as alternatives (Wanja, D et al., 2020).

In 2021, Kenya introduced a policy framework for aquaculture education which is aimed at strengthening the education around aquaculture programmes in Universities and Vocational Aquaculture Training institutions (Nyonje, B. et al., 2021). This policy has been formed based on the Sustainable Development Goals (SDGs) 1, 2, 4 and 14 with a goal of ensuring food and nutrition security (Nyonje, B. et al., 2021).

AQUACULTURE AND ANTIBIOTIC USE IN KENYA

In Kenya, the majority of aquaculture farming is freshwater with 75% of fish farms growing Nile tilapia (*Oreochromis niloticus)* and 15% of farms focusing on the African catfish (*Clarias guriepinus)* (Safina. M et al., 2012; Opiyo, M et al., 2018). The practice in Kenya is mostly an earthen pond based semi-intensive aquaculture system (pond farming) which contributes to 90% of the total aquatic production. This is because its establishment capital costs are low and farmers can opt to fertilize their ponds with livestock manure or inorganic fertilizers to supplement feeds which have been considered to be a limiting factor in this sector (Munguti. J et al., 2012 ; Opiyo, M et al., 2018 ; J.M. Munguti et al., 2014). This predisposes the aquaculture systems to antibiotic resistance pathogens and antibiotic resistance genes from these livestock wastes which can be consequently transferred to human through fish food (Pham, D et al., 2015; Okocha, R. C et al., 2018; Abia, A. L. K., & Lanza, G. R. 2020). The earthen pond system is also durable, requires small water administration and is characterized with fast growth performance in fish and fingerlings in comparison with other systems like the use of cages. The source of water for use in aquaculture activities is mainly from rivers, spring waters and streams constituting 72% of water used in aquaculture farming in Kenya. Fish feeds are rarely available and farmers opt to use livestock and poultry feeds which are commonly supplemented with antibiotics to enhance growth thereby accidentally introducing antibiotics to aquaculture farms (J.M. Munguti et al., 2014; Opiyo, M et al., 2018). Up to 2500kg/ha production can be achieved per year from this system of production. In 2015, an estimated 60,277 fish ponds were operational in Kenya (Opiyo, M et al., 2018). Aquaculture production has been increasing immensely since the introduction of ESP-FFEPP in 2009 until 2014 when drastic drop was noted (Opiyo, M et al., 2018). The reduction was associated with poor water retention capacity in some of the regions, limited and poor extension services, limited technical capacity support, improper husbandry practises, low quality farm inputs, dependency on donor and government support, lack of value addition and poor marketing infrastructure (Opiyo, M et al., 2018).

There is increasing demand for fish protein in the country, forcing Kenya to import about 5900MT from other intensively producing countries like China, Korea, India, Japan, Pakistan and Uganda (Opiyo, M et al., 2018). Importation of animal food products is associated with risks of food safety concerns especially where regulations are not strictly adhered to on management of residue levels in the exporting country, disease transmission as some pathogens might be embedded in food products (Ndraha et al., 2017; OIE, 2010). Management practices, method of aquaculture production and aquatic sites environment also vary from regions globally. Therefore, food safety concerns may arise from diseases and pathogens, environmental contaminants finding their way into aquaculture foods (Okocha, R. C et al., 2018).

AMR remains an understudied area since no surveillance has been done to evaluate antibiotic use and consumption in the aquaculture sector in Kenya (Wanja, D et al., 2020).

Wanja, D et al., 2020 conducted a study to determine antibiotic susceptibility on isolates sampled from farmed fish in Kirinyaga county; they found many of the 48 bacterial isolates were resistant to common antibiotics and disinfectants, with a multiple antibiotic resistance index ranging from 0.1 to 0.8. The results implied that most of the bacterial isolates were due to fertilization of ponds using organic manure from the livestock integrated system.

The results of Wanja, D et al., 2020 study also support other work indicating the risk of AMR to those that may handle or consume fish produced in aquatic ponds in Kenya (Pham, D et al., 2015; Okocha, R. C et al., 2018; Abia, A. L. K., & Lanza, G. R.2020).

Available studies tend to show low usage of antimicrobials in the aquaculture systems which is unlike the actual state on the ground (Wanja, D et al., 2020). This is believed to be due to lack of monitoring and concrete estimation of quantity and existence of antimicrobial resistance and use in the aquaculture sector in most of the countries globally (Wanja, D et al., 2020). Oxytetracycline is reported to be a commonly used antibiotic in most of the aquaculture farms in Kenya, especially in hatchery systems, as a prophylactic measure (Opiyo, M et al., 2018).

FISH HEALTH MANAGEMENT IN KENYA

Fish diseases are suspected to cause about 40 to 100% losses of fish life in the aquaculture farms in Kenya, in conjunction with poor pond water quality. Some common bacterial fish infections in Kenya include Saprolegniasis (a fungal infection), haemorrhagic disease and pop-eye disease. Parasitic infections include; myxozoans, monogeneans, nematodes such as *Diplostomum spp* and *Dactylogyrus spp*, acanthocephalans, digenean trematodes and cestodes (Wanja, D. W. et al., 2020) (Opiyo, M et al., 2018).

Biosecurity and good husbandry practices are not well observed in most of the farms across the country (Opiyo, M et al., 2018). The country has been lacking quarantine facilities and with importation of brooding stock, there are risks of diseases and parasites transmission among aquaculture farms. Farmers have also not been treating water before they use them in ponds (Wanja, D et al., 2020; Opiyo, M et al., 2018). Literature indicates that Kenyan farmers do practice disinfection of farm equipment and culture facilities, and apply chemicals such as potassium permanganate, sodium chloride to manage fungal and bacterial infections (Opiyo, M et al., 2018). Disinfection especially egg disinfection, culture facilities, equipment is a key tool in inhibition of fungal and bacterial growth. It reduces parasitic load within the aquaculture environment and sometimes can be used in disease eradication as a stamping out effort (Jia, Beibei et al., 2017; Wanja, D et al., 2020). Some of the tested disinfectants found to be effective include hydrogen peroxide, formalin, iodine and quaternary ammonium compounds (Jia, Beibei et al., 2017; Wanja, D et al., 2020). However, these chemicals need to be handled with caution regarding volumes of administration, potential toxicity and potential pollution to the neighboring ecosystem as effluents (Wanja, D et al., 2020).

Farmers are expected to observe early disease detection and prevention through pond checks in the morning and maintain daily records on water quality (pH, temperature and dissolved oxygen), fish behavioral changes and mortalities. This enables removal of dead fish for proper disposal and early intervention through animal health professional assistance (Jia, Beibei et al., 2017). It is advisable that farmers treat water especially when it is sourced from potential pathogens contaminated sites (Opiyo, M et al., 2018). Appropriate stocking densities, 3 fish of 200g per square meter, should be observed as overstocking predisposes to vulnerability of aquatic health and reduced growth performance. Accepted stocking rate is 5,000-20,000 Nile tilapia/ha and 60-300 African catfish/ha (Jia, Beibei et al., 2017; Opiyo, M et al., 2018; FAO).

Production cycle for Nile tilapia is 6 months and 12 months for African catfish (Ferreira et al., 2018). Farmers are encouraged to adopt the use of probiotics and quality feed supplements and also to avail quality feeds as they are essential in prophylaxis (Jia, Beibei et al., 2017). Sharing of equipment with neighboring farms should be avoided as they act as carriers of pathogens from one farm to another. Fingerlings should be sourced from pathogen free farms, disinfected, isolated and quarantined before released into the existing stock (Jia, Beibei et al., 2017). Footbaths are recommended to be placed at entry points to the aquaculture farms and be used by all visitors and vehicles in and out of the farm to prevent spread of pathogens into and out of the farm (Jia, Beibei et al., 2017). In Kenya, management practices and prophylaxis are dependent on farmers' knowledge and experience (Opiyo, M et al., 2018). In Kenya, the industry is limited by technical capacity on fish diseases, diagnostic laboratories, quarantine facilities and strict surveillance systems (Opiyo, M et al., 2018; FAO, 2015).

AMR IN THE AQUATIC FOOD CHAIN: SAFETY AND SECURITY CONCERNS

Risks of fish diseases in Kenya as reported by Wanja, D et al., 2020 calls for observation of biosecurity measures to prevent infections related to mortality and high use of antibiotics for prophylaxis and curative purposes. With lack of clear regulations on antibiotic use in aquaculture farms in Kenya, there are chances of inappropriate use that would result in deposition of antimicrobial residues in the food chain (Opiyo, M et al., 2018). Long-term human consumption of these residues in animal food products can result in Antimicrobial Resistance (AMR) development and adverse health effects such as morbidity and mortality; of particular concern is AMR within highly ranked critical antibiotics, preserved for use in extremely dangerous infections in humans (Brunton, L. A et al., 2019; Bortolotte, A. R et al., 2021. A study by Iwu, et al., 2020 have detected antimicrobial residues exceeding recommended maximum levels in aquatic food products exported from LMIC countries.

1.2 STATEMENT PROBLEM

Environmental spread of AMR and antimicrobial determinants via aquaculture, involving pathways between crop production and local water sources, is understudied in Kenya.

Use of antimicrobials in aquaculture farming is high compared to other food animals, resulting in the detection of antimicrobial residues in fish for human consumption, and other aquaculture products. Long-term consumption of these residues in food poses an unquantified threat to human health and AMR development (Bueno, I et al., 2017; Mesalhy Aly, S., & Albutti, A. (2014). More information is needed about farmers knowledge, attitudes and practice regarding use of antibiotics in the Kenya context, and implications for environmental transmission of AMR and AMR determinants. Globally, most of the farmers use antimicrobials based on biased information obtained from sellers, drug manufacturers and by financial incentives (Pham, D et al., 2019; Lim, J. M et al., 2020). Data on residues is still lacking in LMICs and therefore a research gap necessity (Iwu, C et al., 2020).

1.3 HYPOTHESIS

There is a need to optimise fish farmer knowledge, attitude and practice around purpose and safety of antimicrobial use in aquaculture farming in Nairobi, Kenya.

1.4 AIM AND OBJECTIVE

To assess practice, farmers' knowledge and attitude on the purpose and safety of antimicrobial use in aquaculture farming in Kenya.

3 MATERIALS AND METHODS

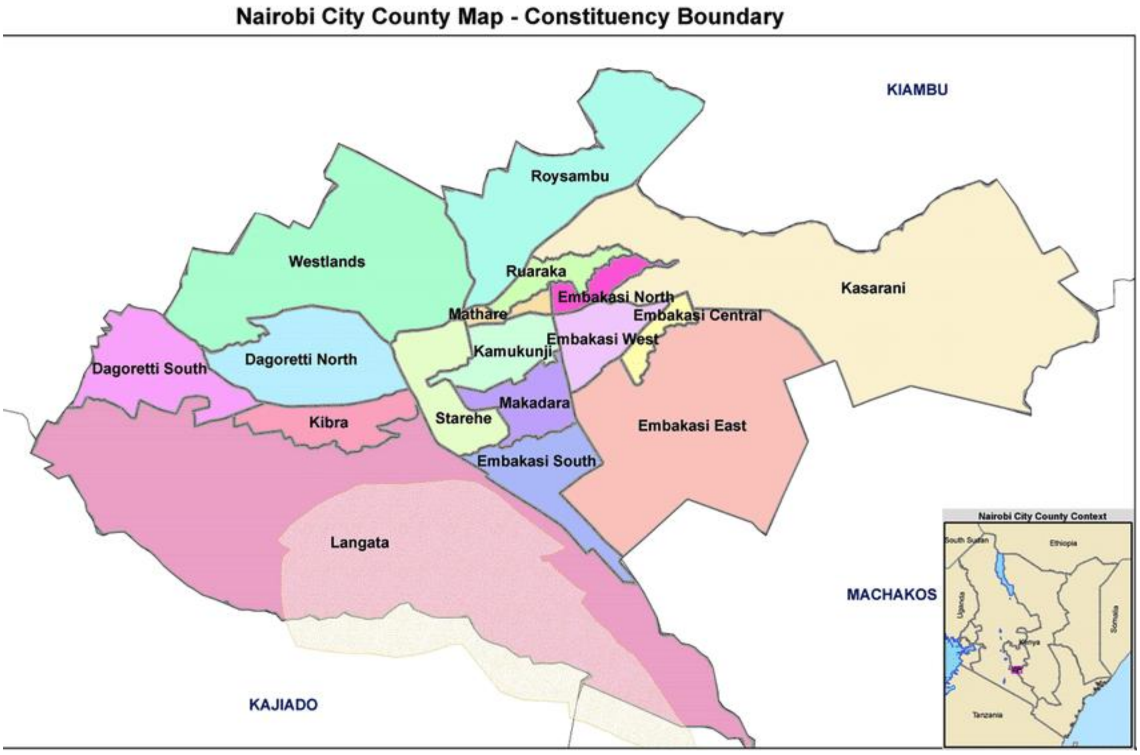
3.1 STUDY AREA

This study was conducted within Nairobi County which consists of 9 sub-counties. These sub-counties include Dagoretti south, Kamukunji, Langata, Embakasi north and west, Kasarani, Embakasi east, Central and South, Dagoretti North, Starehe and Roysambu. Nairobi has a total area coverage of 696km^2 and a total population of 4.397million as per the 2019 national census

(KNBS, 2019). The Nairobi area is situated within **Latitude:** -1° 16' 59.99" S and **Longitude:** 36° 49' 0.01" E.

3.2 STUDY AREA MAP

Figure 1: Study area map



3.3 STUDY DESIGN AND SAMPLE SIZE DETERMINATION

Aquaculture farmers were recruited via support from the Nairobi County fisheries office, who provided a prospective list of 24 farmers from their database of fish farmers within Nairobi County. The researcher made efforts to contact the farmers through phone calls to arrange for the study exercise. Some of these farmers were dropped from the study as they indicated to be no longer participating in aquaculture farming due to challenges of water shortages hence ponds drying up, unavailability of feeds and inadequate market access for their outputs. The rest of the farmers were interviewed and asked to recruit more farmers for the study, following a snowball approach. This process was repeated until the farmers within Nairobi County were exhausted, leaving a total sample size of 21. This process was achieved through the support of sub county extension officers who apprised the farmers of the intended field visits to enable easier reception of the researchers. Three of the farmers withdrew from the study due to their unavailability and only 18 farmers participated in the study.

3.4 QUESTIONNAIRE ADMINISTRATION AND SAMPLE COLLECTION

The researcher first contacted the farmers via phone call to provide the farmer with information about the study and to invite them to participate. Farm visits were carried out after prior planning with the individual farmers through phone calls. A database containing farmers information was obtained from the sub county fisheries department. Access authorization to the farmers was obtained through the sub county chief administrators prior to the day of actual visits. On arrival at the farm, farmers were provided with a paper copy of the information sheet and consent form. The researcher read through the information sheet to enable the farmer to understand the requirements of the intended study. This detailed information on the topic of study, the research institutions involved, funders for the research project, reasons for undertaking the study, the study population, benefits of the study, risks associated with participation in the study, confidentiality of participants and media of raising concerns, complaints about the study and feedback. Thereafter, a consent form was presented to the farmer to express their satisfaction through signing the form to participate in the study or not. A semi-structured questionnaire was administered to the farmers using Kobo Toolbox from an electronic open data kit (ODK-collect).

3.5 DATA MANAGEMENT AND ANALYSIS

Data was subjected to cleaning and processing before the actual analysis. Data was then exported in xlsx format to STATA. Further data analysis was done using the STATA software (Stata/IC 16.1 for Mac (intel 64-bit) Revision 06 APR 2021. Descriptive statistics was used to generally summarize the data. Categorical data were summarized in frequencies and percentages. Mean and standard deviations were reported for continuous variables. Median and range values were presented in most scenarios due to the small sample size. Responses to the qualitative variables such as knowledge on antibiotics, antibiotic resistance and withdrawal period terms were categorized into themes; good and poor understanding based on the definition of the respective terms provided by (OIE, 2018; WHO, 202; Okocha, R. C. et al., 2018). For the terms 'antibiotics/antimicrobials', words such as 'medicines/drugs' used for 'treatment/prevention' of 'infections' caused by 'bacteria', 'viruses' in a statement were considered correct definitions. For the term "antimicrobial resistance", words such as 'loss of effectiveness/strength/treatment failure' of 'antibiotics/antimicrobials' caused by 'microorganisms/bacteria/viruses/fungi' being 'resistant/immune/stronger than' the administered medicines.

Creating composite variables for Knowledge, Attitude and Practice

Each survey question was scored as a binary 'correct/incorrect' or 'favourable/unfavourable' response. The sum of each individual participant's answers was calculated for each of the knowledge, attitude and practice sections of the questionnaire to create three composite variables i) knowledge of antibiotic use, ii) attitude towards prudent antibiotic use and iii) practice around antibiotic use. Those whose answers deemed 75% or more correct as per the scientific understanding of the questions, were considered to have i) sufficient knowledge on antibiotic use, ii) favourable attitude towards prudent antibiotic use or iii) adequate practice around antibiotic use (Pham et al. (2019)).

Knowledge on antibiotic use

For the composite 'knowledge on antibiotic use', respondents were asked to choose an appropriate response for the six statements; 'All farmed fish need to be given antimicrobials to support their growth', 'Every sick animal needs to be given antimicrobials', 'Is it ok to give a different dose of antibiotic/antimicrobial than what has been prescribed to the stock', 'Antibiotic or antimicrobials should not be administered once the fish conditions improve', 'Proper use of antibiotics reduce risks of antibiotic resistance or antimicrobial resistance' and 'It is necessary to stop antibiotics/antimicrobials use during harvesting or sale of fish'. A sum score of 4 or more was considered a sufficient knowledge on antibiotic use.

Attitude towards prudent use of antibiotics

For the composite variable; attitude towards prudent use of antibiotics, three questions; 'Is it important to consult a veterinarian or animal health service provider before antibiotic or antimicrobial use?', 'Is it important to use antibiotics to promote growth in fish production?' and 'Is it important to use antibiotics for disease prevention?' were asked and a correct score of 2 or more was considered a favourable attitude towards prudent antibiotic use.

Practice around antibiotic use

For composite variable; practice around antibiotic use, respondents were categorised into two; those using and those not using antibiotics. Three questions/statements; 'Main reason for not using or using antibiotics', 'Scenarios that would prompt use of antibiotics in the farm', 'How to know which antibiotics to use in case of signs of illness (signs of infection)' were evaluated for both categories and a sum score of 2 or more was considered adequate practice for those not using antibiotics in the farm at the time of this study. For those that were using antibiotics, further five questions responses; 'How often do you seek AHSP advice before using antibiotics', 'Do you seek prescription', 'Do you usually follow the prescription?', 'Where do you source antibiotics?' and 'What's the fate of expired and used drug packaging?' were summed up and a score of 6 or more was considered adequate practice around antibiotic use.

Chi square test was applied for univariable analyses to determine association between various independent variables especially against the mentioned categories (knowledge on antibiotic use, attitude towards prudent antibiotic use and practice around antibiotic use).

3.6 ETHICAL APPROVAL

Ethical approval was sourced from Faculty of Ethics Board Committee, University of Nairobi, Reference number; FVMBAUEC/2021/334. Also, a research permit was obtained from NACOSTI, reference number; NACOSTI/P/21/5757 to facilitate the research work.

4. RESULTS

Eighteen (18) fish farmers participated in this study out of the 21 farmers that were identified through the snowballing sampling technique. The remaining 3 farmers were unavailable to participate in the study. Within the 18 farms visited, only 55 aquaculture ponds were confirmed to exist within an area coverage of 3.35 hectares within the Nairobi County. This number of aquaculture ponds is exclusive of the three farms that were unavailable for the study.

4.1 FARM DESCRIPTIVE CHARACTERISTICS

Table 1 below presents descriptive characteristics for 18 respondents. This survey included multiple choice options for the following variables: role of respondent, type of production systems, fate of waste water, aquaculture as an integrated farming system and market for aquatic produce. Only respondents who reported to treat water before use were the only ones who responded to the variable; treatment chemical as shown in Table 1 below.

Table 1: Descriptive characteristics among sampled aquaculture farms within Nairobi County, Kenya 2022.

Variables	Frequency (f) (N=18)	% (100)
Subcounty		
Dagoretti south	4	22.22

Dagoretti North	1	5.56
Kasarani	9	50
Ruaraka	1	5.56
Embakasi West	1	5.56
Embakasi South	1	5.56
Kamkunji	1	5.56
Roysambu	0	0
Starehe	0	0
Role of respondent		
Owner	9	50
Manager	15	83.33
Worker	6	33.33
Respondent's gender		
Female	2	11.11
Male	16	88.89
Respondent's age		
36-60	10	55.56
18-35	3	16.67
>60	5	27.78
Respondent's level of education		
Primary	3	16.67
Secondary	4	22.22
Tertiary	11	61.11
Production system (farmers' distribution)		
Dams	2	7.41
Ponds	17	62.96
Raceways	1	3.70
Reservoirs	1	3.70
Tanks	6	22.22
Contribution of fish farming to household income		
<25%	6	33.33
25-50%	8	44.44
51-75%	3	16.67
>75%	1	5.56
Farming duration	Median 9	Range 44 years
<10years	12	66.67
11-20years	3	16.67
>20years	3	16.67
Water treatment before use in aquatic farming		
No	15	83.33
Yes	3	16.67
Treatment chemical (N=3)		
Chlorine	1	33.33
Lime (calcium oxide)	2	66.67
Fate of waste water		

Use in	17	94.4
Released to the open	7	38.89
Sometimes recycled	1	5.56
Never drained	1	5.56
Aquaculture as an integrated farming system (livestock keeping)		
Avian (chicken,	12	66.67
Bovine (cattle)	7	38.89
Caprine (goats)	6	33.33
Porcine (pigs)	3	16.67
Ovine (sheep)	2	11.11
None	5	27.78
Market for aquatic produce		
Subsidence	13	72.22
Local market	10	55.56
Neighbours.	1	5.56
Institutions	2	11.11
Other	3	16.67
Antimicrobial use frequency		
Daily	1	5.56
Sometimes	1	5.56
Never	16	88.96
Household size		
<10	7	38.89
11-400	7	38.89
>400	4	22.22
Farming experience		
<2years	5	27.78
3-10years	7	38.89
11-20 years	3	16.67
>20 years	3	16.67
Distance from farm		
<4kilometres	14	77.78
4-10kilometres	3	16.67
>10kilometres	1	5.56
Qualification		
Agriculture	6	33.33
Aquaculture	2	11.11
Non-	8	44.44
None	2	11.11

Respondents had qualifications from different disciplines, with the most common type of course being agricultural courses such as agriculture, agribusiness, horticulture, organic farming and vegetable production, as attended by six of the farmers. Another two of the farmers had taken an aquaculture science course, whilst the remaining farmers reported a variety of professional backgrounds, including: two drivers, one engineer, one plumber, one sociologist, one teacher, one carpenter, and one government workshop trainee. Two farmers reported having no qualification.

4.2 HOUSEHOLD SIZE

Fish farms within Nairobi had a wide range of household size with the smallest household size of 2 and a highest household size of 4000. The extremely large number was due to the fact that some of the farms were owned by learning institutions. Thirteen (13) farms had a household size of 30 and below. The rest of the five (5) farms had a household size of 320 to a maximum of 4,000. Some of these farms were situated in learning institutions and therefore the reason for a wider variation observed as a mean and standard variation of 649.6667(1273.473).

4.3 FARMING EXPERIENCE

Respondents were asked about the number of years they have engaged in fish farming, irrespective of the region where the farm has been located. The years of farming experience as per the responses indicated a minimum of 1 year of experience and the highest experience of 36 years in fish farming. Twelve (12) out of the 18 farmers had less than 10 years of experience, a representation of 66.67% of the surveyed farmers.

4.5 DISTANCE FROM FARM TO DRUG STORES

This section shows proximity of the fish farms within Nairobi to drug stores. Among the farmers surveyed, 14(77.78%) were situated less than 4km away from the drug stores, 3(16.67%) were situated 4-10km away from drug stores and only 1(5.56%) was 33km away from the drug store.

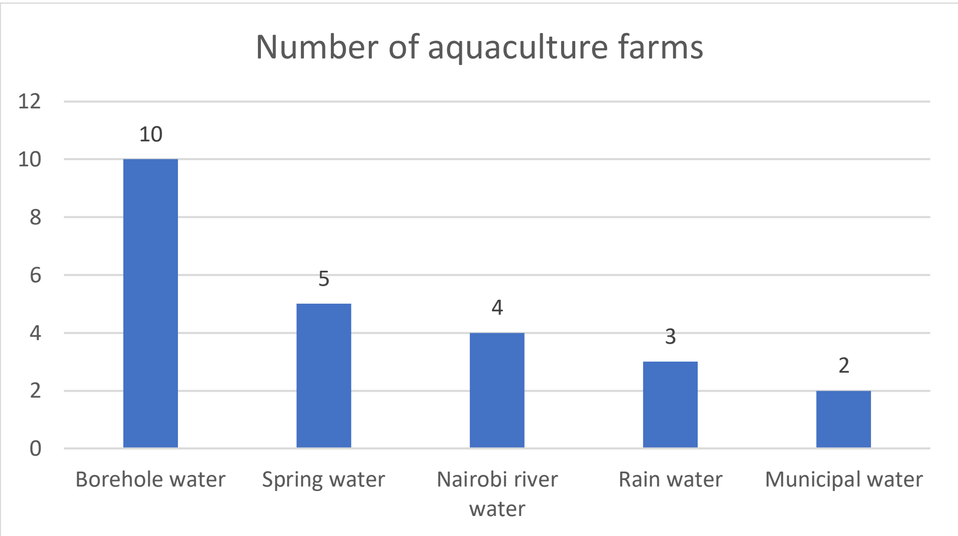
4.6 DURATION OF THE AQUATIC FARM EXISTENCE

The farmers were asked how long their farms have existed in their current format. Six (33.34%) of the farms have operated for less than 10 years, with a range of 1 to 45 years. 12(66.67%) of the farms have been operating for less than 10 years, with a median of 9 years.

4.7 SOURCES OF WATER USED IN THE FARM

Pond water originated from different sources, with most sourcing their water from boreholes, followed by spring and river water. Ten respondents (55.56%) use borehole water, 5(27.78%) use spring water, 4(22.22%) obtain water from Nairobi River, 3(16.67%) use rain water and 2(11.11%) use municipal water. Some of the farmers obtained water from a single source while others use water from a combined source as shown below. Rain water was only used as a secondary source of water, to supplement borehole and river water sources. Of the 10 respondents using borehole water, 7 people said they used exclusively this source, whilst 2 with rain water and 1 each supplemented with river or municipal water.

Figure 2: Sources of water used in the farm



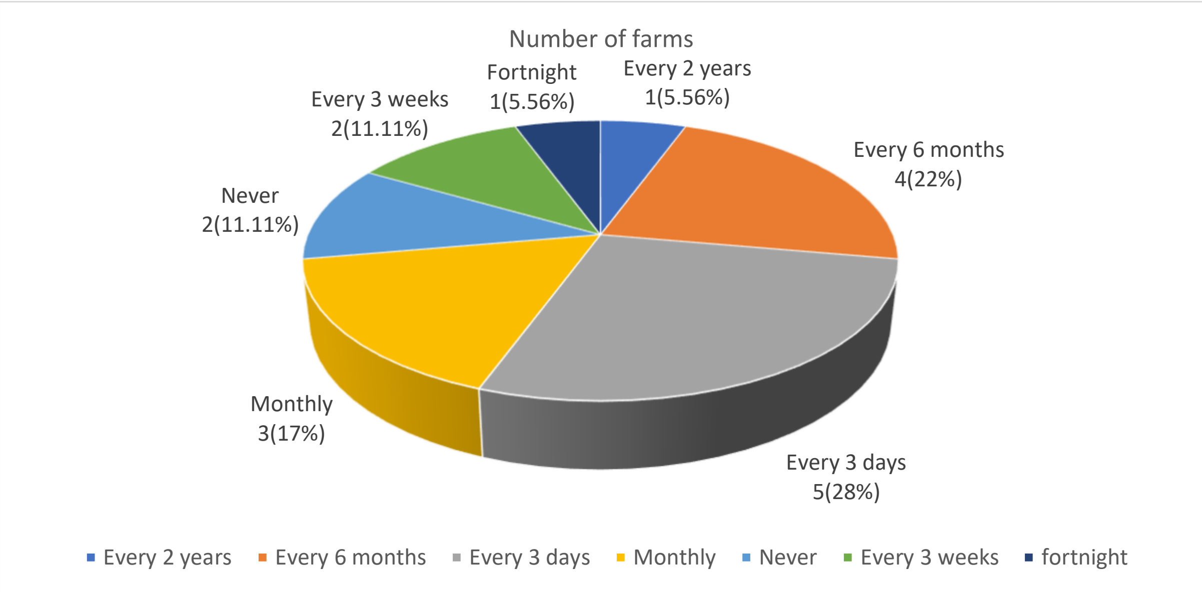
4.8 WATER TREATMENT BEFORE USE IN AQUATIC PRODUCTION

Farmers were asked whether they treat their waters before use in aquatic farming. Only 3(16.67%) of the surveyed farmers reported to be treating water before using it in their farms while 15(83.33%) do not use any form of treatment to the water. Among the three farmers who treat water, two (66.67%) of them used lime (Calcium oxide) and one (33.33%) used chlorine to treat the water.

4.9 AQUATIC PRODUCTION SYSTEM FREQUENCY OF DRAINAGE

Farmers were asked to state the frequency in which they drain their aquatic systems. As shown in the figure below, the majority of farmers (5) drained the systems every 3 days. One (5.56%) reportedly drains every fortnight, three (17%) do it monthly, four (22%) of the farmers drain after every 6 months and one (5.56%) drains their pond every 2 years. Two (11.11%) farmers reported that they never drain their systems.

Figure 3: Drainage frequency distribution among aquatic farms within Nairobi County



4.10 FATE OF WASTEWATER FROM THE AQUATIC SITES

Surveyed farmers were asked where they dispose of waste water drained from their aquatic farms, with multiple choice options. As shown in Table 1, 17(94.44%) of the surveyed farmers used water from their farming systems for crop and vegetable farming. Seven (38.89%) released waste water from their farms into the open environment. One of the two farmers who never drained the farm water sometimes recycled the water for farm chores such as washing of farming equipment.

4.11 MARKET FOR HARVESTED AQUATIC PRODUCTS

Fish produced from the surveyed farms were either used for subsistence or sold to various consumers. Most (13) were producing fish for subsistence use, whilst some also sold their produce. Ten (55.56%) farms were selling the harvested fish to the local market, 2(11.11%) farms sold their produce to institutions such as schools, nearby community centers, and one farm sold harvested fish to its neighbors. One of the farms does not sell for consumption but rear as a hobby and two farms had not harvested before as they were new into farming.

4.12 ANTIMICROBIAL USE DURING THE CURRENT PRODUCTION CYCLE.

Farmers were asked whether they have been using antimicrobials during that production cycle. Only two farmers reported to use antibiotics on a daily basis. The majority, 16(88.89%), indicated that they have not used antimicrobials in their farms during the most recent production cycle.

4.13 AQUACULTURE AS AN INTEGRATED FARMING SYSTEM

Of the surveyed farmers, 13 also reported to be keeping livestock alongside the aquaculture farming. Amongst these 13 farmers, 12 (66.67%) farms were rearing avian (e.g. chicken, ducks), seven (38.89%) were keeping cattle, six (33.33%) were keeping goats, three (16.67) farms were keeping pigs and two (11.11%) farms were keeping sheep. Only five (27.78%) farms were not keeping any other livestock alongside fish rearing. This distribution is presented in Table 1.

5.0 KNOWLEDGEMNT ASSESSMENT

5.1 DISEASES

Farmers were asked to name common diseases they are experiencing in their farms. Half of the farmers reported that they have not experienced any form of diseases in their farms. The remainder mentioned some of the commonly occurring diseases to be bacterial, parasitic, fungal, viral infections and non-infectious diseases. Two farmers were not able to classify the diseases they commonly observed in their farms; they only reported seeing 'white spots' on fish skins. When asked what they thought the causes of the diseases might be, farms suggested a range of answers, including "bacteria, fungi and poor-quality water", "low oxygen levels, cannibalism", "cold stress", "poor hygiene", "lack of oxygen, whitish lesions on oral mucosa", "inherited from hatchery sites", "don't know" and "water shortage resulting in low oxygen levels".

Table 2: Recognition of diseases distribution in aquatic farms within Nairobi, Kenya 2022

Common diseases	*Frequency*	*Percent*
None	9	50
Bacterial infections	3	16.67
Non-infectious diseases	3	16.67
Parasitic infections	2	11.11
Viral infections	2	11.11
Fungal infections	1	5.56
Other "white spots on fish skin'	2	11.11

Majority of the farmers reported that they didn't know how to manage fish diseases. Some didn't know what to do in case of disease occurrence and "just watched the fish die". Some farmers isolated the dead fish, drained the ponds and refilled with fresh water as a way of improving pond hygiene and water quality. One of the farmers would resort to some traditional misconception of applying avocado fruit into the pond water with the hope of curative response.

One other farmer reported to sprinkle sodium chloride into the pond as they believed that the chemical has some antibacterial activity.

5.2 UNDERSTANDING OF TERMS ANTIMICROBIALS OR ANTIBIOTICS/ ANTIBIOTIC OR ANTIMICROBIAL RESISTANCE (ABR/AMR).

Farmers were asked if they were familiar with the terms 'antimicrobials' or 'antibiotics'; seventeen out of the 18 farmers were familiar with either term. Farmers were then asked to describe the terms from their own understanding. Eight farmers (47.06%) expressed good understanding of the terms antibiotics (antimicrobials) while nine (52.94%) of them could not explain correctly what the terms meant. All the farmers were familiar with the term antimicrobial resistance and only eight (44.44%) expressed good understanding of the term. It was notable from the farmers' descriptions of the term antibiotics that the majority of these farmers could not distinguish antibiotics from other general medicines such as anti-inflammatories and antihistamines among others.

Table 3: Antibiotic or antimicrobial/ABR/AMR terms awareness among aquaculture farmers within Nairobi County, Kenya 2022.

Variable	***Frequency***	***Percent***
Awareness on terms antibiotics/antimicrobials	**N=18**	
Yes	17	94.44
No	1	5.56
Understanding of the term antibiotic/antimicrobials	**N=17**	
Responses related to good understanding	8	47.06
Responses related to lack of understanding	9	52.94
Awareness on terms; antibiotics/antimicrobials resistance	**N=18**	
Yes	18	100.00

No	0	0.00
Understanding of the term ABR/AMR	**N=18**	
Responses related to good understanding	8	44.44
Responses related to lack of understanding	10	55.56

5.3 SOURCES OF INFORMATION ABOUT ANTIBIOTIC OR ANTIMICROBIALS AND THEIR PRESENCE IN COMMERCIAL FEEDS

The majority of famers (14, 82.35%) learnt of the term antibiotics or antimicrobials in a conference or a workshop, followed by school, animal health service providers, extension officers, other farmer, friends and relatives, television and the internet (see Table 4).

Table 4: Sources of information about antibiotics or antimicrobials and their presence in commercial feeds

Source of information	**Frequency**	**Percent**
Conference/Workshop	14	82.35
School	6	35.29
Animal health service provider	5	27.41
Extension officer	2	11.76
Other farmers	2	11.76
Friends/Relatives	2	11.76
Television	2	11.76
Internet	1	5.88
Presence of antibiotics/antimicrobials in commercial feeds	**Frequency**	**Percent**
Several types of commercial feeds contain antibiotics/antimicrobials	8	44.44
None of the commercial feeds contain antibiotics/antimicrobials	3	16.67
I don't know	7	38.89
All types of commercial feeds contain antibiotics/antimicrobials	0	0

Farmers were asked to select from multiple choices about the presence of antibiotics/antimicrobials in commercial feeds. Eight (44.44%) of the farmers felt that several of the feeds contain antibiotics or antimicrobials. Three (16.67%) of them felt that none of the commercial feeds contain such chemicals. Seven (38.89%) of the farmers had no idea about this concern and responded “I don’t know” as listed in the table 10 above. These responses were attributed to the most commercialized local feed manufacturer (Unga feeds) and the starter and grower feeds recently donated to the aquaculture farmers by the Netherland’s aquatic feed company. Due to limited availability and high costs of the aquaculture feeds in the country, most of the farmers use farm formulated rations of vegetables, shrimps and Omena *(Rastrineobola argentea)* to feed their ponds.

5.5 KNOWLEDGE AND AWARENESS OF THE TERM WITHDRAWAL PERIOD

Withdrawal period in aquaculture farming refers to the period through which treated aquatic animals are not supposed to be permitted into the food chain (Okocha, R. C. et al., 2018). Various classes of antibiotics have different pharmacokinetic properties and therefore the variation in withdrawal periods as guided by the manufacturers of these products in the product labels (Okocha, R. C. et al., 2018). Farmers stand to be advised by the animal health service providers on such food safety practice as guided by the Kenya Veterinary policy, 2015. Thirteen (72.22%) of the surveyed farmers had heard of the term withdrawal period concerning antibiotic use. Five (27.78%) of the farmers never had the term before. Famers who were aware of the term further explained their understanding of the concept. Several responses were recorded and were as follows; “period that medicine is used that cannot harm human”, “sparing a period of time in farm to get fertile before use again or spray farm with drug and wait before harvesting for consumption”, “using drug in fish farm and waiting for some days before harvesting for consumption”, “after using drug and it’s not effective, you try a new one”, “period of rest after giving antibiotics to animal to allow the antibiotic levels to drop”, “After using antimicrobials you dispose the production system water and replace with fresh water”, “Not using products (food) once you introduce antibiotics and anthelmintics”, “Stopping using antibiotics by choice”, “Time given to animal once administered with a drug before consuming its products”, “At least waiting before harvesting after using antimicrobials”, “Don't remember”.

Table 5: Familiarity and knowledge of the term withdrawal period.

Withdrawal period awareness	**N=18**	**Percent**
“yes” response	13	72.22
“no” response	5	27.78
Understanding of the term withdrawal period	N=13	
Responses related to good understanding of the concept	7	53.85
Responses related to lack of understanding of the term	6	46.15

The distribution of this data is presented in table 5 and shows that only seven out of the 13 respondents who were familiar with the term had a clear understanding of what the term withdrawal period meant. Consequently, the rest of the farmers may fail to acknowledge the significance of observation of withdrawal period and thus result in deposition of drug residues in the food chain. This would pose major public health concerns related to development of antimicrobial drug resistance, hypersensitivity reaction, carcinogenicity, mutagenicity, teratogenicity, bone marrow depression, and disruption of normal intestinal flora.

5.6 KNOWLEDGE ON USE OF ANTIBIOTICS/ANTIMICROBIALS (AB/AM)

Table 6:Distribution of various variables addressing farmers' knowledge on purpose and safety of antimicrobial use.

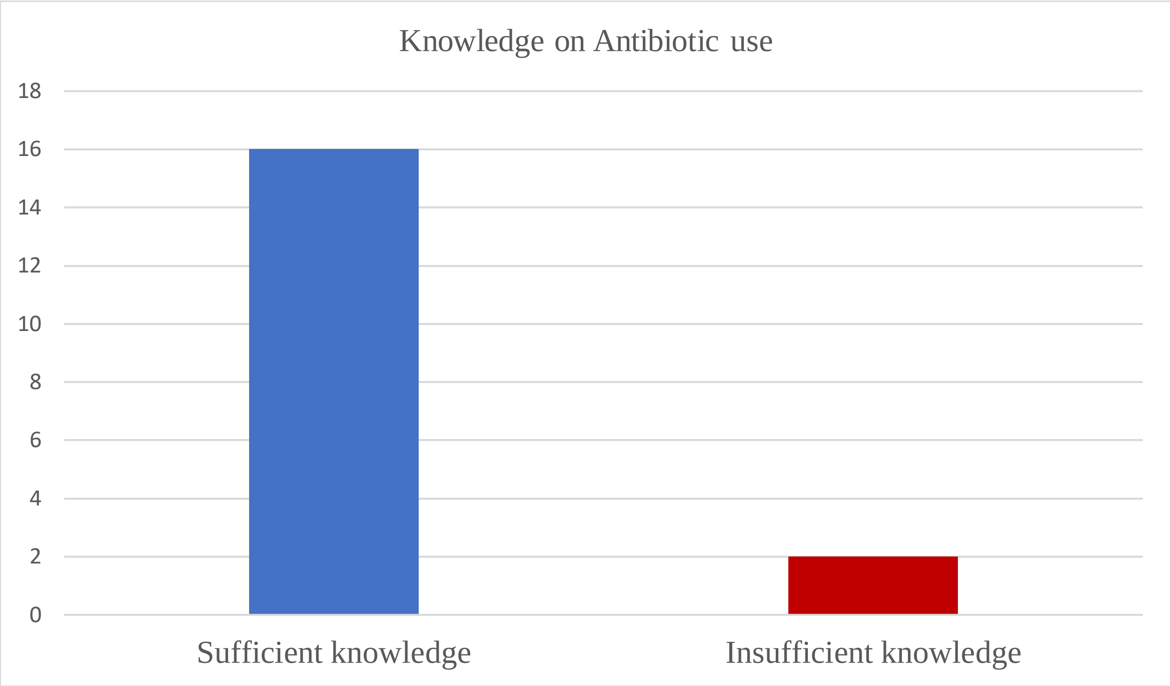
Use of AB/AM to support fish growth	**Frequency**	**Percent**
Strongly disagree	10	55.56
Strongly agree	4	22.22
Agree	2	11.11
Disagree	1	5.56
I don't know	1	5.56
Use of AB/AM on any sick animals/fish	**Frequency**	**Percent**
Strongly disagree	5	27.78
Strongly agree	4	22.22
Agree	4	22.22
Disagree	5	27.78
I don't know	0	0.00
Administering different dose other than AHSP prescription	**Frequency**	**Percent**
Strongly disagree	11	61.11
Strongly agree	1	5.56
Agree	1	5.56
Disagree	5	27.78
I don't know	0	0.00
Withdrawing AB therapy on health improvement.	**Frequency**	**Percent**
Strongly disagree	7	38.89
Strongly agree	2	11.11
Agree	1	5.56
Disagree	7	38.89
I don't know	1	5.56
Proper use of AB/AM reduces risks of ABR/AMR	**Frequency**	**Percent**
Strongly agree	13	72.22
Agree	4	22.22
Disagree	1	5.56
Strongly disagree	0	0.00
I don't know	0	0.00
Necessity to withdraw AB/AM use during fish harvesting for sale	**Frequency**	**Percent**
Strongly agree	15	83.33
Agree	3	16.67
Disagree	0	0.00
Strongly disagree	0	0.00

I don't know	0	0.00

Ten out of 18 farmers strongly disagreed with the use of antibiotics for growth promotion in aquaculture farming. Eleven farmers (61.11%) strongly disagreed with the use of different doses of antibiotics to that prescribed by the animal health professional. Fourteen farmers equally strongly disagreed and disagreed with the withdrawal of antibiotic therapy on improvement of sick animal health. Majority of the farmers also showed the importance of withdrawing antibiotic use during harvesting of aquatic products for human consumption. Also, the majority of the farmers strongly disagreed and disagreed with the use of antibiotics for treatment of any sick fish as not all illness requires antibiotics intervention.

Sum of each individual participant's answers was calculated for the knowledge section of the questionnaire. According to a 75% cut-off for correct responses to 6 knowledge statements, we found that the surveyed farmers generally had a sufficient knowledge on the antibiotic usage as shown in the figure 4 below.

Figure 4: Knowledge on antibiotic use



6.0 ATTITUTUDE ASSESSMENT

Respondents were asked to choose appropriate response to various statements to determine their attitude towards prudent use of antibiotics. Questions such as; 'Is it important to consult a veterinarian or animal health service provider before antibiotic or antimicrobial use?', 'Is it important to use antibiotics to promote growth in fish production?' and 'Is it important to use antibiotics for disease prevention?' were asked for attitude towards prudent use of antibiotics.

On the other hand, questions such as; 'What impact does antibiotic resistance have on the environment?', 'What impact does antibiotic resistance have on human health?', 'What impact does antibiotic resistance have on animal health?', 'What impact does antibiotic resistance have on household income?' and 'What impact does vaccination, hygiene and biosecurity measures as part of farm management reduce antibiotic/antimicrobial use?' were asked to address rational use of antibiotics.

Table 7: Distribution of various variables addressing attitude assessment of respondents against antibiotic use and rational use of antibiotics.

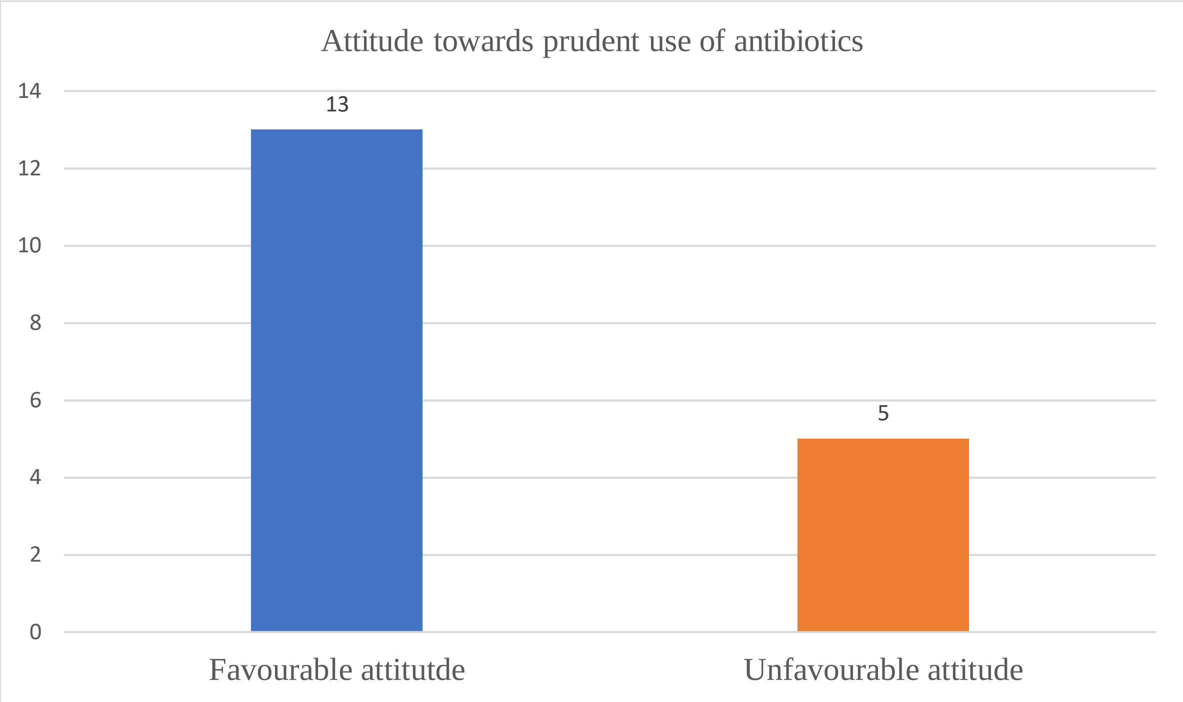
Seeking AHSP advise before AB/AM use	Frequency (N=18)	Percent (100)
Strongly agree	13	72.22
Agree	5	27.78
Strongly disagree	0	0.00
Disagree	0	0.00
I don't know	0	0.00
Using AB/AM for growth promotion	**Frequency (N=18)**	**Percent (100)**
Strongly disagree	6	33.33
Strongly agree	2	11.11
Agree	3	16.67
Disagree	7	38.89
I don't know	0	0.00
Using AB/AM for disease prevention	**Frequency (N=18)**	**Percent (100)**
Strongly disagree	3	16.67
Strongly agree	6	33.33
Agree	5	27.78
Disagree	3	16.67
I don't know	1	5.56
Impact of ABR/AMR on environment	**Frequency (N=18)**	**Percent (100)**
Extremely negative	4	22.22
Somewhat negative	9	50.0
I don't know	2	11.11
Neutral	2	11.11
Somewhat positive	1	5.56
Extremely positive	0	0.00
Impact of ABR/AMR on human health	**Frequency (N=18)**	**Percent (100)**
Extremely negative	4	22.22
Somewhat negative	11	61.11
I don't know	1	5.56
Neutral	1	5.56
Somewhat positive	1	5.56
Extremely positive	0	0.00
Impact of ABR/AMR on animal health	**Frequency (N=18)**	**Percent (100)**
Extremely negative	4	22.22
Somewhat negative	11	61.11
I don't know	1	5.56
Somewhat positive	1	5.56
Extremely positive	0	0.00
Neutral	0	0.00
Impact of ABR/AMR on household income	**Frequency (N=18)**	**Percent (100)**

Extremely negative	6	33.33
Somewhat negative	9	50.0
I don't know	1	5.56
Neutral	1	5.56
Somewhat positive	1	5.56
Extremely positive	0	0.00
Impact of vaccination and biosecurity measures in reduction of ABU/AMU	**Frequency (N=18)**	**Percent (100)**
Extremely positive	8	44.44
Somewhat positive	10	55.56
Somewhat negative	0	0.00
I don't know	0	0.00
Neutral	0	0.00
Extremely negative	0	0.00

Respondents were asked to choose from a range of given choices for various statements regarding attitudes on antimicrobial use and antimicrobial resistance. Majority of the respondents (13) "*strongly agree*" that it is important to consult a veterinarian or animal health service provider before antibiotic or antimicrobial use in the farm. Majority of the respondents postulated that the impact of antimicrobial resistance is "*somewhat negative*" on the environment (50%), household income (50%), human (61.11%) and animal health (61.11%). Ten (55.56%) respondents postulated that there is a "*somewhat positive*" impact of vaccination and generally upholding biosecurity measures such as hygiene as a form of farm management in reduction of antimicrobial use in the aquaculture farms. The rest of the respondents thought that vaccination and biosecurity measures had an "*extremely positive*" impact in reduction of antibiotic use in the aquaculture farms. Six (33.33%) farmers which represents the majority of the respondents "*strongly agree*" with the use of antibiotics in disease prevention only.

Sum of each individual participant's answers was calculated for the attitude section of the questionnaire. It revealed that 13 out of 18 surveyed farmers generally had a favourable attitude towards prudent antibiotic use in aquaculture, as shown in the figure 5 below.

Figure 5: Attitude towards prudent use of antibiotics



7.0 PRACTICE ASSESSMENT

7.1 ANTIBIOTIC/ANTIMICROBIAL USE

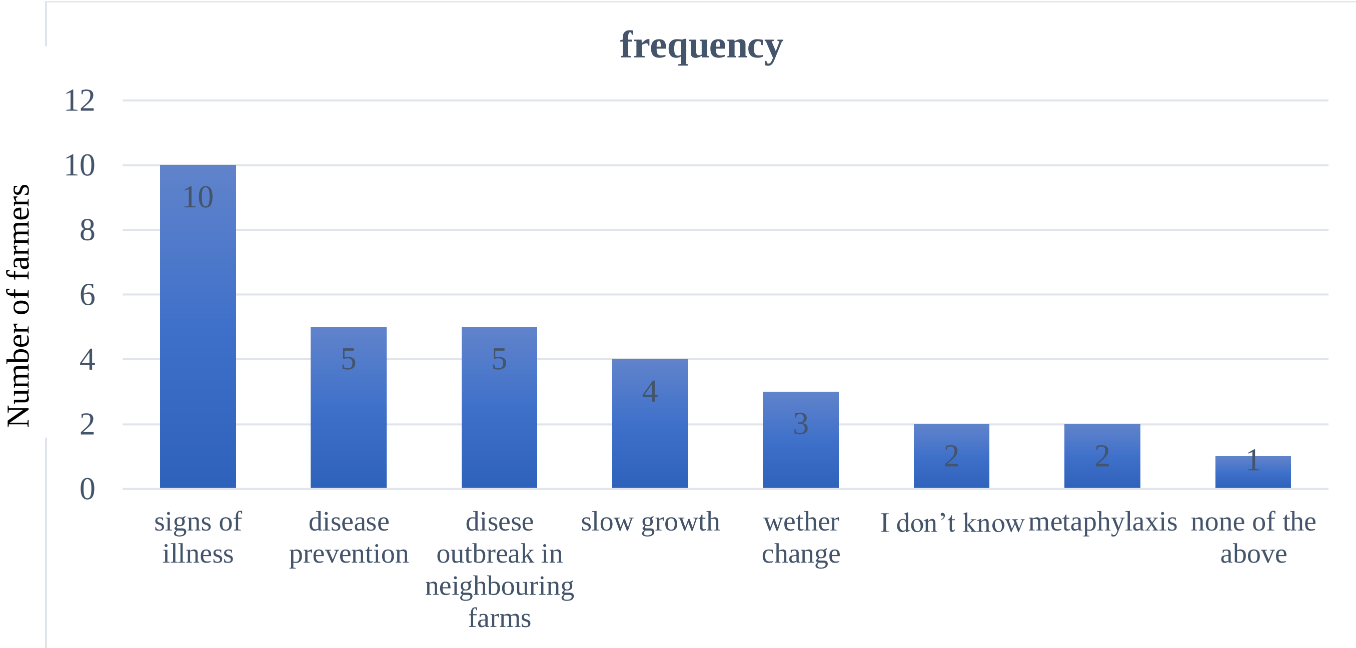
Majority of the farmers, 15 (83.33%) were not using antibiotics in their aquatic farming. They had reasons to why they were not using antibiotics which they stated as follows; seven (46.69%) respondents reported that they have never had any fish disease in their aquaculture farms, two (13.34%) respondents did not know the specific antibiotics that are meant for use in management of fish diseases, two (13.34%) respondents reported that they lacked knowledge on fish diseases and could not tell whether the fish were sick or not, one respondent was clearly aware of the negative impacts of antibiotic use in animal food products and therefore opted not to use antibiotics for aquaculture farming. Another respondent stated that the fish diseases were rare and not serious and therefore wasn't a need for antibiotic intervention. The last farmer was not keen in monitoring the aquaculture farm for any disease occurrence and could not tell whether there was an incidence of disease or not probing no use of the antibiotics. Only 2 (11.11%) of the surveyed farmers were using antibiotics. Main reasons for using antibiotics in aquatic farming were for disease prevention and infection treatment. Both farmers seek prescription from a veterinarian before using the antibiotics which they reported to always follow. These two farmers were obtaining the antibiotics from the veterinary pharmacies except for one of the farmers who also sourced the antibiotics from other farmers. The commonly used antibiotics at the point of this study were tetracyclines and colistin powders.

Table 8: Antibiotic/antimicrobial use in aquaculture farms within Nairobi County, Kenya 2022.

Variable	Frequency	Percent
Antibiotic/antimicrobial use in fish farming	**N=18**	
yes	2	11.11
no	15	83.33
I don't know	1	5.56
Seeking prescription from veterinarian before using the antibiotic	**N=2**	
yes	2	100
no	0	0.00
Following the prescription	**N=2**	
Always	2	100
Observation of withdrawal period	**N=2**	
Always	1	5.56
Sometimes	1	5.56
Source of the antibiotics	**N=2**	
Agrovets (veterinary pharmacies)	2	11.11
Other farmers	1	5.56
Commonly used antibiotics in aquaculture farming	**N =2**	
Tetracyclines	1	5.56
Colistin	1	5.56

In addition to the above, farmers were generally asked to give scenarios that can prompt usage of antibiotics in their farms. The figure 4 below shows their responses.

Figure 6: Scenarios that would prompt aquatic farmers within Nairobi County, Kenya to use antibiotics in their farms, 2022.



Reasons prompting antibiotic usage

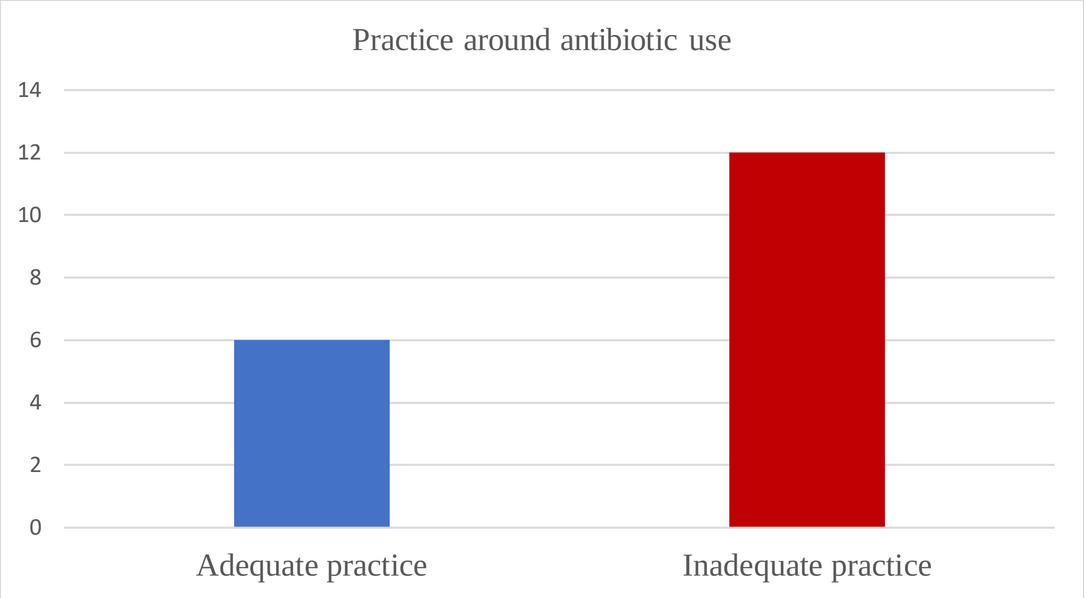
Farmers commented on where they would generally seek advice on which antibiotics to use in their farms when need be. A further question was asked to find out how often they would do that. The data on that is as presented in the Table 9 below;

Table 9: Knowledge on antibiotics to use in case of "signs of illness" among farmers.

Sources of advice	Frequency	Percent
Consult veterinarian	9	50
Own experience	4	22.22
Drug sellers	4	22.22
Other farmers	4	22.22
Friends/relatives	1	5.56
Don't know	1	5.56
Prefer not to use antibiotics	6	33.33

Sum of each individual participant's answers was calculated for the practice section of the questionnaire. It revealed that the surveyed farmers generally had an inadequate practice around antibiotic use as shown in the Figure 6 below.

Figure 6: Practice around antibiotic use



7.2 FATE OF USED/EXPIRED ANTIBIOTICS

The two farmers who use antibiotics in their aquaculture farms dispose of used and expired antibiotics. Both of the farmers dispose into a general waste pit and burned them. One (5.56%) of the two farmers at times drain into a draining pond and reuse the packaging containers (drug container closure system) to pack fish feeds. The above practice would lead to leaching of the antibiotics into the surrounding ecosystem; soil, terrestrial plants and nearby waterways. Consequently, increasing selective pressure of antibacterial resistant genes and antimicrobial resistant genes in the environment. Additionally, usage of drug packaging would result in introduction of antibiotics in fish feeds which would later end up in the aquaculture components; fish body tissues, fish pond water and the fish pond sediments. This therefore predisposes to antimicrobial resistance determinants spread and resistance development.

7.3 Other chemicals used in the aquaculture farms within Nairobi County

Farmers were asked to identify chemicals other than the antibiotics they use in their aquaculture farms and their responses were as shown in the Table 10 below;

Table 10: Other chemicals used in aquaculture farms within Nairobi County.

Chemicals used in the farm	Frequency	Percent
Sodium chloride	3	16.67
Lime (calcium oxide)	2	11.11
Inorganic fertilizer (DAP/CNN)	1	5.56
Organic manure	1	5.56
Gonadotropin	2	11.11
Alpha-17-methyltestosterone	1	5.56
Chlorine dioxide	1	5.56
Sodium hypochlorite	1	5.56
Glutaraldehyde	1	5.56

Sodium chloride was reported by three respondents. They assumed its role in management of pathogens due to its antibacterial activity. Some of the farmers sprinkled lime in the fish pond water to buffer the pond pH in order to cease effects brought by acidification of the aquatic environment such as limited fish growth rates, interference with the reproduction cycle due to reduced calcium levels and death from 'acidic shock'. The pH of pond water is advisable to be maintained at 6 to 8 pH levels. High alkalinity disposes fish to skin and gills damage resulting in interruption of respiration and normal metabolic waste elimination in fish and therefore death from toxicity. High pH especially pH above 8 also increases toxicity from ammonia. Some of the farmers were also using both organic and inorganic fertilizers in their ponds as a direct source of feed to fish and also to indirectly enhance growth of aquatic plants such as algae which are source of feed to the fish. Use of the organic fertilizers predispose to risk of introducing antibiotic residues into the ponds and pathogens which may result in disease outbreak and consequently use of antibiotics for disease management. Some of the farmers used hormonal compounds such as gonadotropin and alpha-17-methyltestosterone in breeding. Gonadotropin was used to enhance reproduction in female fish due to its critical role in superovulation (Munoz-Cueto J.A et al., 2020). Alpha-17-methyltestosterone was used in breeding for sex reversal (modify the fingerlings sex into male) to produce monosex population of male fish. The hormone is also known for its growth promotion (Hagar. E, 2021). Male fish are known for their efficient utilization of feeds into growth and therefore fast achievement of market weight as compared to female fish that utilizes more feeds and take longer to reach market weight as some of its energy is focussed on reproduction. Sodium hypochlorite and chlorine was basically used to purify and disinfect water (Mokoena, M.M et al., 2021). These two chemicals are known to remove pathogens such as *Escherichia coli* and *cyanobacteria* organisms (Mokoena, M.M et al., 2021). Glutaraldehyde was used for disinfection of the used aquaculture farm equipment because of its antimicrobial activity.

8.0 FACTORS RELATED TO KAP ON AMU AND AMR IN AQUACULTURE PRODUCTION WITHIN NAIROBI COUNTY, KENYA.

Univariable analyses of independent survey variables are presented against four dependent outcomes of interest in Table 11: Knowledge on antibiotic use, Table 12: Attitude towards antibiotic use, Table 13: Practice around antibiotic use. The sum of each individual participant's answers was calculated for each of the knowledge, attitude and practice sections of the questionnaire. Those whose answers deemed 75% or more correct as per the scientific understanding of the questions, were considered to have sufficient knowledge on antibiotic use, favourable attitude towards prudent antibiotic use and adequate practice around antibiotic use. Chi square test was applied for univariable analyses to determine association between various independent variables especially against the mentioned categories (knowledge on antibiotic use, attitude towards prudent antibiotic use and practice around antibiotic use).

Table 11: Univariable analysis on knowledge on antibiotic use of interviewed aquaculture farmers within Nairobi County, Kenya.

Variables	Total		Sufficient knowledge on antibiotic use		Insufficient knowledge on antibiotic use		Score (Pearson Chi²)	p-value
	(N=18)	**100%**	**(n=16)**	**88.89%**	**(n=2)**	**11.11%**		
Age	18	100					1.800	0.407
Youth			5	100.00	0	0		
Adult			8	80.00	2	20.00		
Elderly			3	100	0			
Gender	18	100					3.4453	0.063
Female			1	50.00	1	50.00		
Male			15	93.75	1	6.25		
Level of education	18	100					3.6562	0.161
Primary			2	66.67	1	33.33		
Secondary			3	75.00	1	25.00		
Tertiary			11	100.00	0	0.00		
Farming income	18	100					2.8125	0.421
<25%			5	83.33	1	16.67		
25-50%			8	100.00	0	0.00		
51-75%			2	66.67	1	33.33		
>75%			1	100.00	0	0.00		
Subcounty	18	100					1.4063	0.965
Dagoretti North			1	100.00	0	0.00		
Dagoretti South			3	75.00	1	25.00		
Embakasi South			1	100.00	0	0.00		
Embakasi West			1	100.00	0	0.00		
Kamkunji			1	100.00	0	0.00		
Kasarani			8	88.89	1	11.11		
Ruaraka			1	100.00	0	0.00		
Disease presence in the farm	18	100					0.0281	0.867
No			7	87.50	1	12.50		
Yes			9	90	1	10.00		

Number of information source types	18	100					11.2500	**0.024**
None			0	0.00	1	100		
One source type			8	100.00	0	0.00		
Two sources type			5	100.00	0	0.00		
Four sources type			2	66.67	1	33.33		
Five sources type			1	100.00	0	0.00		
Years of farming experience	18	100					4.5000	0.212
<5years			4	66.67	2	33.33		
5-10years			6	100.00	0	0.00		
11-20years			3	100.00	0	0.00		
>20years			3	100.00	0	0.00		
Farm size	18	100					0.6429	0.725
<1000m3 (small scale)			12	85.71	2	14.29		
1000-10,000m3 (medium scale)			2	100.00	0	0.00		
>10,000m3 (large scale)			2	100.00	0	0.00		
Qualification	18	100					18.000	**0.000**
Agricultural related training			6	100.00	0	0.00		
Aquaculture			2	100.00	0	0.00		
Non-agricultural/livestock related training			8	100.00	0	0.00		
None			0	0.00	2	100.00		

Univariable analysis did not determine statistically significant associations between survey variables and farmer's knowledge on antibiotic use, with the exception of number of information source types (p=0.024) and qualification (p=0.000). Qualification appears to hold a strong association with aquaculture farmers knowledge about antibiotic use in Nairobi.

Table 12: Univariable analysis on attitude towards prudent antibiotic use of interviewed aquaculture farmers within Nairobi County, Kenya.

Variables	Total		Favourable attitude towards prudent antibiotic use		Unfavourable attitude towards prudent antibiotic use		Score (Pearson Chi²)	p-value
	(N=18)	**100%**	**(n=13)**	**72.22%**	**(n=5)**	**27.78%**		
Age	18	100					0.2215	0.895
18-35			4	80.00	1	20.00		
36-60			7	70.00	3	30.00		
>60			2	66.67	1	33.33		
Gender	18	100					0.5538	0.457
Female			1	50.00	1	50.00		
Male			12	75.00	4	25.00		
Level of education	18	100					2.7818	0.249
Primary			1	33.33	2	66.67		
Secondary			3	75.00	1	25.00		
Tertiary			9	81.82	2	18.18		
Farming income	18	100					9.4846	**0.023**
<25%			5	83.33	1	16.67		
25-50%			7	87.50	1	12.50		
51-75%			0	0.00	3	100.00		
>75%			1	100.00	0	0.00		
Subcounty	18	100					3.0462	0.803
Dagoretti North			1	100.00	0	0.00		
Dagoretti South			2	50.00	1	50.00		
Embakasi South			1	100.00	0	0.00		
Embakasi West			1	100.00	0	0.00		
Kamkunji			1	100.00	0	0.00		
Kasarani			6	66.67	3	33.33		
Ruaraka			1	100.00	0	0.00		
Disease presence in the farm	18	100					0.6785	0.410
No			5	62.50	3	37.50		
Yes			8	80.00	2	20.00		
Number of information source types	18	100					4.5415	0.338

None			0	0.00	1	100		
One source type			6	75.00	2	25.00		
Two sources type			3	60.00	2	40.00		
Four sources type			3	100.00	0	0.00		
Five sources type			1	100.00	0	0.00		
Years of farming experience	18	100					0.5538	0.907
<5years			5	83.33	1	16.67		
5-10years			4	66.67	2	33.33		
11-20years			2	66.67	1	33.33		
>20years			2	66.67	1	33.33		
Farm size	18	100					1.9780	0.372
<1000m3 (small scale)			9	64.29	5	35.71		
1000-10,000m3 (medium scale)			2	100.00	0	0.00		
>10,000m3 (large scale)			2	100.00	0	0.00		
Qualification	18	100					3.6692	0.299
Agricultural related training			6	100.00	0	0.00		
Aquaculture			1	50.00	1	50.00		
Non-agricultural/livestock related training			5	62.50	3	37.50		
None			1	50.00	1	50.00		
Knowledge on antibiotic use	18	100					0.5538	0.457
Sufficient			12	75.00	4	25.00		
Insufficient			1	50.00	1	50.00		

From the univariable analysis of various variables against attitude towards prudent use of antibiotics, only farming income showed a statistically significant association with a p=0.023.

Table 13: Univariable analysis on practice around antibiotic use of interviewed aquaculture farmers within Nairobi County, Kenya.

Variables	Total		Adequate practice around antibiotic use		Inadequate practice around antibiotic use		Score (Pearson Chi^2)	p-value
	(n=18)	**100%**	**(n=6)**	**33.33%**	**(n=12)**	**66.67%**		
Age	18	100					0.1500	0.928
18-35			2	40.00	3	60.00		
36-60			3	30.00	7	70.00		
>60			1	33.33	2	66.67		
Gender	18	100					0.2812	0.596
Female			1	50.00	1	50.00		
Male			5	31.25	11	68.75		
Level of education	18	100					2.3523	0.308
Primary			0	0.00	3	100.00		
Secondary			1	25.00	3	75.00		
Tertiary			5	45.45	6	54.55		
Farming income	18	100					2.8125	0.421
<25%			3	50.00	3	50.00		
25-50%			3	37.50	5	62.50		
51-75%			0	0.00	3	100.00		
>75%			0	0.00	1	100.00		
Subcounty	18	100					10.6250	0.101
Dagoretti North			1	100.00	0	0.00		
Dagoretti South			1	25.00	3	75.00		
Embakasi South			1	100.00	0	0.00		
Embakasi West			1	100.00	0	0.00		
Kamkunji			0	0.00	1	100.00		
Kasarani			1	11.11	8	88.89		
Ruaraka			1	100.00	0	0.00		
Disease presence in the farm	18	100					0.4500	0.502
No			2	25.00	6	75.00		
Yes			4	40.00	6	60.00		
Number of information source types	18	100					3.600	0.463
None			0	0.00	1	100		
One source type			4	50.00	4	50.00		
Two sources type			2	40.00	3	60.00		
Four sources type			0	0.00	3	100.00		
Five sources type			0	0.00	1	100.00		
Years of farming experience	18	100					2.2500	0.522
<5years			3	50.00	3	50.00		
5-10years			2	33.33	4	66.67		
11-20years			0	0.00	3	100.00		
>20years			1	33.33	2	66.67		

Farm size	18	100					0.6429	0.725
<1000m3 (small scale)			4	28.57	10	71.43		
1000-10,000m3 (medium scale)			1	50.00	1	50.00		
>10,000m3 (large scale)			1	50.00	1	50.00		
Qualification	18	100					2.8125	0.421
Agricultural related training			3	50.00	3	50.00		
Aquaculture			0	0.00	2	100.00		
Non-agricultural/livestock related training			3	37.50	5	62.50		
None			*0*	*0.00*	*2*	*100.00*		
Knowledge on antibiotic use	18	100					1.1250	0.289
Sufficient			6	37.50	10	62.50		
Insufficient			0	0.00	2	100.00		
Attitude towards prudent use of antibiotics	18	100					3.4615	**0.063**
Favourable			6	46.15	7	53.85		
Unfavourable			0	0.00	5	100.00		

All the tested survey variables had no significant statistical association with practice around antibiotic use as an outcome dependent variable except for attitude towards prudent use of antibiotics with a p=0.063.

8.0 DISCUSSION

Inappropriate use of antibiotics is one of the major predisposing factors to antimicrobial resistance development. To subvert the challenge of unemployment and to also increase sources of economic livelihoods in the country, the majority of Kenyans are venturing into aquaculture farming. Limited studies have been conducted on antimicrobial use in aquaculture farming in Kenya. Data on the types of antibiotics and amount estimates are essential in creating new knowledge, informing on policies that can be translated into actions to prevent and contain antimicrobial resistance. This study was conducted to assess knowledge, attitude and practice around antimicrobial use among the aquaculture farmers within Nairobi County, Kenya.

In Nairobi County, Kenya, aquaculture production has dropped drastically since 2014 with only 18 farmers being actively functioning currently. In 2015, 870 ponds had been dug within Nairobi County with a coverage of 26.1hactares compared to the 55 ponds (3.35hactares) at the point of this study. This result is in agreement with Opiyo et al. (2018), a finding that ascribed the drop to water inadequacy in some parts of Nairobi County away from the Nairobi River, limited and poor extension services to farmers resulting into losses through mortalities due to mismanagement, dependency on donor and government support which is currently lacking and low-quality farm inputs.

In this study, most of the farmers (44%) earn up to 25-50% household income from the fish farming with 33.3% earning less than a quarter of household income and only one farm earning more than 75%. The majority of farmers (56%) obtain water for use in aquaculture farms from boreholes within the farm setting.

A study by Sargenti et al. (2020) considered aquaculture farming systems as a significant source of antimicrobial pollution to the environment. This is in agreement with the scenario observed in this study where 94.4% of aquaculture farmers were re-using wastewater from the aquaculture ponds for vegetable and crop farming, whereby antimicrobials and their metabolites if present may find their way into the food chain through absorption and accumulation in food crop (He et al., 2016; Pandey et al., 2018). Also, in this study, 38.89% of the aquaculture farmers released waste water from the aquaculture ponds directly into the open environment; nearby water streams, soil and terrestrial plantations. Some farmers (22.22%) reported to be sourcing water from Nairobi River for use in aquaculture production to which was not subjected to any form of treatment before use. Nairobi River is known for its potential harboring of various contaminants such as pharmaceuticals including antibiotics (Ngumba et al., 2016) and (Bagnis et al., 2020). Some of the farmers also used organic manure from poultry and livestock waste to fertilize the fish ponds and as a direct feed to the fish. This practice agrees with a study by Munguti et al (2020) that documented aquaculture farmers using fertilizers as an alternative for fish feeds especially due to the challenge of fish feed unavailability. There is a chance of direct transfer of antimicrobial resistance genes, antimicrobial residues and antimicrobial resistant bacteria across these various components of the ecosystem due to such practices; use of organic manure in aquaculture, draining waste water from aquaculture site into the environment, using the waste water from fish ponds for vegetable and crop farming as well as sourcing water for use in aquaculture farms from a antimicrobial contaminated water source as has been documented previously (Watts et al., 2017; Binh et al., 2018; Lulijwa et al., 2020).

This study investigated aquaculture farmers' understanding of terms 'antibiotics/antimicrobials' and 'antimicrobial/antibiotic resistance'. It revealed that the majority of the aquaculture farmers in Nairobi County had a poor understanding of the term antibiotics and antimicrobial resistance and a good understanding of what withdrawal period means. Seventeen out of the 18 farmers had heard of the term 'antibiotics' and only eight of them could explain fairly well what they were. All of the surveyed farmers had heard of antimicrobial resistance and only eight of them could describe correctly what the term meant. Seventy-two (72) percent of the farmers were aware of the term withdrawal period and 53.85% of them explained correctly what it meant. Majority (77.78%) of the farmers confirmed to have learnt of these terms during farmers conferences and workshops and also a high number of the farmers having heard from animal health service providers. These findings are contrary to a study carried in Vietnam, Pham et al., 2019 where a number of aquaculture farmers had a good understanding of all the three terms. Majority of the farmers (83.33%) were not using antibiotics in their aquaculture farms, a practice ascribed to other major reasons such as the aquaculture farmers' lack of knowledge on fish diseases, unawareness and unavailability of specific antibiotics for fish diseases management. Also, eight (44.44%) of the farmers believed that several commercial feeds contain antimicrobials.

Aquaculture farmers within Nairobi County could not clearly describe and categorize diseases they observed occurring in their farms into bacterial, viral, fungal, parasitic or non-infectious. They struggled explaining the clinical signs they observed and this clearly indicated farmers' knowledge gap on fish diseases.

The results from this study also revealed that aquaculture farmers from Nairobi County, Kenya have sufficient knowledge on antibiotic use. Majority disagreed (61.12%) to use of antibiotics for growth promotion, 55.56% disagreeing to use of antibiotics in any sick animal unless its deemed necessary as some of the illness may not necessarily be infectious but rather non-infectious originating from parasites, poor water quality, mismanagement practices such as overstocking and poisoning among others. Also, 88.89% disagree with the use of different doses of antibiotics from what has been prescribed by the veterinarian. All farmers strongly recommended withdrawal of antibiotic use in fish ponds during harvesting for consumption. Seventy-eight (78%) of the farmers indicated that dosing must be completed irrespective of observed improvement on health of the fish and 94% of them agreeing to the fact that proper use of antibiotics is amongst best options to reducing risks of antimicrobial resistance development. The findings Pham et al., 2019 also reported a low number (1%) of aquaculture farmers in Vietnam proposing to use antibiotics for growth promotion with the majority (69%) indicating to use antibiotics primarily for infection response. This study also reveals that 61.16% of Nairobi farmers "agreeing" and "strongly agreeing" to use antibiotics to prevent diseases differ with study by Pham et al., 2019 indicating only 20% preferring to use antibiotics for disease prevention.

This study also agrees with Pham et al., 2019 that aquaculture farmers demonstrate different levels of awareness on presence of antibiotics in commercial feeds. The results of this study indicates that 44% of aquaculture farmers in Nairobi thought that several feeds contain antibiotics with 39% not knowing whether commercial feeds contain antibiotics or not. This could be either true or not unless the various feeds are analyzed for presence of antibiotics in them. This is very key since feeds could be a source of antibiotics into the aquatic site that may as well result in selection pressure of antimicrobial resistance bacteria and antimicrobial resistance genes and antimicrobial residues which predispose to AMR development. However, fish feeding was recognized as a challenge to most of the farmers as they applied farm based feed formulations such as using shrimps, leafy vegetables and cereal milling by-products based on their own experiences. Only a few farmers were able to afford commercial feed from a local manufacturer company (Unga feeds). Some of the farms had also received fish growers and starters' feed donations from a Holland company.

Majority of the farmers fairly recognized the negative impact of antimicrobial resistance on environment, human and animal health and on household income. They consistently agreed to the fact that antibiotic resistance has "somewhat" or "extremely" negative effects on the environment (72.2%), human health (83.3%), animal health (83.3%) and household income (83.3%). This result is similar to Pham et al. (2019) that reported about the same response distribution, 69.4%, 72%, 78% and 81% farmers respectively.

Farmers also agreed that application of biosecurity measures as part of farm management has "somewhat positive" (55.6%) or "extremely positive" (44.4%) impact in reduction of antimicrobial use at the farm level. This result is in harmony with Pham et al. (2019) which reported 96% of farmers agreeing to hygiene and biosecurity measures being the ultimate way of reducing antibiotic resistance. Majority of the farmers also recognized that loss of effectiveness of antibiotics could have "very serious" (38.89%) or "serious" consequences on treatment of human infections and "very serious" (50%) or "serious" (27.78%) consequences on treatment of animal infections. This was relatively a low positive response as compared to 92% and 93% for treatment in human and animal respectively by Pham et al. (2019) study among Vietnamese producers.

Results from this study indicated that farmers preferred seeking for professional advice before using antibiotics. This was represented by 72.2% famers choosing "strongly agree" while 27.78% "agree" to seek animal health service provider advice before using antibiotics. This is in contrast to a report by Ström et al. (2019) stating that aquaculture farmers used antibiotics without clear diagnosis of diseases by animal health professionals.

Majority of aquaculture farmers (83.3%) within Nairobi County, Kenya do not use antibiotics in their farms. From this study conducted, only 11.1% of surveyed farmers reported to be using antibiotics. This result is contrary to the finding by Pham et al. (2019) that all Vietnamese farms used at least one antibiotic at one point throughout the production cycle. Tetracycline and colistin were reported to be the antibiotics being used by aquaculture farmers in Nairobi County Kenya. A study by Ström et al. (2019) found out that the most commonly used antibiotics in Upper Delta of Vietnam were sulfamethoxazole-trimethoprim combination and amoxicillin. In Kenya, no specific antibiotics have been approved for use in the aquaculture industry by the Kenya Veterinary medicines Directorate which is the state authority mandated with regulation of veterinary medicines. This is unlike other countries like China, USA and Europe where 13, 4 and 5 antibiotics have been authorized for use respectively as reported by studies done by Lie et al. (2017) and Topp et al. (2017). Therefore, it is true that regulatory policies are independent regionally a reason to varying use of antibiotics globally. Tetracyclines as most used antimicrobial in aquaculture farms followed by sulphonamides, penicillins and phenicols (Tuševljak et al., 2013; Pham et al., 2019; Schar et al., 2020). Tetracycline is one of the authorized antibiotics to be used in aquaculture farming in Europe (Iwu, C et al., 2020). Schar et al. (2020) reported use of critically important antimicrobials (CIA) for human medicine as per World Health Organisation list in aquaculture. This is confirmed to be true as colistin has been found to be in use by one aquaculture farmer in Nairobi County. The two farmers using antibiotics administer them through bath treatment (pouring the antibiotic directly into water) unlike the Ström et al. (2019) study, which reported majority of aquaculture farmers administering antibiotics through feeds with only a few farmers applying bath treatment.

The preferred source of antibiotics by these two farmers was from veterinary pharmacy with one farmer sourcing his antibiotics from other livestock farmers. Both the two farmers sought prescription from a veterinarian before using the antibiotics and they always followed them. One of the farmers "always" observed the withdrawal period during harvesting for sale while the other one doing it "sometimes". Famers (83.3%) who were not using antibiotics had reasons. They included, not having encountered diseases in their farms (60%), not knowing specific antibiotics for use in management of fish diseases (20%), lack of knowledge of fish diseases (26.7%), fish diseases being rare and not serious (6.67%) and being aware of negative impacts of using antibiotics in food animals (6.67%).

Overall, this study reports that 88.89% of the surveyed farmers have sufficient knowledge on antibiotic use, and 72.22% a favorable attitude towards prudent antibiotic use. However, this study found that 66.67% of the farmers reported inadequate practice around antibiotic use. There have been national awareness raising campaigns in Kenya through various AMR research projects and antimicrobial stewardship leadership and these explain the sufficient knowledge and favourable attitude towards prudent use of antibiotics observed among farmers. However, farmers have shown failure to translate that knowledge into practice therefore raising a gap on antimicrobial use practice.

Lack of reported Antibiotic use does not equate to prudent use of antibiotics in aquaculture in Kenya. Most farmers report not using antibiotics but 44.44% believe antibiotics are in feed and

38.89% are not sure if antibiotics are present in feed or not. In addition, 26.7% could not recognise fish disease and 13.34% of the farmers also reporting not to know specific antibiotics for use in fish diseases.

Knowledge on prudent use of antibiotics in aquaculture is varied but particularly weak in areas of: presence of antibiotics in feeds and use of antibiotics in prevention of diseases.

Aquaculture appears to serve as an important pathway for environmental AMR transmission, with circular use of river water as pond water, distribution of pond water in livestock and vegetable/crop farming and disposal into the surrounding ecosystem. The disposal of expired antibiotics into draining ponds, general waste pits is also a risk to environmental direct transfer of AMR determinants. Use of drug (antibiotics) used packaging closure systems to repack animal feeds is of a major food safety concern as risk of exposing the consumer to antibiotic is immense.

While attitudes to prudent use of antibiotics in aquaculture appear favourable, this does not appear to translate into good practice. Inadequate practice is reported by most of the farmers not telling correctly scenarios that would prompt them to use antibiotics in the farm as for some, antibiotic use would be driven by 'weather change', 'diseases outbreaks in the neighbouring farms', in cases of metaphylaxis and for disease prevention. Some farmers would also borrow antibiotics from neighbouring farmers, friends and relatives to use in their farms in cases of signs of illness. Use of critical antibiotic in human medicine such as colistin was also reported by a farmer.

9.0 CONCLUSIONS

This study provides an interesting finding, the farmers interviewed reported limited usage of antibiotics in aquaculture farming within Nairobi County, Kenya. This is believed to be as a result of multifactorial causes ranging from rare occurrence of fish diseases, failure of recognition of diseases by farmers and unavailability of specific antibiotics authorized by VMD for fish diseases management. Overall, the study has shown that there is relatively poor understanding of the terms ‘antibiotics’ and ‘antimicrobial resistance’ amongst the aquaculture farmers within Nairobi County. However, these farmers have demonstrated to have sufficient knowledge on antibiotic use, a favourable attitude towards antibiotic use and resistance and an inadequate practice around antibiotic use.

Farmers have also shown limited knowledge around fish diseases and therefore need the Ministry of Livestock and Agriculture, Department of Fisheries in partnership with the Directorate of Veterinary Services (DVS) and other relevant stakeholders to strengthen sensitization to these farmers on fish health and antibiotic stewardship leadership. There is need for drug regulatory authority such as Kenya Veterinary Medicines Directorate (VMD) to authorize specific antibiotics for use in aquaculture farming in order to reduce or prevent usage of critically important antibiotics for human medicine as per WHO such as colistin that was found to be in use. Some of the farmers who were initially actively involved in fish farming stopped due to water unavailability. Therefore, there's a need for such farmers to be supported through water project initiations to enable sustainability in this industry. Additionally, there is a need for farmers to be enlightened on fish nutrition as most of the farmers were not aware of what feeds were exact for fish feeding. This would be achieved through initiatives such as the DVS liaising with feed manufacturing companies to invest in fish feeds to sustain the fish farming industry.

There is a need for the government to give farmers capital support and proper extension programmes to enable them adopt new farming technologies, innovations and best management practices for an optimized production.

Most of these challenges have been addressed in the existing policies and therefore need to be implemented to directly impact positively into the aquaculture sector.

10.0 LIMITATIONS OF THIS STUDY

Past studies carried out in Kenya around aquaculture production reported a high number of active fish farming activities across the nation. This gave a wide variation by the fact that only a few farms were found to be active within Nairobi County. The existing databases of aquaculture farmers at the fisheries' offices were not up to date and this was a challenge in sample size determination. However, this did not affect the results as obtained in this report as fisheries extension officers were accessible to support in reaching out to farmers in their respective sub-counties.

Covid-19 pandemic with total lockdown measures especially in the major cities of republic of Kenya especially Nairobi City delayed access to farmers in order for the survey to be achieved. However, this was handled by close engagement with the sub-county administrative officials and the State Department of Fisheries to enable progress for the survey under strict observation of Covid-19 measures.

The results of this study are based on self-reported data and therefore chances of social desirability bias. However, fish, water and pond sediment samples were collected for antibiotic residues analyses. These will form the basis for validation of certain self-reported responses via comparison with data from the laboratory analyses.

10.0 FUTURE WORKS

There is ongoing laboratory analysis for fish, water and fish pond sediment samples collected from the same surveyed aquaculture farms. This is on antibiotic residue analysis. This will form part of a publication for this work once concluded.

11.0 DATA AVAILABILITY

The survey data used to support the findings of this study are available from the corresponding author upon request.

12.0 CONFLICT OF INTEREST

I Dr. Elvis Madara declare there is no conflict of interest regarding submission of this report.

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