

Study of the Multidrug Resistance of Enterobacteria Isolated from Waters and Tilapia Fishes from Fish Farms in the Sud-Comoé Region, Côte d'Ivoire

Affou Séraphin Wognin^{1,2*}, Aubin Cyrille Toulé³, Amino Elise N'guessan¹, Nangan Michel Koné¹, Natalie Kouadio-Guessennd⁴

¹Department of Biochemistry-Genetics, Peleforo Gon Coulibaly University, Korhogo, Côte d'Ivoire

²Microbiology, Ecotoxicology and Radioecology Laboratory, Ivorian Anti-Pollution Center (CIAPOL), Abidjan, Côte d'Ivoire

³Oceanographic Research Center, Abidjan, Côte d'Ivoire

⁴Bacteriology and Virology Laboratory, Pasteur Institute, Abidjan, Côte d'Ivoire

Email: *seraphinwn@gmail.com

How to cite this paper: Wognin, A.S., Toulé, A.C., N'guessan, A.E., Koné, N.M. and Kouadio-Guessennd, N. (2024) Study of the Multidrug Resistance of Enterobacteria Isolated from Waters and Tilapia Fishes from Fish Farms in the Sud-Comoé Region, Côte d'Ivoire. *Advances in Microbiology*, 14, 567-577.

<https://doi.org/10.4236/aim.2024.1411039>

Received: September 29, 2024

Accepted: November 12, 2024

Published: November 15, 2024

Copyright © 2024 by author(s) and Scientific Research Publishing Inc.

This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

Microbial resistance to antibiotics is a global problem that threatens the lives of millions of people and affects several sectors, including aquaculture. The aim of the present study is to contribute to the monitoring of multi-resistant enterobacterial strains circulating in fish ponds in the Sud-Comoé region of south-eastern Côte d'Ivoire, more specifically in the Aboisso and Tiapoum departments. To this end, 20 samples of Tilapia fish (*Oreochromis niloticus*) and 60 samples of farm water were collected from 5 fish farms in the Sud-Comoé region. Microbiological analyses were based on the isolation and identification of enterobacteria on Mac Conkey + Cefotaxime medium. These analyses resulted in the isolation of 73 strains of enterobacteria, including 58 from fish and 15 from fish pond water samples. Antibiotic sensitivity tests carried out on enterobacteria isolated from water and fish samples showed high levels of resistance (100%) to the beta-lactam family (Amoxicilin + clavulanic acid, Cefotaxime). *Klebsiella pneumoniae* and *Enterobacter spp.* showed resistance to Ciprofloxacin (100%) and (25%) respectively. The study also showed that strains of Enterobacteriaceae were resistant to all 3 families of antibiotics, notably Beta-lactams, Fluoro-quinolones and Aminoglycosides. The presence of multi-resistant Enterobacteriaceae in fish and pond water samples represents a public health risk.

Keywords

Multidrug Resistance, Enterobacteriaceae, Tilapia Fish, Fishponds

1. Introduction

Antimicrobial resistance (AMR) today represents one of the most serious threats to global public health [1]. According to the Food and Agriculture Organization of the United Nations, when antimicrobials are used inappropriately, they can pose a serious health risk to consumers [2]. Indeed, the number of deaths per year worldwide due to antibiotic resistance is currently estimated at 700,000, including 5500 in France. The most alarmist predictions predict 10 million deaths per year in 2050, including 4.1 million in Africa [3]. It should be noted that a study carried out on antibiotic resistance in the commensal flora of Asian aquaculture fish showed that out of 203 strains isolated, 150 were resistant to the 10 antibiotics tested (oxytetracycline, chloramphenicol, sulfonamides, nalidixic acid, ampicillin, streptomycin, oxolinic acid...) [4].

Furthermore, in Africa, several sectors (animal, human and aquaculture) are affected by antimicrobial resistance (AMR), in particular the aquaculture sector, which uses large quantities of antibiotics to control numerous ichthyo-pathogens (vibriosis, furunculosis, pasteurellosis, streptococcosis, myxobacteriosis, etc.) and improve yields [5]. In addition, some studies on the resistance profile of bacteria isolated from aquatic environments highlight the resistance of *E. coli* to amoxicillin, azithromycin, penicillin, erythromycin and other antibiotics [6] [7].

Sustainable management of antimicrobial resistance requires the adoption of a strategic plan based on the surveillance, prevention and treatment of infections in humans and animals, and the reduction of inappropriate antimicrobial use in all sectors.

In Côte d'Ivoire, aquaculture plays a strategic role in both food security and socio-economic development [8]. However, Ivorian production covers only 30% of its needs [9]. Despite low production levels, fish farming plays a key economic, social and nutritional role [9]. In addition, little work has been carried out in Côte d'Ivoire on the resistance and microbiological quality of fish and water from the aquaculture environment. Yet the quantity of inputs used in this sector is significant. Hence the interest of this study, whose general objective was to contribute to the surveillance of multi-resistant bacteria isolated from fish farms in the Sud-Comoé region. More specifically, the aim was to:

- Identify enterobacteria in water and Tilapia fish (*Oreochromis niloticus*) from fish farms in the Sud-Comoé region;
- Determine the resistance profile of enterobacteria strains isolated from water and Tilapia fish (*Oreochromis niloticus*) from fish farms in the Sud-Comoé region.

2. Material and Methods

2.1. Material

2.1.1. Study Material

The study material consisted of fish named Tilapia (*Oreochromis niloticus*) (**Figure 1**) and water samples taken from fish farms in the Sud-Comoé region.



Figure 1. Samples of tilapia fish (*Oreochromis niloticus*) taken from Aketchi farms in the Sud-Comoé region.

2.1.2. Sampling Equipment

The sampling equipment consisted of one (01) liter bottle for water sampling, a cooler containing dry ice for sample preservation, a pH meter for pH measurement, a marker, gangs, adhesive tape for bottle labeling, distilled water for rinsing the pH meter after each pH measurement and stomacher bags for fish sampling.

2.1.3. Culture Media and Reagents for Bacterial Isolation and Identification

Mac-conkey agar, UTI agar and Le Minor rack were used to test for enterobacteria. Buffered peptone water, Rapapport Vassiliadis broth (RVS) and Hektoen agar were used respectively for pre-enrichment, enrichment and as a selective medium for the detection and isolation of Salmonella. A concentration of 2 mg per liter of the antibiotic Ceftazidime was added to Mac Conkey agar for the detection of antibiotic-resistant Enterobacteriaceae. Kovac reagent was used for the indole test.

2.2. Methods

2.2.1. Study Area

The study was carried out in two departments (Aboisso and Tiapoum) of Sud-Comoé region in southern Côte d'Ivoire.

2.2.2. Sampling

The sampling phase of water and Tilapia fish (*Oreochromis niloticus*) in fish farms took place from July 2022 to September 2022. Two Departments were selected (Aboisso, Tiapoum). The Departments were selected on the basis of their large number of fish farms. Samples were taken from a total of 5 fish farms in both departments (**Figure 2**). Samples for microbiological analysis were taken under

aseptic conditions: gloves were used to protect hands during sampling. A total of 80 samples were taken, including 20 fish samples and 60 water samples. On each farm, two ponds were selected for water and fish sampling: the growth pond and the maturity pond. In each pond, one (01) fish sample consisted of five (05) fish taken at random using a net by the fish farmers. Water samples were taken upstream, in the middle and downstream of each pond using a sterile one (01) liter bottle. Fish samples were collected and packed in stomacher bags and water samples were collected in 500 mL sterile bottles. Samples were then placed in a cooler containing carboglass and transported immediately to the lab for analysis.

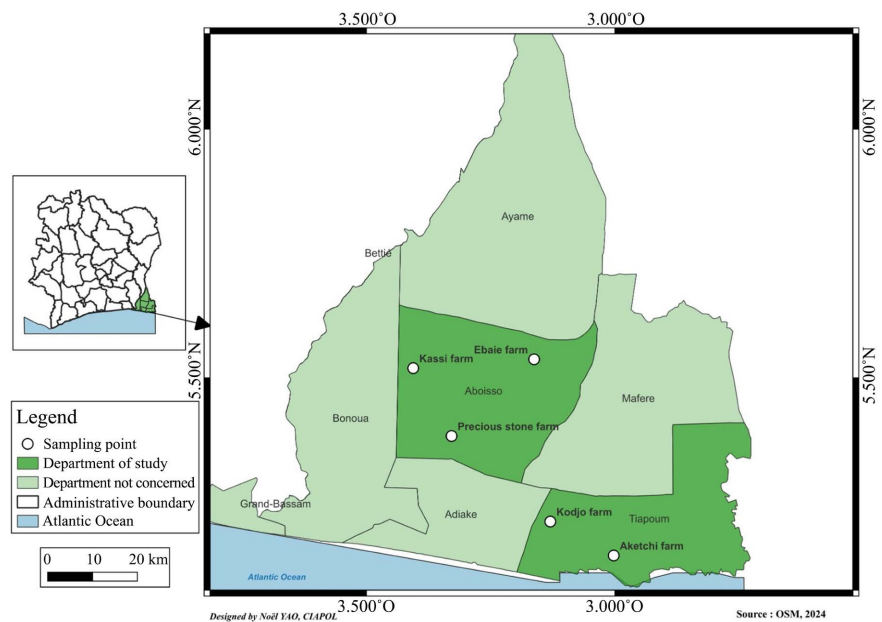


Figure 2. Map of the Sud-Comoé region and sampling points.

2.2.3. Microbiological Analysis

Bacteriological Analysis of Fish

Bacteriological analyses focused on enterobacteria in water samples and various organs (skin, gills and viscera).

The stock solution consisted of 25 g of fish tissue (viscera, skin and gills) weighed and introduced into a sterile bottle containing 225 mL of buffered peptone water. The whole mixture was homogenized using a magnetic stirrer, and the flasks were then placed in an oven at 37°C for 24 hours. For *Salmonella* testing, 0.1 mL of each pre-enriched suspension (EPT) was inoculated into Rapaport-Vassiliadis broth for enrichment and incubated at 42°C for 24 hours. Using a sterile Pasteur pipette, the enriched suspension of each tissue was Z streaked onto Hektoen selective medium and the Petri dishes incubated at 37°C for 24 hours. For resistant enterobacteria, 0.1 mL of each pre-enriched suspension (EPT) was spread onto Mac Conkey + Ceftazidime antibiotic-supplemented media and Mac Conkey media for resistant and non-resistant enterobacteria. Petri dishes and tubes were then incubated at 37°C for 18 to 24 hours. Colonies obtained after 24

hours were transferred to UTI agar (nutrient medium) and the plates were then incubated at 37°C for 24 hours.

Bacteriological Analysis of Water

Microbiological analyses of pond water were carried out using the membrane filtration method, with decimal dilutions made from the samples. A volume of 1 mL of each dilution was taken and filtered through a 0.45 µm porosity membrane filter. The membranes were removed and placed in Petri dishes containing Mac Conkey agar, then incubated at 37°C for 24 hours. At the end of incubation, red colonies were counted on Petri dishes with colony counts between 15 and 150. After incubation, presumptive red colonies of Enterobacteriaceae on Mac Conkey + Ceftazidime medium were transferred to UTI chromogenic medium. On UTI agar, red colonies are characteristic of either *E. coli* or *Proteus vulgaris*, while blue colonies are either *Enterobacter spp.* or *Klebsiella pneumoniae*. Blue and red colonies were then isolated and transferred to nutrient agar for biochemical characterization. All identified Enterobacteriaceae were subjected to an antibiogram test.

2.2.4. Expression of Results

The total number of colonies in the dilutions was calculated using the following formula [10].

$$N = \frac{\sum \text{Colonies}}{V(n1 + 0, \ln 2)d}$$

With:

N: number of bacteria expressed per log CFU/mL of water;

ΣColonies: sum of colonies on interpretable membranes;

Volume of water filtered on interpretable membranes (in mL);

d: dilution factor;

n1: number of Petri dishes inoculated with the first dilution;

n2: number of Petri dishes inoculated with the second dilution.

The loads obtained were then expressed in Log CFU/100mL of water.

2.2.5. Statistical Analysis

Analysis of variance (ANOVA) was performed using Statistica software version 7.1 to study significant differences between the variables measured (pH, average microbial load). In the event of a significant difference between the parameters studied, means and standard deviations were classified using the Newman-Keuls test at a significance level (α) of 5%. Statistical differences with a probability value of less than 0.05 were considered significant. When the probability is greater than 0.05, statistical differences are not significant. Band diagrams were plotted using Excel 2013.

3. Results

3.1. Loads of Enterobacteria Isolated on Mac Conkey Medium from Fish Farm Water Samples

Average enterobacteria loads in farm water ranged from 3.65 to 5.62 Log

CFU/100mL. The highest average load was obtained from the Ebalé farm with 5.62 Log CFU/100mL, while the lowest average load (3.74 Log CFU/100mL) was obtained from the Aketchi farm (Figure 3). Statistical analysis reveals that there is a significant difference ($P < 0.05$) between the different average loads of Enterobacteriaceae in the water samples analyzed.

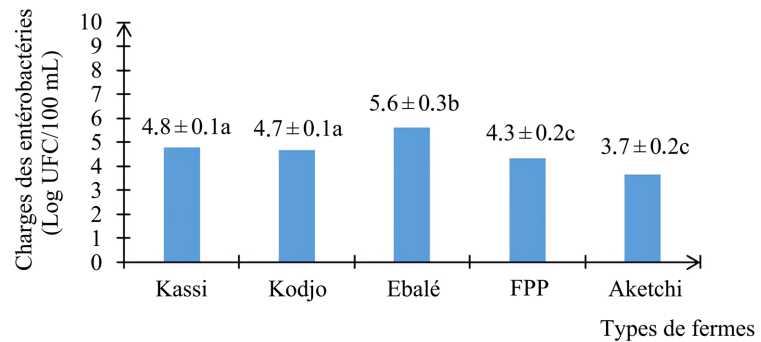


Figure 3. Variation of loads in Log CFU/100mL of enterobacteria on Mac Conkey medium.

3.2. Loads of Ceftazidime-Resistant Enterobacteriaceae Isolated from Fish Farm Water Samples

Average loads of Ceftazidime-resistant Enterobacteriaceae ranged from 2.04 to 2.92 Log CFU/100mL. The highest load was obtained at the Ebalé farm with 2.92 Log CFU/100mL. The lowest load (2.04 Log CFU/100mL) was obtained on the Kodjo and Aketchi farms (Figure 4). Statistical analysis reveals that there is a significant difference ($P < 0.05$) between the different enterobacteria loads in the water samples analyzed.

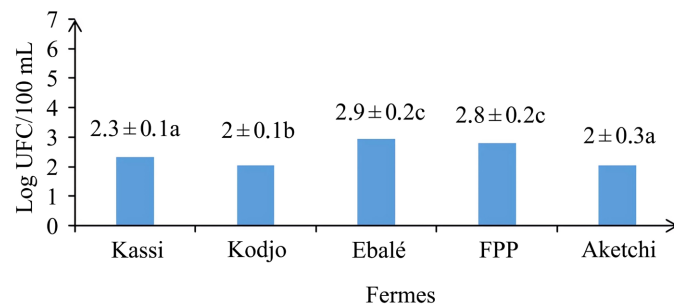


Figure 4. Variation of loads in Log CFU/100mL of Ceftazidime-resistant Enterobacteriaceae, values bearing the same letters are not significantly different according to the Newman-Keul test ($\alpha = 0.05$).

3.3. Frequency of Isolation of Enterobacteria from Water Samples from Fish Farms in the Sud-Comoé Region

Enterobacter spp., *Klebsiella pneumoniae*, *E. coli* and *Proteus vulgaris* were the main species isolated from water samples. The most frequently isolated species were *Enterobacter spp.* and *E. coli*, with a frequency of isolation of 46.67% and 40% respectively (Figure 5).

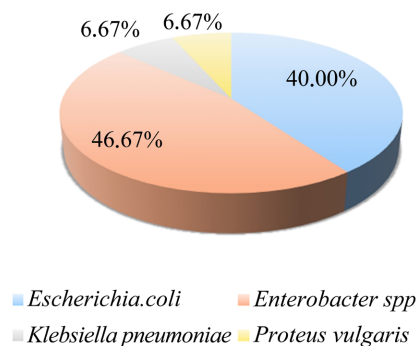


Figure 5. Proportion (%) of enterobacteria isolated from water samples.

3.4. Frequency of Isolation of Enterobacteria from Fish Samples from Fish Farms in the Sud-Comoé Region

Bacteriological analysis of skin, gills and viscera revealed a total of 58 enterobacteria, including *Enterobacter spp.* (12.07%), *Klebsiella pneumoniae* (24.14%), *E. coli* (53.45%) and *Proteus vulgaris* (10.34%) (**Figure 6**). Among the organs analyzed, gills were the most contaminated with bacteria, with 22 isolated enterobacteria (37.93%), followed by skin, with 19 isolated enterobacteria (32.76%), and viscera, with 17 isolated enterobacteria (29.31%). The normality of the distribution of enterobacteria identified according to organ follows a normal distribution according to the Kolmogoro and Chappiro Wilk Test (**Table 1**).

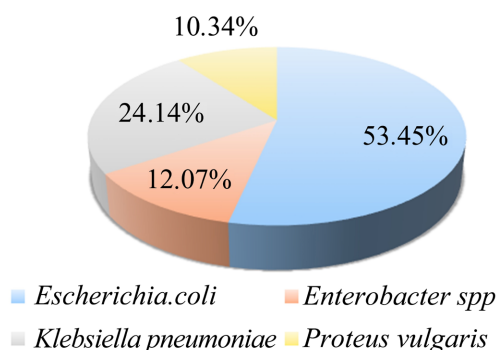


Figure 6. Proportion (%) of enterobacteria isolated from fish.

Table 1. Distribution of enterobacteria isolated from different organs of fish from fish farms.

Germ	Organs			Total	Percentage (%)
	Skin	Viscera	Gills		
<i>Escherichia coli</i>	19	11	01	31	53.45
<i>Klebsiella pneumoniae</i>	00	00	14	14	24.14
<i>Proteus vulgaris</i>	00	06	00	06	10.34
<i>Enterobacter spp.</i>	00	00	07	07	12.07
Total	19	17	22	58	100
Percentage (%)	32.76	29.31	37.93	100	

3.5. Antibiotic Resistance Profile of Enterobacteria Isolated from Fish Farms in the Sud-Comoé Region

Sensitivity tests carried out on enterobacteria identified in fish (**Table 2**) from fish farms were carried out using the antibiotic families (beta-lactams, fluoro-quinolones, aminoglycosides). Bacteria isolated from fish samples showed high levels of resistance (100%) to two beta-lactam antibiotics (Amoxicillin + Clavulanic acid, Ceftazidime). Resistance (55.56%) of *E. coli* strains to Imipenem was also observed. In the fluoroquinolone family, only *E. coli* strains showed 55.56% resistance to nalidixic acid. However, an average resistance (22%) of *E. coli* was observed with both Ciprofloxacin and Aminoglycosides (Amikacin, Gentamicin). All *Klebsiella pneumoniae* strains (100%) were resistant to nalidixic acid. Resistance rates of 50% for *Enterobacter spp.* were observed with nalidixic acid and Gentamicin, and 33% for *Proteus vulgaris* with respect to Imipenem, nalidixic acid, Ciprofloxacin, Gentamicin and Amikacin.

When sensitivity tests were carried out on the enterobacteria identified in the water samples. We also observed a high level of resistance (100%) to two beta-lactam antibiotics (Amoxicillin + Clavulanic acid, Ceftazidime) in all strains isolated. Resistance rates of 100% were observed in *Klebsiella pneumoniae* and *Proteus vulgaris* with Ciprofloxacin and nalidixic acid. Strains of *E. coli* and *Enterobacter spp.* showed resistance rates of 75% and 62.5% respectively to Gentamicin (**Table 3**).

Table 2. Antibiotic resistance levels of enterobacteria identified in fish from fish farms in the Sud-Comoé region.

Antibiotic families	<i>K. pneumoniae</i> (N = 02)		<i>Escherichia coli</i> (N = 09)		<i>Enterobacter spp</i> (N = 02)		<i>Proteus vulgaris</i> (N = 03)	
	R	S	R	S	R	S	R	S
Beta-lactam								
Amoxicillin + clavulanic acid (AMC)	2 (100)	0 (0)	9 (100)	0 (0)	2 (100)	0 (0)	3 (100)	0 (0)
Ceftazidime (CAZ)	2 (100)	0 (0)	9 (100)	0 (0)	2 (100)	0 (0)	3 (100)	0 (0)
Imipenem (IPM)	1 (50)	1 (50)	5 (55.56)	4 (44.44)	0 (0)	2 (100)	1 (33.33)	2 (66.67)
Fluoro-quinolones								
Nalidixic acid (NA)	2 (100)	0 (0)	5 (55.56)	4 (44.44)	1 (50)	1 (50)	1 (33.33)	2 (66.67)
Ciprofloxacin (CIP)	1 (50)	1 (50)	2 (22.22)	7 (77.78)	0 (0)	2 (100)	1 (33.33)	2 (66.67)
Aminosides								
Gentamicin (CN)	1 (50)	1 (50)	2 (22.22)	7 (77.78)	1 (50)	1 (50)	1 (33.33)	2 (66.67)
Amikacin (AK)	1 (50)	1 (50)	2 (22.22)	7 (77.78)	0 (0)	2 (100)	1 (33.33)	2 (66.67)

Table 3. Antibiotic resistance levels of enterobacteria identified in water samples from fish farms in the Sud-Comoé region.

Antibiotic families	<i>K. pneumoniae</i> (N = 01)		<i>E. coli</i> (N = 04)		<i>Enterobacter spp</i> (N = 08)		<i>Proteus vulgaris</i> (N = 01)	
	R	S	R	S	R	S	R	S
Beta-lactam								
Amoxicillin + clavulanic acid (AMC)	1 (100)	0 (0)	4 (100)	0 (0)	8 (100)	0 (0)	1 (100)	0 (0)
Ceftazidime (CAZ)	1 (100)	0 (0)	4 (100)	0 (0)	8 (100)	0 (0)	1 (100)	0 (0)
Imipenem (IPM)	0 (0)	1 (100)	1 (25)	3 (75)	2 (25)	6 (75)	0 (0)	1 (100)
Fluoroquinolones								
Nalidixic acid (NA)	0 (0)	1 (100)	1 (25)	3 (75)	4 (50)	4 (50)	1 (100)	0 (0)
Ciprofloxacin (CIP)	1 (100)	0 (0)	1 (25)	3 (75)	2 (25)	4 (75)	0 (0)	1 (100)
Aminosides								
Gentamicin (CN)	0 (0)	1 (100)	3 (75)	1 (25)	5 (62.5)	3 (37.5)	0 (0)	1 (100)
Amikacin (AK)	0 (0)	1 (100)	0 (0)	4 (100)	3 (37.5)	5 (62.5)	0 (0)	1 (100)

NB: S = Susceptible, R = Resistant, N = Number of bacteria.

4. Discussion

Enterobacteriaceae identified in water samples from fish farms consisted mainly of *Enterobacter spp*, *E. coli*, *Klebsiella pneumoniae*. This corroborates studies carried out by Samira *et al.* [11] on aquaculture stations in Malaysian Borneo, which found *Enterobacter spp*, *E. coli*, *Klebsiella pneumoniae* in the water and fish from the fish farms. The results of our study disagree, however, with those of Kathleen *et al.* [12] on the antibiotic resistance of various bacteria from the aquaculture waters of Limbang in Malaysian Borneo. These authors also observed the presence of *Enterobacter spp*, *E. coli*, *Klebsiella pneumoniae* in water samples with sensitivity rates (100%) to Ceftazidime. Resistance rates differing from those observed in our study have also been reported by Cui-Yi *et al.* [13]. In a study of antimicrobial resistance in *E. coli* strains from farm farms and their environment in Zhanjiang, China, these authors observed resistance rates of over 70% to amoxicillin, ampicillin, penicillin and tetracycline. A high level of resistance to beta-lactams (Amoxicillin + Clavulanic acid, Ceftazidime) was observed for all strains of Enterobacteriaceae isolated in this study. This result could be explained by the high selection pressure due to the often abusive and uncontrolled use of antibiotics, in particular beta-lactam antibiotics (Amoxicillin + Clavulanic acid, Ceftazidime, etc.) in both human and veterinary medicine.

The strains of enterobacteria identified in fish farm samples are mainly *Enterobacter spp*, *E. coli* and *Klebsiella pneumoniae*. This result is similar to that of Raymond *et al.* [14] on the bacteriological quality of fish from Lac municipal Obili in Yaoundé, Cameroon. The bacterial contamination rates of the fish analyzed

showed that *E. coli* (53.45%) was the most isolated bacterium followed by *Klebsiella pneumoniae* (24.14%) in the fish samples analyzed. On the other hand, in a study carried out on bacteria in fish taken from fish farms in the Sud-Comoé region of Côte d'Ivoire, Adingra *et al.* [15] showed that *E. coli* was the most isolated bacterium (63%). This high prevalence of *E. coli* could be linked either to contamination of pond water by farmers through faecal contamination or by the farm environment.

The distribution of Enterobacteriaceae strains by organ shows that the gills are the area of greatest concentration of isolated Enterobacteriaceae. These results are similar to those obtained by Giatsis *et al.* [16] and Sullam *et al.* [17]. This high presence of bacteria in this part of the fish could be linked to the fact that many bacterial species, including those identified, live in aquatic environments and remain in constant contact with fish [15].

Overall, the strains of Enterobacteriaceae isolated both from Tilapia fish (*Oreochromis niloticus*) and from the waters of fish ponds in the Sud-Comoé region showed high levels of resistance to the antibiotics commonly used in human and veterinary medicine.

5. Conclusion

The general objective of this study is to contribute to the monitoring of antibiotic resistance in enterobacteria from fish ponds in the Sud-Comoé region. The study of the resistance profile of enterobacteria isolated from samples of Tilapia fish (*Oreochromis niloticus*) and fish pond water from the Sud-Comoé region isolated bacteria such as *E. coli*, *Klebsiella pneumoniae*, *Enterobacter spp.* and *Proteus vulgaris* with high levels of resistance to a number of marker antibiotics.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] OMS (2017) Liste prioritaire mondiale des bactéries résistantes aux antibiotiques pour guider la recherche. la découverte et le développement de nouveaux antibiotiques.
- [2] Bouslema, Z., Mkaouer, A., Tliba, I. and Hassine, A.B. (2016) Plan de surveillance des résidus d'antibiotiques dans les poissons d'élevage. *INSTM Bulletin: Marine and Freshwater Sciences*, **43**, 87-90.
- [3] OMS (2016) Plan d'action mondial pour combattre la résistance aux antimicrobiens. 32.
- [4] Samira, S. and Guichard, B. (2009) Bacterial Antibiotic Resistance in Aquaculture. In: Montet, D. and Ray, R.C., Eds., *Aquaculture Microbiology and Biotechnology*, Vol. 1, Science Publishers, 133-157. <https://doi.org/10.1201/b10182-6>
- [5] Ouedraogo, A.S., Pierre, H.J., Banuls, A.L., Ouedraogo, R. and Godreuil, S. (2017) Émergence et propagation de la résistance aux antibiotiques en Afrique de l'Ouest: Facteurs contributifs et évaluation de la menace. *Tropical Health and Medicine*, **27**, 147-154.

- [6] Sidrach-Cardona, R. and Bécares, E. (2013) Résistance des bactéries indicatrices fécales aux antibiotiques dans les zones humides construites expérimentales. *Ecological Engineering*, **50**, 107-111. <https://doi.org/10.1016/j.ecoleng.2012.01.001>
- [7] Sidrach-Cardona, R., Hijosa-Valsero, M., Marti, E., Balcázar, J.L. and Becares, E. (2014) Prévalence des bactéries fécales résistantes aux antibiotiques dans une rivière affectée à la fois par une usine de production d'antibiotiques et par des rejets urbains traités. *Science of the Total Environment*, **489**, 220-227. <https://doi.org/10.1016/j.scitotenv.2014.04.100>
- [8] FAO (2014) Vue générale du secteur aquacole national Côte d'Ivoire. Département des pêches et de l'aquaculture, 9.
- [9] Coulibaly, R. (2010) Analyse de la contribution de la pêche à l'économie ivoirienne. Université de Cocody-Abidjan DESS, Hautes Etudes en Gestion de la Politique Economique Auditrice GPE, 11ème promotion, 30.
- [10] Mohamed, N.S. (2017) Étude de la qualité microbiologique des poissons frais d'eau douce vendus dans la commune urbaine d'Antananarivo.
- [11] Samira, S., Hoangnam Kha, N., Ratanaporn, L., Gérard, L., Thierry, L., Thierry, G. and Didier, M.C. (2004) Département Amélioration des Méthodes pour l'Innovation Scientifique.
- [12] Kathleen, M.M., Samuel, L., Felecia, C., Reagan, E.L., Kasing, A., Lesley, M., Toh, S.C. (2016) Résistance aux antibiotiques de diverses bactéries issues de l'aquaculture à Bornéo. *Revue internationale de microbiologie*, **2016**, Article ID: 2164761. <https://doi.org/10.1155/2016/2164761>
- [13] Cui-Yi, L. (2021) Résistance antimicrobienne d'*E. coli* des fermes aquacoles et de leur environnement à Zhanjiang, Chine.
- [14] Raymond, S.M., Jean, M.N. (2018) Evaluation du niveau de contamination bactériologiques et chimique des poissons pêchés dans les lacs Municipal ,Obili et le cours d'eau Mfoundi, Yaoundé-Cameroun. *Journal of Applied Biosciences*, **125**, 12607-12616.
- [15] Adingra, A.A., Goré Bi, T. and Blé, M.C. (2010) Evaluation de la charge bacterienne chez le tilapia oreochromis niloticus. *Abidjan (Côte d'ivoire) Article Agronomie Africaine*, **22**, 217-225.
- [16] Giatsis, C., Sipkema, D., Smidt, H., Heilig, H., Benvenuti, G., Verreth, J., Verdegem, M. (2015) L'impact de l'environnement d'élevage sur le développement du microbiote intestinal des larves de tilapia. *Rapports scientifiques*, **5**, Article No. 18206. <https://doi.org/10.1038/srep18206>
- [17] Sullam, K.E., Essinger, S.D., Lozupone, C.A., O'Connor, M.P., Rosen, G.L. and Knight, R. (2012) Facteurs environnementaux et écologiques qui façonnent les communautés bactériennes intestinales des poissons: Une méta-analyse. *Molecular Ecology*, **21**, 3363-3378. <https://doi.org/10.1111/j.1365-294X.2012.05552.x>