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Health risks linked to the contamination of fried fish sold on the streets of Abidjan (Côte d'Ivoire) by *Staphylococcus aureus*, *Escherichia coli* and *Bacillus cereus*

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ABSTRACT

Fish has many nutritional benefits that are good for consumers' health. However, fish is highly perishable due to its composition. The objective of this study was to assess the risk of infection associated with the consumption of fried fish contaminated with *Staphylococcus aureus, Escherichia coli*, and *Bacillus cereus*. A total of 291 samples of fried fish from 10 municipalities in Abidjan were analyzed using the isolation and identification method followed by an antibiogram. The prevalence rates were 4.12% (*Staphylococcus aureus*), 0.34% (*Escherichia coli*), and 6.19% (*Bacillus cereus*). *Staphylococcus aureus* was mainly found in sole fish (family Cynoglossidae) from the municipality of Adjame, and *Bacillus cereus* in horse mackerel (family Carangidae) from the municipality of Koumassi. The sensitivity of the bacteria was tested with eight families of antibiotics and revealed that *Escherichia coli* was sensitive to the antibiotics tested. As for *Staphylococcus aureus* and *Bacillus cereus*, the resistance rates observed were 75% and 22.22%, respectively. The resistance rates of the isolated *Staphylococcus aureus* strains were 58.33% (penicillin), 66.67% (sulfonamides-trimethoprim) and 8.33% (aminoglycosides). In contrast, resistance in *Bacillus cereus* was observed in the macrolide (16.67%), lincosamide (11.11%), aminoglycoside (5.56%) and fosfomycin (5.56%) families. Although the cooking process requires high temperatures, fried fish sold in Abidjan poses some risk of infection to consumers. However, only compliance with good hygiene and manufacturing practices will guarantee consumer safety.

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INTRODUCTION

Fish is a foodstuff with high nutritional value, but also a valuable supplement in diets low in protein, vitamins, and essential minerals. It is an important source of food and sustenance worldwide, providing nearly 60% of the protein available to the vast majority of populations, particularly in Africa (FAO, 2016). Its importance in the human diet can be summarized in several points. In addition to being an excellent source of protein, it is rich in essential micronutrients, vitamins (D, A, and B), minerals (calcium, iodine, zinc, iron), and fatty acids (exceptionally rich in omega-3 long-chain polyunsaturated fatty acids) (Médale and Kaushik, 2008; Rasul *et al.*, 2021). Furthermore, consumption of this foodstuff is believed to be beneficial in the prevention of various diseases, including cardiovascular disease, prostate cancer, immunological disorders, and neurological and cardiovascular growth disorders in infants and children (Shahidi, 2004; Sirot, 2010). Despite the benefits associated with eating fish, studies have shown that poor handling and storage techniques are sources of contamination for these foods by bacteria such as *Salmonella*, thermotolerant coliforms (*Escherichia coli*), presumed pathogenic *Staphylococcus*, anaerobic sulfite-reducing bacteria, yeasts and molds, total aerobic mesophilic flora, *Bacillus cereus*, etc., exposing consumers to foodborne infections and making fish consumption a public health issue (OMS, 2003; Adedeji *et al.*, 2012; Hamade, 2024). Approximately 91 million cases of foodborne illness are observed in Africa each year (OMS, 2015). In addition, fish consumption was suspected to be the cause of 8% of collective food poisoning cases observed in France in 2016, and the suspected pathogens in 6% of cases were *Bacillus cereus*, 5% *Staphylococcus aureus*, and 3% *Clostridium perfringens* (SPF, 2021). According to Olsen *et al.*, (2000) and Schlundt, (2002), fish is implicated in 25% of foodborne illnesses in the United States. Just as there are several types of poisoning linked to food contamination, there is also another worrying scourge in the field of public health and agri-food, namely the emergence of resistant microorganisms. Indeed, numerous resistances have been observed in several bacteria, with rates reaching 100% for certain antibiotics (acquired resistance of *Staphylococcus saprophyticus* to Fosfomycin and Novobiocin) (CA-SFM/EUCAST, 2017).

In Côte d'Ivoire, and more particularly in the city of Abidjan, fish remains the most accessible food for many households, even the most modest, with an average consumption of around 24.9 kg per capita per year (Kouadio *et al.*, 2023). Fish has the advantage of being cheaper than meat and provides nearly 70% of the animal protein consumed by the population (Monney *et al.*, 2022). Several techniques are used to cook fish, including frying. Fried fish is particularly popular and is often eaten in restaurants, maquis (small local restaurants), and homes. Fried fish is appreciated for its taste and crispy texture, and is often accompanied by traditional dishes such as attieke (*Cassava semolina*) and fried plantains.

Although this technique is commonly used for cooking fish, there is still no scientific data on the bacteria that may be responsible for the microbiological risk of fried fish, let alone bacteria that may be resistant to antibiotics. In this context, it would be wise to assess the risk associated with the consumption of fried fish in the city of Abidjan due to bacteria such as *Staphylococcus aureus, Escherichia coli,* and *Bacillus cereus.*

MATERIALS AND METHODS

The biological material (Fig. 1) consisted of fried fish from Sosso (*Dicentrarchus labrax*), tuna (*Thunnus* spp), sole (*Solea solea*), mackerel (*Scomber scombrus*), carp (*Cyprinus* spp), and horse mackerel (*Trachurus trachurus*).

Study sites and selection criteria

Samples were collected in ten districts of the city of Abidjan, notably in the districts of Cocody (Allocodrome market), Bingerville (market), Abobo (market), Yopougon (Siporex market), Port-Bouet (market), Blokauss (market), Adjame (market), Attecoube (market), Koumassi (large market), and

Marcory (large market). These municipalities were chosen for their popularity and, above all, for the large number of places selling fried fish. The sales sites selected were those located in restaurants and in certain markets in various municipalities. The fish were sampled by type and packaged in food packaging by the traders, then transported in an aseptic cooler containing ice to the laboratory for analysis.

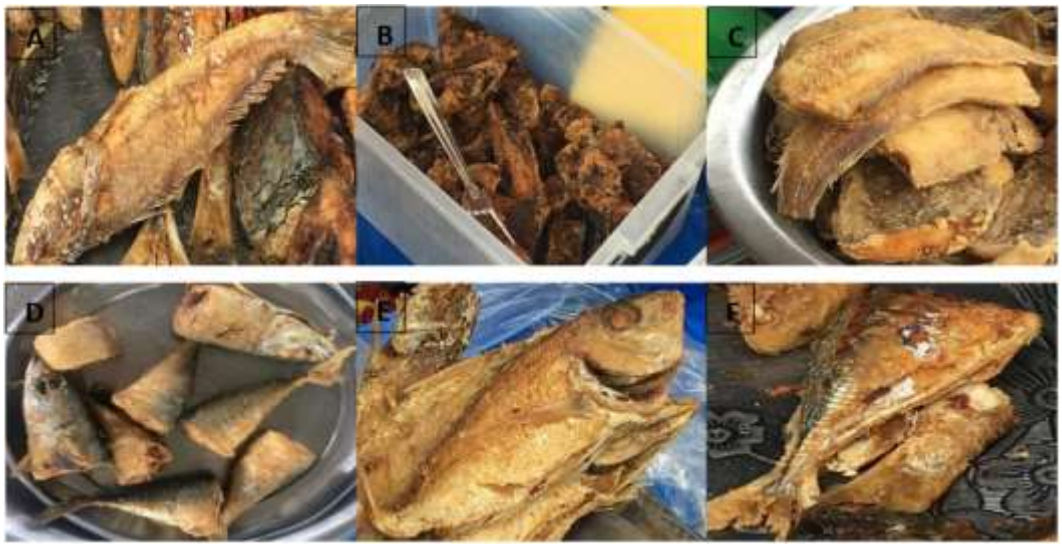

Fig. 1. Different types of fried fish used **A**: Sosso (*Dicentrarchus labrax*); **B** : Tuna (*Thunnus* spp); **C**: Sole (*Solea solea*); **D** : Mackerel (*Scomber scombrus*) ; **E** : Carp (*Cyprinus* spp); **F** : Horse Mackerel (*Trachurus trachurus*)

Table 1. Distribution of samples analyzed according to sampling sites

Sampling sites	Carp (*Cyprinus* spp)	Tuna (*Thunnus* spp)	Horse Mackerel (*Trachurus trachurus*)	Sole (*Solea solea*)	Mackerel (*Scomber scombrus*)	Sosso (*Dicentrarchus* labrax)	Total
Cocody	0	6	3	6	6	3	24
Bingerville	0	6	3	0	0	3	12
Abobo	3	6	3	6	0	3	21
Yopougon	3	6	3	6	6	6	30
Port-Bouët	0	6	6	6	6	6	30
Blokauss	6	6	6	6	6	6	36
Adjame	6	6	6	6	6	6	36
Attecoube	6	6	6	6	6	6	36
Marcory	6	6	6	6	6	6	36
Koumassi	6	6	6	6	6	0	30
Total	36	60	48	54	48	45	291

Sample size

The distribution of samples according to fish species (6) and sampling areas (10) is shown in Table 1. According to this table, 291 fish samples were collected, including 36 carp (*Cyprinus* spp), 60 tuna (*Thunnus* spp), 48 horse mackerel (*Trachurus trachurus*), 54 sole (*Solea solea*), 48 mackerel (*Scomber scombrus*), and 45 sosso (*Dicentrarchus labrax*).

Isolation of *Escherichia coli* strains

The isolation of *Escherichia coli* strains consisted of inoculating 0.1 mL of the inoculum (stock suspension) onto Rapid *E. coli* 2 agar using the spread technique, then incubating the Petri dishes at 44°C for 24 hours. After 24 hours, the characteristic smooth, S-type, purple-colored colonies were transferred to Plat Count Agar for bacterial identification.

Isolation of *Staphylococcus aureus* strains

This step consisted of inoculating 0.1 mL of the stock suspension onto Petri dishes containing Baird Parker agar supplemented with potassium tellurite and egg yolk using the spread plate technique, then incubating

the Petri dishes at 37°C for 48 hours. At the end of the incubation period, the black, shiny colonies with a clear halo (due to protease) and an opaque zone (due to lipase) were transferred to Plat Count Agar for bacterial identification.

Isolation of *Bacillus cereus* strains

To isolate *Bacillus cereus* strains, 0.1 mL of the stock suspension was seeded onto Petri dishes containing Mössel agar supplemented with egg yolk and Polymyxin B using the spread plate technique, then incubated at 30°C for 48 hours. At the end of 48 hours, pink colonies with a clear halo around the colony (protease) and an opaque halo around the culture (lecithinase) were transferred to Plat Count Agar for bacterial identification.

Identification of presumptive *Escherichia coli* strains

Escherichia coli was identified from characteristic colonies obtained on Rapid'*E. coli* medium using the standard bacteriological method for identifying Enterobacteriaceae, as described by Le Minor and Richard (1993).

Identification of presumptive strains of *Staphylococcus aureus*

The identification of presumptive colonies of *Staphylococcus aureus* was performed using Gram staining, catalase, oxidase, mannitol fermentation and motility tests, DNAse and free staphylocoagulase tests.

Identification of presumptive strains of *Bacillus cereus*

Presumptive strains of *Bacillus cereus* were confirmed using Gram staining and catalase tests. Microscopic observation of Gram staining also revealed the spores of *Bacillus cereus*, which are colorless.

Antibiogram of strains

Antibiotic sensitivity was determined using the agar diffusion technique described by the Antibiogram Committee of the French Society of Microbiology (CA-SFM/EUCAST, 2017).

The method used was the antibiotic disc diffusion technique in agar medium on Muller-Hinton medium. The antibiogram was performed with 24-hour-old strains. To do this, strains of *Staphylococcus aureus*, *Escherichia coli*, and *Bacillus cereus* were seeded on PCA (Plat Count Agar) at 37°C for 24 hours, which yielded isolated, young colonies. Bacterial suspensions were then prepared by placing a fragment of the colonies in a saline solution (0.9% sterile physiological saline) to achieve a turbidity equivalent to that of the 0.5 McFarland standard. Seeding was performed by vertically applying the tip of a swab dipped in the bacterial suspension to the entire Muller-Hinton agar, then the plates were left to dry for 5 minutes at room temperature before the antibiotics were applied. The antibiotic discs were then placed using a disc dispenser due to a maximum limit. The different families of antibiotics tested, their load, and the critical interpretation diameters of the discs applied during the study enabled the sensitivity of the *Staphylococcus aureus*, *Escherichia coli*, and *Bacillus cereus* strains to be determined.

After 24 hours of incubation, the inhibition zones were read using ADAGIO, a system consisting of data management software and an imaging device connected to a computer. ADAGIO automatically measures and processes the sizes of the bacterial inhibition zones around the antibiotic discs in order to interpret the different bacterial phenotypes. The different diameters of the inhibition zones obtained around the antibiotic discs were interpreted as Susceptible (S), Intermediate (I), or Resistant (R) according to the criteria defined by CA-SFM/EUCAST, (2017).

RESULTS

Contamination rate of samples and frequency of germ isolation

The analyses carried out showed that 89.3% of the samples were not contaminated with the germs being tested for. However, 10.7% of the samples were contaminated. The prevalence of contaminating germs was 4.12% (12 strains) for *Staphylococcus*

aureus strains, 6.19% (18 strains) for *Bacillus cereus*, and 0.34% (1 strain) for *Escherichia coli* (Table 2).

Table 2. Overall contamination level of the samples analysed

Not contaminated	*S. aureus*	*B. cereus*	*E. coli*
89.3%	4.12%	6.19%	0.34%

Sample contamination rates according to sampling site

Depending on the origin of the samples, *Escherichia coli* was isolated only in the municipality of Adjame, representing 100% of samples. A single strain of *Bacillus cereus* was isolated in Bingerville (5.56%) and Yopougon (5.56%).

In the municipality of Port-Bouet, six strains were isolated (33.33%), in Adjame two strains were isolated (11.11%), and eight strains were isolated in the municipality of Koumassi (44.44%). It appears that Koumassi is the municipality with the highest incidence of *Bacillus cereus*, while no strains of *Bacillus cereus* were isolated in the municipalities of Cocody, Abobo, Blokauss, Attecoube, and Marcory (Table 3).

As for *Staphylococcus aureus* strains, seven strains were isolated in the municipality of Adjame (58.33%), and two strains, or 16.67%, were isolated in the municipality of Bingerville. In the municipalities of Cocody, Port-Bouet, and Attecoube, one strain was isolated, representing a frequency of 8.33%. The municipality with the highest incidence of *Staphylococcus aureus* is Adjame, while no *Staphylococcus aureus* strains were isolated in the municipalities of Abobo, Yopougon, Blokauss, Marcory, and Koumassi (Table 3).

Table 3. Frequency of occurrence of *Bacillus cereus*, *Staphylococcus aureus* and *Escherichia coli* strains by municipality

Municipalities	Target microorganisms		
	Bacillus cereus	*Staphylococcus aureus*	*Escherichia coli*
Bengerville	6%	17%	
Yopougon	6%		
Port-Bouet	33%	8%	
Adjame	11%	58%	
Koumassi	44%		
Attecoube		8%	
Abobo			100%
Cocody		8%	

Table 4. Frequency of occurrence of *Bacillus cereus*, Staphylococcus aureus and *Escherichia coli* strains according to the species of fried fish analyzed

Microorganisms	Fried fish					
	Mackerel	Sole	Sosso	Horse Mackerel	Tuna	Carp
Bacillus. cereus	22%	11%	11%	33%	22%	0
Staphylococcus aureus	ND	25%	8%	25%	8%	8%
Escherichia coli	ND	ND	ND	ND	100%	ND

ND: not detected

Contamination rates of samples according to fish type

Analysis of the samples showed variability in contamination by the bacteria tested for. Of all the fried fish collected, only tuna was contaminated with *Escherichia coli*. One strain of *Escherichia coli* was isolated from a sample of tuna from the municipality of Abobo.

Bacillus cereus strains were isolated from six (33.33%) of the horse mackerel samples. As for mackerel, four strains of *Bacillus cereus* were isolated, representing 22.22%, and four strains (22.22%) were also isolated from tuna. In sole and sosso fish, two strains were isolated in each matrix, representing 11.11% respectively. The highest rate of *Bacillus cereus* strains was found in the horse

mackerel samples (33.33%), while no *Bacillus cereus* strains were found in the carp samples (Table 4).

According to Table 4, six strains of *Staphylococcus aureus* (50%) were isolated from sole samples, three (25%) were isolated from horse mackerel, and one strain was isolated from tuna, sosso, and carp, accounting for 8.33%. The sole species was the most contaminated with *Staphylococcus aureus* strains (50%), while no *Staphylococcus aureus* strains were found in the mackerel samples.

Phenotypic profile of bacterial resistance to antibiotics

By measuring the diameter of the inhibition zones for each strain for each of the antibiotics tested, the strains were characterized as sensitive, resistant, or intermediate.

Antibiotic resistance profiles

Escherichia coli

Analysis of the resistance profile of the single strain of *Escherichia coli* isolated from tuna from the municipality of Adjame shows that it is sensitive to all families of antibiotics tested in this study. *Escherichia coli* strain was sensitive to β-lactam families (AMP, AMC, AMX, CTX, CAZ, FEP, FOX), quinolones (NAL, NOR, CIP), aminoglycosides (GME, TMN, AKN), and other families such as phenicols (CHL), sulfamide-trimethoprim (SXT) and tygecyclin (TGC) (Fig. 2).

Staphylococcus aureus

The resistance profiles of the twelve strains of *S. aureus* were determined for fifteen antibiotics. The antibiogram of the *S. aureus* strains revealed that 75% of the strains (09) were resistant to various antibiotics, including 58.33% to penicillin, 8.33% to the aminoglycoside family (tobramycin, kanamycin, and amikacin), except for gentamicin, to which they were 100% sensitive, 66.67% to trimethoprim, and 16.66% to trimethoprim/sulfamethoxazole. However, sensitivities were observed in the second-generation cephalosporin, glycopeptide, fluoroquinolone, macrolide, lincosamide, and other families tested (Fig. 3).

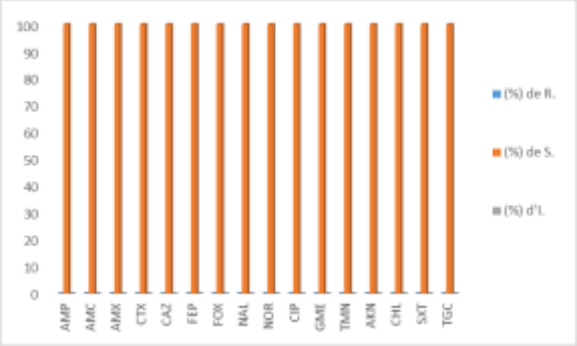

Fig. 2. Resistance profile of the *E. coli* strain

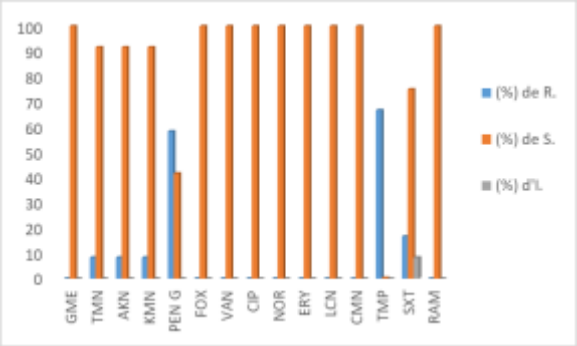

Fig. 3. Resistance profile of *S. aureus* strains

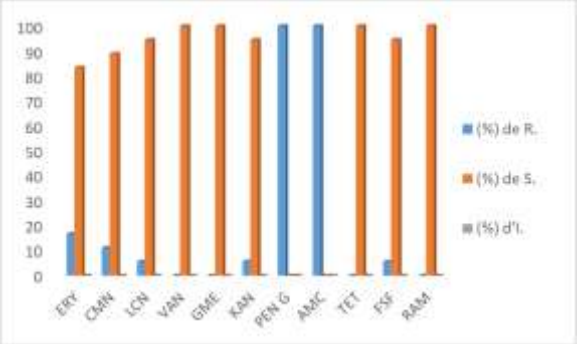

Fig. 4. Resistance profile of *B. cereus* strains

Bacillus cereus

Eleven antibiotics were used to perform the antibiogram on 18 *Bacillus cereus* strains. The different families of antibiotics tested were β-lactams (AMC, PEN G), macrolides and lincosamides (ERY, CMN, LCN), aminoglycosides (GME, KAN), and other families such as glycopeptides (VAN), aminopenicillin tetracyclines (TET), fosfomycin (FSF), and rifampicin (RAM). The test revealed a resistance rate of 22.22% (four strains) among *Bacillus cereus* strains to the macrolide and lincosamide family, aminoglycosides, and fosfomycin. The study therefore found a resistance rate of 16.67% to the macrolide family,

11.11% to the lincosamide family, 5.56% to the aminoglycoside family, and 5.56% to other families, including fosfomycin. In addition, natural resistance to the β-lactam families (penicillin and aminopenicillin) tested was observed in 100% of the strains tested (Fig. 4).

DISCUSSION

For most foodborne illnesses or food poisoning caused by fish consumption, processing methods are relatively inadequate, resulting in spoilage of the processed fish. Therefore, smoking, drying, salting, frying, fermentation, or a combination of these traditional methods of treatment and preservation are used to improve the stability of fish (Ndife *et al.*, 2022).

Furthermore, frying, which is an easily available means of preserving fish, is one of the main methods of processing fish.

In our study, the fish most contaminated by *Bacillus cereus* strains was the horse mackerel (*Trachurus trachurus*), unlike the carp (*Cyprinus* spp), in which no *Bacillus cereus* strains were found. As for *Staphylococcus aureus* strains, they were absent in the mackerel (*Scomber scombrus*) species and were most commonly found in the sole (*Dicentrarchus labrax*) species. Microbes inherent in fish are killed by frying. Therefore, any microbial contamination on fried fish is considered to be the result of contamination after frying.

Microbes on fried fish are considered to originate from handling after frying by retailers, buyers, and the place of sale (Simiyu *et al.*, 2021).

Most foodborne illnesses or food poisoning related to fish consumption are linked to processing and preservation methods. Smoking, drying, salting, frying, fermentation, or a combination of these traditional processing and preservation methods are used to improve the stability of fish (Ndife *et al.*, 2022). Frying, an accessible means of preserving fish, is one of the main methods of fish processing.

In this study, fish were analyzed. The fish most contaminated with *Bacillus cereus* strains was horse mackerel (*Trachurus trachurus*), unlike carp (*Cyprinus* spp), in which no *Bacillus cereus* strains were found. As for *Staphylococcus aureus* strains, they were absent in mackerel (*Scomber scombrus*) and were most often found in sea bass (*Dicentrarchus labrax*). Fried fish should be free of microbes. Therefore, any microbial contamination on fried fish is considered to be the result of contamination after frying. Microbes present on fried fish are considered to originate from handling after frying by retailers, buyers, and the point of sale (Simiyu *et al.*, 2021).

In a similar study conducted in Nigeria by (Ohalete *et al.*, 2013) on fried and smoked fish, 10 germs were isolated, including those found in this study. The presence of *Bacillus*, a germ capable of spore formation, and *Staphylococcus aureus*, capable of secreting heat-stable toxins, may pose a risk to consumer health. Hygiene measures must be observed during and after frying food (Teklemariam *et al.*, 2015). According to Osarenmwinda *et al.* (2019), poor personal hygiene and failure to follow good hygiene practices during the preparation, storage, and packaging of cooked and fried street food ready for consumption increase the risk of contamination.

The municipality of Koumassi had the highest incidence of *Bacillus cereus*, while Adjamé had the highest incidence of *Staphylococcus aureus*. These bacteria are potentially pathogenic. A study in China showed that ready-to-eat foods, although very convenient for consumers, are frequently contaminated with pathogenic bacteria such as *Bacillus cereus*, *Listeria monocytogenes*, and *Staphylococcus aureus* (Hwang and Park, 2015; Yang *et al.*, 2016). *Bacillus cereus* can contaminate a wide variety of foods. Its spores are highly adhesive, making them resistant to cleaning processes. Food poisoning by *Bacillus cereus* manifests as vomiting and diarrhea, although most cases are mild and resolve spontaneously.

However, the emetic toxin (cereulide) secreted by *Bacillus cereus* is often responsible for fatal food poisoning (Leong *et al.*, 2023).

The frequency of occurrence of *Bacillus cereus* isolated from fried fish in this study was 6.19%, lower than the value obtained (25.2%) by Yobouet *et al.*, (2016) during his work in Côte d'Ivoire on the contamination of attiéké and raw milk by *Bacillus cereus*. The different nature of the biological matrices can explain this difference. The isolated *Bacillus cereus* strains possessed spores, which could explain their presence in the analyzed samples despite frying. Their presence can also be explained by inadequate storage (thawing and refreezing) of fresh fish and inappropriate handling of these products during sale (N'Guessam *et al.*, 2018). According to Amor, (2019), foods that have undergone heat treatment are often implicated in *Bacillus cereus* food poisoning. Besides foodborne illnesses, *Bacillus cereus* can also cause non-gastrointestinal diseases such as endocarditis and endophthalmitis (Drobniewski, 1993). As for *Staphylococcus aureus*, it is commensal with the handler and is therefore heavily involved in most food poisoning worldwide. The prevalence of *Staphylococcus aureus* during the study was 4.12%. This value remains lower than that obtained in 2021 by Zinzendorf *et al.* (2021), which was 28.3% isolated from various foods.

Contamination of fried fish samples by Staphylococcus aureus can be explained by improper food handling (or even poor sanitary conditions) or by exposing the fish to room temperature after frying. *Staphylococcus aureus* food poisoning is one of the most frequent causes of gastroenteritis and the second most frequently reported type of foodborne illness worldwide (Schelin *et al.*, 2011). *Staphylococcus aureus* produces a wide variety of extracellular toxins.

Staphylococcal enterotoxins (ES) have proven emetic activity. These toxins are resistant to proteolytic enzymes in the human digestive tract and to heat (Schelin *et al.*, 2011).

The frequency of *Escherichia coli* isolation was 0.34%. Although low, the presence of *Escherichia coli* suggests possible fecal contamination and raises questions about vendors' hygiene practices. The level of *Escherichia coli* contamination is lower than the 29.87% obtained by Kouamé (2018) in their study on the resistance of *Escherichia coli* isolates in bovine excrement from the Port-Bouet slaughterhouse (Abidjan). This difference is entirely logical since the digestive tract is the natural reservoir of *Escherichia coli*.

Antibiotic resistance is a major issue for both human and animal health. The emergence and spread of antibiotic-resistant strains of bacteria are calling into question the effectiveness of these treatments. Preserving the effectiveness of antibiotics is therefore a real public health challenge, requiring an integrated approach based on the One Health concept, which promotes a unified approach to human and animal health.

In our study, antibiotic sensitivity testing of the isolated *Escherichia coli* strain revealed that it was 100% sensitive to all antibiotics tested. These analysis results differed from those of Pormohammad *et al.* (2019). These authors reported an increase in *Escherichia coli* resistance to antibiotics in their study. Furthermore, their results showed that the prevalence of ESBL antibiotic resistance and multidrug-resistant *Escherichia coli* strains was higher in animal isolates than in human isolates (Pormohammad *et al.*, 2019).

As for the *Staphylococcus aureus* strains isolated during this study, tests showed that 25% were sensitive to antibiotics and 75% were resistant. Resistance to aminoglycosides is a major current problem in the clinical field. Aminoglycosides act on the bacterial ribosome, and strains that exhibit such resistance do so by producing enzymes (Mainardi, 2015). These enzymes have several modes of action, which are either modification of the ribosomal target or modification or efflux of the antibiotic. Among the *Staphylococcus aureus* strains isolated, one strain showed resistance to aminoglycosides (8.33%),

particularly kanamycin, tobramycin, and amikacin, thus presenting a KTR phenotype. Other resistances were to sulfonamide-trimethoprim (66.67%) and penicillin (58.33%). Resistance to sulfonamide-trimethoprim is due to a mutation in microbial DNA. As for penicillin resistance, it shows that the isolated strains possess penicillinase or β-lactamase. This enzyme allows them to render the antibiotic inactive at the bacterial wall level. It can be observed that the resistance rates of *Staphylococcus aureus* obtained in this study remain generally lower than those obtained in Algeria by Wafaa (2013), particularly for penicillin (62.96% of resistant strains obtained in Algeria) and aminoglycosides (18.51% of resistant strains obtained in Algeria).

All strains of *Bacillus cereus* were resistant to penicillin and aminopenicillin tested; this allows us to confirm the identification of the isolated strains, as the *Bacillus cereus* species is naturally resistant to penicillin G, amino- and carboxy-penicillin, and cephalosporins (CA-SFM/EUCAST, 2017). In this study, 22.22% of *Bacillus cereus* strains were resistant to the tested antibiotics, while 77.78% were susceptible. Resistance was observed with antibiotics (macrolides, lincosamides, aminoglycosides) that normally act on the ribosome and bacterial cell wall (fosfomycin). The percentages of antibiotic resistance were 5.56% for fosfomycin, 16.67% for erythromycin, 11.11% for clindamycin, 5.56% for lincomycin, and 5.56% for kanamycin. This indicates that *Bacillus cereus* strains produce enzymes capable of altering the structure or targets of these antibiotics or that they exhibit active efflux mechanisms. In other studies, the authors have reported multidrug resistance in some *Bacillus cereus* strains.

This is the case of Yobouet *et al.* (2016), which isolated strains of *Bacillus cereus* resistant to tetracycline (94.8%), vancomycin (56.4%), gentamicin (70.9%), erythromycin (66.3%), and clindamycin (83.7%). Our results, however, remain lower.

This study revealed a real risk of consuming fried fish contaminated with pathogenic species of the genera *Staphylococcus aureus*, *Escherichia coli*, and *Bacillus cereus* sold in the municipalities of Abidjan. The probabilities are 4.12% for *Staphylococcus aureus*, 0.34% for *Escherichia coli*, and 6.19% for *Bacillus cereus*. *Staphylococcus aureus, Escherichia coli*, and *Bacillus cereus* strains are important pathogens that can produce intestinal enterotoxins that cause diseases such as gastroenteritis, diarrhoea (sometimes bloody), and vomiting. These pathogens have already been implicated in numerous epidemics leading to deaths.

Compliance with food storage rules, good handling practices, and hygiene rules for staff, utensils, and sales premises by retailers should help reduce the risk of contamination. For consumers, it would be advisable to favour hot meals, avoid vendors whose food is not protected, and also follow hygiene rules in order to protect their health.

CONCLUSION

This study was conducted as part of an assessment of the risk of infection associated with the consumption of fried fish sold in the municipalities of Abidjan through contamination by pathogenic species of the genera *Staphylococcus aureus*, *Escherichia coli*, and *Bacillus cereus*. It assessed the risk of consuming fried fish due to the presence of *Bacillus cereus*, *Escherichia coli*, and *Staphylococcus aureus* and studied the antibiotic resistance of these bacteria. Strains of *Staphylococcus aureus*, *Escherichia coli*, and *Bacillus cereus* were isolated from fried fish. Samples of unsatisfactory microbiological and sanitary quality, and therefore likely to pose a risk to consumer health, were also identified due to the presence of these strains in the fish sold. The determination of the resistance profiles of the strains of *Staphylococcus aureus*, *Escherichia coli*, and *Bacillus cereus* isolated from fried fish shows that they possess mechanisms of resistance to certain families of antibiotics. This indicates that antibiotic-resistant bacterial strains are emerging. The consequence would be the spread of this resistance to other pathogenic bacteria and difficulty in treating infections caused by resistant bacteria.

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