Available online on 15.08.2024 at http://jddtonline.info

Journal of Drug Delivery and Therapeutics

Open Access to Pharmaceutical and Medical Research

Open Access Full Text Article

Research Article

Phenotypic characterization and antibiotic resistance of enterobacteria strains isolated from samples of patients in the towns of Moundou and Sarh in Chad

Kadidja Gamougam[1], Mayoré Atéba Djibrine[2]*, Abdoulahi Ousman Hissein[3], Abdelsalam Tidjani[3]

[1] *Laboratoires du Centre Hospitalier – Universitaire de Référence Nationale (CHU-RN) de N'Djamena-Tchad. BP 130*

[2] *Institut National Supérieur du Sahara et du Sahel d'Iriba, Tchad*

[3] *Faculté des Sciences de Santé Humaine, Université de N'Djamena, P.O. Box 1117, N'Djamena-Tchad*

Article Info:

Article History:

Received 17 May 2024
Reviewed 28 June 2024
Accepted 21 July 2024
Published 15 August 2024

Cite this article as:

Gamougam K, Djibrine MA, Hissein AO, Tidjani A, Phenotypic characterization and antibiotic resistance of enterobacteria strains isolated from samples of patients in the towns of Moundou and Sarh in Chad, Journal of Drug Delivery and Therapeutics. 2024; 14(8):22-27

DOI: http://dx.doi.org/10.22270/jddt.v14i8.6719

*Address for Correspondence:

Mayoré Atéba Djibrine, Institut National Supérieur du Sahara et du Sahel d'Iriba, Tchad

Abstract

Today, enterobacteria constitute one of the most predominant causes of nosocomial and acquired infections in our communities. The bactericidal action of antibiotics on bacteria is used therapeutically, unfortunately the latter have started to develop resistances. Antibiotic resistance remains a major global public health issue, a serious problem in some of the world's poorest countries such as Chad.

The objective of this study is to identify the strains of enterobacteria coming from samples of patients admitted to the Moundou and Sarh health centers, and to report their resistance profiles. A total of 278 samples consisting of urine (133) and stools (145) were collected in the laboratories of the two provincial hospitals of Sarh and Moundou between September and December 2021. The samples were processed and analyzed according to standard microbiology methods. The study of the sensitivity of different strains of enterobacteria with 14 antibiotic disks was evaluated by the disk diffusion method in agar medium.

A total of 278 samples (urine, stool) including 111 strains of Enterobacteria, including 55 strains of *E. coli*, *Enterobacter* spp (n=17), *klebsiella* (n=11), *Salmonella* (n=9), *Serratia* (n=7), *Citrobacter* (n=6) and *Shigella* (n=2) were isolated in the laboratory in the towns of Moundou and Sarh in Chad. The antibiogram carried out on all isolated strains of enterobacteria expressed a resistance ranging between 33.3% and 83.3% to 3rd generation cephalosporins, 30.3% and 50.0% to aminoglycosides. On the other hand, a strain of *Salmonella* is resistant to imipenem in Sarh.

This study shows a high level of resistance acquired to different families of antibiotics by our bacterial strains studied. This resistance highlights the need to adapt therapeutic regimens to local epidemiology.

Keywords : Characterization, Phenotype, Antibiotic resistance, Enterobacteria, Cities, Chad.

INTRODUCTION

Consumption of antibiotics kills the bacteria that cause disease and also kills those that protect the body against infections1. According to Public Health France, at the molecular level, resistance to antibiotics results either from chromosomal mutations (modification of genes already present) or from the acquisition of plasmids which are transmitted from bacteria to bacteria[2]. Plasmid resistance is the most widespread (80% of acquired resistance) and can concern several antibiotics, or even several families of antibiotics, in which case we speak of multi-resistance[2].

In the United States, infections caused by antibiotic-resistant germs are difficult and sometimes impossible to treat[3]. Beta-lactams (mainly cephalosporins and extended-spectrum carbapenems) and fluoroquinolones are the main therapeutic choices to treat infections caused by these microorganisms[4]. However, resistance to these compounds has been reported more and more frequently in Europe in recent years[4,5].

The main causes associated with this antibiotic resistance are overuse, inappropriate prescription, extensive agricultural use as well as the regulatory obstacle to the development of new antibiotics. Unlike developed countries, in developing countries, antibiotics are not regulated and can be found over the counter[6,7].

The impact of antibiotic resistance has health and economic consequences[8,9]. In sub-Saharan Africa, the mortality rate linked to antimicrobial resistance is estimated at 27.3 deaths per year per 100,000 inhabitants[9].

In Chad, some work carried out by independent researchers revealed strong resistance in a wide variety of sample types[10, 11, 12, 13, 14, 15, 16].

The objective of this study is to identify the strains of enterobacteria coming from samples of patients admitted to the Moundou and Sarh health centers, and to report their resistance profiles.

MATERIAL AND METHODS

Period, setting and location of study

This prospective and transversal study, which took place in two stages, was conducted in two main cities in the south of Chad, namely Moundou and Sarh.

A first stage took place from September to December 2021, and related to the collection of samples, their cultivation and conservation of the strains in the provincial hospitals of the respective cities.

A second stage which was carried out from February to April 2022, concerned the transport of the strains to the laboratory of the National University Reference Hospital Center (CHU-RN) of N'Djamena, their awakening, their identification and the antibiogram.

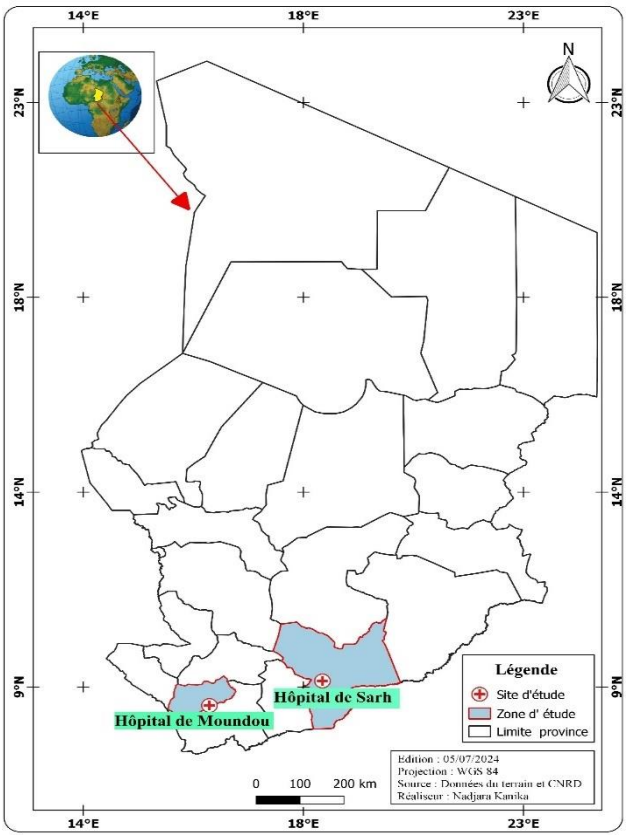

Figure 1: Geographic location of the study sites (Jean-Pierre Gami et Hassan Nadjara Kanika, 2022)

Sampling

The study involved 278 samples from 2 types of samples taken from hospitalized or non-hospitalized users were collected from 133 urines and 145 stools from patients of all ages in the pots and cultured them.

Isolation and identification of bacteria

The culture was carried out on CLED (Citrate Lactose Electrolyte Deficient) agar media for urine, Mac Conkey supplemented with ceftriaxone for stools. All strains preserved in Trypcase soy agar were brought back to the CHU-RN laboratory for reisolation, identification and antibiogram.

Morphological identification by Gram staining and biochemical identification by the oxidase test and using API 20E galleries from Biomérieux and Enterosystem 18R. The digital profile of the strain was established and interpreted according to the API 20E analytical catalog (bioMérieux, France) or Enterosystem 18R from Liofilmchem to determine the name.

Antimicrobial susceptibility testing

The antibiogram was carried out by the diffusion method or Kirby Bauer by flooding with an inoculum at the Optical Density (OD) of 0.5 McF on Muller Hinton medium with 14 antibiotic disks in 120 square Petri dishes. mm. This method was used for all strains. The interpretation of the diameters as Sensitive (S), Intermediate (I) or Resistant (R) was done in accordance with the standards of the Antibiogram Committee of the French Society of Microbiology[17]. The reading was done on the basis of the inhibition diameters. E. coli ATCC 25922 was used as a control strain. The antibiotics used were: Beta-Lactamines Ampicillin (10µg), Amoxicillin + Clavulanic Acid (10µg), Ticarcillin (75µg), Cefalotin (30µg), Cefotaxime (30µg), Ceftriaxone (5µg), Imipenem (10µg), Meropenem (10µg)); Aminosides Gentamicin (30 µg, 10 µg), Amikacin (30 µg)); Quinolone and Fluoroquinolones Nalidixic acid (30 µg), Ciprofloxacin (5 µg), Levofloxacin (5 µg)); Sulfonamides, Trimethoprim-sulfamethoxazole (1.25/23.75µg)).

Resistance phenotypes to β-lactams, aminoglycosides, quinolones, and various antibiotics were determined for all strains. The strains were subjected to the synergy test for the search for ESBL according to the recommendations of EUCAST (2017)[18]. The synergy test was carried out by placing the AMC and C3G (ceftriaxone, cefotaxime, cefixime) or aztreonam discs 3 cm apart. The presence of ESBL was revealed by the appearance of synergy between the discs giving a so-called "champagne cork" appearance.

Data processing Statistical analyzes of data

The data collected was entered into Excel and analyzed using Statistical Package for the Social Sciences (SPSS) and Excel software. Differences were considered significant when $p < 0.05$.

RESULTS

Prevalence of enterobacteria

A total of 278 samples were collected in the 2 hospitals in cities located in the south of the country (see Figure 1), including 145 stools and 133 urine. The results are presented in Tables 1.

Of the 278 samples (urine and stool combined) analyzed, the overall prevalence of enterobacteria was 39.92%. Of the 111 strains of enterobacteria isolated, we note a predominance of *Escherichia coli* (n=55) followed by the genus *Enterobacter* (n=17) and *klebsiella* (n=11).

The *Salmonella* genus is found mainly in Moundou (8/9) as is the *Serratia* genus in Sarh (n=7). The genera *Citrobacter* (n=6) and *Shigella* (n=2) are identified only in Sarh and the genus *Proteus* (n=4) only in Moundou (Table 2).

Table 1 : Distribution of germs by sample type

Germs	Sample type		Total
	Stools (n = 145)	Urine (n = 133)	
Citrobacter freundii	00	06	06
Enterobacter Spp	09	08	17
Escherichia coli	34	21	55
Klebsiella Spp	07	04	11
Proteus mirabilis	02	02	04
Salmonella Spp	07	02	09
Serratia Spp	02	05	07
Shigella flexneri	00	02	02
Total	**61**	**50**	**111**

Table 2: Distribution of Enterobacteria by site

Germs	Collection site		Total	Proportion
	Moundou	Sarh		(%)
Citrobacter freundii	00	06	06	2.15
Enterobacter Spp	11	07	17	6.11
Escherichia coli	26	29	55	19.78
Klebsiella Spp	03	08	11	3.95
Proteus mirabilis	04	00	04	1.43
Salmonella Spp	08	01	09	3.24
Serratia Spp	01	06	07	2.52
Shigella flexneri	00	02	02	0.72
Total	**53**	**59**	**111**	**39.92**

Enterobacteriaceae resistance phenotypes

The samples of 2 pathological products are examined by culture, biochemical identification and antibiogram carried out with selected antibiotic disks. The following results are observed :

In Sarh as well as in Moundou, the germs identified have varying sensitivity to the antibiotics tested. The overall resistance to aminopenicillins and 1st generation cephalosporins for the 2 cities is between 91 and 98%. For 3rd generation cephalosporins, the resistance rate is generally higher in Sarh than in Moundou; but remains the same in the 2 cities 75.8% in Sarh and 80.7% in Moundou for *Escherichia coli* with ceftriaxone, an extended spectrum beta-lactamase. No carbapenemase in Moundou, but in Sarh a strain of *Salmonella* resistant to imipenem. The strains have reduced sensitivity to quinolones and fluoroquinolones, much more resistance to nalidixic acid on average 78% for the 2 cities for *Escherichia coli*. *Salmonella*, *Shigella* and *Serratia* strains have good sensitivity (100%) to fluoroquinolones and aminoglycosides in Sarh, whereas in Moundou the *salmonella* strains are 62.5% resistant to ciprofloxacin and 37.5% to levofloxacin. A sensitivity to aminoglycosides of around 40%, but Amikacin still remains a little more active than gentamicin. Trimethoprim/Sulfonamides remain the least active antibiotic of all the strains identified. They are even 100% resistant to *Escherichia coli*, *Klebsiella*, *Enterobacter*, *Serratia* (K.E.S), *Shigella* and *Salmonella* in Sarh and to *Escherichia coli*, *Klebsiella*, *Serratia* and *Proteus* in Moundou. *Salmonella* at 87.5% and *Enterobacter* at 90.9% in Moundou.

In addition to betalactamase, some strains have associated resistance to fluoroquinolones and aminoglycosides for strains of *Escherichia coli*, *Klebsiella* and *Enterobacter*.

The resistance phenotypes of enzyme-producing Enterobacteriaceae are diverse, ranging from penicillinase (high and low level), cephalosporinase, extended spectrum beta-lactamase (ESBL) through multi-resistant bacteria to carbapenemase.

Table 3: Resistance phenotype of germs isolated in Moundou

Germs / Antibiotics	*Entero spp (n = 11)*		*E. coli (n = 26)*		*Kleb spp (n = 3)*		*Proteus spp (n = 4)*		*Salmo. (n = 8)*		*Serrat. spp (n = 1)*	
	R	S	R	S	R	S	R	S	R	S	R	S
Beta-Lactams												
Ampicillin	11	00	26	00	03	00	04	00	07	01	01	00
Amoxicillin + Clavulanic acid	11	00	26	00	03	00	04	00	08	00	01	00
Ticarcillin	11	00	26	01	03	00	01	03	08	00	01	03
Cefalotin	11	00	26	00	03	00	04	00	08	00	01	00
Cefotaxime	08	03	21	05	01	02	02	02	04	04	01	00
Ceftriaxone	02	09	05	21	01	02	02	02	06	02	00	01
Imipenem	00	11	00	26	00	03	00	04	00	08	00	01
Meropenem	00	11	00	26	00	03	00	04	00	08	00	01
Quinolone and Fluoroquinolones												
Nalidixic acid	08	03	21	05	01	02	03	01	05	03	00	01
Ciprofloxacin	05	06	21	05	01	02	03	01	05	03	00	01
Levofloxacin	05	06	21	05	01	02	03	01	03	05	00	01
Aminoglycosides												
Gentamicin	06	05	14	12	01	02	03	01	02	06	00	01
Amikacin	07	04	09	17	01	02	03	01	00	08	00	01
Sulphonamides												
Trimethoprim-sulfamethoxazole	10	01	00	26	03	00	04	00	07	01	01	00

R = Resistant ; S = Sensitive ; *Entero. spp = Enterobacter Spp ; E. coli = Escherichia coli* ; **Kleb. spp** = *Klebsiella spp* ; *Proteus m. = Proteus mirabilis* ; *Serrat.spp. = Serratia spp* ; Salmo.. = = *Salmonella*

Table 4 : Resistance phenotype of germs isolated in Sarh

Germs / Antibiotics	*Citrobac. f. (n = 6)*		*Entero. spp (n = 6)*		*E. coli (n = 28)*		*Kleb. spp (n = 7)*		*Salmo. (n = 1)*		*Serrat. spp. (n = 3)*		*Shige. f. (n = 2)*	
	R	S	R	S	R	S	R	S	R	S	R	S	R	S
Beta-Lactams														
Amoxicillin	06	00	06	00	28	00	07	00	01	00	03	00	02	00
Ampicillin	06	00	06	00	27	01	07	00	01	00	02	01	02	00
Amoxicillin + Clavulanic acid	06	00	06	00	27	01	07	00	01	00	02	01	02	00
Ticarcillin	06	00	06	00	27	01	07	00	01	00	00	03	02	00
Cefalotin	06	00	04	02	28	00	07	00	01	00	03	00	02	00
Cefotaxime	02	04	02	04	21	07	05	02	01	00	00	03	01	01
Ceftriaxone	02	04	02	04	21	07	06	01	01	00	00	03	01	01
Imipenem	00	06	00	06	02	26	01	06	01	00	00	03	00	02
Meropenem	00	06	00	06	02	26	01	06	01	00	00	03	00	02
Quinolone and Fluoroquinolones														
Nalidixic acid	02	04	02	04	21	07	05	02	01	00	00	03	01	01
Ciprofloxacin	02	04	02	04	19	09	05	02	00	01	00	03	00	02
Levofloxacin	02	04	02	04	19	09	03	04	00	01	00	03	00	02
Aminoglycosides														
Gentamicin	02	04	02	04	13	15	04	03	00	01	00	03	00	02
Amikacin	02	04	02	04	13	15	04	03	00	01	00	03	00	02
Sulphonamides														
Trimethoprim-sulfamethoxazole	04	02	06	00	28	00	07	00	01	00	03	00	02	00

R = Resistant ; S = Sensitive ; *Citrobac. f. = Citrobacter freundii ; Entero. spp = Enterobacter Spp ; E. coli = Escherichia coli ; Kleb. spp = Klebsiella spp ; Salmo. = Salmonella ; Serrat.spp. = Serratia spp ; Shige. f. = Shigella flexneri.*

DISCUSSION

In the two cities in the south of the country, namely Moundou and Sarh, out of the 278 samples analyzed, 111 strains were isolated. The results obtained showed a prevalence of enterobacteria of 39.92%, these results are higher than those of Hamadou and al. in 2023[16], 21%. The genus *Escherichia coli* 49.55% (55/111) is predominant followed by *Enterobacter* spp 15.31%, *Klebsiella* spp 9.91%, *Salmonella* spp 8.11% and *Serratia* spp 6.30%, a superposable result to several studies on enterobacteria. In Sarh (50%) and Moundou (49.05%) of *Escherichia coli*, results lower than those of N'Djamena, Yandai et al., in 2019[13] (64.5%), Hamadou et al. 2023[16], 74%, Ouchar et al. in 2019[12], 63.83% and 21.28%, Djimabi et al. 63.93% in Togo[19], but comparable to those of Ebongue et al. 2015 (Douala)[5] *Escherichia coli* 48.5%.

The overall resistance to aminopenicillins for the 2 southern cities is above 90% (91-98%), a result similar to that of Yandai et al. (96.66-100%) in 2019 in Chad[13]. Amoxicillin associated et the beta-lactamase inhibitor such as clavulanic acid is inhibited by 98.30% in Sarh and 100% in Moundou, results well above those of Santos et al. (62.85%) in July 2020 in Brazil[20].

Resistance to 3rd generation cephalosporins is present in a large number of enterobacteria. In Sarh, *Escherichia coli* has a resistance to ceftriaxone of 64.4% and 68% in Moundou, a result beyond that observed by Cardinale et al. (41.3%) in the population of N'Djamena[21] (Cardinale et al., 2020).

These results are consistent with those of Ouchar et al. (2019)[12] which confirm that betalamase-producing enterobacteria are mainly *Escherichia coli*, i.e. 71.9%, and *Klebsiella* pneumoniae (16/89). An extended spectrum beta-lactamase developed by all strains, these results confirm those of Da et al. (2022) taking stock of resistance in Sub-Saharan Africa, the results can reach 80% in community infections[22].

In Sarh a *Salmonella* strain resistant to imipenem and 3rd generation cephalosporins, resistant to nalidixic acid but sensitive to fluoroquinolones and aminoglycosides, a strain with a resistance profile different from those identified in N'Djamena in 2019 by Hamadou et al. (2017)[16] which are resistant to ciprofloxacin (80%) and gentamicin (80%). Unlike Sarh where the carbapenemase rate observed in *Escherichia coli* 7.14% and increasing according to the study by Ouchar et al. (Ouchar et al., 2019)[12], in Moundou, none are resistant to the carbapenems identified.

The data indicate a spread of multi-resistant bacteria to the main classes of antibiotics. In addition to betalactamase, certain strains have associated resistance (coreristance) to fluoroquinolones and aminoglycosides for *Escherichia coli* strains, 2 of which are resistant to all antibiotics tested. (7.14%), *Klebsiella* (66.66% for ciprofloxacin and 50% for gentmicin) and *Enterobacter* (33.33% for aminoglycosides and fluoroquinolones) in Sarh. In Moundou, *Escherichia coli*, in addition to resistance to C3G and fluoroquinolones (68.75%), co-resistance to gentamicin of 37.5%, a strain of *Klebsiella* ozanae multi-resistant to all antibiotics tested except carbapenems. these multi-resistances are also found in N'Djamena in 2019 by Hamadou et al. (2023)[16].

The strains have reduced sensitivity to quinolones and fluoroquinolones, much more resistance to nalidixic acid at 75.86% in Sarh and 80.86% in Moundou for *Escherichia coli*. and for *Klebsiella* spp 33.33% in Moundou and 75% in Sarh. A rate higher than those reported by Yandai et al. in 2019 (31.66% - 43.47%)[13], but lower than those of Ouchar et al. (91.67-100%)[12] in 2019 in N'Djamena.

Strains of *Salmonella*, *Shigella* and Serratia have good sensitivity (100%) to fluoroquinolones and aminoglycosides in Sarh, whereas in Moundou the strains of *salmonella* are 62.5% resistant to ciprofloxacin, rates lower than those of Hamadou et al. 80% between 2017-2019[16] and Ouchar et al in 2019, 90.28 for ciprofloxacin and 80.85 for levofloxacin[12]. A result above that of Guillard et al in 2020[23].

Reduced sensitivity to aminoglycosides, approximately 40% resistance to gentamicin compared to 73.61 for Ouchar et al. in 2019[12], 33.96% for Amikacin remains a little more active in Moundou, a rate higher than those of Ouchar et al. in 2019 13, 15.28 for amikacin.

Trimethoprim - sulfamethoxazole remains the least active antibiotic of all because *Escherichia coli*, *Klebsiella*, *Enterobacter*, *Serratia* (K.E.S), *Shigella* and *Salmonella* in Sarh and *Escherichia coli*, *Klebsiella*, *Serratia* and *Proteus* in Moundou are 100% resistant to Trimethoprim-sulfamethoxazole. *Salmonella* at 87.5% and *Enterobacter* at 90.9% in Moundou, a rate comparable to that reported by Yandai et al. (65% - 95.65%) in N'Djamena in 2019[13].

CONCLUSION

The enterobacteria identified in urine and stools in Moundou and Sarh are mainly *Escherichia coli* followed by the K.E.S. group. This result is consistent with several other studies carried out around the world and in Chad, particularly in N'Djamena.

In terms of sensitivity to antibiotics, our work confirms that certain enterobacteria tested are multi-resistant to the different antibiotics used. These different resistances are mainly due to self-medication, poor compliance with instructions and inadequate prescriptions. This situation is a real challenge to initiate mass awareness-raising on the risks linked to bacterial resistance. The control of multi-resistant enterobacteria strains in the environment through the strengthening of technical capacities for their detection must receive close attention from the competent authorities.

Acknowledgement

The authors sincerely thank the general management and all the staff of Hospital of Moundou and Hospital of Sarh for their multifaceted support and all the staff of the National Reference Teaching Hospital. We would also like to thank the International Health Support Center for its material support and finally we thank the Solidarity Fund for Innovative Projects for its financial support during the Laboratory analyses.

Conflicts of interest

The authors declare that they have no competing interests.

REFERENCES

1. Khanal P, Antibiotic resistance: causes and consequences. Eur. J. Biomed. Pharm. Sci,, 2020 ;7:327-331

2. Santé Publique France (SPF), Surveillance de la résistance bactérienne aux antibiotiques en soins de ville et en établissements pour personnes âgées dépendantes. Mission nationale Primo. Résultats synthétiques, année 2022. Saint-Maurice : Santé publique France; 2023 :12 p. Disponible à partir de l'URL: http://www.santepubliquefrance.fr

3. CDC (Center of Disease Control and Prevention / United States), Antibiotic resistance threat report; 2019.

4. Coque TM, Baquero F, Canton R, Increasing prevalence of ESBL-producing Enterobacteriaceae in Europe. Euro Surveill. 2008 ;13(47):pii=19044. Available online: http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=19044 https://doi.org/10.2807/ese.13.47.19044-en

5. Ebongue CO, Evolution de la résistance aux antibiotiques des entérobactéries isolées à l'Hôpital Général de Douala de 2005 à 2012, Panafrican Medical Journal ; 2015;20(227)

https://doi.org/10.11604/pamj.2015.20.227.4770 PMid:26140070 PMCid:PMC4482524

6. Ayukekbong JA, Ntemgwa M, Atabe AN, "The threat of antimicrobial resistance in developing countries: causes and control strategies", Antimicrobial Resistance and Infection Control, 2017;6:47. https://doi.org/10.1186/s13756-017-0208-x PMid:28515903 PMCid:PMC5433038

7. Llor C, Bjerrum L, "Antimicrobial resistance: risk associated with antibiotic overuse and initiatives to reduce the problem", Ther Adv Drug Saf, 2014;5(6):229-41. https://doi.org/10.1177/2042098614554919 PMid:25436105 PMCid:PMC4232501

8. Laxminarayan R, Duse A, Wattal C, et al., Antibiotic resistance-the need for global solutions, Lancet Infect Dis, 2013, 13: 1057-98 https://doi.org/10.1016/S1473-3099(13)70318-9 PMid:24252483

9. Antimicrobial Resistance Collaborators (ARC). Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. Lancet. 2022;399(10325):629-655. DOI: https://doi.org/10.1016/S0140-6736(21)02724-0 .

10. Ndoutamia G, Fissou HY, Bessibaye N. Antimicrobial resistance in exendided spectrum betalactamase (EBSL) -produicing Escherichia coli from humain urinary tract infections in N'Djaména in Chad. African Journal of Microbiology Rechearch. 2015;9(11):776-780. https://doi.org/10.5897/AJMR2014.7338

11. Bodering A, Guelmbaye N, Bongo NN, Albert N. Utilisation des antibiotiques et profil de résistance des souches de Salmonella spp. et Escherichia coli isolées des exploitations avicoles des villes de N'Djaména et Doba au Tchad. Int. J. Biol. Chem. Sci. 2017;11(4):1669-1684 https://doi.org/10.4314/ijbcs.v11i4.21

12. Ouchar OM, Manon L, Mallorie H, Abelsalam T, Julio B, Abibatou D, Calèbe S, Kadidja G, Christian C, Dominique D, Anne-Laure B, Hélène J-P, Yann D, Fabrice C, Sylvain G. Spread of NDM-5 and OXA-181 Carbapenemase-Producing Escherichia coli in Chad. Americ. Soci. for Microb. 2019;63(11):1-5. https://doi.org/10.1128/AAC.00646-19 PMid:31405861 PMCid:PMC6811454

13. Yandai FH, Guelmbaye N, Bessimbaye N. Prevalence and resistance profile of Escherichia coli and Klebsiella pneumoniae isolated from urinary tract infections in N'Djamena, Tchad. Int. J. Biol. Chem. Sci. 2019;13(4):2065-2073. https://doi.org/10.4314/ijbcs.v13i4.13

14. Bessimbaye N, Mayoré AD, Djimadoum M, Frank EZR, Choua O, Nicolas B. Biochemical, resistance and epidemiological profile of Salmonella and Shigella gastroenteritis isolated in chad from 2010-2020. Euro. Jour. of Biotech. and Biosc.. 2021;9(4):1-10.

15. Mayoré AD, Bessimbaye N, Bodering A, Evariste B, Abdelsalam T, Nicolas B. Resistance profile of Salmonella isolated from food sold in the streets of N'Djamena, Chad. Afr. J. Microbiol. Res. 2021;15(6):334-3340. https://doi.org/10.5897/AJMR2021.9475

16. Hamadou A, Ban-bo BA, Traore AK, Kadidja G, Nikiema EM, et al. Prevalence of Esbl-Producing Enterobacteriaceae Strains Isolated to the University Hospital Center of N'Djamena and their Sensitivity to Antibiotics. J Bacteriol Mycol. 2023;10(2):1208.

17. Comité de l'antibiogramme de la Société française de microbiologie, European Committee on Antimicrobial Susceptibility Testing (CA-SFM/EUCAST). Recommandations 2020. Version 1.2. 2020, 181p.

18. European Committee on Antimicrobial Susceptibility Testing (EUCAST). Eucast guidlines for detection of resistance mechanisms and specific resistances of clinical and/or epidemiological importance. Version 2.01. 2017, 43p

19. Fortune Djimabi Salah et al. Augmentation de la résistance aux antibiotiques des Entérobactéries isolées à l'Institut National d'Hygiène de Lomé de 2010 à 2017. Journal of Interventional Epidemiology and Public Health. 2021;4(3):3. https://doi.org/10.37432/jieph.supp.2021.4.3.03.3

20. Santos AL, Dos Santos AP, Ito CRM, Queiroz PHPD, de Almeida JA, de Carvalho Júnior MAB et al., Profile of enterobacteria resistant to beta-lactams. Antibiotics, 2020;9(7):410. https://doi.org/10.3390/antibiotics9070410 PMid:32679663 PMCid:PMC7400480

21. Cardinale M, Bourbotte SF, Scheiwe C, Boulezaz S, Ridet M, Philippe L. Antimicrobial resistance in N'Djamena (Chad): Four-year experience of the French Forward Medical and Surgical Team engaged in the "Barkhane Operation". Méd. et Malad. Infecti. 2020;50 (8):665-669. https://doi.org/10.1016/j.medmal.2019.12.009 PMid:32035720

22. Da L, Somé D, Yehouenou C, Somé C, Zoungrana J, Ouédraogo AS et al., État des lieux de la résistance aux antibiotiques en Afrique subsaharienne. Médecine et Maladies Infectieuses Formation, 2023;2(1):3-12. https://doi.org/10.1016/j.mmifmc.2023.01.003

23. Guillard T, Jacquier H, Muggeo A, Cambau E. Entérobactéries et fluoroquinolones : mécanismes de résistance et antibiogramme. Biol. Méd. 2020;665-669. DOI: https://doi.org/10.1016/S2211-9698(20)73303-0