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DEDICATION

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DEDICATION

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Abstract:

Antibiotic resistance among bacteria in pet populations poses a significant threat to both animal and human health due to the risk of zoonotic transmission. This study aimed to investigate the prevalence and diversity of multidrug-resistant (MDR) bacteria in a wide range of domestic and exotic pets in Guelma, Algeria. Samples were collected from various pets including cats, dogs, hamsters, squirrels, monkeys, budgies, cockatiels, goldfinches, parrots, fennec foxes, terrestrial turtles, koi fish, goldfish, and red cap oranda. Bacterial isolates were identified using biochemical and microbiological techniques, and antibiotic susceptibility was tested against a panel of commonly used antibiotics. A total of 16 bacterial isolates were identified, encompassing species such as *Salmonella spp.*, *Citrobacter koseri, Serratia spp., Enterobacter sakazakii, Ochrobactrum anthropi, Staphylococcus spp., and Aeromonas hydrophila*. High resistance rates were observed against penicillin, amoxicillin, vancomycin, and rifamycin, whereas gentamicin showed the highest efficacy. The findings highlight a concerning prevalence of multidrug-resistant bacteria in pet populations of Guelma, emphasizing the urgent need for regular surveillance, prudent antibiotic use, and increased awareness to prevent the spread of resistant bacteria to humans and safeguard effective treatments.

Keywords: Antibiotic resistance, Bacteria, Domestic pets, Exotic pets, Guelma, Zoonotic spillover, Zoonotic risk.

Résumé:

La résistance aux antibiotiques parmi les bactéries présentes dans les populations d'animaux de compagnie constitue une menace significative pour la santé animale et humaine en raison du risque de transmission zoonotique. Cette étude visait à examiner la prévalence et la diversité des bactéries multirésistantes (BMR) dans une large gamme d'animaux domestiques et exotiques à Guelma, en Algérie. Des échantillons ont été prélevés sur divers animaux de compagnie, notamment des chats, des chiens, des hamsters, des écureuils, des singes, des perruches ondulées, des cockatiels, des chardonnerets élégants, des perroquets, des renards fennecs, des tortues terrestres, des poissons koï, des poissons rouges et des red cap oranda. Les isolats bactériens ont été identifiés à l'aide de techniques biochimiques et microbiologiques, et la sensibilité aux antibiotiques a été testée contre un panel d'antibiotiques couramment utilisés. Au total, 16 isolats bactériens ont été identifiés, comprenant des espèces telles que *Salmonella spp.*, *Citrobacter koseri*, *Serratia spp.*, *Enterobacter sakazakii*, *Ochrobactrum anthropi*, *Staphylococcus spp.* et *Aeromonas hydrophila*. Des taux élevés de résistance ont été observés contre la pénicilline, l'amoxicilline, la vancomycine et la rifamycine, tandis que la gentamicine a montré la plus grande efficacité. Les résultats mettent en évidence une prévalence préoccupante des bactéries multirésistantes dans les populations d'animaux de compagnie de Guelma, soulignant l'urgence d'une surveillance régulière, d'une utilisation raisonnée des antibiotiques et d'une sensibilisation accrue afin de prévenir la propagation des bactéries résistantes aux humains et de préserver l'efficacité des traitements.

Mots clés: Animaux de compagnie, Animaux exotiques, Bactéries, Contagion zoonotique, Guelma, Résistance aux antibiotiques, Risque zoonotique.

ملخص البحث:

تشكل مقاومة المضادات الحيوية بين البكتيريا الموجودة في مجتمعات الحيوانات الأليفة تهديدًا كبيرًا لصحة الحيوان والإنسان نظرًا لخطر الانتقال الحيواني المنشأ. هدفت هذه الدراسة إلى التحقيق في انتشار وتنوع البكتيريا المقاومة لعدة أنواع من المضادات الحيوية (MDR)في مجموعة واسعة من الحيوانات الأليفة المنزلية والغريبة في قالمة، الجزائر. تم جمع عينات من عدة أنواع من الحيوانات الأليفة، بما في ذلك القطط، الكلاب، الهامستر، السناجب، القرود، الببغاوات، الكوكاتيل، الحسون، الببغاوات الرمادية، ثعالب الفنك، السلاحف البرية، أسماك الكوي، الأسماك الذهبية، وأسماك *ريد كاب أوراندا* .تم تحديد العزلات البكتيرية باستخدام التقنيات البيوكيميائية والميكروبيولوجية، وتم اختبار مدى حساسيتها للمضادات الحيوية ضد مجموعة من المضادات الحيوية المستخدمة بشكل شائع. تم تحديد 16 عزلة بكتيرية في المجموع، شملت أنواعًا مثل *Salmonella spp.*، *Citrobacter koseri*، *Serratia spp.*، *Enterobacter sakazakii*، *Ochrobactrum anthropi*، *Staphylococcus spp.*و *Aeromonas hydrophila*. لوحظت معدلات مقاومة عالية ضد البنسلين، الأموكسيسيلين، الفانكومايسين، والريفاميسين، بينما أظهرت الجنتاميسين الفعالية الأكبر. تسلط النتائج الضوء على الانتشار المقلق للبكتيريا المقاومة لعدة مضادات حيوية بين الحيوانات الأليفة في قالمة، مما يؤكد الحاجة الملحة إلى مراقبة منتظمة، والاستخدام الحكيم للمضادات الحيوية، وزيادة الوعي لمنع انتشار البكتيريا المقاومة إلى البشر والحفاظ على فعالية العلاجات.

الكلمات المفتاحية: البكتيريا، انتشار الأمراض الحيوانية المنشأ، الحيوانات الأليفة الغريبة، الحيوانات الأليفة المنزلية، قالمة، مخاطر الأمراض الحيوانية المنشأ، مقاومة المضادات الحيوية.

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List of Abbreviations

Abbreviations	Signification
MDR	Multi-Drug resistant
AMR	Antimicrobial resistance
AST	Antibiotic Susceptibility Testing
MRSA	Methicillin-Resistant Staphylococcus aureus
MSA	Mannitol Salt Agar
HEK	Hektoen
SSA	Salmonella Shigella Agar
ADH	Arginine Dihydrolase
LDC	Lysine Decarboxylase
ODC	Ornithine Decarboxylase
H2S	Hydrogen Sulfide
URE	Urease
IND	Indole
VP	Voges-Proskauer
TDA	Direct antiglobulin test

IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
CN/GEN	Gentamicin
P/PEN	Penicillin
FOX	Cefoxitin
VN/VAN	Vancomycin
RD/RIF	Rifampicin
C/CHL	Chloramphenicol
AMX	Amoxicillin
ASTS	Antibiotic Sensibility Test Standard

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Introduction

1. Introduction:

In recent years, the domestication of both common and exotic animals has become increasingly popular in urban and semi-urban regions of Algeria. Recent study reported a diversity and large spectrum of both exotic pets and nonnative bacteria in northeast Algeria **(Bara et al., 2025).**

While these animals often serve as companions or tourist attractions, they can also act as reservoirs for zoonotic pathogens, including multidrug-resistant (MDR) bacteria. Improper handling, poor hygiene, and uncontrolled antibiotic use in pet shops and private households may contribute to the transmission of antimicrobial-resistant organisms from animals to humans **(Guardabassi et al., 2004 ; Schmidt et al., 2015).**

This study investigates the bacterial flora and antimicrobial resistance profiles of microorganisms isolated from domestic and exotic pets in Guelma, with a focus on their potential as public health threats.

2. Research Questions:

• What bacterial species are present in selected domestic and exotic pets in the Guelma region?

• Do the isolated bacterial species show resistance to commonly used antibiotics?

3. Study Objectives:

• To isolate and identify bacteria from various sample types taken from exotic and domestic animals.

• To evaluate the antimicrobial susceptibility profiles of the isolated bacterial strains.

• To assess potential public health risks associated with antimicrobial resistance in these animals.

Chapter 1

Literature Review

1. Overview:

Zoonotic diseases, which spread between animals and humans, have become a substantial and escalating worldwide public health threat. The growing popularity of exotic and domestic pets creates additional pathways for human exposure to multiple zoonotic pathogens. Dogs, cats, and birds serve as reservoirs of various infectious agents, including bacteria, viruses, and parasites, which can cause medical conditions ranging from mild to deadly. Several zoonotic diseases spread by pets include salmonellosis, staphylococcosis (including Methicillin-resistant Staphylococcus aureus or MRSA), chlamydiosis, leptospirosis, and cat scratch disease (CSD) (*Bartonella henselae*) **(Naik et al., 2025; Basit et al., 2024).**

Various bird species such as canaries, parrots, parakeets, finches, and budgerigars act as vectors for *Coxiella burnetii* , *Salmonella spp*., *Mycobacterium spp*., *Listeria monocytogenes* , and avian influenza viruses, which represent significant health threats to people **(Rahman et al., 2020).**

The growing antimicrobial resistance (AMR) concern makes this situation more complex due to the transmission of resistant bacteria between pets and humans, which decreases available treatment options while raising morbidity and mortality rates **(Jelocnik et al., 2025; Bhat, 2021)**. Scientists predict that ten out of every twelve infectious diseases affecting humans originate from animals, whereas four out of every eight newly discovered human diseases stem from animal sources **(Lee, 2023; Centers for Disease Control and Prevention, nd).** Zoonotic diseases lead to approximately 2.4–2.5 billion human illnesses along with 2.7 million annual deaths worldwide and primarily affect low-income workers engaged in livestock production in low- and middle-income nations **(Rahman et al., 2020; Lee, 2023; World Economic Forum, 2022).**

Zoonotic diseases create health system threats while establishing enormous economic burdens by causing substantial damage to animal trading ventures, harming visitors' tourism activities, and reducing local economic potential due to decreased livestock value and lowered community productivity **(Food and Agriculture Organization of the United Nations, nd; Rahman et al., 2020).**

Notable zoonoses develop due to direct exposure to animals and also spread through water, contaminated objects (fomites), or insects acting as vectors **(Food and Agriculture Organization of the United Nations, nd; World Health Organization, 2004).** The occurrence of zoonotic diseases increases due to globalization and urbanization, along with

rising domestic and wildlife animal trade, environmental changes, agricultural intensification, and shifting climate patterns, all of which enhance human-wildlife-domestic animal contact **(Lee, 2023; World Health Organization, 2004).** Because zoonotic outbreaks are dynamic and unpredictable, their control and prevention require coordinated international responses from veterinary services and human health organizations **(World Health Organization, 2004).**

Studying these issues in specific regions such as Guelma, Algeria, is particularly relevant due to the increasing pet ownership-including exotic species-combined with limited veterinary surveillance and public health infrastructure, which may facilitate the unnoticed spread of zoonotic and resistant pathogens **(Basit et al., 2024).**

Zoonotic pathogens transmitted from both domestic and exotic pets pose major public health risks to humans. Pets can carry antibiotic-resistant pathogenic bacteria, complicating infection treatment and management **(Jelocnik et al., 2025; Bhat, 2021).** Currently, there is insufficient research on zoonoses and antimicrobial resistance in exotic pets, as most monitoring and stewardship programs primarily focus on livestock rather than companion animals. Research on zoonotic agents and antimicrobial resistance is essential because exotic pets have been identified to transmit unique zoonotic agents, ranging from *Salmonella* serotypes to *Pasteurella multocida*, and they may serve as reservoirs of antimicrobial resistance genes **(Varela et al., 2022).**

Scientific studies indicate zoonoses comprise around 75% of modern epidemic infections, and these diseases frequently spread from exotic pet species and wildlife (Souza, 2011). Recent human outbreaks of severe acute respiratory syndrome (SARS), Ebola virus, salmonellosis, and monkeypox have been linked back to nondomestic species **(Souza, 2011; Centers for Disease Control and Prevention, 2003).** Studies on rescued European exotic pets indicated that 13.7% possessed at least one zoonotic infection categorized as dangerous, while exotic rescued strays showed zoonotic infections in 50% of the specimens **(AAP, 2021).** A wide array of pathogens that infect exotic pets becomes undetectable because specific screening is limited by the shortage of veterinary workers who attend to these types of pets **(AAP, 2021).** The exotic pet trade requires more regulatory oversight since millions of wild animal species interact with human beings and other animals, creating conditions that facilitate infectious disease transmission **(AAP, 2021).**

Moreover, the bidirectional transmission of pathogens and resistance genes between humans and pets, including reverse zoonoses, is an emerging concern that remains under-investigated

(Jelocnik et al., 2025). There is growing recognition that not only can pets transmit zoonotic pathogens to humans, but humans can also infect their pets with diseases such as influenza, norovirus, and even COVID-19, creating complex transmission cycles that can facilitate the emergence of new, potentially more dangerous strains **(Brown, 2008).** The risks are heightened in family homes, where exotic pets are often marketed as "easy to keep" or "low maintenance," and vulnerable populations such as children, the elderly, and immunocompromised individuals are at greatest risk of severe outcomes from zoonotic infections **(World Animal Protection, 2024; Chomel et al., 2007).**

In regions like Algeria, where veterinary diagnostics and antimicrobial stewardship are less developed, these issues are compounded by a lack of data on the prevalence and resistance profiles of zoonotic bacteria in pets, especially exotic species. The under-recognition and under-surveillance of both zoonoses and AMR in companion animals, combined with increasing pet ownership and limited public health infrastructure, underscore the urgent need for targeted studies to fill these knowledge gaps and inform effective public health and veterinary interventions **(Sun et al., 2024; Varela et al., 2022).**

Studies have widely documented bacterial infections that household pets, including dogs and cats, transmit as zoonotic diseases through their pathogen reservoirs, which contain *Leptospira canicola* (leptospirosis), *Salmonella enterica* (salmonellosis), *Campylobacter jejuni* (campylobacteriosis), and methicillin-resistant *Staphylococcus aureus* (MRSA) **(Rahman et al., 2020; Chomel, 2014).** Medical professionals report brucellosis, pasteurellosis, colibacillosis (*E. coli*), tuberculosis, and cat scratch fever (*Bartonella henselae*), together with more than 70 zoonotic pathogens that affect dogs and cats **(Bhat, 2021; Naik et al., 2025; Tekchandani et al., 2024)**. Parasitic and fungal elements that can transmit from pets to humans remain major public health risks in the context of pet ownership, with echinococcosis, leishmaniasis, onchocercosis, toxoplasmosis, ringworm, and sporotrichosis among the most important zoonoses affecting pet populations.

Pet ownership continues to grow worldwide, but dogs and cats maintain their positions as the dominant household pet varieties in both developed and developing regions. The public tends to underestimate zoonotic transmission risks because most pet owners are unaware of the extensive diseases that can occur in their pets **(Tekchandani et al., 2024).** The common roundworms of dogs and cats, called *Toxocara canis* and *Toxocara cati*, induce larva migrans syndromes in humans by accidental ingestion of eggs from contaminated surroundings, thus

becoming one of the prevalent zoonotic infections in pets throughout the United States and other developed nations.

Birds kept as pets have also been implicated in transmitting zoonotic pathogens such as *Coxiella burnetii*, *Chlamydia psittaci*, and various enteric bacteria **(Naik et al., 2025).** Notably, canaries, finches, sparrows, parrots, parakeets, and budgerigars can transmit *Salmonella spp., Listeria monocytogenes, Erysipelothrix rhusiopathiae*, *Mycobacterium spp*., and even viruses like fowl pox and Newcastle disease virus, with avian influenza A H5N1 and Q fever posing serious public health threats. Game and ornamental birds can also transmit bacterial zoonoses such as *Pasteurella spp., Klebsiella spp., Yersinia spp., Pseudomonas spp., Staphylococcus aureus*, and *E. coli* **(Tekchandani et al., 2024).**

More researchers identify exotic pets, particularly reptiles together with small mammals, as key sources that transmit zoonotic infections to humans. Reptile *Salmonella* species exist within their bodies but only sporadically appear in their feces, which might make owners vulnerable to infections **(Varela et al., 2022; Smith and Whitfield, 2012).** The transmission of zoonotic diseases to humans from household pets has been connected to turtles, alongside ornamental fish, baby chicks, gerbils, frogs, and lizards, especially affecting children under five years and those with weakened immune systems. The consumption of pet treats, together with frozen rodents and raw food diets in pet foods, has been identified as a zoonotic infection source **(Smith and Whitfield, 2012).**

The transmission dynamics of these diseases are complex and influenced by factors such as close human-animal contact, environmental contamination, animal husbandry practices, and hygiene behaviors **(Basit et al., 2024; Smith and Whitfield, 2012; Stull et al., 2013; Damborg et al., 2016).** Contamination of feed and water, animal bites, scratches, fecal-oral routes, and direct contact with animal waste are all common modes for disseminating zoonotic diseases. Socio-demographic factors, such as educational level and occupation, have been shown to significantly influence knowledge, attitudes, and practices (KAP) related to zoonoses **(Tekchandani et al., 2024)**. Furthermore, individuals at higher risk of infections (children under five, elderly over 65, and immunocompromised persons) are often present in households, and a significant proportion of pet owners allow pets in bedrooms, increasing exposure risk **(Stull et al., 2013; Smith and Whitfield, 2012)**.

Global attention has risen toward antimicrobial-resistant zoonotic bacteria because companion animals act as both sources and carriers of multidrug-resistant pathogens **(Jelocnik et al., 2025;**

Bhat, 2021; Damborg et al., 2016). Prevention and control efforts become more difficult because dogs and cats, along with exotic pets, now harbor multidrug-resistant bacteria with zoonotic potential. Research has shown insufficient data exist about pathogen occurrence alongside resistance profiles within pet communities, specifically across developing areas **(Damborg et al., 2016; Tekchandani et al., 2024)**.

In Algeria and similar regions, data on the prevalence of zoonotic bacteria and their resistance patterns in pets are scarce, limiting the ability to implement evidence-based control measures **(Basit et al., 2024)**. Urbanization and increased human-animal interactions further exacerbate the risk of zoonotic and resistant infections, highlighting the need for integrated One Health approaches that consider human, animal, and environmental health **(Basit et al., 2024; Smith and Whitfield, 2012)**. Global travel, animal trade, climate change, and the increasing number of exotic pets also contribute to the emergence and re-emergence of zoonoses, making comprehensive surveillance and public awareness essential for effective prevention and control **(Smith and Whitfield, 2012)**.

Ultimately, this research aspires to enhance disease surveillance, improve treatment outcomes, and foster collaboration among veterinary, medical, and environmental health sectors to safeguard community health in Algeria **(Kardjadj et al., 2019; Razali et al., 2020).**

Chapter 2

Materials and Methods

1. Study Area:

The study was conducted in Guelma Province, northeastern Algeria, particularly in:

- **Guelma City Center (36.4620° N, 7.4261° E):** An urban area with several pet shops, veterinary clinics, and private households where domestic and exotic animals are commonly kept.
- **Hammam Debagh (36.4674° N, 7.2498° E):** A semi-urban area known for its thermal springs and tourist animal shops, where animals are often housed under less controlled sanitary conditions.

These locations were selected for their diversity of animal hosts and the close contact between humans and animals, increasing the potential for zoonotic transmission.

2. Sample Collection:

A total of **14 animals** were sampled from pet shops, private homes, and tourist animal shops. The species, their scientific names, and the types of samples collected are listed below:

Table 1. Checklist of pets and exotic pets sampled during this survey.

Animals	**Scientific Name**	**Sample Type**
Koi fish	*Cyprinus rubrofuscus*	Water
Red Cap Oranda	*Carassius auratus*	Water
Goldfish	*Carassius auratus*	Water
Parrot	*Psittacus erithacus*	Feces, feathers
Budgie	*Melopsittacus undulatus*	Feces
Cockatiel	*Nymphicus hollandicus*	Feces, feathers
Goldfinch	*Carduelis carduelis*	Feces
Terrestrial turtle	*Testudo graeca*	Feces

Fennec fox	*Vulpes zerda*	Fur, feces
Squirrel	*Atlantoxerus getulus*	Feces, cage swab
Monkey	*Macaca fascicularis*	Feces
Hamster	*Mesocricetus auratus*	Feces
Cat	*Felis catus*	teeth swab
Dog	*Belgische Herdershond*	Fur, feces

3. Bacterial Cultivation:

After sample collection, materials were pre-enriched in nutrient broth and incubated at 37°C for 24 hours **(ISO/CEI, 2012)**. Then, samples were streaked on three different selective and differential media:

- **Mannitol Salt agar**: for Gram-positive cocci, especially Staphylococcus spp.
- **SS agar (Salmonella-Shigella)**: for detecting enteric bacteria.
- **Hektoen enteric agar**: for detecting Gram-negative enteric bacteria.

Plates were incubated again at 37°C for 24 hours for colony growth.

4. Bacterial identification:

4.1. Gram-Staining coloration:

- Smears of bacterial colonies were prepared on clean glass slides and heat-fixed.
- Crystal violet was applied for 1 minute, rinsed, then iodine for 1 minute.
- Decolorization was done with ethanol for 15–30 seconds.
- Slides were counterstained with safranin for 1 minute, rinsed, and air-dried.
- Observations were made under oil immersion microscopy **(O'Neil et al., 2013)**.

4.2. Catalase Test:

- A small portion of a colony was transferred to a slide.
- A drop of 3% hydrogen peroxide was added.
- Immediate bubbling indicated a positive result.

4.3. Oxidase Test:

- A colony was smeared on oxidase test paper.
- A positive result was indicated by a color change to purple or black within 30 seconds.

4.4. Biochemical identification:

To identify the bacterial isolates, we used API identification systems, including API 20E, API 20NE, and API Staph, depending on Gram staining and colony morphology **(Muñoz-Ibarra et al., 2022)**.

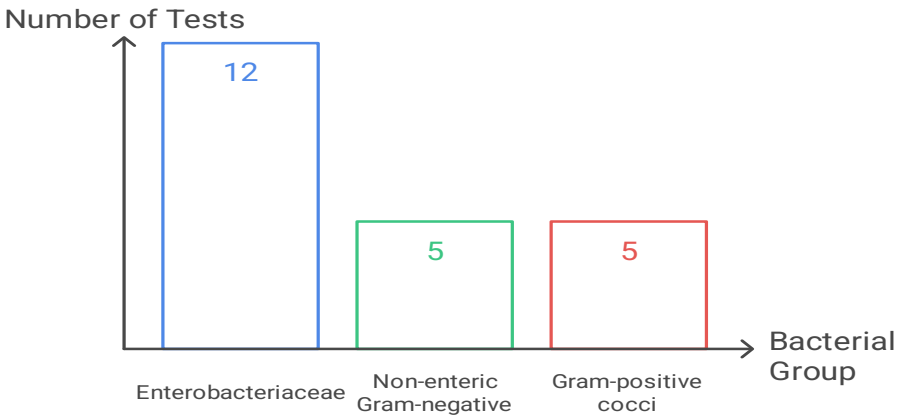


Figure 1. Distribution of API by Bacterial Group.

4.4.1. Preparation of Bacterial Suspension:

- Isolated bacterial colonies were transferred from fresh culture plates into a sterile test tube containing **distilled and sterile water**.
- The suspension was mixed thoroughly until a **homogeneous turbidity** was achieved, following the manufacturer's instructions for proper inoculum preparation.

4.4.2. API 20E (for Enterobacteriaceae and other Gram-negative):

- **Activation:** An API 20E strip was placed in the incubation tray.
- **Inoculation:** Each cupule was filled with the bacterial suspension.
- **Anaerobic Conditions:** The following tests were overlaid with sterile mineral oil: **ADH** (arginine dihydrolase), **LDC** (lysine decarboxylase), **ODC** (ornithine decarboxylase), **H2S** (hydrogen sulfide), and **URE** (urease).
- **Incubation:** 24 hours at 37°C.

4.4.3. Reagents Used After Incubation:

- **TDA test:** 1 drop of TDA reagent (reddish-brown = positive)
- **IND test (Indole):** 1 drop of Kovac's reagent (red ring = positive)
- **VP test (Voges-Proskauer):** 1 drop each of VP1 and VP2 reagents (pink = positive)
- **Interpretation:** The profile number was obtained using the result grid and interpreted via the APIweb Database (Biomérieux©).

4.4.4. API 20NE (for non-Enterobacteriaceae):

- Inoculation followed the same procedure using distilled water suspension.
- Each microtube was filled carefully, with no oil overlay required.
- Incubation at 37°C for 24 hours.

4.4.5. Reagents Used:

- **IND (Indole):** Kovac's reagent
- **NO3 (Nitrate reduction):** NIT 1 and NIT 2 reagents (red = positive)
- Final identification was achieved via APIweb Database (Biomérieux©).

4.4.6. API Staph (for Gram-positive cocci):

- Bacterial colonies were suspended in distilled water and homogenized.
- The strip was filled with the suspension directly.
- Incubation was done at 37°C for 24 hours in a humid chamber.

4.4.7. Reagents Used:

- **URE test:** color change to pink = positive
- **NO3 test:** 1 drop each of NIT 1 and NIT 2 (red = positive)
- Identification was performed using the APIweb Database (Biomérieux©).

5. Antimicrobial Susceptibility Testing:

5.1. The disk diffusion method (Kirby-Bauer):

A suspension was prepared by mixing bacterial colonies in sterile nutrient broth. The mixture was incubated at 37°C for 3 hours to activate the bacteria. Then, a sterile swab was used to inoculate Mueller-Hinton agar plates for antibiotic testing.

5.2 Antibiotics Tested:

The following 7 antibiotics were tested, with their corresponding classes (see table below).

Table 2. Kinds of antibiotics used during antimicrobial susceptibility testing.

Antibiotic	**Abbreviation / Doses**	**Class**
Gentamicin	*CN / 10 µg*	Aminoglycoside
Penicillin	*P / 10 units*	Beta-lactam (Penicillin class)
Cefoxitin	*FOX / 30 µg*	Beta-lactam (Cephamycin)
Vancomycin	*VN / 30 µg*	Glycopeptide

Amoxicillin	*AMX / 25 µg*	Beta-lactam (Aminopenicillin)
Rifamycin	*RD / 5 µg*	Rifamycin
Chloramphenicol	*C / 30 µg*	Amphenicol

5.3. Assessment of Antimicrobial Susceptibility:

5.3.1. Measurement of inhibition diameter:

After 24 hours of incubation, the plates were removed from the incubator, and the zones of inhibition around each antibiotic disk were measured using a ruler or caliper in millimeters.

5.3.2. Resistance versus Sensibility:

The measurements were compared to antibiotics sensibility test standard “ASTS” guidelines (see Institut Pasteur, Algeria) to classify the bacterial isolates as resistant (R), intermediate (I), or sensitive (S) to each antibiotic tested.

Chapter 3

Results and Discussion

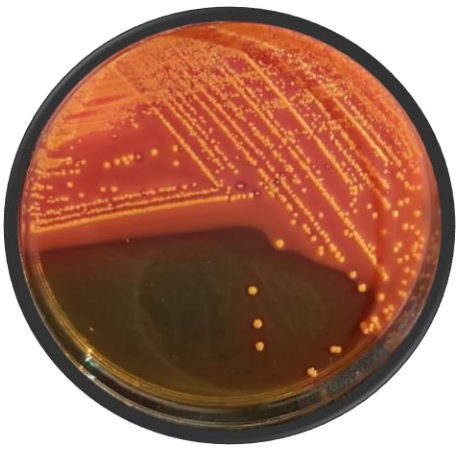
I. Results:

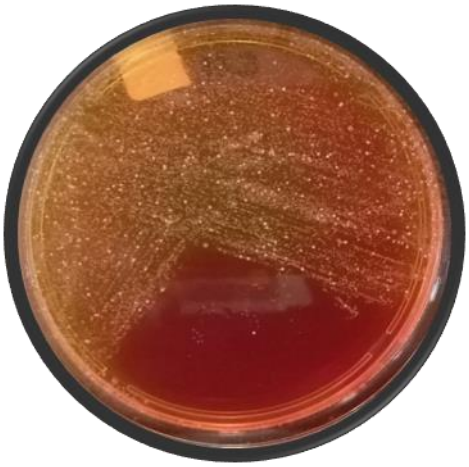
1. Characterization of species and diversity:

1.1 Media Identification:

The bacterial colonies isolated from different samples exhibit a variety of forms, colors, and appearances. Depending on the medium used for bacterial isolation, we observed a multispectral range of colony types, as illustrated in Tables 3, 4, 5, and 6.

Table 3. Examples of Macroscopic Colony Observations on Different Culture Media

Sample and Culture Medium	Colony Morphology Documentation	Macroscopic Characteristics Assessment
Red cap Oranda (HEK)		– **Colony Color:** Creamy, opaque, off-white to light yellow – **Colony Size**: Medium to large – **Colony Shape**: Circular with smooth, regular edges – **Elevation:** Slightly raised – **Surface:** Moist, glistening, smooth
Squirrel (HEK)		– **Colony Color:** Orange to salmon-pink colonies – **Colony Size:** Small to medium, round – **Colony Shape**: Circular, smooth edges – **Elevation:** Slightly raised – **Surface**: Moist, glistening

Cockatiel **(MSA)**		– **Colony Color**: Pale, creamy white colonies – **Colony Size:** Small to medium – **Colony Shape**: Circular, smooth-edged – **Elevation:** Slightly raised – **Surface:** Smooth, moist, glistening
Dog **(MSA)**		– **Colony Color:** Small, pale, white to off-white colonies – **Colony Size**: Small, pinpoint to very small – **Colony Shape:** Circular, smooth-edged – **Elevation:** Slightly raised – **Surface:** Smooth, glistening
Koi fish **(SSA)**		– **Colony Color:** Dark, almost black or very dark purple colonies – **Colony Size:** Medium to large, with some coalescing in heavily streaked areas – **Colony Shape:** Circular, smooth-edged – **Elevation:** Slightly raised – **Surface:** Moist, glistening

Squirrel **(SSA)**		– **Colony Color**: Pink to dark pink colonies – **Colony Size:** Medium, round, well-isolated in streaked areas – **Colony Shape:** Circular, smooth edges – **Elevation:** Slightly raised – **Surface:** Moist, glistening.

Table 4. Identification of Bacterial Colonies on Mannitol Salt Agar

Samples	Sample type	Results	Observation
Koi fish	Water	Negative	/
Red cap Oranda	Water	Positive	Colonies are pale yellow, irregular, and spreading with a moist, glistening texture. The medium shows a clear yellow color change, indicating mannitol fermentation.
Goldfish	Water	Positive	Large, raised, creamy white colonies with no significant color change in the medium, indicating no mannitol fermentation.
Parrot	Feather	Positive	Small, circular, white, smooth, and moist colonies are present on a red medium with no significant color change, indicating no mannitol fermentation.
	Feces	Negative	/
Budgies (parakeets)	Feces	Positive	Small, circular, white colonies with a smooth and moist texture are observed. The medium remains mostly red, showing no significant color change and indicating no mannitol fermentation.
Cockatiels	Feces	Positive	Very small, pinpoint, white colonies appear along the streak lines. Colonies are circular and smooth, and the medium stays red, with no color change.

Goldfinch	Feces	Positive	Irregular, spreading yellow colonies with a moist texture, indicating mannitol fermentation. The medium has turned yellow around the colonies, reflecting acid production.
Terrestrial turtle	Feces	Negative	/
Fennec fox	Fur	Positive	Numerous white colonies of varying sizes are present, mostly circular and smooth. The colonies are moist, and the medium shows a noticeable yellow color change, especially where the growth is dense, indicating mannitol fermentation.
	Feces	Positive	Few, small, white colonies are present, circular and smooth in texture. The medium remains red without any yellowing, indicating no mannitol fermentation.
Squirrels	Cage swab	Positive	Large, pale yellow colonies are present, circular with a smooth and glistening texture. There is a clear yellow color change in the medium around the colonies, showing mannitol fermentation.
	Feces	Positive	Many very small, pinpoint, white colonies are visible, circular and smooth in appearance. The medium remains mostly red with no

			significant yellowing, indicating no mannitol fermentation.
Monkey	Feces	Negative	/
Hamster	Feces	Positive	Small, circular, white, smooth, and moist colonies are present on a red medium with no significant color change, indicating no mannitol fermentation.
Cat	Teeth swab	Positive	Small, circular colonies with a smooth and moist texture, exhibiting a yellowish to cream color.
Dog	Feces	Negative	/

Table 5. Identification of Bacterial Colonies on Hektoen Enteric Agar

Samples	**Sample type**	**Results**	**Observation**
Koi fish	Water	Negative	/
Goldfish	Water	Positive	Small, smooth, moist, yellowish to cream-colored colonies, mostly circular with smooth edges, in streaks on yellowed Hektoen medium.
Parrot	Feather	Negative	/
	Feces	Positive	yellowish hues colonies, spreading irregular or droplet-like in form, moist and glistening in texture, and small to medium in size.
Budgies (parakeets)	Feces	Negative	/
Cockatiels	Feces	Positive	Small, smooth, moist,

			yellowish to cream-colored colonies, mostly circular with smooth edges, in streaks on yellowed Hektoen medium.
Goldfinch	Feces	Positive	Greenish-black, medium to large, irregular spreading colonies with slightly raised, smooth, moist, and glistening surfaces on Hektoen agar, showing no color change in the medium.
Terrestrial turtle	Feces	Positive	/
Fennec fox	Fur	Negative	/
	Feces	Positive	Individual, distinct yellowish to cream-colored colonies, mostly circular with smooth edges, small to medium in size, slightly raised, smooth and moist texture, causing the Hektoen medium to change from dark green to yellow where growth occurs.
Squirrels	Cage swab	Negative	/
Monkey	Feces	Positive	Individual, mostly circular colonies with some confluent growth along streaks; yellowish to cream-colored, small to medium in size, slightly raised, smooth, moist, and glistening, causing yellowing of the original dark green Hektoen agar where growth occurs.

Hamster	Feces	Positive	Small, smooth, moist, yellowish to cream-colored colonies, mostly circular with smooth edges, in streaks on yellowed Hektoen medium.
Cat	Teeth swab	Positive	The round, well-defined colonies appear yellowish-orange with a smooth, glossy texture. They are slightly raised on the reddish-brown agar, which shows no significant green or black discoloration, indicating minimal changes in the Hektoen medium.
Dog	Feces	Positive	Streaked growth pattern with small, yellowish to cream-colored colonies that are smooth and moist; individual colonies are indistinct, elevation is unclear, and the Hektoen medium shows yellow/orange color change where bacteria grow.
	Fur	Positive	Small, smooth, moist, yellowish to cream-colored colonies, mostly circular with smooth edges, in streaks on yellowed Hektoen medium.

Table 6. Identification of Bacterial Colonies on Salmonella-Shigella Agar

Samples	Sample type	Results	Observation
Red cap Oranda	Water	Positive	The bacterial colony on SS agar appears irregular with rough, wrinkled texture and spreading form . It has a light tan color with flat to slightly raised elevation.
Goldfish	Water	Negative	/
Parrot	Feather	Negative	/
	Feces	Negative	/
Budgies (parakeets)	Feces	Negative	/
Cockatiels	Feces	Positive	The colonies are round and well-defined, with a pale pink to lavender color. They have a smooth, glossy, and moist texture and are slightly raised above the surface of the reddish-brown SS agar. The medium itself shows no significant color change, blackening, or discoloration, indicating no hydrogen sulfide production or strong lactose fermentation.
Goldfinch	Feces	Positive	The colonies on the SS medium are round with well-defined edges and a smooth, moist texture. They appear yellowish,

			contrasting with the reddish-brown agar. Their elevation is slightly raised, but not overly convex. There are no visible black precipitates, indicating no hydrogen sulfide production, and the agar color remains unchanged, showing minimal metabolic effects.
Terrestrial turtle	Feces	Negative	/
Fennec fox	Fur	Negative	/
	Feces	Positive	This plate displays numerous small, round, and well-defined colonies with a bright pink color. The colonies are smooth, moist, and slightly raised. The SS agar retains its original reddish-brown color without any blackening or other discoloration, showing no evidence of hydrogen sulfide production or significant fermentation activity.
Squirrels	Cage swab	Negative	/
Monkey	Feces	Positive	Individual mostly circular colonies, some confluent along streaks, pink to cream-colored, small to medium in size, slightly raised, smooth, moist, and glistening, causing pinkish

			discoloration of the SS medium. One colony exhibits black precipitation, indicating hydrogen sulfide production.
Hamster	Feces	Positive	The colonies remain round with well-defined edges, showing a smooth texture and slightly raised elevation. The SS medium also displays blackening, reflecting metabolic activity.
Cat	Teeth swab	Negative	/
Dog	Feces	Positive	Numerous small, circular colonies are scattered along the streak lines. These colonies appear light pink and have a smooth, moist, and shiny surface. They are slightly elevated from the agar. The SS medium remains unchanged in color, with no blackening or greenish hues, suggesting minimal metabolic activity affecting the medium.
	Fur	Positive	The plate features many small, round, and well-separated colonies, each with a distinct pale pink to light purple hue. The colonies are smooth, moist, and slightly raised. The reddish-brown medium does

			not display any noticeable blackening or color shifts, indicating the absence of hydrogen sulfide production and minimal fermentation.

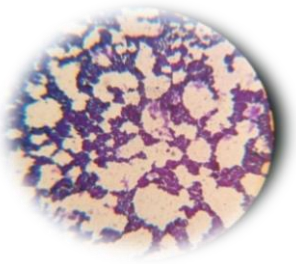
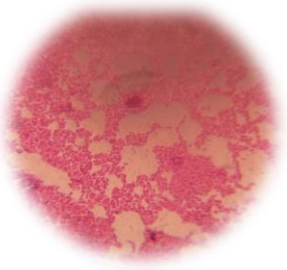
2. Gram Staining and API system Biochemical Test:

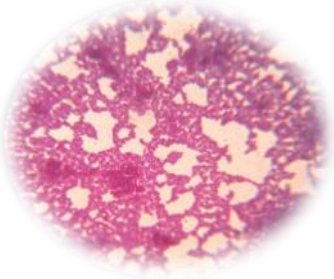
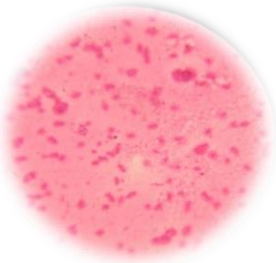
2.1 Identification based on Gram Staining:

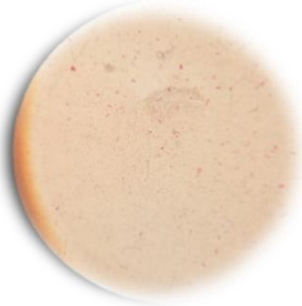
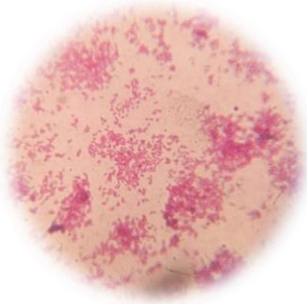
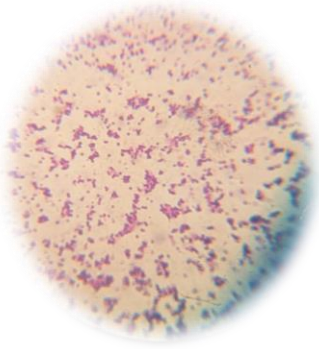
Gram staining helped differentiate the bacterial isolates based on their shape and Gram reaction. Both Gram-positive cocci and bacilli were observed, indicating the presence of bacteria with thick peptidoglycan cell walls. Several isolates also showed Gram-negative bacilli, recognized by their pink color under the microscope, typical of bacteria with thinner cell walls and an outer membrane.

The variation in shapes and Gram reactions reflects a diverse bacterial population across the samples. This staining step provided essential preliminary information for further identification and classification.

Table 7. Microscopic Morphology of Bacterial Isolates on Various Culture Media Observed via Gram Staining

	***Atlantoxerus getulus: (mannitol agar)*** • 100× oil immersion magnification. • cocci (spherical). • Gram-positive.
	***Atlantoxerus getulus: (Hektoen agar)*** • 100× oil immersion magnification. • Rode-shaped (bacilli). • pink or rose-colored.

	• Gram-negative.
	***Nymphicus hollandicus:*** • 100× oil immersion magnification. • cocci (spherical). • Gram-positive.
	***Carduelis carduelis:*** • 100× oil immersion magnification. • Gram-negative bacilli • pink or rose-colored
	***Psittacus erithacus:*** • 100× oil immersion magnification. • rod-shaped (bacilli). • Gram-positive
	***Melopsittacus undulates:*** • 100× oil immersion magnification. • rod-shaped (bacilli). • Gram-positive.
	***Carassius auratus:*** • 100× oil immersion magnification. • rod-shaped bacteria (bacilli). • Gram-negative

	***Nymphicus hollandicus:*** • 100× oil immersion magnification. • Cocci. • Gram-positive.
	***Atlantoxerus getulus:*** • 100× oil immersion magnification. • Cocci. • Gram-positive.
	***Vulpes zerda*: (Hektoen agar)** • 100× oil immersion magnification. • rod-shaped (bacilli). • Gram-negative.
	***Vulpes zerda*: (mannitol agar)** • 100× oil immersion magnification. • rod-shaped (bacilli). • Gram-negative.
	***Belgian Shepherd*: (mannitol agar)** • 100× oil immersion magnification. • cocci • Gram-positive

2.2 Biochemical tests:

2.2.1 Catalase and Oxidase Activity Test:

The catalase and oxidase test applied during our identification is resumes in Table 8.

Table 8. Results of catalase and oxidase enzyme availability in different bacteria.

Bacterium	Catalase	Oxidase
Aeromonas spp.	+	+
Citrobacter spp.	+	-
Enterobacter spp.	+	-
Kluyvera spp.	+	-
Kocuria spp.	+	+
Ochrobactrum spp.	+	+
Pasteurella spp.	+	+
Pseudomonas spp.	+	+
Salmonella spp.	+	-
Serratia spp.	+	-
Staphylococcus spp.	+	-

2.2.2 Catalase Test:

The **catalase test** detects the enzyme **catalase**, which breaks down **hydrogen peroxide (H_2O_2)** into **water and oxygen**.

- **Purpose**: Protects bacteria from oxidative damage by reactive oxygen species.
- **Catalase-positive bacteria**: Typically, **aerobic** or **facultative anaerobes** they use or tolerate oxygen, so they need catalase to neutralize H_2O_2.

Figure 2. Illustration of Positive Catalase Test.

2.2.3 Oxidase Test:

The **oxidase test** checks for the presence of **cytochrome c oxidase**, an enzyme in the **electron transport** chain used in **aerobic respiration**.

- **Oxidase-positive bacteria**: Use cytochrome c in their respiratory chain (often strict aerobes or some facultative anaerobes that prefer aerobic respiration).
- **Oxidase-negative bacteria:** Use a different type of terminal oxidase or fermentative metabolism, like most Enterobacteriaceae.

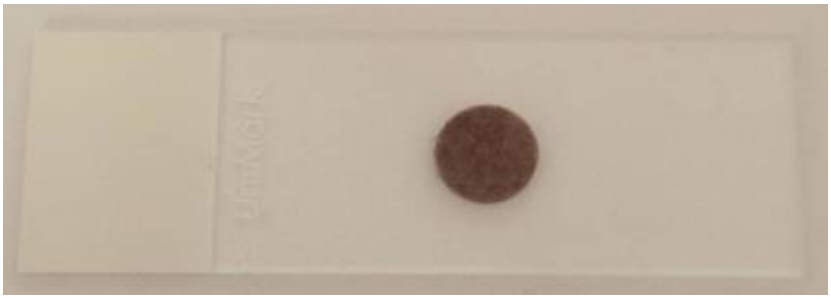


Figure 3. Illustration of Positive Oxidase Test.

2.3 API Systems identification:

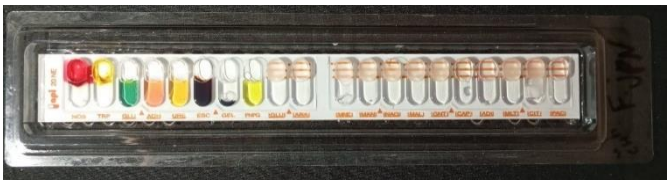
A total of 22 distinct biochemical profiles were obtained using three standardized commercial identification systems: API 20E, API NE, and API Staph. selected based on the Gram reaction and morphological characteristics of the bacterial isolates (Table 9).

- Using **API 20E**, which is designed for the identification of Enterobacteriaceae and other Gram-negative rods, we identified members of the Enterobacteriaceae family, including (*Citrobacter*, *Serratia*, *Enterobacter*, *Salmonella*, and *Kluyvera*).

- The **API NE** system, tailored for non-Enterobacteriaceae Gram-negative rods, enabled the identification of Pseudomonadaceae (*Pseudomonas*), *Aeromonadaceae* (*Aeromonas*), *Brucellaceae* (*Ochrobactrum*), and *Pasteurellaceae* (*Pasteurella*).
- The **API Staph** system was utilized for the identification of Gram-positive cocci, enabling the detection of members belonging to the *Staphylococcaceae* (*Staphylococcus*) and *Micrococcaceae* (*Kocuria*) families. This system, designed specifically for staphylococci and related genera.

This stratified approach ensured accurate phenotypic identification through biochemical profiling based on enzyme activity and metabolic capabilities, supporting reliable classification at the genus and, in some cases, species level.

Table 9. Biochemical Identification of Bacterial Isolates Using API Systems.

Bacterium\Reference	**Biochemical Profiles**
Salmonella spp. ***7646773.***	
Ochrobactrum anthropic. ***1567741.***	
Pseudomonas luteola. ***1467741.***	

Aeromonas hydrophila. ***5567747.***	
Kocuria varians. ***4106401.***	
Staphylococcus xylosus. ***6773713.***	
Pasteurella spp. ***7730000.***	

In addition to the primary representative species identified for each bacterial family, further biochemical characterization revealed a broader diversity within certain groups:

- ***Enterobacter sakazakii: 3354773.***
- ***Enterobacter cloacae: 3305573.***
- ***Citrobacter koseri amalonaticus: 3354153.***
- ***Serratia marcescens: 5357773.***
- ***Serratia odorifera: 5346773.***
- ***Kluyvera spp: 5144573.***
- ***Staphylococcus simulans: 6213551.***
- ***Staphylococcus auricularis: 6712001.***
- ***Staphylococcus saprophyticus: 6634111.***

The application of API identification systems provided a comprehensive overview of the biochemical diversity among the bacterial isolates. By employing API 20E, API NE, and API Staph, we successfully identified a wide range of Gram-negative and Gram-positive bacteria, representing multiple families with varying ecological and clinical significance. This method allowed for the detection of both commonly encountered and less frequent species.

3. Antimicrobial Susceptibility Testing:

Antibiotic susceptibility testing was performed to evaluate the resistance profiles of the bacterial isolates identified through biochemical methods. Using a panel of commonly prescribed antibiotics: Gentamicin, Penicillin, Cefoxitin, Vancomycin, Amoxicillin, Rifamycin, and Chloramphenicol (Table 10).

we assessed the susceptibility, intermediate resistance, and resistance patterns of the isolates. The results provide valuable insights into the antimicrobial resistance (AMR) profiles of the bacterial strains, highlighting potential challenges for treatment, especially in the context of multidrug-resistant (MDR) organisms.

Table 10. AST Patterns of Identified Bacterial Isolates

Samples	Medium	Species	GEN	PEN	FOX	VAN	AMX	CHL	RIF
Koi fish	**SSA**	*Salmonella spp.*	S (18)	R	R (6)	R	R	S (24)	R (8)
Red cap Oranda	**HEK**	*Pseudomonas luteola*	S (20)	R (14)	S (22)	R (14)	S (18)	S (20)	S (22)
Parrot (feces)	**SSA**	*Enterobacter sakazakii*	I (14)	R	S (19)	R	R	R (12)	R (10)
Parrot (feathers)	**MSA**	*Ochrobactrum anthropi*	I (14)	R (26)	S (24)	R (10)	S (26)	I (14)	S (20)
Budgies (feces)	**MSA**	*Staphylococcus simulans*	S (20)	R	R	R	R	R (12)	I (18)
Cockatiel (feathers)	**MSA**	*Staphylococcus saprophyticus*	S (16)	S (34)	S (26)	R (10)	S (36)	R	S (32)

Goldfinch (feces)	**HEK**	*Citrobacter koseri*	R	R	R	R	R (6)	R (6)	R (8)
Terrestrial turtle (feces)	**HEK**	*Pasteurella spp.*	I (14)	R	I (16)	R	R (14)	R (20)	R (8)
Fennec fox (feces)	**HEK**	*Enterobacter cloacae*	I (14)	R	R	R	R	S (20)	I (8)
Squirrels (feces)	**SSA**	*Serratia marcescens*	I (14)	R	R	R	R	R	R (8)
Squirrels (feces)	**HEK**	*Serratia odorifera*	I (14)	R	R	R	I (14)	R	R (14)
Squirrels (cage swab)	**MSA**	*Staphylococccus auricularis*	S (20)	S (20)	R (12)	R (14)	S (24)	S (22)	S (26)
Hamster (feces)	**MSA**	*Kocuria varians*	S (16)	R	R (14)	R	I (16)	R	R (8)
Cat (teeth)	**MSA**	*Staphylococccus xylosus*	R (12)	R (6)	R (18)	R (10)	R (12)	R	R (3)
Cat (teeth)	**HEK**	*Aeromonas hydrophila*	S (20)	R	R	R	R	R	R (8)
Dog (feces)	**SSA**	*Kluyvera spp.*	I (14)	R	S (18)	R	R	R	R (10)

3.1 Overview of Tested Antibiotics and Interpretation:

The table reports susceptibility (S), intermediate resistance (I), and resistance (R) of various bacterial isolates against seven antibiotics: Gentamicin (GEN), Penicillin (PEN), Cefoxitin (FOX), Vancomycin (VAN), Amoxicillin (AMX), Chloramphenicol (CHL), and Rifamycin (RIF). The numbers in parentheses indicate the diameter of the inhibition zone in millimeters, which reflects the degree of susceptibility.

3.1.1 Patterns of Resistance and Susceptibility:

- High Resistance Observed:
- Vancomycin (VAN) shows widespread resistance across all isolates, indicating a total inefficacy against these bacteria.
- Penicillin (PEN) also shows high resistance, particularly among Gram-negative isolates such as *Salmonella spp.*, *Enterobacter sakazakii*, and *Citrobacter koseri*…
- Amoxicillin (AMX) resistance is common, especially in isolates from wild animals (eg, Goldfinch, Terrestrial turtle, Fennec fox).
- Rifamycin (RIF) resistance is common, especially in isolates like *Salmonella spp.* and *Serratia* species.

3.1.2 Antibiotics with Better Activity:

- Gentamicin (GEN) shows generally good activity, with many isolates marked susceptible (S) or intermediate (I). For example, *Pseudomonas luteola* and *Staphylococcus saprophyticus* are susceptible.
- Cefoxitin (FOX) susceptibility is variable but shows effectiveness against some isolates such as *Enterobacter sakazakii* and *Ochrobactrum anthropi*.
- Chloramphenicol (CHL) shows susceptibility in several isolates, including *Pseudomonas luteola* and *Enterobacter cloacae*, but resistance is also common.

3.1.3 Species-Specific Observations:

- ***Salmonella* spp. (Koi fish):** Resistant to PEN, FOX, VAN, AMX, and RIF but susceptible to GEN and CHL, indicating multidrug resistance with some treatment options remaining.
- ***Pseudomonas luteola* (Red cap Oranda):** Displays susceptibility to most antibiotics except PEN and VAN, suggesting it may be easier to treat.
- ***Enterobacter sakazakii* (Parrot feces):** Resistant to PEN, VAN, AMX, CHL, and RIF; only susceptible to FOX, indicating limited treatment options.
- ***Ochrobactrum anthropi* (Parrot feathers):** Mixed susceptibility; resistant to PEN and VAN, susceptible to FOX, AMX, and RIF.
- ***Staphylococcus species* (Budgies, Cockatiels, Squirrels):** Generally resistant to PEN and VAN, but susceptibility varies for other antibiotics like GEN, FOX, and CHL.

- ***Citrobacter koseri* (Goldfinch):** Shows resistance to all tested antibiotics, indicating a highly resistant strain.
- ***Pasteurella* spp. (Terrestria turtle):** Mostly resistant, with intermediate susceptibility to GEN and FOX.
- ***Enterobacter cloacae* (Fennec fox):** Intermediate susceptibility to GEN and RIF, susceptible to CHL, but resistant to most others.
- ***Serratia species* (Squirrels):** Mostly resistant to all antibiotics tested, indicating multidrug resistance.
- ***Kocuria varians* (Hamster):** Susceptible to GEN, resistant to PEN and FOX, intermediate to AMX.
- ***Aeromonas hydrophila* (Cat teeth):** Susceptible only to GEN, resistant to all other antibiotics.

3.1.4 Multidrug Resistance (MDR) Concerns:

Many isolates show multidrug resistance, especially those from wild or exotic animals (eg, *Salmonella* spp., *Citrobacter koseri*, *Serratia* spp.). This highlights the challenge of treating infections caused by these bacteria and underscores the importance of ongoing surveillance and prudent antibiotic use.

3.1.5 Medium Influence:

The isolates were cultured on different media (SSA = Salmonella-Shigella agar, Hek = Hektoen agar, MSA = Mannitol Salt agar), which may influence growth characteristics but does not affect antibiotic susceptibility results directly. The medium column helps contextualize the isolate source.

3.2 Resistance Patterns:

Antibiotic susceptibility testing revealed universal resistance to vancomycin among all isolates. High resistance rates were also observed for penicillin, chloramphenicol, rifamycin, amoxicillin, and cefoxitin. In contrast, gentamicin showed the lowest resistance and remained the most effective antibiotic tested. These results highlight the widespread multidrug resistance among bacterial isolates from domestic and exotic pets, emphasizing the importance of prudent antibiotic use (Figure 4).

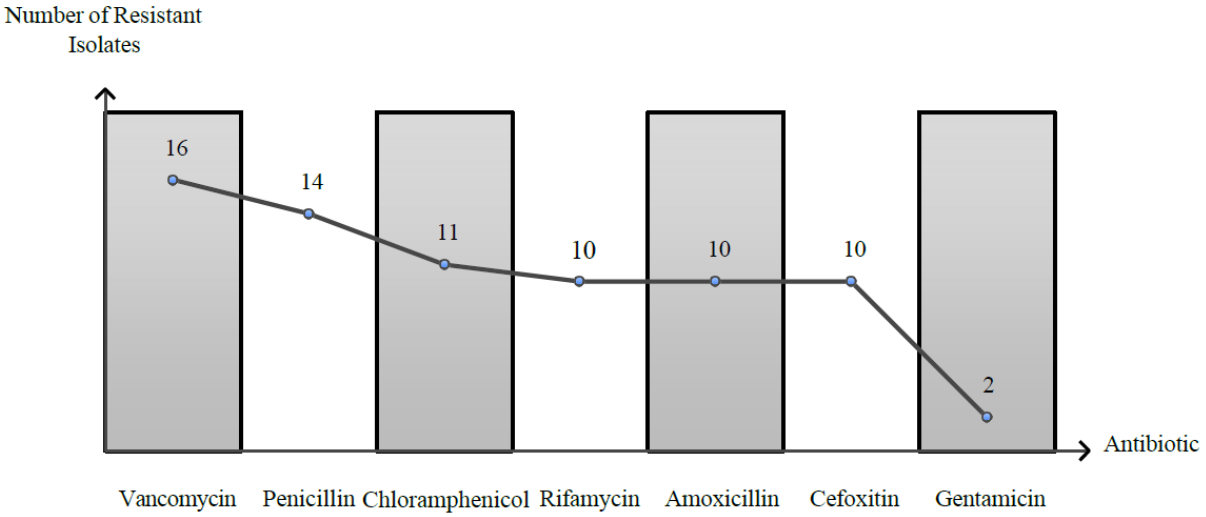


Figure 4. Antibiotic Resistance rates in Bacteria.

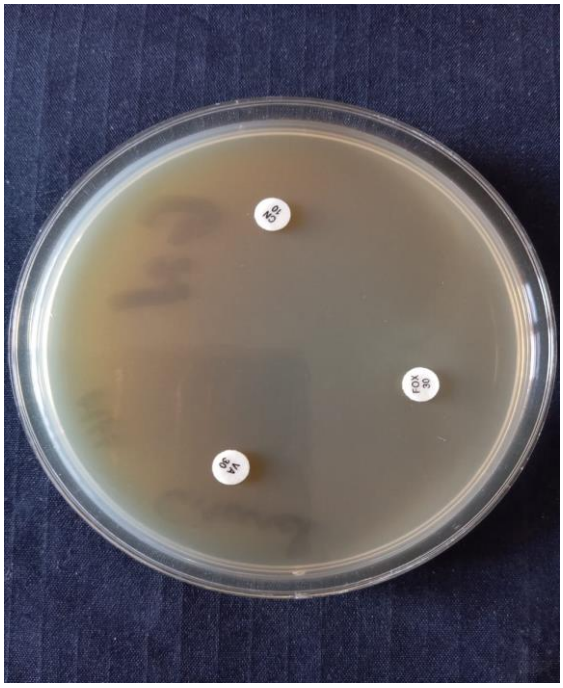


Figure 5. Example of Multidrug Resistance Detection

3.3 Susceptibility Patterns:

Among the antibiotics tested, gentamicin demonstrated the highest level of sensitivity, remaining effective against both Gram-negative and Gram-positive isolates. Cefoxitin, amoxicillin, rifamycin, and chloramphenicol showed moderate activity, while penicillin was rarely effective and vancomycin showed no activity against any isolate. These findings highlight the limited options for effective antibiotic therapy among bacteria isolated from domestic and exotic pets (Figure 6).

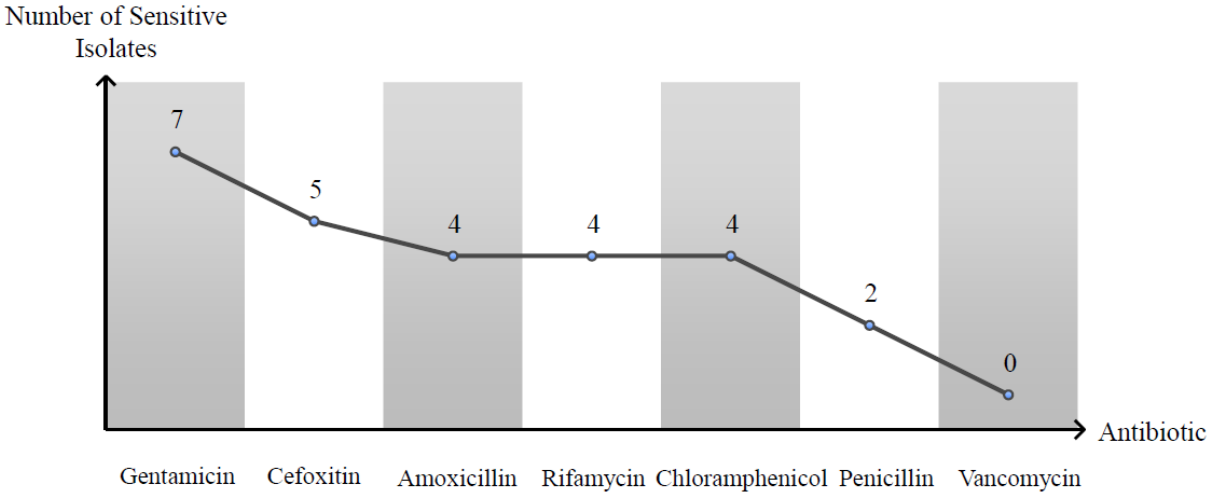


Figure 6. Antibiotic Effectiveness Comparison

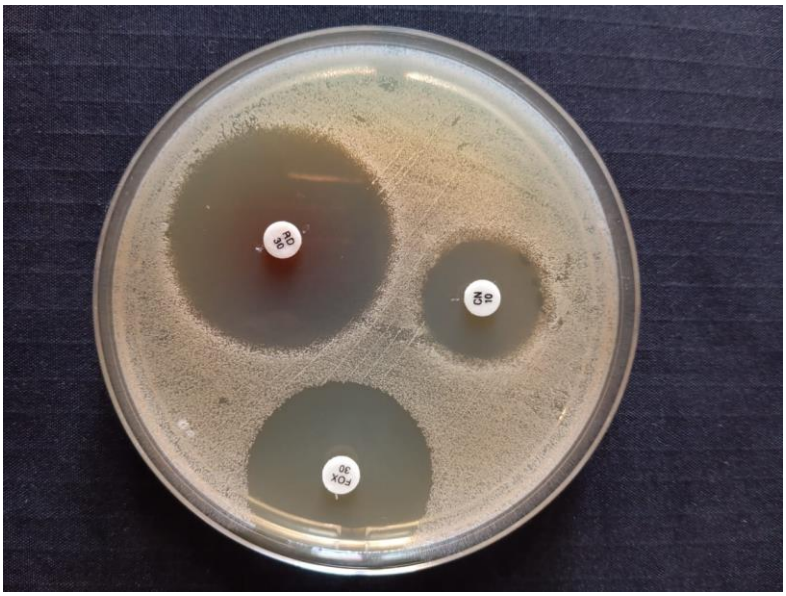


Figure 7. Example of Broad Sensitivity Observed

3.4 Intermediate Patterns:

A small proportion of isolates exhibited intermediate susceptibility, most notably to gentamicin, and to a lesser extent to amoxicillin, rifamycin, cefoxitin, and chloramphenicol. These intermediate responses were predominantly observed among Gram-negative bacteria. No intermediate susceptibility was detected for penicillin or vancomycin. This highlights the partial and uncertain efficacy of several antibiotics against the bacterial isolates studied (Figure 8).

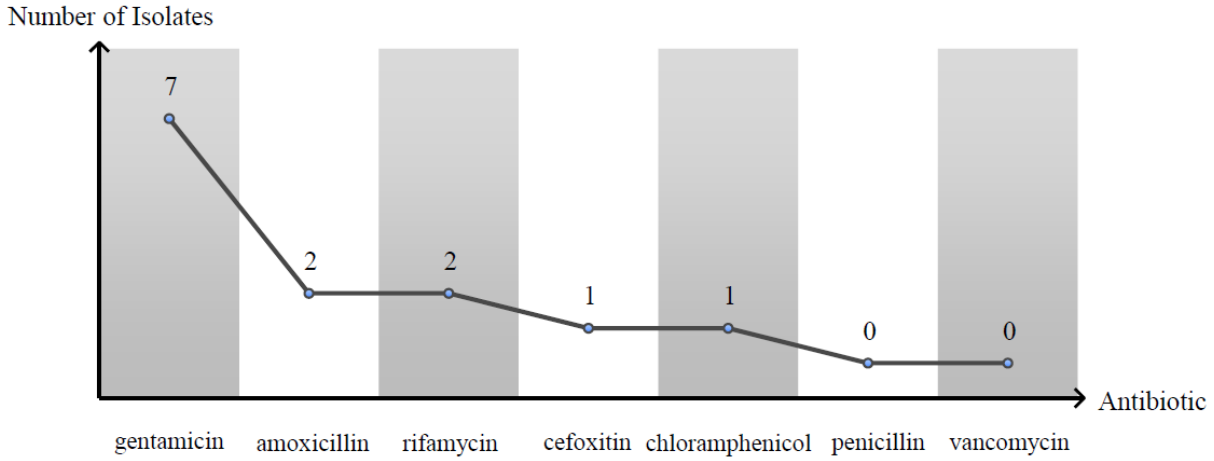


Figure 8. Antibiotic Intermediate Effectiveness Comparison.

Figure 9. Example of Intermediate Effectiveness

II. Discussion:

Our study revealed a diverse array of bacterial species isolated from both domestic and exotic pets in Guelma, with a notable prevalence of antimicrobial resistance across the sampled population. Through the use of selective and differential media, Gram staining, and biochemical identification (including API systems), we identified a wide range of Gram-negative and Gram-positive bacteria, such as Enterobacteriaceae, Pseudomonadaceae, Staphylococcaceae, and others, reflecting substantial microbial diversity among the pet samples.

Antibiotic susceptibility testing showed that resistance to commonly used antibiotics is widespread. Vancomycin and penicillin exhibited the highest rates of resistance, particularly

among Gram-negative isolates, limiting their effectiveness for empirical treatment. Chloramphenicol, Rifamycin Amoxicillin and also demonstrated high resistance rates across both Gram-positive and Gram-negative groups, with especially pronounced resistance in isolates from wild and exotic animals like goldfinches, turtles, and fennec foxes. Notably, multidrug resistance (MDR) was frequently observed among isolates from exotic pets, including *Salmonella spp., Citrobacter koseri*, and *Serratia spp.*, which were resistant to nearly all tested antibiotics except for occasional susceptibility to Gentamicin or Chloramphenicol.

Gentamicin emerged as the most effective antibiotic in our study, with the majority of isolates-regardless of Gram reaction-showing susceptibility or intermediate responses. Cefoxitin, Amoxicillin, Rifamycin and Chloramphenicol displayed moderate activity, with a mix of susceptible and intermediate results, particularly among Gram-positive isolates. Intermediate susceptibility was most commonly noted with Gentamicin, Amoxicillin, rifamycin, Cefoxitin and Chloramphenicol, suggesting partial therapeutic potential, especially with optimized dosing strategies.

Species-specific analysis highlighted the complexity of resistance patterns. For example, *Salmonella spp*. isolated from koi fish were resistant to most antibiotics except Gentamicin and Chloramphenicol and Rifamycin, while *Citrobacter koseri* from goldfinch samples showed resistance to all tested antibiotics. In contrast, some isolates such as *Pseudomonas luteola* and *Staphylococcus saprophyticus* remained susceptible to a broader range of antibiotics, indicating variability in resistance even within similar environments.

Overall, these findings highlight the significant challenge posed by antimicrobial resistance in both domestic and exotic pets. The high prevalence of multidrug-resistant bacteria, particularly among exotic species, supports the hypothesis that such animals may serve as important reservoirs for resistant and potentially zoonotic pathogens. This highlights the urgent need for ongoing surveillance, responsible antibiotic stewardship, and further research into the mechanisms and transmission dynamics of resistance in companion animals.

Our study provides compelling evidence that both domestic and exotic pets in Guelma harbor a diverse range of bacterial species with significant antimicrobial resistance. The consistently high resistance rates to penicillin and vancomycin, especially among Gram-negative isolates, are concerning and suggest that these antibiotics are largely ineffective against many pet-associated bacteria in this region. This pattern aligns with global trends, where overuse and

misuse of broad-spectrum antibiotics have contributed to the rapid emergence and dissemination of resistant strains in both human and veterinary medicine.

Amoxicillin and rifamycin also exhibited high resistance rates, further limiting the options for empirical treatment of infections in pets. The presence of such resistance in both Gram-positive and Gram-negative isolates, particularly in bacteria from exotic species like goldfinches, turtles, and fennec foxes, highlights the broad impact of antimicrobial resistance across different animal hosts. This supports the hypothesis that exotic pets, in addition to domestic ones, may serve as important reservoirs of multidrug-resistant (MDR) and potentially zoonotic bacteria.

The detection of multidrug-resistant isolates especially Citrobacter koseri, Staphylococcus xylosus, Serratia spp and Aeromonas hydrophila are particularly worrisome. These bacteria not only resist multiple classes of antibiotics but are also recognized as potential zoonotic pathogens, posing a risk to both animal and human health. The identification of these last species and their resistant to all of almost tested antibiotics underscores the urgent need for surveillance and the development of alternative therapeutic strategies.

On a more positive note, gentamicin demonstrated the highest overall effectiveness, with most isolates showing susceptibility or intermediate responses. This suggests that, despite widespread resistance to other agents, Gentamicin and Cefoxitin remains a viable option for treating a broad spectrum of infections in both domestic and exotic pets. Amoxicillin, Rifamycin and chloramphenicol showed moderate activity, indicating that they may still be useful in certain cases, particularly when guided by susceptibility testing.

Intermediate susceptibility patterns, especially with gentamicin, Amoxicillin and Rifamycin, indicate that while some bacteria are not fully susceptible, these antibiotics could still be effective with optimized dosing or in combination therapies. This finding highlights the importance of individualized treatment plans based on susceptibility profiles rather than empirical use of antibiotics.

The diversity of species-specific resistance patterns underscores the complexity of antimicrobial resistance in bacteria associated with pets. Multidrug resistance was notably observed in *Salmonella* spp. from koi fish, *Enterobacter sakazakii* from parrots, *Enterobacter cloacae* from fennec foxes, *Kluyvera* spp. from dogs, *Staphylococcus simulans* from budgies, *Pasteurella* spp. from terrestrial turtles, and *Kocuria varians* from hamsters, indicating that a wide range of exotic and domestic pets can harbor resistant bacteria. Conversely, some isolates remained susceptible to several antibiotics, including *Pseudomonas*

luteola, *Staphylococcus saprophyticus*, *Ochrobactrum anthropi*, and *Staphylococcus auricularis*. These findings demonstrate that antimicrobial resistance is not uniform across all species or isolates and underscore the need for targeted surveillance and antimicrobial stewardship in diverse pet populations.

In summary, these findings confirm the hypothesis that both domestic and exotic pets in Guelma can serve as reservoirs for antimicrobial-resistant bacteria, with exotic species showing a particularly high prevalence of multidrug resistance. This underscores the need for prudent antibiotic use, regular surveillance, and the implementation of infection control measures in both pet care and public health settings. The results also highlight the importance of ongoing research to better understand the mechanisms and transmission dynamics of resistance in companion animals.

In this study, we isolated and identified a diverse range of bacterial species from a wide variety of domestic and exotic pets in Guelma, Algeria, including cats, dogs, hamsters, squirrels, monkeys, budgies, cockatiels, goldfinches, parrots, fennec foxes, terrestrial turtles, koi fish, goldfish, and red cap oranda. Our bacterial isolation yielded numerous species, such as *Salmonella spp., Citrobacter koseri, Serratia spp., Enterobacter sakazakii, Ochrobactrum* anthropi, *Staphylococcus spp., Pasteurella spp., Enterobacter cloacae, Kocuria varians, Aeromonas hydrophila, and Kluyvera spp.* We identified 16 distinct bacterial species using 22 biochemical bacterial profiles. This represents a notably higher diversity and number of isolates compared to the recent study by **(Bara et al., 2025)**, which reported 37 biochemical profiles corresponding to 17 bacterial species isolated from 54 exotic animals across five northeastern Algerian provinces over a three-year period. In contrast, our results were obtained within a single year, further emphasizing the richness and variety of bacterial flora in the sampled animals from Guelma, Algeria.

While **(Bara et al., 2025)** focused primarily on exotic pets and identified a predominance of enterobacteria (53%) and Gram-negative bacteria (72%), our study expands on this by including a broader range of animal species-including both domestic and exotic pets-and documenting a wider spectrum of bacterial species. The higher number of isolates and species in our study likely reflects differences in sampling scope, animal diversity, and possibly environmental factors specific to Guelma.

The antibiotic resistance patterns observed in our both study among bacterial isolates from domestic and exotic pets in Guelma are in strong agreement with global trends reported in the

literature. Widespread resistance to penicillin, vancomycin, amoxicillin, and rifamycin was detected, particularly among Gram-negative bacteria such as *Pasteurella spp. Salmonella spp., Aeromonas spp. Serratia spp. Citrobacter koseri*, and *Enterobacter sakazakii* **(Guardabassi et al., 2004 ; Wedley et al., 2017).** This mirrors findings by **(Guardabassi et al., 2004),** who reported high levels of resistance to β-lactam antibiotics in companion animal isolates, and by **(Wedley et al., 2017),** who found that penicillins and vancomycin are frequently ineffective against Enterobacteriaceae from pets.

The high resistance to amoxicillin and rifamycin, especially in isolates from wild and exotic animals such as goldfinch, terrestrial turtle and fennec fox, is consistent with observations by **(Dolejska & Literak, 2019),** who emphasized that wildlife and exotic pets are important but under-recognized reservoirs for multidrug-resistant (MDR) bacteria, including zoonotic pathogens. Similarly, a study by **(Radhouani et al., 2014)** demonstrated that wild birds in Europe frequently carry Enterobacteriaceae resistant to multiple antibiotic classes, highlighting the potential for transmission of MDR bacteria from wildlife to humans and domestic animals.

Species-specific resistance patterns in our study, such as multidrug resistance (MDR) in *Salmonella spp. from* koi fish *and Citrobacter koseri* from goldfinch, align with recent findings that reptiles and birds frequently carry MDR Enterobacteriaceae , including *Salmonella* and *Citrobacter*, with resistance to multiple commonly used antibiotics. Notably, **(Wang et al., 2024)** reported the emergence of MDR *Salmonella* strains in pet turtles in China, demonstrating high rates of resistance to ampicillin, streptomycin, sulfonamides, and tetracycline, and provided genomic evidence suggesting interspecies transmission between pet turtles and children with diarrhoea.

Highlights that pet turtles as significant reservoirs of MDR strains, supporting the role of exotic pets in harboring resistant zoonotic bacteria. These findings are consistent with **(Greig et al., 2015),** who documented MDR *Salmonella* in pet reptiles and amphibians. Collectively, these studies confirm that exotic pets and wildlife are important reservoirs of MDR bacteria, underscoring the need for surveillance and antimicrobial stewardship to mitigate zoonotic transmission risks.

The detection of *Serratia* species and *Enterobacter sakazakii* with resistance to nearly all tested antibiotics in our study echoes concerns raised by **(Poirel et al., 2018),** who described the global emergence of highly resistant Enterobacteriaceae, including Serratia and Enterobacter, in both domestic and wild animals.

Gentamicin's strong activity against most isolates in our study is supported by several reports **(Guardabassi et al., 2004; Dolejska & Literak, 2019),** which note that aminoglycosides remain among the most effective options for treating infections caused by resistant Gram-negative bacteria in animals. However, the emergence of intermediate resistance to Gentamicin, Amoxicillin and Rifamycin among some isolates is also reflected in the literature, indicating the potential for further resistance development **(Wedley et al., 2017; Radhouani et al., 2014).**

The prevalence of MDR bacteria, especially among exotic pets, is a growing concern. Our findings of MDR in Salmonella spp., Citrobacter koseri, and Serratia spp. are in line with those of **(Dolejska & Literak, 2019; Radhouani et al., 2014),** who both reported that exotic pets and wild birds can serve as significant reservoirs for MDR and zoonotic bacteria. The One Health implications of this are substantial, as outlined by **(Robinson et al., 2016)** and the World Health Organization **(WHO, 2017),** which stress the interconnectedness of human, animal, and environmental health in the context of antimicrobial resistance.

Importantly, our study adds to the growing body of evidence that both domestic and exotic pets contribute to the dissemination of resistant bacteria, potentially facilitating zoonotic transmission. This is particularly relevant given the close contact between humans and their pets, as highlighted by **(Guardabassi et al., 2004).** The detection of highly resistant strains in exotic pets, which are often less studied, underscores the need for enhanced surveillance and responsible antimicrobial stewardship in both veterinary and public health sectors.

Our findings underscore the urgent need for ongoing surveillance of antimicrobial resistance (AMR) in pet populations, including both domestic and exotic species. Exotic pets, due to their close contact with humans and potential to harbor multidrug-resistant (MDR) bacteria, represent a significant but under-recognized reservoir for AMR pathogens. Continuous monitoring can help detect emerging resistance patterns early and inform targeted interventions to mitigate zoonotic transmission risks **(Muñoz-Ibarra et al., 2022)**; **(Cardoso et al., 2023).**

Future research should prioritize elucidating transmission pathways of resistant bacteria between pets, humans, and the environment. Molecular epidemiology studies focusing on resistance gene mechanisms and mobile genetic elements will deepen understanding of how resistance spreads within and across species **(Yang Liu et al., 2025).** Genomic investigations, such as those demonstrating interspecies transmission of MDR *Salmonella* between pet turtles and children, highlight the value of whole-genome sequencing in tracking resistance dissemination **(Wang et al., 2024).**

Intervention strategies tailored to exotic pet populations are also critical. This includes prudent antimicrobial use guided by susceptibility testing and enhanced veterinary public health communication to pet owners about zoonotic risks **(Arnecke et al., 2024).** Studies assessing the impact of stewardship programs in veterinary settings and evaluating alternative therapies or vaccines could provide practical tools to reduce AMR emergence **(Broens & van Geijlswijk, 2021).**

In summary, integrating surveillance, molecular research, and intervention development under a One Health framework is essential to address the complex challenge of antimicrobial resistance in pet populations and safeguard both animal and human health.

Conclusion

1. Highlights:

This study highlights the critical importance of monitoring antibiotic resistance in pet populations in Guelma, both to safeguard effective treatments and to prevent the potential spread of resistant bacteria to humans. By examining a diverse group of animals including traditional pets like cats, dogs, and hamsters, as well as exotic and wild species such as goldfinches, terrestrial turtles, fennec foxes, parrots, koi fish, monkeys, cockatiels, goldfish, red cap oranda, squirrels, and budgies we discovered a concerning prevalence of multidrug-resistant (MDR) bacteria.

Our findings revealed that many isolates, particularly those from wild and exotic animals, exhibited high levels of resistance to commonly used antibiotics such as Penicillin, Vancomycin, Amoxicillin, and Rifamycin. Notably, Gram-negative bacteria like *Citrobacter koseri, , Serratia spp., Aeromonas luteola, Kluyvera spp., Pasteurella spp.,Enterobacter sakazakii and Salmonella spp.,* were resistant to nearly all tested antibiotics, leaving only limited treatment options such as Gentamicin, which showed the highest overall effectiveness in our panel. Even among Gram-positive isolates, resistance to Penicillin and Vancomycin was widespread. These patterns indicate that infections caused by these bacteria could be extremely difficult to treat, posing a serious threat to both animal and public health.

The presence of MDR bacteria in pets especially exotic species should be recognized as a significant public health concern in Guelma. Close contact between humans and their pets increases the risk of zoonotic transmission, making it essential to raise awareness among veterinarians, pet owners, and the general public about the dangers of antimicrobial resistance. Education on responsible antibiotic use, regular surveillance, and prompt reporting of resistant infections are crucial steps to prevent further spread.

In summary, our results demonstrate that antimicrobial resistance among pet-associated bacteria in Guelma is a serious and growing issue. Addressing this challenge requires coordinated efforts in surveillance, stewardship, and public education to protect both animal and human health now and in the future.

2. Limitations:

Our study has several limitations that should be acknowledged. Firstly, the diversity of exotic pets included in our sampling was limited, with a particular lack of reptiles and amphibians, which are well-known reservoirs for multidrug-resistant bacteria. This restricts the

generalizability of our findings to the broader population of exotic pets in the region and may underestimate the true diversity of antimicrobial resistance present in less-represented taxa. Additionally, the antibiotic susceptibility testing was performed using a relatively narrow panel of antibiotics gentamicin, vancomycin, penicillin, cefoxitin, chloramphenicol, rifamycin, and amoxicillin. The absence of other important antibiotic families, such as fluoroquinolones, carbapenems, and macrolides, limits our ability to fully characterize the resistance profiles of the isolates. Consequently, our results may not capture the complete spectrum of resistance, and future studies should aim to include a wider range of both animal species and antibiotic classes to provide a more comprehensive understanding of antimicrobial resistance patterns in companion animals in Guelma.

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Appendice

Turtle (Testudo graeca).

(20-04-2025) At 9:45 AM.

By: Mazari Yasmina Lina.

Cockatiel (*Nymphicus hollandicus*). (14-04-2025) At 03:28 PM. By: Kaddeche Abderrahmen.

Squirrel (*Atlantoxerus getulus*). (14-04-2025) At 03 :48 PM.

By: Kaddeche Abderrahmen.

Parrot *(Psittacus erithacus).*

(14-04-2025) At 3:27 PM.

By: Kaddeche Abderrahmen.

Goldfinch (*Carduelis carduelis*).

(14-04-2025) At 3:29 PM.

By: Kaddeche Abderrahmen.

Budgie (*Melopsittacus undulatus*).

(15-04-2025) At 9:00 AM.

By: Soudani Sofia.

Fennec fox (*Vulpes zerda*)

(19-04-2025) At 02:18 PM.

By: Bara Mouslim.

Monkey (*Macaca fascicularis*).

(22-04-2025) At 9:14 AM.

By: Kaddeche Abderrahmen.

Hamster (*Mesocricetus auratus*).

(21-04-2025). At 9 :00 AM.

By: Mazari Yasmina Lina.

Red Cap Oranda *(Carassius auratus)*.

(14-04-2025). At 3 :07 PM.

By: Kaddeche Abderrahmen.

Goldfish (*Carassius auratus*).

(14-04-2025). At 3 :08 PM.

By: Mazari Yasmina Lina.

Koi fish (Cyprinus rubrofuscus).

(14-04-2025). At 3:09 PM.

By: Mazari Yasmina Lina.

Cat (*Felis catus*).

(20-03-2025). At 9:00 AM.

By: Mazari Yasmina Lina.

Dog (*Belgische Herdershond*).

(20-04-2025). At 9:05 AM.

By: Kaddeche Abderrahmen.

Collected Samples and Storage Materials.

(22-04-2025). At 11:31 AM.

By: Kaddeche Abderrahmen.

Table de lecture 1* : Valeurs critiques des diamètres des zones d'inhibition et des CMI pour *Entérobactéries*.

Antibiotiques testés	Charge des disques	Diamètres critiques (mm)			CMI critiques (µg/ml)			Commentaires
		R	I	S	R	I	S	
Ampicilline	10µg	≤ 13	14 – 16	≥ 17	≥ 32	16	≤ 8	La réponse à l'ampicilline est valable pour l'amoxicilline.
Amoxicilline +Ac.clavulanique	20/10µg	≤ 13	14 – 17	≥ 18	≥ 32/16	16/8	≤ 8/4	Les breakpoints des céphalosporines et de l'aztréonam ont été révisés en fonction des propriétés PK-PD et des données cliniques. Ainsi, l'application de ces breakpoints dépend du respect de posologies précises : céfazoline (2g toutes les 8h), céfoxitine (2g toutes les 6h), céfotaxime (1g toutes les 8h).
Céfazoline	30µg	≤ 19	20 – 22	≥ 23	≥ 8	4	≤ 2	
Cefoxitine	30µg	≤ 14	15 – 17	≥ 18	≥ 32	16	≤ 8	Suite à la révision des breakpoints des céphalosporines, la lecture interprétative anciennement basée sur la détection ou non d'une BLSE, n'est plus nécessaire. La réponse R, I ou S se fait en se référant aux seuls diamètres mesurés.
Céfotaxime	30µg	≤ 22	23 – 25	≥ 26	≥ 4	2	≤ 1	A souligner cependant que la détection phénotypique de la BLSE garde tout son intérêt dans les études épidémiologiques et en hygiène hospitalière.
Céfazoline (Infections non compliquées du tractus urinaire)	30µg	≤ 14	----	≥ 15	≥ 32	----	≤ 16	Les résultats de la céfazoline permettent de prédire les résultats pour les céphalosporines orales : céfador, céfdinir, céfpodoxime, céfprozil, céfuroxime axétil, céfalexine et loracarbef quand elles sont utilisées pour le traitement des infections non compliquées du tractus urinaire dues à *E. coli*, *K. pneumoniae* et *P. mirabilis*. Céfpodoxime, céfdinir et céfuroxime axétil peuvent être testés individuellement car certaines souches peuvent être sensibles à ces antibiotiques alors qu'elles sont résistantes à la céfazoline. L'application de ces breakpoints dépend du respect des posologies suivantes : 1g toute les 12h.
Aztréonam	30µg	≤ 17	18 – 20	≥ 21	≥ 16	8	≤ 4	Les critères d'interprétation sont basés sur la posologie de 1g toutes les 8h.
Imipénème	10µg	≤ 19	20 - 22	≥ 23	≥ 4	2	≤ 1	Les breakpoints des carbapénèmes ont été révisés en fonction des propriétés PK-PD et des données cliniques. L'application de ces breakpoints dépend du respect des posologies suivantes : Imipénème : 500 mg toutes les 6h ou 1 g toutes les 8h, Ertapénème : 1g toutes les 24h.
Méropenème	**10µg**	**≤ 19**	**20 - 22**	**≥ 23**	**≥ 4**	**2**	**≤ 1**	
Ertapénème	10µg	≤ 18	19 - 21	≥ 22	≥ 2	1	≤ 0,5	La détection phénotypique d'une carbapénémase par le test MHT est réservée aux études épidémiologiques
Amikacine	30µg	≤ 14	15 – 16	≥ 17	≥ 64	32	≤ 16	
Gentamicine	10µg	≤ 12	13 – 14	≥ 15	≥ 16	8	≤ 4	
Acide nalidixique	30µg	≤ 13	14 – 18	≥ 19	≥ 32	---	≤ 16	La sensibilité diminuée aux fluoroquinolones est détectée chez les salmonelles isolées d'infections extra-intestinales en testant l'acide nalidixique à l'antibiogramme. Valable pour les entérobactéries autres que *Salmonella* Typhi et *Salmonella* spp.
Ciprofloxacine	5µg	**≤21**	**22 – 25**	**≥ 26**	**≥1**	**0,5**	**≤0,25**	
Ciprofloxacine *Salmonella* spp.	**5µg**	**≤ 20**	**21 – 30**	**≥ 31**	**≥ 0,06**	**0,12 - 0,5**	**≤ 1**	
Chloramphénicol	30µg	≤ 12	13 – 17	≥ 18	≥ 32	16	≤ 8	Ne pas reporter en routine pour les souches isolées d'ITU sauf pour les salmonelles. Valable pour *S.*Typhi et *Salmonella* spp. extra-intestinales.
Colistine	CMI	-------	--------	-------	>2**	-----	≤2**	**La détermination de la CMI par microdilution en milieu liquide, CBDE (technique d'élution des disques) et CAT (dilution en milieu gélosé) sont acceptables (voir tests complémentaires). Le disque et le E-test ne doivent pas être utilisés*. Pour l'usage thérapeutique des polymixines se referer à l'international consensus guidelines*****
Furanes	300µg	≤ 14	15 – 16	≥ 17	≥ 128	64	≤ 32	
Fosfomycine	200µg	≤ 12	13 - 15	≥ 16	≥ 256	128	≤ 64	Indiqué uniquement pour les souches d'*E.coli* isolées d'infections urinaires. Le disque de 200µg contient 50µg de glucose-6-phosphate. La CMI est déterminée par la technique de dilution en gélose supplémentée de 25µg/ml de glucose 6-phosphate.
Triméthoprime+ Sulfaméthoxazole	1.25/ 23.75µg	≤ 10	11 – 15	≥ 16	≥ 4/76	------	≤ 2/38	

*Tableau extrait du Document M100. 30th ed. 2020. Performance standards for antimicrobial susceptibility testing. ** Extraits des recommandations de l'EUCAST 2020.
***Tsuji BT, Pogue JM, Zavaxcki AP, et al. International concensus guidelines for the optimal use of the polymyxins. (Pharmacotherapy 2019; 39 (1):10–39) doi: 10.1002/phar.2209)
Abréviations : PK-PD : Pharmacocinétique – pharmacodynamique. BLSE : β-Lactamase à Spectre Etendu.
MHT : Modified Hodge Test. ITU : Infection du Tractus Urinaire. CMI : Concentration Minimale Inhibitrice.CBDE : Colistin Broth Disk Elution, CAT : Colistin Agar Test.

Table de lecture 2* : Valeurs critiques des diamètres des zones d'inhibition et des CMI pour *Pseudomonas aeruginosa*.

Antibiotiques testés	Charge des disques	Diamètres critiques (mm)			CMI critiques (µg/ml)			Commentaires
		R	I	S	R	I	S	
Ticarcilline**	75 µg	≤ 15	16 - 23	≥ 24	≥ 128	32 - 64	≤ 16	Les valeurs critiques pour la pipéracilline (avec ou sans tazobactam) et la ticarcilline (avec ou sans ac clavulanique), sont basées sur une posologie d'au moins 3g toutes les 6 h.
Ticarcilline + ac. clavulanique	75/10µg	≤ 15	16 - 23	≥ 24	≥ 128/2	32/2 – 64/2	≤ 16/2	Détecter une BLSE en plaçant le disque de TCC entre le disque de CAZ et le disque d'ATM.
Pipéracilline	100 µg	≤ 14	15 - 20	≥ 21	≥ 128	32 - 64	≤ 16	L'application des breakpoints pour les céphalosporines dépend du respect de posologies précises. céftazidime et aztréonam : 1 g toutes les 6h ou 2g toutes les 8h.
Pipéracilline+ tazobactam	100 µg/10 µg	≤ 14	15 - 20	≥ 21	≥ 128/4	32/4 – 64/4	≤ 16/4	
Céftazidime	30 µg	≤ 14	15 – 17	≥ 18	≥ 32	16	≤ 8	
Aztréonam	30 µg	≤ 15	16 – 21	≥ 22	≥ 32	16	≤ 8	
Imipénème	10 µg	≤ 15	16 – 18	≥ 19	≥ 8	4	≤ 2	En cas de diamètre R ou I, faire une détection de carbapénémases Valeurs critiques basées sur une posologie de 1g toutes les 8 h ou 500mg toutes les 6 h.
Méropénème	**10 µg**	**≤ 15**	**16 – 18**	**≥ 19**	**≥ 8**	**4**	**≤ 2**	
Amikacine	30 µg	≤ 14	15 – 16	≥ 17	≥ 64	32	≤ 16	
Gentamicine	10 µg	≤ 12	13 – 14	≥ 15	≥ 16	8	≤ 4	
Nétilmicine	30 µg	≤ 12	13 – 14	≥ 15	≥ 32	16	≤ 8	
Tobramycine	10 µg	≤ 12	13 - 14	≥ 15	≥ 16	8	≤ 4	
Ciprofloxacine	5µg	**≤18**	**19 - 24**	**≥25**	**≥ 2**	**1**	**≤0,5**	
Lévofloxacine	5µg	**≤ 14**	**15 - 21**	**≥ 22**	**≥4**	**2**	**≤1**	
Fosfomycine***	---	---	-----	---	---	----	---	Des observations cliniques suggèrent que les infections dues à des souches pour lesquelles la CMI de la fosfomycine est ≤ 128 mg/L (ECOFF) pourraient être traitées avec de la fosfomycine.
Colistine	**CMI**	---	-----	---	**≥4****	-----	**≤ 2****	**La détermination de la CMI par microdilution en milieu liquide, CBDE (technique d'élution des disques) et CAT (Dilution en milieu gélosé) sont acceptables (voir tests complémentaires.) Le disque et le E-test ne doivent pas être utilisés*. Pour l'usage thérapeutique des polymixines se referer à l'international consensus guidelines*****

*Tableau extrait du Document M100. 30th ed. 2020. Performance standards for antimicrobial susceptibility testing.
** Extrait du document M100 S25 2015. Performance standards for antimicrobial susceptibility testing.
*** Extraits des recommandations 2020 du CASFM/EUCAST.
****Extrait du Document M100. 29th ed. 2019. Performance standards for antimicrobial susceptibility testing.
*****Tsuji BT, Pogue JM, Zavaxcki AP, et al. International concensus guidelines for the optimal use of the polymyxins. (Pharmacotherapy 2019; 39(1):10–39) doi: 10.1002/phar.2209
Abréviations : BLSE : β-Lactamase à Spectre Etendu. TCC : ticarcilline + acide clavulanique. CAZ : céftazidime. ATM: aztréonam.
CMI : Concentration Minimale Inhibitrice. ECOFF: Epidemiological cut-off value. CBDE : Colistin Broth Disk Elution, CAT : Colistin Agar Test.

Table de lecture 3* : Valeurs critiques des diamètres des zones d'inhibition et des CMI pour *Acinetobacter* spp.

Antibiotiques testés	Charge des disques	Diamètres critiques (mm)			CMI critiques (µg/ml)			Commentaires
		R	I	S	R	I	S	
Ticarciline**	75 µg	≤ 14	15 - 19	≥ 20	≥ 128	32-64	≤ 16	Le disque de TCC doit être placé à côté du disque de CAZ. Une synergie entre les 2 disques indique la présence d'une BLSE. Les critères d'interprétation pour l'imipénème sont basés sur la posologie de 500mg toutes les 6h.
Ticarciline + ac.clavulanique	75/10µg	≤ 14	15 - 19	≥ 20	≥ 128/2	32/2-64/2	≤ 16/2	
Pipéracilline	100 µg	≤ 17	18 – 20	≥ 21	≥ 128	32-64	≤ 16	
Pipéracilline+ tazobactam	100 µg/10 µg	≤ 17	18 – 20	≥ 21	≥ 128/4	32/4-64/4	≤ 16/4	
Ceftazidime	30 µg	≤ 14	15 – 17	≥ 18	≥ 32	16	≤ 8	
Imipénème	10 µg	≤ 18	19 - 21	≥ 22	≥ 8	4	≤ 2	
Méropénème	**10 µg**	**≤ 14**	**15 - 17**	**≥ 18**	**≥ 8**	**4**	**≤ 2**	
Amikacine	30 µg	≤ 14	15 – 16	≥ 17	≥ 64	32	≤ 16	
Gentamicine	10 µg	≤ 12	13 – 14	≥ 15	≥ 16	8	≤ 4	
Tobramycine	10 µg	≤ 12	13 – 14	≥ 15	≥ 16	8	≤ 4	
Nétilmicine	CMI	----	-----	----	≥ 32	16	≤ 8	
Ciprofloxacine	5µg	≤ 15	16 – 20	≥ 21	≥ 4	2	≤ 1	
Lévofloxacine	5µg	≤ 13	14 – 16	≥ 17	≥ 8	4	≤ 2	
Doxycycline	30µg	≤ 9	10 – 12	≥ 13	≥ 16	8	≤ 4	Si résistance à doxycycline, réponse valable pour tétracycline.
Triméthoprime+ sulfaméthoxazole	1.25/23.75µg	≤ 10	11 – 15	≥ 16	≥ 4/76	-----	≤ 2/38	
Colistine	CMI	------	-----	------	≥ 4***	-----	≤ 2***	**La détermination de la CMI par microdilution en milieu liquide est la seule méthode approuvée. Le CBDE (technique d'élution des disques), le CAT (Dilution en milieu gélosé), le disque et le E-test ne doivent pas être utilisés*.Pour l'usage thérapeutique des polymixines se referer à l'international consensus guidelines****

*Tableau extrait du Document M100. 30th ed. 2020. Performance standards for antimicrobial susceptibility testing.
** Extrait du document M100 S25 2015. Performance standards for antimicrobial susceptibility testing.
***Extrait du Document M100. 29th ed. 2019. Performance standards for antimicrobial susceptibility testing.
****Tsuji BT, Pogue JM, Zavaxcki AP, et al. International concensus guidelines for the optimal use of the polymyxins. (Pharmacotherapy 2019; 39(1):10–39) doi: 10.1002/phar.2209
Abréviations : BLSE : β-Lactamase à Spectre Etendu. TCC : ticarcilline + acide clavulanique. CAZ : ceftazidime. CMI : concentration Minimale Inhibitrice, CBDE : Colistin Broth Disk Elution, CAT : Colistin Agar Test.

Table de lecture 5* : Valeurs critiques des diamètres des zones d'inhibition et des CMI pour *Staphylococcus* spp.

Antibiotiques testés	Charge des disques	Diamètres critiques (mm)			CMI critiques (µg/ml)			Commentaires
		R	I	S	R	I	S	
Pénicilline	10 UI	≤ 28	---	≥29	≥0,25	-----	≤ 0,12	Le test de la ß-lactamase confirme les cas douteux. Interprétation valable pour toutes les pénicillines inactivées par les ß-lactamases (ampicilline, ticarcilline, pipéracilline ...).
Oxacilline (*S.aureus et S.lugdunensis*)	-----	-----	-----	-----	≥4	-----	≤ 2	Le disque d'oxacilline n'est pas fiable. Tester le disque de céfoxitine 30 µg pour détecter la résistance à la méticilline de *S.aureus* et des staphylocoques à coagulase négative.
Cefoxitine (*S.aureus et S.lugdunensis*)	30 µg	≤ 21	---	≥22	≥8	-----	≤ 4	
Oxacilline (S.C.N. sauf *S.lugdunensis*)	-----	----	---	-----	≥0,5	-----	≤ 0,25	**Pour les staphylocoques (autre que *S.lugdunensis, S.epidermidis, S. pseudintermedius et S. schleiferi*) les isolats dont la CMI à l'oxacilline est comprise entre 0.5et 2µg/ml peuvent être MecA négatif.Pour les infeions sévères, ces souches peuvent être testées pour le MecA ou la PLP2a, si le résultat est négatif elles peuvent etre reportées sensibles à l'oxacilline.**
Céfoxitine (S.C.N.sauf *S.lugdunensis, S. pseudintermedius et S. schleiferi*)	30 µg	≤ 24	---	≥25	---	----	---	
Gentamicine	10 µg	≤ 12	13 – 14	≥ 15	≥ 16	8	≤4	Les souches résistantes à la gentamicine sont résistantes à tous les autres aminosides sauf à la streptomycine. **
Amikacine(*S.aureus*)	30 µg	≤ 16	---	≥18	≥16	----	≤8	La détermination de la résistance à l'amikacine est mieux détectée avec la kanamycine :
Amikacine(SCN)	30 µg	≤ 19	---	≥22	≥16	----	≤8	kanamycine(30 µg) : R < 18 mm pour *S.aureus*, R < 22 mm pour les SCN **
Erythromycine	15 µg	≤ 13	14 – 22	≥23	≥ 8	1-4	≤0.5	Détecter la résistance inductible en plaçant le disque d'érythromycine à côté du disque de clindamycine. En présence d'une image d'antagonisme, répondre « Résistance à l'érythromycine et à la clindamycine ».
Clindamycine	2µg	≤ 14	15 – 20	≥21	≥4	1-2	≤ 0.5	
Vancomycine (S. aureus)	**CMI**	---	---	-----	≥16	4 – 8	≤2	Le disque de vancomycine ne permet pas de différencier les souches vanco « S » et « I » de *Staphylococcus aureus*, ni de différencier les souches vanco « S », « I » et « R » de S.C.N., car les diamètres d'inhibition sont similaires. La détermination de la CMI de la vancomycine est obligatoire.
Vancomycine (SCN)	**CMI**	---	---	---	≥32	8 – 16	≤4	
Teicoplanine	**CMI**	---	---	---	≥32	16	≤8	
Ofloxacine	5µg	≤ 14	15 – 17	≥18	≥4	2	≤1	
Ciprofloxacine	5µg	≤ 15	16 – 20	≥21	≥4	2	≤1	
Lévofloxacine	5µg	≤ 15	**16 – 18**	**≥19**	≥4	2	≤1	
Triméthoprime+ sulfaméthoxazole	1.25/23.75µg	≤ 10	11 – 15	≥16	≥ 4/76	----	≤2/38	
Rifampicine	5µg	≤ 16	17 – 19	≥20	≥ 4	2	≤1	
Tétracycline	30µg	≤ 14	15 – 18	≥19	≥16	8	≤ 4	Les souches sensibles à la tétracycline, sont sensibles à la doxycycline et à la minocycline.
Chloramphénicol	30µg	≤ 12	13 – 17	≥18	≥32	16	≤ 8	
Quinupristine-dalfopristine	15µg	≤ 15	16 – 18	≥19	≥4	2	≤1	A reporter pour les souches de *S. aureus* méticilino-sensibles. Interprétation valable pour la pristinamycine.
Acide fusidique**	10 µg	≤ 24	----------	≥ 24	> 1		≤ 1	
Fosfomycine IV**	**200µg**	**< 23**	---------	**≥ 23**	> 32		≤ 32	**La méthode de référence pour la détermination de la CMI est la dilution en milieu gélosé en présence de glucose-6phosphate (25 mg/l)**

*Tableau extrait du Document M100 . 30th ed . 2020. Performance standards for antimicrobial susceptibility testing.
** Extraits des recommandations du CASFM/EUCAST 2020
Abreviations : SCN : Staphylocoque à Coagulase Négative. CMI : Concentration Minimale Inhibitrice.IV : Intra veineuse.

Table de lecture 6* : Valeurs critiques des diamètres des zones d'inhibition et des CMI pour *Enterococcus* spp.

Antibiotiques testés	Charge des disques	Diamètres critiques (mm)			CMI critiques (µg/ml)			Commentaires
		R	I	S	R	I	S	
Ampicilline	10µg	≤16	---	≥ 17	≥ 16	------	≤ 8	Interprétation valable pour amoxicilline. Les résultats des tests de sensibilité à l'ampicilline doivent être utilisés pour prédire l'activité de l'amoxicilline.
Tétracycline	30µg	≤ 14	15 – 18	≥ 19	≥ 16	8	≤ 4	Interprétation valable pour la doxycycline.
Vancomycine	30µg	≤ 14	15 – 16	≥ 17	≥ 32	8-16	≤ 4	Rechercher la sensibilité diminuée aux glycopeptides. Confirmer par la CMI de vancomycine et de teicoplanine en cas de réponse R ou I ou de screening test positif. Pour les souches dont la CMI est entre 8 et 16µg/ml, il faut confirmer l'identification biochimique.
Teicoplanine	30µg	≤ 10	11 – 13	≥ 14	≥ 32	16	≤ 8	
Gentamicine de haut niveau	120µg	≤ 6	7 – 9	≥ 10	> 500	------	≤500	CMI en milieu solide (BHI agar)
Streptomycine de haut niveau	300µg	≤ 6	7 – 9	≥ 10	> 1000 > 2000	------ ------	≤1000 ≤2000	CMI en milieu liquide (BHI bouillon) CMI en milieu solide (BHI agar)
Ciprofloxacine	5µg	≤ 15	16 – 20	≥ 21	≥ 4	2	≤ 1	
Lévofloxacine	5µg	≤ 13	14 –16	≥ 17	≥ 8	4	≤ 2	
Erythromycine	15µg	≤ 13	14 – 22	≥ 23	≥ 8	1-4	≤ 0,5	
Furanes	300µg	≤14	15 – 16	≥ 17	≥ 128	64	≤ 32	
Rifampicine	5µg	≤ 16	17 – 19	≥ 20	≥ 4	2	≤ 1	
Fosfomycine	200µg	≤ 12	13 –15	≥ 16	≥ 256	128	≤ 64	Recommandé pour les souches d'*E.faecalis* isolées du tractus urinaire.
Quinupristine-dalfopristine	15µg	≤ 15	16 –18	≥ 19	≥ 4	2	≤ 1	A reporter pour les souches d'*E.faecium* vancomycine résistant. Interprétation valable pour la pristinamycine.
Chloramphénicol	30µg	≤ 12	13 –17	≥ 18	≥ 32	16	≤ 8	Interpretation non valable pour les souches urinaires. Interprétation valable pour thiamphénicol.
Tigécycline**	CMI	---	---	---	> 0,25	---	≤ 0,25	Réponse en cas de multirésistance. Des CMI supérieures à la concentration critique de sensibilité sont très rares. L'identification et le test de sensibilité devront être répétés. En cas de confirmation, la souche devra être envoyée à un centre de référence et catégorisée «résistant».

*Tableau extrait du Document M100. 30th ed . **2020**. Performance standards for antimicrobial susceptibility testing.
** Extraits des recommandations de l'EUCAST 2020.
Abréviations : CMI : Concentration Minimale Inhibitrice. BHI : Brain-Heart Infusion.

Table de lecture 7* : Valeurs critiques des diamètres des zones d'inhibition et des CMI pour *Vibrio* spp.

Antibiotiques testés	Charge des disques	Diamètres critiques (mm)			CMI critiques (µg/ml)			Commentaires
		R	I	S	R	I	S	
Ampicilline	10 µg	≤ 13	14 – 16	≥ 17	≥ 32	16	≤ 8	Interprétation valable pour amoxicilline.
Amoxiciline+Ac.clavulanique	20/10µg	≤ 13	14 – 17	≥ 18	≥ 32/16	16/8	≤ 8/4	Le disque d'AMC doit être appliqué près du disque de CTX : une image de synergie indique la présence d'une BLSE.
Céfotaxime	30 µg	≤ 22	23 – 25	≥ 26	≥ 4	2	≤ 1	
Tétracycline	30 µg	≤ 11	12 - 14	≥ 15	≥ 16	8	≤ 4	Interprétation valable pour doxycycline. Pour la doxycycline l'interprétation est valable uniquement pour *V.cholerae*
Triméthoprime+ sulfaméthoxazole	1.25/23.75µg	≤ 10	11 - 15	≥ 16	≥ 4/76	---	≤ 2/38	
Chloramphénicol	30 µg	≤ 12	13 - 17	≥ 18	≥ 32	16	≤ 8	
Azithromycine	CMI	----	----	----	----	----	≤ 2	Réponse valable uniquement pour *V.cholerae*
Ciprofloxacine	5 µg	≤ 15	16 - 20	≥ 21	≥ 4	2	≤ 1	
Colistine	10 UI	----	----	----	----	----	----	Intérêt diagnostique.
Furanes	300 µg	----	----	----	----	----	----	Lecture interprétative.
Acide nalidixique	30 µg	----	----	----	----	----	----	Lecture interprétative.
Composé vibriostatique 0/129	----	----	----	----	----	----	----	Intérêt diagnostique.

*Tableau extrait du Document M45, 3rd ed Vol. 35, n°17. 2016. Methods for antimicrobial dilution and disk susceptibility testing of infrequently isolated or fastidious bacteria.

Abreviations : AMC : Amoxiciline + Acide clavulanique. CTX : céfotaxime. BLSE : β-Lactamase à Spectre Etendu.

Table de lecture 8* : Valeurs critiques des diamètres des zones d'inhibition et des CMI pour *Haemophilus influenzae et Haemophilus parainfluenzae*.

Antibiotiques testés	Charge des disques	Diamètres critiques (mm)			Valeurs critiques des CMI			Commentaires
		R	I	S	R	I	S	
Ampicilline	10 µg	≤ 18	19 – 21	≥ 22	≥ 4	2	≤ 1	Interprétation valable pour amoxicilline. La majorité des souches d'*H.influenzae* résistantes à ampicilline et amoxicilline produisent une β-lactamase type TEM. Il faut effectuer un test de détection de la β-lactamase.
Amoxicilline + Ac. clavulanique	20/10 µg	≤ 19	---	≥ 20	≥ 8/4	-----	≤ 4/2	Le disque d'AMC doit être placé à côté du disque de CTX pour détecter une éventuelle souche productrice de BLSE.
Cefotaxime ou Ceftriaxone	30 µg	---	---	≥ 26	---	------	≤ 2	
Ampicilline**	2 µg	**<18**	**---**	**≥18**	>1	----	≤ 1	Les disques d'ampicilline à 2µg et de céfalotine à 30µg servent à la détection des souches BLNAR chez *H.influenzae*.
Acide nalidixique (dépistage) **	30 µg		---	≥ 23	----	----	----	Permet de détecter la sensibilité diminuée aux fluoroquinolones (faire CMI des fluoroquinolones si NAL résistant).
Ciprofloxacine	5µg	---	---	≥21	---	---	≤1	
Lévofloxacine	5µg	---	---	≥17	---	---	≤2	
Azithromycine	15 µg	---	---	≥ 12	---	---	≤ 4	
Chloramphénicol	30 µg	≤ 25	26 – 28	≥ 29	≥ 8	4	≤ 2	
Tétracycline	30 µg	≤ 25	26 – 28	≥ 29	≥ 8	4	≤ 2	Réponse valable pour doxycycline.
Rifampicine	5µg	≤ 16	17 – 19	≥ 20	≥ 4	2	≤ 1	
Triméthoprime + sulfaméthoxazole	1,25/23,75 µg	≤ 10	11 – 15	≥ 16	≥ 4/76	1/19-2/38	≤ 0,5/9,5	

Tableau extrait du Document M100 . 30th ed. 2020. Performance standards for antimicrobial susceptibility testing.

** Extraits des recommandations de l'EUCAST 2020 .

Abréviations : AMC : amoxicilline + acide clavulanique. CTX : céfotaxime. BLSE : β-Lactamase à Spectre Etendu. NAL : acide Nalidixique.

BLNAR : β-Lactamase Négative Ampicilline Résistant. CMI : Concentration Minimale Inhibitrice.

Table de lecture 9 *: Valeurs critiques des diamètres des zones d'inhibition et des CMI, pour *Streptococcus* spp. groupe *viridans* (Autres que *S. pneumoniae*).

Antibiotiques testés	Charge des disques	Diamètres critiques (mm)			Valeurs critiques CMI (µg/ml)			Commentaires
		R	I	S	R	I	S	
Péniciline	....	....	....	....	≥ 4	0,25-2	≤ 0,12	Ne pas tester de disque de pénicilline ou d'ampicilline. Il faut déterminer la CMI de ces 2 molécules.
Ampiciline	....	....	....	....	≥ 8	0,5-4	≤ 0,25	
Céfotaxime	30µg	≤ 25	26-27	≥ 28	≥ 4	2	≤ 1	
Gentamicine**	....	....	....	....	> 250	....	≤ 250	Il faut déterminer la CMI de la gentamicine dans les infections sévères. Interprétation des résultats : CMI ≤ 250 mg/L : la souche est sauvage (BNR) et la synergie est possible avec les pénicillines (ou les glycopeptides) en cas de sensibilité à ces derniers antibiotiques. CMI > 250 mg/L : la souche a acquis un HNR à la gentamicine, ainsi qu'à la kanamycine, tobramycine, dibékacine, amikacine, sisomicine et nétilmicine, mais pas à la streptomycine dont la sensibilité doit être évaluée séparément si nécessaire. La synergie avec les pénicillines ou les glycopeptides est abolie.
Erythromycine	15µg	≤ 15	16-20	≥ 21	≥ 1	0,5	≤ 0,25	
Clindamycine	2µg	≤ 15	16-18	≥ 19	≥ 1	0,5	≤ 0,25	
Tétracycline	30µg	≤ 18	19-22	≥ 23	≥ 8	4	≤ 2	Les souches sensibles à la tétracycline sont considérées comme sensibles à la doxycycline et à la minocycline.
Vancomycine	30µg	....	....	≥ 17	....	....	≤ 1	Déterminer la CMI de la vancomycine dans les infections sévères.
Chloramphénicol	30µg	≤ 17	18-20	≥ 21	≥ 16	8	≤ 4	
Rifampicine**	5µg	< 17	....	≥ 22	> 0,5	....	≤ 0,06	
Quinupristine-dalfopristine	15µg	≤ 15	16 – 18	≥19	≥4	2	≤1	Interprétation valable pour la pristinamycine.
Ofloxacine	5µg	<12	13-15	≥16	≥8	4	≤ 2	
Lévofloxacine	5µg	<13	14-16	≥17	≥8	4	≤ 2	

Tableau extrait du Document M100 . 30th ed . 2020. Performance standards for antimicrobial susceptibility testing.

** Extraits des recommandations du CASFM / EUCAST 2020.

Abreviations : CMI : Concentration Minimale Inhibitrice. BNR : Bas Niveau de Résistance. HNR : Haut Niveau de Résistance.

Table de lecture 10 : Valeurs critiques des diamètres des zones d'inhibition et des CMI, pour *Streptococcus* spp. groupe β hémolytiques.

Antibiotiques testés	Charge des disques	Valeurs critiques des diamètres d'inhibition (mm)			Valeurs critiques CMI (µg/ml)			Commentaires
		R	I	S	R	I	S	
Penicilline	10UI	----	----	≥ 24	----		≤ 0,12	
Ampicilline	10µg	----	----	≥ 24	----		≤0,25	
Erythromycine	15µg	≤ 15	16-20	≥ 21	≥ 1	0.5	≤ 0,25	Détecter la résistance inductible en plaçant le disque d'érythromycine à côté du disque de clindamycine. En présence d'une image d'antagonisme, répondre « Résistance à érythromycine et clindamycine ».
Clindamycine	2µg	≤ 15	16-18	≥ 19	≥ 1	0.5	≤ 0,25	
Tétracycline	30µg	≤ 18	19-22	≥ 23	≥ 8	4	≤ 2	Les souches sensibles à la tétracycline sont considérées comme sensibles à la doxycycline et à la minocycline.
Ofloxacine	5µg	≤ 12	13-15	≥ 16	≥ 8	4	≤ 2	
Lévofloxacine	5µg	≤ 13	14-16	≥ 17	≥ 8	4	≤ 2	
Vancomycine	30µg	----	----	≥ 17	----	----	≤1	Pour les diamètres inférieurs à 17 mm, déterminer la CMI et vérifier l'identification bactérienne.
Quinupristine-dalfopristine (S.pyogenes)	15µg	≤ 15	16 – 18	≥19	≥4	2	≤1	interprétation valable pour la pristinamycine.
Chloramphénicol	30µg	≤17	18-20	≥21	≥16	8	≤4	
Gentamicine**	500µg	< 17	----	≥17	>250	----	≤250	Diamètre d'inhibition ≥17 mm ou CMI ≤ 250 mg/L : la souche est sauvage (bas niveau de résistance) et la synergie est possible avec les pénicillines (ou les glycopeptides) en cas de sensibilité à ces derniers antibiotiques. Pour les autres aminosides, le profil peut être différent. Diamètre d'inhibition < 17 mm ou CMI > 250 mg/L : la souche a acquis un haut niveau de résistance à la gentamicine, ainsi qu'à la kanamycine, tobramycine, dibékacine, amikacine, sisomicine et nétilmicine. La synergie avec les pénicillines ou les glycopeptides est abolie.

Tableau extrait du Document M100 . 30th ed . 2020. Performance standards for antimicrobial susceptibility testing.
** Extraits des recommandations du CASFM / EUCAST 2020.
Abréviations : CMI : Concentration Minimale Inhibitrice.

Table de lecture 11* : Valeurs critiques des diamètres des zones d'inhibition et des CMI pour *Streptococcus pneumoniae*.

Antibiotiques testés	Charge des disques	Diamètres critiques (mm)			Valeurs critiques CMI (µg/ml)			Commentaires
		R	I	S	R	I	S	
Pénicilline parenéerale (non méningite)	CMI	---	---	---	≥ 8	4	≤ 2	Les résultats d'interprétation pour la pénicilline orale peuvent être rapportés pour les souches non isolées de LCR.
Pénicilline parentérale (méningite)	CMI	---	---	---	≥ 0,12	---	≤ 0,06	
Pénicilline orale	CMI	---	---	---	≥ 2	0,12-1	≤ 0,06	
Oxacilline	1 µg		---	≥ 20	---	---	---	La détection des souches de pneumocoques PSDP se fait en testant un disque d'oxacilline (à 1µg ou 5µg). En cas de réponse « R » ou « I », déterminer les CMI de pénicilline, amoxicilline, céfotaxime, imipénème et méropénème.
Amoxicilline	CMI	---	---	---	≥ 8	4	≤ 2	Les valeurs critiques de l'amoxicilline ne s'appliquent pas au LCR car il n'y a pas de valeurs critiques de CMI de l'amoxicilline pour ce site.
Céfotaxime (non méningite)	CMI	---	---	---	≥ 4	2	≤ 1	L'interprétation est valable pour la ceftriaxone.
Céfotaxime (méningite)	CMI	---	---	---	≥ 2	1	≤ 0,5	
Imipénème	CMI	---	---	---	≥ 1	0,25 – 0,5	≤ 0,12	
Vancomycine	30 µg	---	---	≥ 17	---	---	≤ 1	
Erythromycine	15 µg	≤15	16 – 20	≥ 21	≥ 1	0,5	≤ 0.25	
Clindamycine	2µg	≤15	16 – 18	≥ 19	≥ 1	0,5	≤ 0,25	
Lévofloxacine	5µg	≤13	14 – 16	≥ 17	≥ 8	4	≤ 2	
Gémifloxacine	5µg	≤19	20 – 22	≥ 23	≥ 0,5	0,25	≤ 0,12	
Doxycycline	30µg	≤24	25 – 27	≥28	≥ 1	0.5	≤ 0.25	
Chloramphénicol	30 µg	≤20	---	≥ 21	≥ 8	---	≤ 4	
Rifampicine	5µg	≤16	17 – 18	≥ 19	≥ 4	2	≤ 1	
Triméthoprime+sulfaméthoxazole	1,25/23,75µg	≤ 15	16 – 18	≥ 19	≥ 4/76	1/19-2/38	≤ 0,5/9,5	
Quinupristine-dalfopristine	15µg	≤ 15	16 – 18	≥19	≥4	2	≤1	Interprétation valable pour la pristinamycine.

*Tableau extrait du Document M100 . 30th ed . 2020. Performance standards for antimicrobial susceptibility testing.
Abréviations : CMI : Concentration Minimale Inhibitrice. LCR : Liquide céphalorachidien.

Table de lecture 12* : Valeurs critiques des diamètres des zones d'inhibition et des CMI pour *Neisseria gonorrhoeae.*

Antibiotiques testés	Charge des disques	Valeurs critiques des diamètres d'inhibition (mm)			Valeurs critiques des CMI (µg/ml)			Commentaires
		R	I	S	R	I	S	
Pénicilline	10 UI	≤ 26	27 – 46	≥ 47	≥ 2	0,12-1	≤ 0,06	Recherche de β-lactamase La péniciline répond pour l'ampiciline et l'amoxicilline
Céftriaxone	30 µg	---	---	≥ 35	---	---	≤ 0,25	
Ciprofloxacine	5 µg	≤ 27	28 – 40	≥ 41	≥ 1	0,12-0,5	≤ 0,063	
Tétracycline	30 µg	≤ 30	31 – 37	≥38	≥ 2	0,5-1	≤ 0,25	Interprétation valable pour doxycycline.
Spectinomycine	100 µg	≤ 14	15 – 17	≥ 18	≥ 128	64	≤ 32	

*Tableau extrait du Document M100 . 30th ed . 2020. Performance standards for antimicrobial susceptibility testing.

Table de lecture 13* : Valeurs critiques des diamètres des zones d'inhibition et des CMI pour *Neisseria meningitidis*.

Antibiotique	Charge des disques	Concentrations critiques (mg/l)			Diamètres critiques (mm)			Commentaires
		S	I	R	S	I	R	
Pénicilline G	CMI	≤ 0,06	0,125-0,25	> 0,5	---	---	---	Ne pas tester de disque de pénicilline ou d'ampicilline pour N.meningitidis. Il faut déterminer les CMI de ces 2 molécules. Une β-lactamase (très rare) est recherchée par technique chromogénique. L'interprétation pour l'ampicilline est valable pour l'amoxicilline.
Ampicilline	CMI	≤ 0,12	0,25-1	≥ 2	---	---	---	
Céfotaxime	30 µg	≤ 0,12	---	---	≥ 34	---	---	
Ceftriaxone	30 µg	≤ 0,12	---	---	≥ 34	---	---	
Azithromycine	15 µg	≤ 2	---	---	≥ 20	---	---	Peut être appropriée seulement pour la prophylaxie des cas contacts d'infection méningococcique. Ces valeurs critiques ne sont pas applicables dans les cas des maladies méningococciques invasives.
Rifampicine	5 µg	≤ 0,5	1	≥ 2	≥ 25	20 - 24	≤ 19	
Chloramphénicol	30 µg	≤ 2	4	≥ 8	≥ 26	20 – 25	≤ 19	
Ciprofloxacine	5 µg	≤ 0,03	0,06	≥ 0,12	≥ 35	33 – 34	≤ 32	

*Tableau extrait du document M100 . 30th ed . 2020. Performance standards for antimicrobial susceptibility testing.
Abréviations : CMI : Concentration Minimale Inhibitrice.

Table de lecture 14* : Valeurs limites des diamètres des zones d'inhibition pour les souches de référence utilisées pour le contrôle de qualité.

Antibiotiques testés	Charge des disques	*E. coli* ATCC 25922	*S. aureus* ATCC 25923	*P. aeruginosa* ATCC 27853	*S. pneumoniae* ATCC 49619	*H. influenzae* ATCC 49247	*N. gonorrhoeae* ATCC 49226
Amikacine	30µg	19-26	20-26	18-26	----	----	----
Amoxicilline + Ac clavulanique	20/10µg	18-24	28-36	----	----	15-23	----
Ampicilline	10µg	16-22	27-35	----	30-36	13-21	----
Azithromycine	15µg	----	21-26	----	19-25	13-21	----
Ac nalidixique	30µg	22-28	----	----	----	----	----
Aztréonam	30µg	28-36	----	23-29	----	30-38	----
Céfazoline	30µg	21-27	29-35	----	----	----	----
Céfalotine	30µg	15-21	29-37	----	26-32	----	----
Céfoxitine	30µg	23-29	23-29	----	33-41	----	----
Céfotaxime	30µg	29-35	25-31	18-22	31-39	31-39	38-48
Céftriaxone	30µg	29-35	22-28	17-23	----	----	39-51
Ceftazidime	30µg	----	---	22-29	----	27-35	35-43
Ciprofloxacine	5µg	30-40	22-30	25-33	---	34-42	48-58
Colistine	10µg	11-17	----	11-17	----	----	----
Chloramphénicol	30µg	21-27	19-26	----	23-27	31-40	----
Clindamycine	2µg	----	24-30	----	19-25	----	----
Doxycycline	30µg	18-24	23-29	----	25-34	----	----
Ertapénème	10µg	29-26	24-31	13-21	28-35	20-28	---
Erythromycine	15µg	----	22-30	----	25-30	----	----
Fosfomycine	200µg	22-30	25-33	----	----	----	----
Furanes	300µg	20-25	18-22	----	23-29	----	----

Table de lecture 14* (suite): Valeurs limites des diamètres des zones d'inhibition pour les souches de référence utilisées pour le contrôle de qualité.

Antibiotiques testés	Charge des disques	*E. coli* ATCC 25922	*S. aureus* ATCC 25923	*P. aeruginosa* ATCC 27853	*S. pneumoniae* ATCC 49619	*H. influenzae* ATCC 49247	*N. gonorrhoeae* ATCC49226
Gentamicine	10µg	19-26	19-27	17-23	----	----	----
Gémifloxacine	5µg	29-36	27-33	19-25	----	----	----
Imipénème	10µg	26-32	----	20-28	----	21-29	----
Kanamycine	30µg	----	19-26	----	----	----	----
Levofloxacine	5µg	29-37	25-30	19-26	20-25	32-40	----
Nétilmicine	30µg	22-30	22-31	17-23	----	----	----
Ofloxacine	5µg	29-33	24-28	17-21	16-21	31-40	43-51
Oxacilline	1µg	----	18-24	----	≤ 12	----	----
Pénicilline	10UI	----	26-37	----	24-30	----	26-34
Pipéracilline	100µg	24-30	25-33	25-33	----	33-38	----
Rifampicine	5µg	8-10	26-34	----	25-30	22-30	----
Spectinomycine	100µg	----	----	----	----	----	23-29
Tétracycline	30µg	18-25	24-30	----	27-31	14-22	30-42
Ticarcilline	75µg	24-30	----	21-27	----	----	----
Ticarcilline + ac clavulanique	75/10µg	24-30	29-37	20-28	----	----	----
Tobramycine	10µg	18-26	19-29	20-26	----	----	----
Triméthoprime + sulfaméthoxazole	1.25/23.75µg	23-29	24-32	----	20-28	24-32	----
Teicoplanine	30µg	----	15-21	----	----	----	----
Tigécycline	15µg	20-27	20-25	9-13	23-29	23-31	30-40
Vancomycine	30µg	----	17-21	----	20-27	----	----

Tableau extrait du Document M100 . 30th ed . 2020. Performance standards for antimicrobial susceptibility testing.
NB: pour tester les disques de gentamicine 120 µg, il faut utiliser la souche de référence ATCC 29212 (16 – 23 mm).

Table de lecture16*: Valeurs critiques des CMI pour *Yersinia pestis*.

Antibiotiques testés	Valeurs critiques des CMI (µg/ml)			Commentaires
	S	I	R	
Streptomycine	≤ 4	8	≥ 16	
Gentamicine	≤ 4	8	≥ 16	
Ciprofloxacine	≤ 0,25	---	---	Pour les souches non sensibles, l'identification et la CMI doivent être confirmées.
Lévofloxacine	≤ 0,25	---	---	
Tétracycline	≤ 4	8	≥ 16	
Doxycycline	≤ 4	8	≥ 16	
Chloramphénicol	≤ 8	16	≥ 32	
Triméthoprime+sulfaméthoxazole	≤ 2/38	---	≥ 4/76	

*Tableau extrait du Document M45, 3rd ed. **2016**. Methods for antimicrobial dilution and disk susceptibility testing of infrequently isolated or fastidious bacteria.

Table de lecture17*: Valeurs critiques des diamètres des zones d'inhibition et des CMI pour *Campylobacter jejuni/coli*.

Antibiotiques	Charge des disques	Valeurs critiques (mm)			Valeurs critiques des CMI (µg/ml)			Commentaire
		R	I	S	R	I	S	
Erythromycine	15 µg	≤12	13-15	≥ 16	≥ 32	16	≤ 8	Interprétation valable pour l'azithromycine.
Ciprofloxacine	5 µg	≤20	21-23	≥ 24	≥ 4	2	≤ 1	
Tétracycline	30 µg	≤22	23-25	≥ 26	≥ 16	8	≤ 4	La tétracycline peut être utilisée pour déterminer la sensibilité à la doxycycline.
Doxycycline	CMI	--	--	--	≥ 8	4	≤ 2	

*Tableau extrait du Document M45, 3rd ed. **2016**. Methods for antimicrobial dilution and disk susceptibility testing of infrequently isolated or fastidious bacteria.

Table de lecture18*: Valeurs critiques des CMI pour *Helicobacter pylori*.

Antibiotique testé	Valeurs critiques des CMI (µg/ml)			Commentaire
	R	I	S	
Clarithromycine	≥ 1	0,5	≤ 0,25	

*Tableau extrait du Document M45, 3rd ed. **2016**. Methods for antimicrobial dilution and disk susceptibility testing of infrequently isolated or fastidious bacteria.

Table de lecture19*: Valeurs critiques des CMI pour les bactéries anaérobies strictes.

Antibiotiques testés	Valeurs critiques des CMI (µg/ml)			Commentaire
	R	I	S	
Pénicilline	≥ 2	1	≤ 0,5	
Ampicilline	≥ 2	1	≤ 0,5	Interprétation valable pour l'amoxicilline.
Amoxicilline+acide clavulanique	≥ 16/8	8/4	≤ 4/2	
Pipéracilline	≥ 128	64	≤ 32	
Ticarcilline+acide clavulanique	≥ 128/2	64/2	≤ 32/2	
Céfoxitine	≥ 64	32	≤ 16	
Céfotaxime	≥ 64	32	≤ 16	
Céftriaxone	≥ 64	32	≤ 16	
Imipénème	≥ 16	8	≤ 4	
Ertapénème	≥ 16	8	≤ 4	
Tétracycline	≥ 16	8	≤ 4	
Clindamycine	≥ 8	4	≤ 2	
Chloramphénicol	≥ 32	16	≤ 8	
Métronidazole	≥ 32	16	≤ 8	

*Tableau extrait du Document M100 . 30th ed . **2020**. Performance standards for antimicrobial susceptibility testing.

Table 20* : Valeurs critiques des CMI pour *Brucella* spp.

Antibiotiques	Valeurs critiques CMI (µg/ml)			Commentaires
	R	I	S	
Streptomycine	—	—	≤ 8	Valeur critique sensible : ≤ 16 µg/ml si incubation sous CO2 et ≤ 8µg/ml si incubation en atmosphère ordinaire.
Gentamicine	—	—	≤ 4	
Tétracycline	—	—	≤ 1	Les souches non sensibles doivent être confirmées (identification et CMI).
Doxycycline	—	—	≤1	
Triméthoprime+sulfaméthoxazole	—	—	≤ 2/38	

*Tableau extrait du Document M45, 3rd ed. 2016. Methods for antimicrobial dilution and disk susceptibility testing of infrequently isolated or fastidious bacteria.

Table de lecture 21* : Valeurs critiques des CMI pour Corynebacterium spp. (*C.diphteriae* inclus) et genres apparentés.

Antibiotiques	Valeurs critiques CMI (µg/ml)			Commentaire
	R	I	S	
Pénicilline	≥4	0,25 - 2	≤0,12	
Céfotaxime	≥4	2	≤1	
Ceftriaxone	≥4	2	≤1	
Gentamicine	≥16	8	≤4	
Erythromycine	≥2	1	≤0,5	
Clindamycine	≥4	1 - 2	≤0,5	
Quinupristine-Dalfopristine	≥4	2	≤1	
Ciprofloxacine	≥4	2	≤1	
Tétracycline	≥16	8	≤4	
Doxycycline	≥16	8	≤4	
Triméthoprime+sulfaméthoxazole	≥4/76	—	≤2/38	
Vancomycine	—	—	≤2	Les souches non sensibles doivent être confirmées (identification et CMI).

*Tableau extrait du Document M45, 3rd ed. 2016. Methods for antimicrobial dilution and disk susceptibility testing of infrequently isolated or fastidious bacteria.

Table de lecture 22* : Valeurs critiques des diamètres des zones d'inhibition et des CMI pour *Pasteurella* spp.

Antibiotiques testés	Charge des disques	Diamètres critiques (mm)			CMI critiques (µg/ml)			Commentaires
		R	I	S	R	I	S	
Péniciline	10 UI	---	---	≥ 25	---	---	≤ 0,5	Les souches non sensibles doivent être confirmées (identification et CMI).
Ampiciline	10 µg	---	---	≥ 27	---	---	≤ 0,5	
Amoxicilline	CMI	---	---	---	---	---	≤ 0,5	
Amoxicilline +ac.clavulanique	20/1 0µg	---	---	≥ 27	---	---	≤ 0,5/0,25	
Céftriaxone	30 µg	---	---	≥ 34	---	---	≤ 0,12	
Erythromycine	15 µg	≤ 24	25 – 26	≥ 27	≥ 2	1	≤ 0,5	
Azithromycine	15 µg	---	---	≥ 20	---	---	≤ 1	Les souches non sensibles doivent être confirmées (identification et CMI).
Lévofloxacine	5 µg	---	---	≥ 28	---	---	≤ 0,06	
Tétracycline	30 µg	---	---	≥ 23	---	---	≤ 1	
Doxycycline	30 µg	---	---	≥ 23	---	---	≤ 0,5	
Chloramphénicol	30 µg	---	---	≥ 28	---	---	≤ 2	
Triméthoprime+sulfaméthoxazole	1.25/23.75 µg	---	---	≥ 24	---	---	≤ 0,5/9,5	

*Tableau extrait du Document M45, 3rd ed. 2016. Methods for antimicrobial dilution and disk susceptibility testing of infrequently isolated or fastidious bacteria.