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Microbiological Contamination and Antibiotic Resistance of Bacteria Isolated from Circulating Banknotes in Mosul, Iraq

Rana S. Hasan[1], Haitham Abdullah Rajab[2], Ahmed Al Qattan[3], Ali M. Saadi[4*]

[1] Medical Laboratory Techniques Department, Mosul Medical Technical Institute, Northern Technical University, Mosul 41001, Iraq
[2] AL-Nimrod Technical Institute, Northern Technical University, Mosul 41001, Iraq
[3] Department of Anesthesia Techniques, Mosul Medical Technical Institute, Northern Technical University, Mosul 41001, Iraq
[4] Department of Animal Production Technologies, Technical Agricultural College, Northern Technical University, Mosul 41001, Iraq

Corresponding Author Email: ali.mohammed@ntu.edu.iq

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ABSTRACT

Paper currency is considered a major vector for pathogenic organisms between individuals due to its frequent use by many people and its presence in several contaminated environments and inanimate surfaces. This study focused on isolating and identifying bacterial contamination of paper currency and estimating antibiotic sensitivity in Mosul city. A total sample (120) of paper currency was collected during the period August 2025 to October 2025, of which 85 (70.9%) appeared as culture positive. All isolated bacteria were identified based on phenotypic characteristics, including colony morphology, Gram stain, and biochemical tests, and the diagnosis was confirmed by the VITEK 2 system. Antibiotic sensitivity testing (AST) was performed by the disc diffusion method using 10 antibiotic standards according to Clinical and Laboratory Standards Institute (CLSI) guidelines, and most isolates showed high resistance rates. The old paper currency showed the highest contamination with microbes at 83.3%, while the new paper currency showed 58.3%. *Bacillus* spp. is the most isolated bacterium at 22.3%, followed by *E. coli* at 20%, and *Staph. epidermis* as 14.1%, *Staph. aureus* and *Micrococcus lutes* at the same percentage as 8.2%, *Pseudomonas aeruginosa* as 4.7%, *Kleb. Oxytoca* as 3.5% and *Pseudo. stuzeri* as 2.3%, while fungi isolated included Candida as 7%, *Aspergillus* spp. as 5.8%, and Pencillium as 3.5%. The 1000 ID denomination of paper currency had the highest percentage contamination at 36.4%, followed by the 250 ID denomination at 27.1% and the 500 ID denomination at 14.1%, compared with other denominations. The results of the sensitivity test showed that all bacteria isolated had moderate to high average resistance to the antibiotics used in this study. Paper currency is a vector for the transmission of different microbes; it plays an important role in the spread of infectious diseases as they pass from hand to hand, and individuals should practice personal care and hygiene instructions.

1. INTRODUCTION

Globally, banknotes are the most commonly used item with daily contact. Therefore, paper currency can become contaminated during circulation between individuals and can serve as a means of spreading microbes. The potential for paper currency to act as an environmental vector for pathogenic microbes was recognized following research conducted in the 1970s [1]. Paper currency is disinfected in synthesis, but it becomes contaminated after being sent into circulation, from sources such as contact with the atmosphere, handling, counting money, or person-to-person transmission via droplets from sneezing and coughing, and from putting money on unclean surfaces or clothes [2]. Also, an individual's habits in unhygienic conditions and unhygienic living will contaminate the note by retaining currency in shoes, socks, and pockets, or by keeping it under rugs or carpets, or by squeezing it in the hand frequently, which frequently introduces an array of microbes to the note [3].

Additionally, paper currency was manufactured from a mixture of cotton and linen. It provides an optimal environment for colonizing several microorganisms, and these materials assist in carrying a bacterial load approximately three times more than that of polymer-based money due to cotton paper currency's ability to retain moisture, which encourages many contaminated microorganisms [4]. In contrast, polymer paper currency has several physicochemical properties that reduce microbial attachment to its surface [5]. Contamination of paper currency can come from microbes in soil, water, and the normal flora on the body or the handlers. People represent the most numerous group of biological factors associated with paper currency contamination. The main factor in paper currency soiling is finger contact with saliva during counting, which results in fingerprints that accumulate over time and lead to color changes or depreciation of paper currency [2].

Studies in the worldwide have reported to high rates of microbial contamination of paper currency in circulation a crossing different regain, such as studies in Indian rupee [6], Bangladesh Teka [7], Iraq currency [8], and Ghanaian currency [9] and these studies disclose that paper currency were a highest contaminated with pathogenic bacteria at a rates extent from 88% to 100%.

There are several microbial contaminants on banknotes, including bacteria, viruses, and mold or fungi. Nevertheless, bacteria are most frequently isolated as pathogens from money, especially members of Enterobacteriaceae, like *E. coli*, *Klebsiella*, *Serratia marcescens*, *Shigella* spp., and other bacterial pathogens, including *Bacillus* spp., *Staphylococcus* spp., *Pseudomonas* spp., *Clostridium difficile*, *Vibrio cholera*, *Bordetella pertussis*, *Haemophilus influenzae*, *Proteus vulgaris*, and *Acinetobacter*. Moreover, these bacteria can survive for long periods on the surface of currency notes, leading to an increased risk of infection with several diseases [10-13]. Also, yeast-like *Candida albicans* can survive for up to 4 months in a dry state.

This study focuses on identifying potentially harmful bacterial strains that may be transmitted through the circulation of paper currency in Mosul city and assessing their antibiotic resistance.

2. MATERIALS AND METHODS

2.1 Sample collection

120 paper currency notes were collected during the period from August 2025 to October 2025; samples were collected from several sources (banks, markets, meat vendors, fruit and vegetable sellers, and restaurants). Samples were collected from different individuals at several locations and in multiple environments in the current study to improve representativeness and reduce clustering. The paper currencies were divided in two group included 60 newly and 60 old according to visual wear rating and general appearance. Notes spanned issuance/series years from 2008 to 2025.

An employee from a local bank contributed to our efforts in determining the type of paper currency (new or old).

The paper currency notes were classified as ‘new’ or ‘old’ based on a combined criterion of visible wear score and time since issuance.

Wear score: Each note was independently rated by two trained assessors using a 5-point scale:

1 = like new (no visible wear, sharp edges, clear printing);

2 = slight wear (minor folds, slight color fading);

3 = moderate wear (multiple folds, visible dirt, edge rounding);

4 = heavy wear (extensive dirt, tears, faded print);

5 = very heavy wear (barely legible, severe damage).

Notes with a mean score of ≤ 2 were classified as ‘new’; those with a score of ≥ 3 were classified as ‘old’.

Time criterion: Notes issued in the calendar year 2023 or later were also considered ‘new’ only if their mean wear score was ≤ 2 (i.e., no heavy damage). Notes issued before 2020 were automatically considered ‘old’ unless they were considered uncirculated (defined as mean wear score = 1 with no visible folds, stains, tears, or edge rounding).

The series/issuance year was identified with assistance from a local bank employee, who was blinded to the microbiological results. Final labels were assigned strictly according to the predefined criteria.

2.2 Bacteriological analyses

For isolation of microorganisms, sterile saline cotton swabs were used to collect swabs from paper currency, and the swabs were passed through each corner and the central part of both sides of the paper currency. The entire swabs were inserted in peptone water and incubated at 37 °C overnight, after which appropriate serial dilution (10^{-1}, 10^{-2}, 10^{-3}) of the original sample and the spread about 100 µL of 10^{-3} on nutrient agar, MacConkey agar, and blood agar, and incubated at 37 °C for 24 hours. The colonies were detected phenotypically based on colony characteristics, Gram stain, hemolysis, and biochemical tests (catalase test, oxidase test, IMViC test), and by the VITEK 2 system; the bacterial isolates were confirmed by detection. The Quality Control (QC) procedures were determined using *Escherichia coli* ATCC 25922 as a standard reference strain to ensure the reliability of the system and reagents. The result depended on whether the percentage was more than 95%. and isolates with low percentages were retested to determine the bacterial type.

2.3 Antibiotic susceptibility test

AST of bacterial isolates was performed using the Kirby – Bauer disc diffusion method and the guidelines recommended by the Clinical and Laboratory Standards Institute (CLSI) 2021. Bacterial isolates were cultured on Mueller-Hinton agar, and the inoculum was adjusted with a MacFarland standard tube (0.5). It is incubated aerobically at 37 °C for 24 hours, and the diameter of the inhibition zone was measured using a ruler and compared with the recommendations of CLSI 2021. Isolated strains were classified as Susceptible (S), Intermediated (I), or Resistant (R). The antibiotics discs used in the current study were: ampicillin (AMP, 10 µg), amikacin (AK, 10 µg), ceftazidime (30 µg), cefotaxime (CTX, 30 µg), ciprofloxacin (CIP, 5 µg), imipenem (IM, 10 µg), erythromycin (E, 15 µg), and gentamicin (GEN, 10 µg).

3. RESULT

In the current study we collected 120 swab sample from paper currency, 85 (70.9%) was appeared positive culture of contaminated bacteria and 35 (29.1%) appeared negative culture of contaminated bacteria, and the old paper currency shown more contaminated with bacteria at 50 (83.3%) while a new paper currency appeared little contamination with bacteria at 35 (58.3%), it shown in Table 1.

In our study, both Gram-positive and Gram-negative bacteria were isolated from paper currency, as shown in Table 2. *Bacillus* spp. was most bacteria isolated at (22.3%) followed with *E.coli* isolated at (20%), *Staphylococcus epidermis* as (14.1%), *Staphylococcus aureus* and *Micrococcus luteus* at same percentage at (8.2%), *Pseudomonas aeruginosa* at (4.7%), *Klebsiella oxytoca* at (3.5%) and *Pseudomonas stuzeri* at (2.3%) as well as we isolated fungi from paper currency like Penicillium at (3.5%), Aspergillus at (5.8%) and Candida at (7%).

Table 1. The percentage of isolating bacteria from paper currency, depending on the physical condition

No. of Samples	Type of Paper Currency	No. of Paper Currency	Culture Positive	Culture Negative
120	Old	60	50 (83.3%)	10 (16.7%)
	New	60	35 (58.3%)	25(41.7%)
	Total	120	85 (70.9%)	35 (29.1%)

Table 2. The percentage of bacteria and fungi isolated from paper currency

Gram-Positive Bacteria	Number / Percentage
Staphylococcus aureus	7 (8.2%)
Staphylococcus epidermis	12 (14.1%)
Bacillus spp.	19 (22.3%)
Micrococcus luteus	7 (8.2%)
Gram-Negative Bacteria	**Number / Percentage**
Pseudomonas aeruginosa	4 (4.7%)
E. coli	17(20%)
Klebsiella oxytoca	3 (3.5%)
Pseudomonas stuzeri	2 (2.3%)
Fungi	**Number / Percentage**
Penicillium spp.	3 (3.5%)
Aspergillus spp.	5 (5.8%)
Candida spp.	6 (7%)

Percentages are based on the total culture-positive samples (n = 85).

Table 3. The distribution of bacteria and fungi isolated from paper currency according to different domination

Types of Bacteria	Paper Currency Domination ID, No. (%) 250	500	1000	5000	10000	25000	Total
Staphylococcus aureus	1 (14.2%)	3 (42.8%)	1 (14.2)	0 (0%)	1 (14.2%)	1 (14.2%)	7
Staphylococcus epidermis	3 (25%)	1 (8.3%)	4 (33.3%)	2 (16.6%)	1 (8.3%)	1 (8.3%)	12
Bacillus spp.	6 (31.5%)	2 (10.5%)	7 (36.8%)	2 (10.5%)	2 (10.5%)	0 (0%)	19
Micrococcus luteus	1 (14.2%)	1 (14.2%)	3 (42.8%)	1 (14.2%)	0 (0%)	1 (14.2%)	7
Pseudomonas aeruginosa	1 (25%)	0 0%)	2 (50%)	0 (0%)	1 25%)	0 (0%)	4
E. coli	4 (23.5%)	2 (11.7%)	5 (29.4%)	3 (17.6%)	1 (5.8%)	2 (11.7%)	17
Klebsiella oxytoca	1 (33.3%)	0 (0%)	2 (66.6%)	0 (0%)	0 (0%)	0 (0%)	3
Pseudomonas stuzeri	1 (50%)	0 (0%0	1 (50%)	0 (0%)	0 (0%)	0 (0%)	2
Pencillium spp	1 (33.3%)	1 (33.3%)	1 (33.3%)	0	0	0	3
Aspergillus spp.	2 (40%)	1 (20%)_	2 (40%)	0	0	0	5
Candida spp.	2 (33.3%)	1 16.6%)	3 (50%)	0	0	0	6
Total	23 (27.1%)	12 (14.1%)	31 (36.4%)	8 (9.4%)	6 (7.1%)	5 (5.9%)	85 (100%)

Table 4. Antibiotic sensitivity of Gram-positive bacteria

Antibiotics		***Staphylococcus aureus*** **No. 7 (%)**	***Staphylococcus epidermis*** **No. 12 (%)**	***Bacillus*** **spp. No. 19 (%)**	***Micrococcus luteus*** **No. 7 (%)**
AMP	R	4(57.1%)	9(75%)	11(57.8%)	3(42.8%)
	S	3(42.8%)	3(25%)	8(42.1%)	4(57.1%)
AK	R	1(14.2%)	2(16.6%)	3(15.7%)	1(14.2%)
	S	6(85.7%)	10(83.3%)	16(84.2%)	6(85.7%)
AZM	R	1(14.2%)	1(8.3%)	4(21%)	1(14.2%)
	S	6(85.7%)	11(91.6%)	15(78.9%)	6(85.7%)
CTX	R	2(28.5%)	4(33.3%)	9(47.3%)	1(14.2%)
	S	5(71.4%)	8(66.6%)	10(52.6%)	6(85.7%)
CIP	R	3(42.8%)	2(16.6%)	2(10.5%)	2(28.5%)
	S	4(57%)	10(83.3%)	17(89.4%)	5(71.4%)
IM	R	0(0%)	0(0%)	0(0%)	0(0%)
	S	7(100%)	12(100%)	19(100%)	7(100%)

E	R	3(42.8%)	3(25%)	7(36.8%)	2(28.5%)
	S	4(57.1%)	9(75%)	12(63.1%)	5(71.4%)
GEN	R	1(14.2%)	1(8.3%)	4(21%)	1(14.2%)
	S	6(85.7%)	11(91.6%)	15(78.9%)	6(85%)

Table 5. Antibiotic sensitivity of Gram-negative bacteria

Antibiotics		***Pseudomonas aeruginosa*** **No. 4 (%)**	***E. coli*** **No. 17 (%)**	***Klebsiella oxytoca*** **No. 3 (%)**	***Pseudomonas sutzeri*** **No. 2 (%)**
AMP	R	3(75%)	6(35.2%)	2(66.6%)	0(0%)
	S	1(25%)	11(64.7%)	1(33.3%)	2(100%)
AK	R	1(25%)	2(11.7%)	0(0%)	0(0%)
	S	3(75%)	15(88.2%)	3(100%)	2(100%)
AZM	R	1(25%)	4(23.5%)	1(33.3%0	1(50%)
	S	3(75%)	13(76.4%)	2(66.6%)	1(50%)
CTX	R	1(25%)	3(17.6%)	1(33.3%)	0(0%)
	S	3(75%)	14(82.3%)	2(66.6%)	2(100%)
CIP	R	1(25%)	2(11.7%)	0(0%)	0(0%)
	S	3(75%)	15(88.2%)	3(100%)	2(100%)
IM	R	0(0%)	0(0%)	0(0%)	0(0%)
	S	4(100%)	17(100%)	3(100%)	2(100%)
E	R	4(100%)	15(88.2%)	3(100%)	2(100%)
	S	0(0%)	2(11.7%)	0(0%)	0(0%)
GEN	R	2(50%)	4(23.5%)	1(33.3%)	1(50%)
	S	2(50%)	13(76.4%)	2(66.6%)	1(50%)

All paper currency domination appeared contaminated with bacteria, although the highest contamination was detected in 1000 ID category 31 (36.4%), followed by 250, 500, and 5000 ID categories as 23 (27.1%),12 (14.1%), 8 (9.4%) respectively, while the highest categories, like 10000 ID and 25000 ID, showed low contamination by bacteria, with 6 (7.1%) and 5 (5.9%), respectively (Table 3).

AST was done to estimate the susceptibility of bacteria, and the results indicated higher resistance of the isolates to the antibiotics used in the study, as shown in Tables 4 and 5.

4. DISCUSSION

Paper currency is usually handled by many people with different hygienic levels, which are stored in multiple environments. Therefore, it is considered an important factor in the transport of pathogens within a population. Studies have shown that the age of paper currency has a direct effect on its contamination; old paper notes are more contaminated than new ones, and most pathogenic bacteria were isolated from old paper currency [3, 14]. Old paper currency is characterized by discoloration, accumulated dirt, wear, and physical deterioration, while new paper currency does not have these characteristics. Bacteria are a ubiquitous group of microbial contaminants on currency notes due to their daily circulation between individuals. Therefore, they become more tattered and dirtier, thereby facilitating the transfer of pathogenic bacteria among people [15]. As well as folding or squeezing of paper currency, the folding or squeezing of paper currency helps create a suitable environment that could harbor dust particles and microorganisms that may cause a wide range of diseases, such as wound and skin infections, food poisoning, respiratory infections, and gastrointestinal problems [16]. So, the results of the current study agreed with the study that reported the highest bacterial isolation from old paper currency compared with new paper currency in India [17].

There are several studies in many countries on paper currency contamination that report the presence of a wide range of potential pathogenic microorganisms, including bacteria, fungi, parasites, nematodes, protozoa, and viruses [18]. In the present study, Aspergillus spp. and Penicillium are the most frequently isolated fungi, and this result agrees with a local study that reported the isolation of fungi from paper currency in the summer season; it isolated *Aspergillus niger* at 26%, *A. flavus* at 8.8%, and *Penicillium* spp. at 7.1% and Candida at 0.4%, while in winter, at *Pencillium* spp. 28%, *Aspergillus niger* 5.1%, the percentage of isolating due to the nature of summer season characteristics at high temperature and dust, it allow for the transmission of spore at air and leading to surface contamination. In winter, the low temperature and high humidity which less of transport spores and limited spread [19].

In this study, we isolated different types of Gram-positive bacteria, such as *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Bacillus*, and *Micrococcus luteus*, and Gram-negative bacteria, such as *Pseudomonas aeruginosa*, *E. coli*, *Klebsiella oxytoca*, and *Pseudomonas stutzeri*. Most studies established Gram-positive bacteria as the major isolates from contaminated paper currency, and this finding was consistent with our study. Bacillus is the most common type of bacteria isolated in our study; it is a gram-positive bacterium found as normal flora in humans and the environment. It can be transmitted between healthy people and causes various significant infections; therefore, it has been introduced as a common contamination factor of paper currency [20, 21]. A study on AL-Najaf city showed that *Bacillus* spp. was the predominant bacterium isolated from paper currency at 41.2%, whereas our result showed *Bacillus* spp. as the predominant isolate at 22.3% and variation in percentage isolated may be due to several reasons, such as differences in the total sample collected in the current study, different environmental conditions, methods for collecting samples, sample volume, and isolating bacteria techniques [22]. Study of Odaa [23], which refers to isolated *Bacillus* sp. at 30.55%, followed by *Klebsiella* 18.05%, *Staphylococcus aureus* 16.66%, *Staphylococcus epidermidis* 8.33%, and *Staphylococcus aureus* and *E. coli* were also isolated at high percentages among other isolates due to the ability to colonize the skin and anterior nares in healthy individuals [24]. Most studies report that Gram-negative bacteria were the predominant bacteria isolated from paper currency [25]. In our study, the most Gram-negative bacteria isolated were *E. coli*, and this result was the same as in an earlier study in Al-Nasiriyah city, Thi-Qar province, where *E. coli* was isolated, and this result agrees with the current study, which isolated *E. coli* at 20% [24].

Most paper currency from different regions around the world was contaminated with microorganisms, especially *Escherichia coli*, *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Micrococcus luteus*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae* [26, 27]. Some of these bacteria are part of the human normal flora. They can be transmitted from a carrier to an inanimate surface, such as money, as well as through hand-to-hand contact with contaminated money, which can introduce coliforms and *Staphylococcus* spp. between individuals, especially during vending operations. Study in Al-Yamin refers to isolated enteric bacteria from money, such as Klebsiella spp. *E. coli* and *Pseudomonas* spp., and these are coliform bacteria, indicating fecal contamination [10]. So, it plays a critical role in the spread of disease, and the risk of infection depends on the number of bacteria present and their ability to survive in a harsh environment [28]. Wherefore, these results emphasize the potential health hazard associated with handling contaminated currency [29, 30].

A higher contamination rate was observed on smaller categories of paper currency (250, 500, 1000) ID compared with larger categories (5000, 10000, 25000) ID. The 1000 ID category was more contaminated, at 36.4%. this result may be due to it most category are frequently handing and circulated between individual from different site and profession Therefore, the lower denomination paper currency more contamination compare with higher denomination [31] this result agree with study on Al-Anbar Governorate that appeared the 1000 ID denomination was higher number colonies contamination of paper currency [21], in addition other study in Erbil city showed 500 ID have higher value to contamination with bacteria flowed with 100 ID compare with other categories and this due to the smaller denomination paper currency were wide spread and exchangeable among people with different environments [32], also this result was agree with other studies like showed small unit of paper currency is highest contamination study in Sudan [33] that observed the 500 Rails paper currency was were most contaminated compare with 50000 rails paper currency [34]. Low-denominations were more used by people in popular places like markets, transportation, street vendors, and restaurants; therefore, all sites had low hygiene procedures and were more exposed to microbial contamination.

There are relationship between degrees of contamination and type of microbials present on circulating paper currency it related to several factors such as nature material structure that made of paper currency like cotton which compose of fiber that assisted to retains moisture and dirt, long used of paper currency, storge condition and absent of sterilize of paper currency during circulation all factors which provide suitability environment for growth microorganism [2].

Furthermore, most Gram-positive and Gram-negative bacteria isolated in our study showed moderate to high average resistance in the antibiotic sensitivity test. These results indicate the critical role of transmission-resistant bacteria in antibiotic resistance through paper currency and the danger they pose to individuals, such as foodborne illness and nosocomial infections, and these results are consistent with previous studies [35-37].

Bacillus spp. have the ability to form spores, which give them resistance to harsh environments and stresses. So, they can be found in several environments (soil, water, and air), which makes them easily transported between individuals, causing multiple diseases such as intestinal infections [36]. *Bacillus* spp. appeared high level to resistance AMP and CTX and sensitive to Imipenem (IM), this result was agreed with research [36], these resistance due to ability of bacteria to secreted potential beta lactamase enzyme, it control under chromosomal or encoded by plasmid gene and activity of these enzymes were depended on hydrolyzing of beta lactam ring of antibiotics, therefore it gave the protection of bacteria from β-Lactam antibiotics included Penicillins, Cephalosporins, Monobactams and Carbapenems [37, 38].

Table 4 presents the resistance and susceptibility pattern of four Gram-positive bacteria (*Staphylococcus aureus, Staphylococcus epidermidis, Bacillus* spp., *Micrococcus luteus*) towards eight different antibiotics. The results were expressed as the number of isolates and the percentage (%) of sensitive (S) and resistant (R) for each antibiotic. The results show that the sensitivity to the antibiotic IM was 100% across all four types. This is because IM is an antibiotic from the carbapenem group, considered one of the most powerful broad-spectrum antibiotics, and its resistance is relatively rare among common Gram-positive bacteria [39]. This result indicates that it remains the ideal choice for treating infections caused by these organisms in this study, reflecting its very high effectiveness.

As for the antibiotic AMP, sensitivity varied greatly: *Micrococcus luteus* showed the highest sensitivity (57.1%), while *Staphylococcus epidermidis* showed the highest resistance (75%). The reason is that AMP is an older antibiotic from the penicillin group. The high rate of resistance in *S. epidermidis* (75%) and *S. aureus* (57.1%) is clinically expected due to the spread of beta-lactamase enzymes produced by these species, making it unreliable to use alone without allergy testing [40].

While Amikacin (AK) was found to have a very high sensitivity ranging from 83.3% in *S. epidermidis* to 85.7% in other species, because AK is an effective aminoglycoside against many bacteria [41], where the results are considered very good, as the resistance rate does not exceed 16.6% and this reflects this continuous effectiveness of this antido, although caution is necessary in its use due to its renal and auditory side effects [42].

Azithromycin (AZM) was found to have a high sensitivity, ranging between 78.9% (*Bacillus* spp.) and 91.6% (*S. epidermidis*). The reason for this is that AZM is a macrolide [43], and the results indicate good effectiveness, but resistance to *Bacillus* spp. It was relatively the highest (21%).

CTX was less effective compared to previous antibiotics, especially against *Bacillus* spp. The resistance was 47.3%, while *M. luteus* was 85.7% sensitive, due to CTX being a third-generation cephalosporin and the high resistance of *Bacillus* spp. (47.3%) and *S. epidermidis* (33.3%) may indicate the presence of broad-spectrum beta-lactamases (ESBLs) or other resistance mechanisms, limiting its effectiveness against these isolates [44].

CIP has been found to have very good efficacy, especially against *Bacillus* spp. (sensitivity was 89.4%) and *S. epidermidis* (83.3%). The highest resistance was to *S. aureus* (42.8%). This is because CIP is a fluoroquinolone, which makes it highly effective at eliminating Gram-positive bacteria [45].

While E is considered moderately effective, as the highest sensitivity was for *S. epidermidis* (75%) and the lowest for S. aureus (57.1%) and Bacillus spp. (63.1%). This is because E is an older macrolide with moderate activity against Gram-positive bacteria, and high resistance (36.8%-42.8%) is common worldwide due to widespread use and genetic mechanisms of resistance (e.g., erm genes), making it less reliable [46].

Finally, GEN is considered to have high sensitivity, similar to AK, ranging from 78.9% (*Bacillus* spp.) to 91.6% (*S. epidermidis*). This is because GEN is another aminoglycoside, and its good efficacy reflects the continued sensitivity of these isolates to it, and it can often be used in combination therapies (e.g., with penicillins or cephalosporins) to achieve a synergistic effect [47].

In conclusion, the most effective anti-IM is the only antibody for which no resistance has been recorded (0%). Therefore, it is considered the safest and most effective option in this group of isolates. In contrast, the least effective antibiotics (AMP) and CTX have the highest rates of resistance, especially against Staphylococcus epidermidis and Bacillus spp., which calls for avoiding their use as initial treatment without confirming allergy.

Table 5 shows the sensitivity patterns of four Gram-negative bacterial species to a group of antibiotics. These bacteria represent different isolates: *Pseudomonas aeruginosa, E. coli, Klebsiella oxytoca*, and *Pseudomonas sutzeri*. The results were expressed as percentages, along with the numbers of susceptible (S) and resistant (R) isolates for each antibiotic. The data show clear variation in resistance patterns among bacterial species, reflecting substantial differences in the underlying resistance mechanisms of each species and the possibility of different sources of isolates.

Pseudomonas aeruginosa. This isolate showed a remarkable resistance pattern to many antibiotics, with complete resistance (100%) to E and a 50% resistance rate to GEN. Intermediate resistance: 25% of isolates are resistant to AMP, AK, AZM, CTX, and CIP. *P. aeruginosa* is inherently resistant to AMP and macrolides (such as AZM and E). The presence of 25% resistance to AK (considered one of the most important anti-pseudomonas agents) and CIP is a risk indicator. It may indicate the presence of acquired mechanisms of resistance, such as efflux pumps or the production of aminoglycoside-modifying enzymes [19]. However, the complete sensitivity of IM remains an important therapeutic strength.

E. coli. This isolate is considered the most sensitive in general compared to other bacteria, as it shows high and very high sensitivity to AK and CIP at a rate of 88.2%, to CTX at a rate of 82.3%, and to AZM at a rate of 76.4%, and moderately resistant showing marked resistance to AMP of 35.2%, which is very common in *E. coli* due to the production of broad-spectrum beta-lactamase enzymes (TEM-1) [48].

Klebsiella oxytoca. This isolate exhibits a moderate pattern of resistance, with 100% complete E resistance and 66.6% AMP resistance (which is normal due to its endogenous AMP resistance) [49]. It is also fully sensitive (100%) to AK, CIP, and IM. Moderate sensitivity is shown to GEN (66.6%) and CTX (66.6%).

Finally, the *Pseudomonas stutzeri* isolate shows a high sensitivity to most of the antibiotics tested, as it is completely sensitive: 100% sensitivity to AMP, AK, cefotaxime (CTX), CIP, and IM, and its only resistance observed was to E (100%), AZM (50%), and GEN (50%). This pattern of high sensitivity is relatively expected in *P. stutzeri*, which is often more sensitive than *P. Aeruginosa* [50].

Based on these data, IM is the safest and most effective option for all of the isolates mentioned. AK and CIP are very good options, especially for infections caused by *E. coli*. Still, they should be used with caution and only after an allergy has been confirmed in cases of *P. aeruginosa*. The presence of 100% resistance to E and high resistance to AMP confirms the futility of their use. Additional testing to confirm the sensitivity of *K. oxytoca* to broad-spectrum cephalosporins (such as CTX) is recommended to confirm or rule out ESBL production.

5. CONCLUSION

Iraqi paper currency is contaminated with a wide range of microbial-like potential pathogens and fungi. Therefore, they pose a threat to the community, especially to individuals who handle currency notes, and represent a public health risk. As a result, individuals must increase handwashing, sterilize their hands after contact with paper currency, avoid using saliva to calculate paper currency, and practice personal hygiene. The community needs to realize the risks and diseases that result from the inappropriate use of paper currency, and it is better to change paper currency to electronic cards to push money to avoid the spread of multidrug-resistant bacteria in the community.

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