

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/386494855>

COMPARATIVE EVALUATION OF DISINFECTANT EFFECTIVENESS ON CLINICAL BACTERIAL ISOLATES IN A DISK DIFFUSION STUDY.

Article in African Journal of Health Safety and Environment · December 2024

DOI: 10.52417/ajhse.v5i2.526

CITATIONS

0

READS

20

4 authors, including:



Mary Fadeyibi
Kwara State University

6 PUBLICATIONS 58 CITATIONS

SEE PROFILE



Henry Olawale Sawyerr
Kwara State University

131 PUBLICATIONS 1,652 CITATIONS

SEE PROFILE



COMPARATIVE EVALUATION OF DISINFECTANT EFFECTIVENESS ON CLINICAL BACTERIAL ISOLATES IN A DISK DIFFUSION STUDY.

*¹Fadeyibi, M., ²Sawyer, O. H., ²Opasola, A. O. & ³Ishola, O. A.

¹Department of Biological Sciences, Augustine University, Ilara-Epe, Lagos State, Nigeria.

²Department of Environmental Health Science, Kwara State University, Kwara State, Nigeria.

³Department of Pure and Applied Biology, Ladoké Akintola University of Technology, Ogbomosho, Nigeria.

*Corresponding Author's Email: m2020fadeyibi@gmail.com; Phone: +2347031037399

ABSTRACT

This study aimed to assess the efficacy of various disinfectants on clinical bacterial isolates with a focus on *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumonia* and *Pseudomonas aeruginosa*. The clinical isolates were subjected to testing with four disinfectants: Phenols, Formaldehyde, Sodium hypochlorite, and Ethyl alcohol, utilizing the disk-diffusion method. Pathogenic bacteria pose a significant threat, capable of inducing a range of symptoms that can vary from mild to severe and potentially life-threatening, affecting both individuals and other organisms. The widespread use of disinfectants to mitigate microbial growth on inanimate objects highlights the importance of understanding their effectiveness. Formaldehyde emerged as the most effective disinfectant, exhibiting a 92% susceptibility pattern, while Phenol demonstrated an 8% susceptibility. In contrast, sodium hypochlorite and ethyl alcohol presented no area of inhibition against any of the clinical bacterial isolates. Specific susceptibility patterns were observed, with *Escherichia coli*, *Pseudomonas aeruginosa* and *Staphylococcus aureus*, proving susceptible to Formaldehyde at rates of 41%, 32%, and 27%, respectively. Conversely, *Klebsiella pneumonia* demonstrated resistance to Formaldehyde. These findings highlight the variable efficiency of the tested disinfectants. Given the superior efficacy of Formaldehyde against the bacterial isolates, routine testing of disinfectants is recommended to ensure their effectiveness against pathogenic microorganisms.

Keywords: Aseptic techniques, Bacteria, Disinfectants, Effectiveness, Susceptibility

LICENSE: This article by African Journal of Health, Safety and Environment (AJHSE) is licensed and published under the Creative Commons Attribution License 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided this article is duly cited.

COPYRIGHT: The Author(s) completely retain the copyright of this published article.

OPEN ACCESS: The Author(s) approves that this article remains permanently online in the open access (OA) model

QA: This Article is published in line with "COPE (Committee on Publication Ethics) and PIE (Publication Integrity and Ethics)".

INTRODUCTION

In recent years, controlling and preventing microbial growth on inanimate surfaces has become increasingly crucial, particularly in healthcare and laboratory environments (Pérez de la Lastra *et al.*, 2022; Lee and Park, 2023). The effectiveness of disinfectants plays a vital role in mitigating the spread of pathogenic bacteria that significantly impact human health and the ecosystem (Olatunji *et al.*, 2023). An inclusive understanding of the comparative efficacy of various disinfectants is essential for conversant decision-making in disinfection practices. Pathogenic bacteria such as *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae* have been recognized as causative agents of a wide array of infections, ranging from mild to severe and potentially life-threatening (Ahmadpour *et al.*, 2022; Parija, 2023). The capacity of these bacteria to induce harmful symptoms in humans and other affected organisms highlights the critical necessity for effective disinfection measures (Karmakar *et al.*, 2022; Mehta *et al.*, 2022).

To systematically evaluate the efficacy of disinfectants, the disk-diffusion method, a well-established technique in microbiological studies provides a practical and standardized approach (Sheet *et al.*, 2022; Shehbaz *et al.*, 2023). This method consents researchers to quantify the zones of inhibition produced by disinfectants, thereby offering valuable insights into their effectiveness against specific clinical bacterial isolates (Okposhi *et al.*, 2022; Alsaedy and Almilly, 2023). By engaging this technique, the current investigation aims to assess the effectiveness of different disinfectants on clinical bacterial isolates, contributing to the existing knowledge base by rigorously examining and comparing the performance of four disinfectants: phenol, formaldehyde, sodium hypochlorite, and ethyl alcohol.

This research discourses a critical gap in understanding the variable efficacy of disinfectants and underscores the importance of routine testing to ensure the ongoing effectiveness of disinfection protocols. The discoveries from this study are expected to inform best practices in disinfection strategies, particularly in environments where controlling bacterial contamination is paramount for public health and safety. Given the dynamic nature of microbial resistance and the evolution of disinfectant formulations, it is imperative to evaluate the efficacy of varied disinfectants against clinical bacterial isolates continually. Subsequently, the primary aim of this study was to identify suitable disinfectants and systematically appraise their effectiveness against clinically relevant bacterial isolates, thereby enhancing the framework for infection control in healthcare settings (De Oliveira *et al.*, 2020; Nicholas *et al.*, 2023; Waller *et al.*, 2023).

MATERIALS AND METHODS

Study Design

This investigation aims to assess the efficacy of commonly used disinfectants. The disk-diffusion technique was employed to evaluate the effectiveness of phenols, formaldehyde, sodium hypochlorite, and ethyl alcohol against clinical bacterial isolates, including *Pseudomonas aeruginosa*, *Escherichia coli*, *Staphylococcus aureus*, and *Klebsiella pneumoniae*.

Study Area

This research was carried out in Microbiology Laboratory of the Augustine University Ilara-Epe, Lagos State.

Disinfectants employed in the study

The disinfectants employed in this study are detailed in Table 1. Their efficiency was assessed in accordance with the manufacturers' guidelines for preparation.

Table 1: Disinfectants Utilized in the Study

S/No.	Name	Contents	Source
1.	Phenol	Carbonic acid	Microbiology unit of Augustine University, Ilara-Epe, Lagos State
2.	Formaldehyde	37% formaldehyde 40% by volume, 6-13% methanol and water	
3.	Ethyl Alcohol	80% v/v of Alcohol	
4.	Sodium hypochlorite	Sodium hypochlorite 3.5% w/v	

Bacterial Isolates and Disinfectant Sources

Bacterial strains were selected, including Gram-positive organisms like *Staphylococcus aureus* and Gram-negative organisms such as *Escherichia coli*, *Salmonella Typhi*, and *Klebsiella pneumoniae*. Clinical isolates and disinfectants were attained from the Department of Microbiology at Augustine University, Lagos State.

Preparation of Disinfectants Disc

Whatman filter paper was perforated aseptically into 0.5cm diameter discs via a usual bureau paper puncturing apparatus, sterilized and placed in sterile bottles. Each disinfectant (1 ml) was introduced into four separate bottles containing filter paper discs. while the fifth bottle with sterile discs served as a control, receiving 1 ml of distilled water. All discs in the bottles were soaked for 24 hours, a subsequent method drawn by Fitzpatrick *et al.* (2022), with minor modifications.

Test for the effectiveness of the disinfectants on clinical bacterial isolates

Disinfectant testing employed the disk diffusion assay, smearing various disinfectants to segregate sterile filter paper discs (Yusof *et al.*, 2023). Muller-Hinton agar was prepared following the manufacturer's guidelines.

Cultivated agar plates, subculture from nutrient broth isolates, were aseptically alienated into five segments in duplicate, each labeled with the name of a disinfectant and a distilled water disc (control). Gelled syringes were used to place each disinfectant disc onto the labeled sections. The agar rivetted the disinfectant paper disc for 2-3 minutes before incubating at 37°C for 24 hours. Post-incubation and mean inhibition zone in millimeters (mm) were measured for each disinfectant, considering both vertical and horizontal dimensions with a ruler.

Preparation of Stock Disinfectant Solutions for Filter Paper Impregnation

In this study, the process of preparing stock disinfectant solutions for impregnating filter paper is outlined. Table 2 revealed the specific concentrations for each disinfectant. Desired disc concentration was attained by diluting phenol it with water in a 70:30 ratio. Likewise, ethyl alcohol achieved its concentration via a 75:25 water-to-alcohol ratio. Conspicuously, formaldehyde and sodium hypochlorite were utilized with no dilution.

Table 2: Preparation of Stock Disinfectant Solutions for Filter Paper Disc Impregnation

S/No.	Disinfectants	Disinfectant concentration (mL)	Disc Concentration (%)
1.	Phenol	3.0	30
2.	Formaldehyde	10.0	100
3.	Ethyl Alcohol	7.5	75
4.	Sodium hypochlorite	10.0	100

Statistical Analysis

ANOVA was utilized to examine the factors accompanying with the efficacy of various disinfectants. The data were analyzed using IBM SPSS Statistics for Windows, version 21.0. Also, the statistical analysis data, which involved susceptibility and resistance, were processed with Microsoft Excel 2016 to obtain descriptive values of the samples after treatment.

RESULTS AND DISCUSSION

Evaluation of Disinfectant Efficacy and Bacterial Resistance Mechanisms in Clinical Isolates

The study discovered significant differences in the effectiveness of various disinfectants on clinical bacterial isolates, with formaldehyde demonstrating the highest efficacy at a 92% susceptibility rate. This surpassed phenol, which was only effective against *Pseudomonas aeruginosa* (8%), while sodium hypochlorite and ethyl alcohol showed no efficacy against any isolates. This aligns with previous studies by Choroszy-Król *et al.* (2023) and Kaoud *et al.* (2022), who found that formaldehyde was highly effective against pathogens like *Salmonella senftenberg* strains and *Salmonella typhi*. Additionally, Bakht *et al.* (2022) observed that sodium hypochlorite (5%) and ethanol (70%) displayed fluctuating levels of effectiveness, with ethanol being the least effective against *Pseudomonas aeruginosa*. Additionally, Nichols *et al.* (2023) tinted the phenomenon of cross-resistance, where bacteria exposed to sublethal concentrations of disinfectants can develop resistance to other agents, including antibiotics.

Further analysis of susceptibility patterns from Table 3 and Table 4 reinforced Formaldehyde's superiority, particularly against *Staphylococcus aureus* and *Escherichia coli*, where it produced inhibition zones of 43 mm and 28 mm, respectively. These results underscore Formaldehyde's broad-spectrum activity. In contrast, *Klebsiella pneumoniae* displayed complete resistance to all tested disinfectants, including Formaldehyde, which is consistent with its known multidrug resistance and biofilm formation capabilities. *Pseudomonas aeruginosa* also exhibited partial resistance, which could be attributed to its efflux pump systems and protective outer membrane, as reported by Butucel *et al.* (2022). The resistance mechanisms observed in these bacteria focus the limitations of conventional disinfectants in overcoming such defenses. Studies by De Oliveira *et al.* (2020) and Waller *et al.* (2023) further accentuated that resistance genes, such as *qacC* and *qacA*, play a role in bacteria like methicillin-resistant staphylococcus aureus (MRSA), leading to diminished disinfectant efficacy.

The structural resilience of certain pathogens, such as bacterial spores and mycobacteria, plays a key role in their resistance to disinfectants. Spores have vigorous protective layers, and mycobacteria possess lipid-rich cell walls that act as impermeable barriers to biocides. Gram-negative bacteria, including *Escherichia coli* and *Klebsiella pneumoniae*, also demonstrate resistance due to their outer membranes, which prevent the uptake of disinfectants. These observations are supported by studies like those of Mendoza *et al.* (2022) and Yan and Tu (2023), emphasizing the need for alternative strategies to effectively combat these pathogens.

The differential efficacy of disinfectants observed in this study highlights the complex relationship between disinfectant chemistry and bacterial defense mechanisms. Formaldehyde's broad-spectrum action against *Staphylococcus aureus* and *Escherichia coli* demonstrates its potential as an effective hospital disinfectant, while the resistance exhibited by *Klebsiella pneumoniae* and partial resistance in *Pseudomonas aeruginosa* indicate ongoing challenges in controlling nosocomial infections. These results, supported by relevant literature such as Nicholas *et al.* (2023), De Oliveira *et al.* (2020), and Waller *et al.* (2023), underscore the necessity of incessant evaluation and development of disinfectants to overwhelmed bacterial resistance and improve infection control measures.

Table 3: Average Susceptibility Patterns of Impregnated Disinfectant Discs Against Clinical Bacterial Isolates

S/No.	Clinical Bacterial Isolates	Phenol (mm)	Formaldehyde (mm)	Ethyl Alcohol (mm)	Sodium Hypochlorite (mm)	Water (mm)
1	<i>Staphylococcus aureus</i>	0	44.1	0	0	0
2	<i>Escherichia coli</i>	0	28.9	0	0	0
3	<i>Klebsiella pneumoniae</i>	0	0	0	0	0
4	<i>Pseudomonas aeruginosa</i>	9.6	34.3	0	0	0

Table 4: Sensitivity Patterns of Clinical Bacterial Isolates to Disinfectant-Impregnated Discs

S/No.	Samples (mm)/Bacterial Isolates	<i>Staphylococcus aureus</i>	<i>Escherichia coli</i>	Ethyl Alcohol	Sodium Hypochlorite
1	A	0.00±0.00 ^a	0.00±0.00 ^a	0.00±0.00 ^a	9.60±0.84 ^b
2	B	44.0500±1.48 ^d	28.90±1.27 ^b	0.00±0.00 ^a	0.00±0.00 ^c
3	C	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
4	D	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Key: A = Phenol, B = Formaldehyde, C = Ethyl Alcohol, D = Sodium Hypochlorite

The values represent means ± standard deviations from two determinations. Values lacking the same superscript within the same column are deemed significantly different ($p < 0.05$).

Comparative Analysis of Disinfectant Efficacy and Bacterial Susceptibility in Clinical Isolates

The outcomes described in Figure 1 feature the higher effectiveness of formaldehyde among the tested disinfectants, with a 92 % susceptibility rate against clinical bacterial isolates. This surpasses the performance of phenol, which was only effective against *Pseudomonas aeruginosa* with an 8% susceptibility rate, while sodium hypochlorite and ethyl alcohol showed no effectiveness. This aligns with the findings of Choroszy-Król *et al.* (2023), who demonstrated that formaldehyde is highly effective against various pathogens. Likewise, Kaoud *et al.* (2022) observed that formaldehyde and phenol, when applied at high concentrations, significantly reduced bacterial populations such as *Salmonella typhi*. This evidence supports the remarkable antimicrobial power of formaldehyde, which is widely recognized for its aptitude to disrupt cell wall integrity and denature microbial proteins.

The ineffectiveness of sodium hypochlorite and ethyl alcohol detected in this study is consistent with findings by Bakht *et al.* (2022), who conveyed limited efficacy of these disinfectants against *Pseudomonas aeruginosa*. ethyl alcohol was found to be the slightest effective, likely due to the bacterium's ability to resist alcohol-induced cell membrane damage through its biofilm formation and efflux pump mechanisms. Nichols *et al.* (2023) further emphasized that bacteria uncovered to sublethal concentrations of disinfectants can advance resistance not only to those agents but also to antibiotics, signifying a potential for cross-resistance. This phenomenon may explain why the clinical isolates in this

study, including *Staphylococcus aureus*, *Escherichia coli*, and *Klebsiella pneumoniae*, exhibited resistance to several disinfectants.

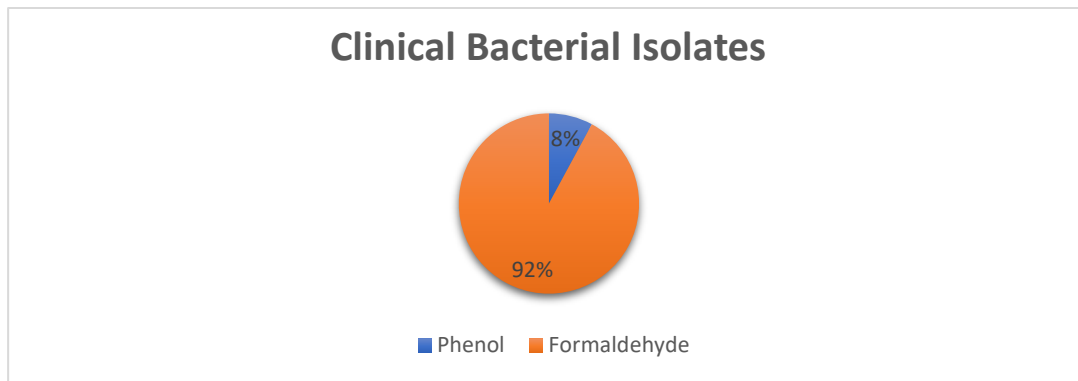


Figure 1: Percentage Effectiveness of Disinfectants Against Clinical Bacterial Isolates

In Figure 2, the susceptibility patterns of clinical isolates tested with formaldehyde buttress its efficacy, with *Staphylococcus aureus* showing the maximum susceptibility at 41%, followed by *Pseudomonas aeruginosa* at 32%, and *Escherichia coli* at 27%. These findings are unswerving with formaldehyde’s broad-spectrum antimicrobial activity, as it can penetrate bacterial cells and induce irreversible impairment by reacting with nucleic acids and proteins. However, *Klebsiella pneumoniae* displayed resistance to formaldehyde, which might be due to its well-documented ability to produce protective biofilms and harbor resistance genes. Studies by Klein *et al.* (2022) confirm that biofilm-forming bacteria often show reduced susceptibility to disinfectants due to the physical barrier that shields them from antimicrobial penetration.

The resistance observed in *Staphylococcus aureus*, particularly methicillin-resistant *Staphylococcus aureus* (MRSA), may be attributed to the presence of plasmids carrying resistance genes such as *qacC* and *qacA*, as noted by De Oliveira *et al.* (2020) and Waller *et al.* (2023). These genes encode efflux pumps that expel disinfectants from the bacterial cell, reducing their effectiveness. The presence of these genetic mechanisms in clinical isolates underscores the challenge of controlling resistant pathogens with traditional disinfectants, emphasizing the need for ongoing research and development of more potent biocides.

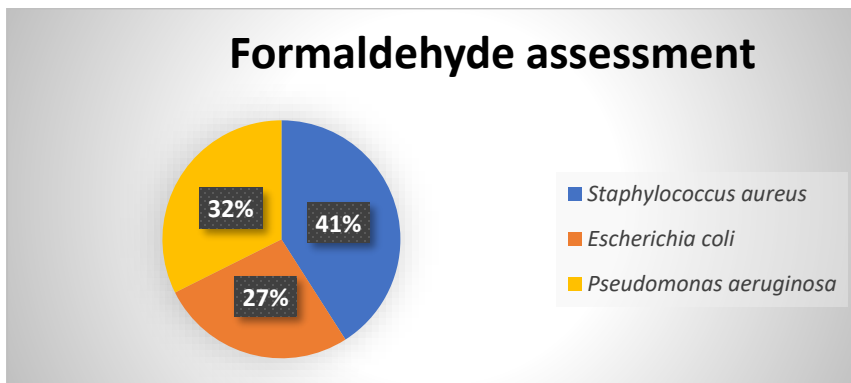


Figure 2: Susceptibility Profiles of Clinical Isolates Used in Formaldehyde Assessment

CONCLUSION

This study highlights the varying efficacy of disinfectants on clinical bacterial isolates, with formaldehyde showing the peak effectiveness. It was particularly potent against *Staphylococcus aureus* and *Escherichia coli*, while phenol was only effective against *Pseudomonas aeruginosa*. In divergence, sodium hypochlorite and ethyl alcohol exhibited rebuff activity against any of the isolates, which is consistent with previous studies that sub bacterial resistance with the chemical composition of disinfectants. formaldehyde's higher performance may be due to its broad-spectrum antimicrobial activity, which disrupts bacterial cell walls and denatures proteins, making it a reliable option for hospital disinfection. Resistance in some bacteria, notably *Klebsiella pneumoniae* and partially in *Pseudomonas aeruginosa*, can be explained by intrinsic defense mechanisms like biofilm formation, efflux pumps, and impervious outer membranes, especially in Gram-negative bacteria. These structures hinder disinfectant penetration and uptake, leading to compact susceptibility. This phenomenon is well-supported in the literature, where biofilm-forming bacteria and those with protective outer membranes often show higher resistance to commonly used biocides.

Besides, the concern of cross-resistance, where bacteria exposed to sublethal levels of disinfectants may also develop resistance to antibiotics, was noted, particularly in *Staphylococcus aureus*. Methicillin-resistant *Staphylococcus aureus* (MRSA) carries plasmids that encode efflux pumps, which expel disinfectants from the cell, reducing their efficacy. These findings underscore the need for ongoing research into more potent disinfectants and strategies to stymie bacterial resistance, particularly in hospital environments where nosocomial infections are a foremost concern.

COMPETING INTERESTS

The authors assert that they possess no competing interests or personal affiliations that could be perceived as influencing the findings presented in this paper.

ACKNOWLEDGMENTS

The authors extend their earnest gratitude to all team members, along with the students, lecturers, technologists, and management at Augustine University, Ilara-Epe, Lagos State, for their priceless support

FUNDING

This study was fiscally supported by Augustine University, Ilara-Epe, Lagos State, Nigeria

AUTHORS' CONTRIBUTIONS

MF conceptualized and designed the study, conducted statistical analyses, drafted the initial manuscript, and contributed to manuscript review and revision. Prof. OH and Dr. OA participated in study conceptualization and design, supervised data collection and statistical analyses, contributed to initial manuscript drafting, and reviewed and revised the manuscript. Mr. OA critically reviewed and revised the manuscript from its preliminary stages to submission.

ETHICS APPROVAL AND PARTICIPANT CONSENT

This research was studied and appropriate by Augustine University, Ilara-Epe, Lagos State, Nigeria. Written informed consent was obtained from all participating students, and consent for publication was not applicable.

REFERENCES

- Alsaedy, N. S. and Almilly, R. F. (2023, March). Production and investigation of a new effective and safe hand antiseptic. In *AIP Conference Proceedings*. 2651(1). AIP Publishing. <https://doi.org/10.1063/5.0105643>
- Bakht, M., Alizadeh, S. A., Rahimi, S., Kazemzadeh Anari, R., Rostamani, M., Javadi, A. and Nikkhahi, F. (2022). Phenotype and genetic determination of resistance to common disinfectants among biofilm-producing and non-producing *Pseudomonas aeruginosa* strains from clinical specimens in Iran. *BMC Microbiology* **22**(1):124.
- Butucel, E., Balta, I., Ahmadi, M., Dumitrescu, G., Morariu, F., Pet, I. and Corcionivoschi, N. (2022). Biocides as biomedicines against foodborne pathogenic bacteria. *Biomedicines* **10**(2):379. Available from: <https://www.mdpi.com/2227-9059/10/2/379>
- Mc Carlie, S., Boucher, C. E., and Bragg, R. R. (2020). Molecular basis of bacterial disinfectant resistance. *Drug Resistance Updates*. **48**:00672. Available from: <https://www.sciencedirect.com/science/article/pii/S136876461930069X>
- Chatterjee, R., Chowdhury, A. R., Mukherjee, D. and Chakravorty, D. (2023). From *Eberthella typhi* to *Salmonella Typhi*: The Fascinating Journey of the Virulence and Pathogenicity of *Salmonella Typhi*. *ACS Omega* **8**(29):25674–25697.
- Choroszy-Król, I., Futoma-Kołoch, B., Kuźnik, K., Wojnicz, D., Tichaczek-Goska, D., Frej-Mądrzak, M., ... & Sarowska, J. (2023). Exposing *Salmonella* Senftenberg and *Escherichia coli* Strains Isolated from Poultry Farms to Formaldehyde and Lingonberry Extract at Low Concentrations. *International Journal of Molecular Sciences*, *24*(19), 14579.
- De Oliveira, D. M., Forde, B. M., Kidd, T. J., Harris, P. N., Schembri, M. A., Beatson, S. A. and Walker, M. J. (2020). Antimicrobial resistance in ESKAPE pathogens. *Clinical Microbiology Reviews* **33**(3):10-1128.
- de Vera, P. J. D., Tayone, J. C. and De Las Llagas, M. C. S. (2022). *Cyperus iria* linn. Roots ethanol extract: its phytochemicals, cytotoxicity, and anti-inflammatory activity. *Journal of Taibah University for Science* **16**(1):854-862.
- Fitzpatrick, S. R., Garvey, M., Flynn, J., O'Brien, B. and Gleeson, D. (2022). Use of different methods for the evaluation of teat disinfectant products. *Journal of Applied Animal Research* **50**(1):31-38.
- Kaoud, H. A., Khalil, M. M. and Abdelhamed, M. (2022). Field trial to monitor the efficacy of some commercial poultry disinfection on *Salmonella typhimurium* through cold fogging. *GSC Advanced Research and Reviews* **10**(1):119-132. Available from: <https://gsconlinepress.com/journals/gscarr/content/field-trial-monitor-efficacy-some-commercial-poultry-disinfection-salmonella-typhimurium>
- Karmakar, S., Bhattacharya, S., Karmakar, S. and Rai, D. K. (2020). Extensively drug-resistant *Klebsiella pneumoniae* pneumonia: A case report. *Journal of Acute Disease* **9**(1):40-42. Available from: https://journals.lww.com/joad/Fulltext/2020/09010/Extensively_drug_resistant_Klebsiella_pneumoniae.6.aspx
- Kauffmann, A. C. and Castro, V. S. (2023). Phenolic compounds in bacterial inactivation: a perspective from Brazil. *Antibiotics* **12**(4):645. Available from: <https://www.mdpi.com/2079-6382/12/4/645>
- Klein, V., Irla, M. and López, M. G., Klein, V. J., Irla, M., Gil López, M., Brautaset, T. and Fernandes Brito, L. (2022). Unravelling formaldehyde metabolism in bacteria: road towards synthetic methylotrophy. *Microorganisms* **10**(2):220. Available from: <https://www.mdpi.com/2076-2607/10/2/220>
- Lee, G. H., Park, S. H., Song, B. M., Kim, D. M., Han, H. J., Park, J. Y. and Tark, D. (2023). Comparative efficacy evaluation of disinfectants against severe acute respiratory syndrome coronavirus-2. *Journal of Hospital Infection* **131**:12-22. Available from: <https://www.sciencedirect.com/science/article/pii/S0195670122003061>

- Mehta, Y., Sutar, A. R., Zirpe, K., Kothari, J. N., Alapati, C., Pathak, M. and Debnath, K. (2022). Prescription-Event monitoring study on safety and efficacy of levonadifloxacin (oral and IV) in management of bacterial infections: findings of real-world observational study. *International Journal of Applied and Basic Medical Research* **12**(1):30-36. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8848560/>
- Mendoza, I. C., Luna, E. O., Pozo, M. D., Vásquez, M. V., Montoya, D. C., Moran, G. C. and León, J. C. (2022). Conventional and non-conventional disinfection methods to prevent microbial contamination in minimally processed fruits and vegetables. *LWT*. **165**:113714. Available from: <https://www.sciencedirect.com/science/article/pii/S0023643822006491>
- Nichols, W. W., Lahiri, S. D., Bradford, P. A. and Stone, G. G. (2023). The primary pharmacology of ceftazidime/avibactam: resistance in vitro. *Journal of Antimicrobial Chemotherapy* **78**(3):569-585. Available from: <https://academic.oup.com/jac/article-abstract/78/3/569/7005425>
- Olatunji, A. O., Olaboye, J. A., Maha, C. C., Kolawole, T. O., & Abdul, S. (2024). Environmental microbiology and public health: Advanced strategies for mitigating waterborne and airborne pathogens to prevent disease. *International Medical Science Research Journal*, *4*(7), 756-770.
- Okposhi, U. S., Shuaibu, K. A., Aleruchi, C., Yusuf, F. A. and Naja'atu, S. H. (2022). Antibiotic Resistance and Phynotypic Detection of AmpC Beta-Lactamase Producing *Escherichia coli* from Urine of Students Attending Fulafia Clinic. *Open Access Library Journal* **9**(7):1-10. Available from: <https://www.scirp.org/journal/paperinformation.aspx?paperid=118501>
- Parija, S. C. (2023). *Textbook of Microbiology and Immunology*. Springer. Available from: <https://link.springer.com/book/9789811933141>
- Pérez de la Lastra, J. M., Anand, U., González-Acosta, S., López, M. R., Dey, A., Bontempi, E. and Morales delaNuez, A. (2022). Antimicrobial resistance in the COVID-19 landscape: is there an opportunity for anti-infective antibodies and antimicrobial peptides? *Frontiers in Immunology* **13**:921483.
- Sheet, A. H. and AL-Azawi, H. A. (2022). Antibiotic susceptibility and biofilm formation of *Pseudomonas aeruginosa* isolated from clinical and environmental hospital samples. *Biochemical and Cellular Archives* **22**:3501-3509. Available from: https://www.researchgate.net/profile/Ahmed-Al-Azawi/publication/363730859_ANTI-BIOTIC_SUSCEPTIBILITY_AND_BIOFILM_FORMATION_OF_PSEUDOMONAS_AERUGINOSA_ISOLATED_FROM_CLINICAL_AND_ENVIRONMENTAL_HOSPITAL_SAMPLES/links/632b7d470a708521500fb2c3/Antibiotic-susceptibility-and-biofilm-formation-of-Pseudomonas-aeruginosa-isolated-from-clinical-and-environmental-hospital-samples.pdf
- Shehbaz, M., Nizamuddin, S., Parveen, A. and Abbas, S. M. (2023). *Salmonella enterica* Serovar Typhi (*Salmonella Typhi*) brain abscess after brain surgery: *Infectious Diseases Journal of Pakistan* **32**(2): 62-64. Available from: <http://ojs.idj.org.pk/index.php/Files/article/view/138>
- Waller, C., Marzinek, J. K., McBurnie, E., Bond, P. J., Williamson, P. T. and Khalid, S. (2023). Impact on *S. aureus* and *E. coli* membranes of treatment with chlorhexidine and alcohol solutions: insights from molecular simulations and nuclear magnetic resonance. *Journal of Molecular Biology* **435**(11):167953. Available from: <https://www.sciencedirect.com/science/article/pii/S0022283623000098>
- Yan, Y. and Tu, J. (2023). *Bioaerosol Characterisation, Transportation and Transmission: Fundamental, Modelling and Application*. Springer Nature. Available from: [https://books.google.com/books?hl=en&lr=&id=2HXJEAQAQBAJ&oi=fnd&pg=PR5&dq=Yan,+Y.,+%26+Tu,+J.+\(2023\).+Bioaerosol+Characterisation,+Transportation+and+Transmission:+Fundamental,+Modelling+and+Application.+Springer+Nature.&ots=HXsMpGFcto&sig=KHXLTnx-jEDAJerpjO7x0zi1Qs](https://books.google.com/books?hl=en&lr=&id=2HXJEAQAQBAJ&oi=fnd&pg=PR5&dq=Yan,+Y.,+%26+Tu,+J.+(2023).+Bioaerosol+Characterisation,+Transportation+and+Transmission:+Fundamental,+Modelling+and+Application.+Springer+Nature.&ots=HXsMpGFcto&sig=KHXLTnx-jEDAJerpjO7x0zi1Qs)
- Yusof, M. N., Buyong, F. and Azmi, W. N. A. W. (2023). Antimicrobial Activity of *Cosmos caudatus* against *Staphylococcus aureus* and *Escherichia coli*. *Journal of Advanced Research in Applied Sciences and Engineering Technology* **30**(2):272-281.