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Antibacterial Efficacy of *Carica papaya* (Pawpaw) Seeds against Some Clinical Bacterial Isolates

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ABSTRACT: The increase in antibacterial resistance has led to the urgent need for novel therapeutic agents, and recently, plant-based antibacterials have emerged as a promising substitute. This study aimed to investigate the antibacterials activity of the aqueous and ethanol extracts of the *Carica papaya* seeds against *Escherichia coli*, *Salmonella typhi*, *Pseudomonas aeruginosa,* and *Staphylococcus aureus. C. papaya* seeds were collected, dried, and ground into powder, followed by the extraction of their bioactive compounds using water and ethanol solvents. The antimicrobial activity of the extracts against selected bacterial isolates using the agar well diffusion method was determined, as well as the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of the extracts. Phytochemical profiling revealed the presence of alkaloids, carbohydrates, proteins, flavonoids, tannins, and glycosides in both aqueous and ethanolic extracts, with phenolic compounds and saponins unique to ethanolic extract. The ethanolic extract showed antimicrobial activity against all the isolates used in the study. *E. coli had* the highest susceptibility of 11.6 ± 3.9 mm, while *S. typhi* showed the least 3.3 ± 0.2 mm. The aqueous extract demonstrated antibacterial activity against *E. coli*, *S. aureus*, and *P. aeruginosa*, while *S. typhi* was resistant. This study confirmed that *C. papaya* seeds contain bioactive phytochemicals with broad-spectrum antibacterial properties, mainly when extracted using ethanol. These findings indicate that *C. papaya* seeds could be utilized in the development of an effective antibiotic, potentially addressing the growing threat of drug-resistant bacteria.

Keywords: Antibacterial, *Carica papaya*, Phytochemical, Minimum inhibitory concentration, Minimum bactericidal concentration.

Introduction

The global threat of antimicrobial resistance (AMR) is a major concern to public health, food security, and economic stability. According to the World Health Organization (WHO), AMR is responsible for an estimated 700,000 deaths annually worldwide, with projections suggesting that by 2050, this number could rise to 10 million deaths per year if no urgent action is taken (Pokharel *et al*., 2019). The economic burden is expected to reach $100 trillion due to increased healthcare costs and productivity losses (Pokharel *et al*., 2019). Antimicrobial resistance (AMR) affects all countries but severely impacts low- and middle-income nations (Pokharel *et al*., 2019). Antibiotics being used inadequately have led to an increase in bacterial resistance, leading to reduced potency of many commonly used drugs (Mittal *et al*., 2020; Mancuso *et al*., 2021). Pathogens such as *Escherichia coli*, *Salmonella typhi*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus* have demonstrated significant resistance to multiple antibiotics, including penicillins, cephalosporins, and fluoroquinolones (Laxminarayan *et al*., 2013; Mancuso *et al*., 2021).

In other to mitigate AMR, medicinal plants have gained increasing attention as viable alternatives to antibiotics due to their rich composition of bioactive compounds with antibacterial properties (Parveen and Some, 2021). Medicinal plants have been used for centuries to treat infectious diseases, as they have been shown from studies to contain bioactive compounds with potent antibacterial properties. These plant-derived compounds, which include alkaloids, flavonoids, tannins, and polyphenols, exhibit broad-spectrum antibacterial activity against resistant pathogens (Jubair *et al*., 2021). Among these, *Carica papaya* (pawpaw) has been studied for its medicinal use, which demonstrated significant antibacterial properties (Dagne *et al*., 2021).

Carica papaya is a tropical fruit which belongs to the Caricaceae family, it is widely known for its pharmacological activities, including antibacterial, antifungal, and anti-inflammatory properties (Khan *et al*., 2022). The seeds of *C. papaya* contain bioactive compounds such as alkaloids, flavonoids, tannins, and saponins, which contribute to their antibacterial activity (Urooj and Sammia, 2018). Previous research has indicated that extracts from papaya seeds exhibit significant inhibitory effects on both Gram-positive and Gram-negative bacteria (Muhamad *et al*., 2017; Lestari *et al*. (2018)).

This study aimed to evaluate the antibacterial efficacy of aqueous and ethanolic extracts of *Carica papaya* seeds against selected pathogenic bacteria, in order to assess their potential as alternative agents in combating antibiotic-resistant infections.

Materials and methods

Collection of plant material: Ripe *Carica papaya* (pawpaw) fruits were purchased from New Benin Market, Benin City, Nigeria. The fruits were cut open, and the seeds were placed in a clean bowl, rinsed, and afterward placed in an open space to dry at room temperature (25±3 ºC) for 5 days. After drying, the seeds were ground into powder using a pestle and mortar to get fine powder, which was stored in an airtight container for analysis.

Source of bacterial isolates: The bacterial isolates used in this study, namely *Escherichia coli*, *Staphylococcus aureus*, *Salmonella typhi*, and *Pseudomonas aeruginosa*, were obtained from the Department of Microbiology Research Laboratory, Faculty of Life Sciences, University of Benin, Benin City, Nigeria.

Identification/confirmation of bacterial isolates: Subcultures were prepared on selective media: Mannitol Salt Agar (MSA) for *S. aureus* and MacConkey Agar for *E. coli*, *S. typhi*, and *P. aeruginosa*. The isolates were Gram-stained and observed under a microscope. Biochemical tests which included catalase, coagulase, oxidase, indole, citrate, urease, and hydrogen sulfide tests were carried out to confirm the bacterial isolates.

Preparation of plant extracts: Fifty grams of finely powdered *Carica papaya* seeds were separately macerated in 700 mL of 80% (v/v) ethanol and 700 mL distilled water. Each mixture was placed in a sealed conical flask and left at room temperature for 72 h, with occasional shaking to facilitate extraction. After the extraction period, the mixture was filtered using Whatman No. 1 filter paper. The ethanol filtrate was then concentrated using a rotary evaporator under reduced pressure at 40–50°C to obtain the crude ethanol extract, while the aqueous filtrate was evaporated over a water bath at 50–60°C until semi-solid extracts were obtained. Both crude extracts were stored in sterile containers at 4°C for subsequent analyses.

Standardization of bacterial isolates: Pure bacterial isolates were inoculated into sterile nutrient broth and incubated at 37°C for 18–24 h to obtain actively growing cultures. The turbidity of each broth culture was adjusted in reference to the 0.5 McFarland standard, which corresponds to approximately 1.5×10^8 CFU/mL. The standardization was to ensure consistency in cell density across all susceptibility testing procedures, including the determination of the MIC and MBC.

Phytochemical profiling: Phytochemical screening of the aqueous and ethanol extracts of *Carica papaya* seeds was carried out using standard procedures as described by Tang and Eisenbrand (1992). Alkaloids, carbohydrates, proteins, vitamin C, steroids, phenolic compounds, saponins, flavonoids, tannins, and glycosides. These qualitative analyses revealed the presence of various bioactive compounds believed to contribute to the antibacterial properties of the seed extracts.

Antimicrobial sensitivity test (Agar well diffusion method): The antimicrobial sensitivity test was carried out using the Agar Well Diffusion method. An aliquot of 0.1 mL of the test organisms were aseptically inoculated on Mueller Hinton Agar in Petri dishes using sterile swab sticks, ensuring uniform coverage of the entire surface. Three wells were created in the agar using a sterile cork borer with a diameter of 6 mm, and 0.1 ml of each extract was added to the wells on the plate. The experiment was carried out in triplicates to minimize probability of error. The plates were then incubated at 37 °C for 24 h. The inhibition zones were measured in millimeters to determine the antibacterial activity of the extracts. Ciprofloxacin (30 µg/ml), a commercially available antibiotic was used as a standard antibiotic (control).

The minimum inhibitory concentration (MIC) of extracts: The minimum inhibitory concentration (MIC) is the lowest concentration, which can inhibit the growth of bacterial cells on culture plates (Kadeřábková *et al*., 2024). The broth dilution method was used in this study. Each sterilized test tube received 10 ml of nutrient broth. Using a sterile digital micropipette, an aliquot of 0.2 µl of the standard suspension of the test organism (0.5 McFarland standard) was added to each test tube. Hundred (100) g/ml, 50 mg/ml, 25 mg/ml, and 12.5 mg/ml concentrations were prepared from the stock solution by serial dilution and were used for the analysis. The test tubes were shaken gently before incubating at 37 °C for 24 h. MIC was observed and recorded based on the turbidity of the individual test tubes. The lowest concentration with which each extract inhibited bacterial growth at 37 °C was recorded as the MIC. Inoculated broth with the test organism was used as a positive control, and sterile broth was used as a negative control.

Minimum bactericidal concentration (MBC) of extracts: To determine the MBC, a loopful of broth was collected from the test tubes used in the MIC determination test that did not show any growth, and streaked onto sterile nutrient agar. Nutrient agar plates streaked with the respective test organisms served as controls. The plates were incubated for 24 h at 37 °C. The concentration at which there was no visible growth was recorded as the minimum bactericidal concentration (MBC).

Results

Phytochemical results: The phytochemical analysis of *Carica papaya* (pawpaw) seed extracts, revealed the presence of an essential class of phytochemicals, which included alkaloids, carbohydrates, proteins, flavonoids, tannins, and glycosides, which were detected in both extracts as shown in Table 1. However, it was observed that the distribution of compounds differed in the two extracts. Phenolic compounds and saponins were absent in the aqueous extract but were present in the ethanol extract. Also, vitamin C and steroids were present in the aqueous extract but were absent in the ethanolic extract**.**

Antibacterial activity: The antibacterial activity of the aqueous and ethanol extracts against selected bacterial isolates is presented in Table 2. The aqueous extract demonstrated varying degrees of inhibition against *Escherichia coli* (7.8 ± 0.9 mm), *Pseudomonas aeruginosa* (5.8 ± 0.9 mm), and *Staphylococcus aureus* (12.9 ± 0.7 mm), but showed no activity against *Salmonella typhi*, indicating complete resistance of the latter. In contrast, the ethanol extract exhibited inhibitory effects on all four bacterial strains, with inhibition zones ranging from 3.3 ± 0.2 mm for *S. typhi* to 11.6 ± 3.9 mm for *E. coli*. A statistical comparison between the aqueous and ethanol extracts indicates that the ethanol extract generally displayed higher antibacterial activity, particularly against *E. coli*, *P. aeruginosa*, and *S. typhi*, where the aqueous extract showed a minimal inhibitory effect. Interestingly, the aqueous extract was more potent against *S. aureus* (12.9 ± 0.7 mm) than the ethanol extract (10.7 ± 0.6 mm), suggesting isolate-specific variability in extract efficacy.

Ciprofloxacin, used as the positive control at 30 µg/ml, produced the highest zones of inhibition across all bacterial strains, with values of 17 mm for *E. coli*, 10 mm for *S. typhi*, 12 mm for P. aeruginosa, and 18 mm for *S. aureus*. According to Clinical and Laboratory Standards Institute (CLSI) breakpoints, *E. coli* and *S. aureus* showed intermediate susceptibility, while *S. typhi* and *P. aeruginosa* were classified as resistant to ciprofloxacin. When compared to ciprofloxacin, both plant extracts demonstrated varied antibacterial effects; however, the ethanol extract showed comparable activity that in some cases approached the efficacy of the control, particularly against *E. coli* and *S. aureus*. Thus, illustrating that the ethanol extract of *Carica papaya* seeds have a promising antibiotic property.

Minimum Inhibitory Concentration (MIC): The minimum inhibitory concentration (MIC) is the lowest concentration, at which the extract can inhibit the growth of bacterial cells on culture plates. The MICs of the extracts on the studied bacterial isolates are presented in Table 3. For the aqueous extract, it was observed that *E. coli* and *S. aureus* had MIC of 50 mg/ml while *S. typhi* and *P. aeruginosa* showed growth even at 100 mg/ml, which indicated that the MIC was >100mg/ml. In contrast, for the ethanolic extract, it was observed that the MIC for *E. coli* was 50 mg/ml and 100 mg/ml for *S. typhi*, *P. aeruginosa*, and *S. aureus*. The MIC values provided insights into the concentration required to inhibit bacterial cell growth.

Minimum Bactericidal Concentration (MBC): The minimum bactericidal concentration (MBC) of the aqueous extract of papaya seeds on the studied bacterial isolates ranged from 50 mg/ml - 100 mg/ml while for *Salmonella typhi* it was >100mg/ml. For the ethanolic extract, the MBC ranged from 50 mg/ml - 100 mg/ml I for all the studied isolates, as shown in Table 4.

Table 1: Phytochemical analysis of aqueous and ethanolic extracts of *Carica papaya* seeds

Chemical Compounds	Aqueous Extract	Ethanolic Extract
Alkaloid	+	+
Carbohydrates	+	+
Proteins	+	+
Vitamin C	+	-
Steroids	+	-
Phenolic Compounds	-	+
Saponins	-	+
Flavonoid	+	+
Tannin	+	+
Glycoside	+	+

Key: + = Present, - = Absent

Table 2: Zones of inhibition (mm) of aqueous and ethanolic extracts of *Carica papaya* seeds on clinical bacterial isolates

Bacterial Isolates	Aqueous Extract	Ethanol Extract	Ciprofloxacin (Control) 30 µg/ml
Escherichia coli	7.81±0.9	11.61±3.9	17.41 ± 0.4
Salmonella typhi	NZ	3.34±0.2	10.34 ± 0.3
Pseudomonas aeruginosa	5.80±0.9	8.52±0.3	12.14 ± 0.2
Staphylococcus aureus	12.92±0.7	10.70±0.6	18.34 ± 0.5

Means ± S.D. are from triplicate measurements. NZ = No Zone of Inhibition

Table 3: Minimum inhibitory concentration (MIC) of *C. papaya* seed extracts on clinical bacterial isolates

Isolates	Extracts							
	Aqueous(mg/ml)				Ethanol(mg/ml)			
	12.5	25	50	100	12.5	25	50	100
Escherichia coli	+	+	-	-	+	-	-	-
Salmonella typhi	+	+	+	+	+	+	+	-
Pseudomonas aeruginosa	+	+	+	+	+	+	+	-
Staphylococcus aureus	+	+	-	-	+	+	+	-
Positive control	+	+	+	+	+	+	+	+
Negative control	-	-	-	-	-	-	-	-

Key: + = Growth, - = No growth

Table 4: Minimum bactericidal concentration (MBC) of *C. papaya* seed extracts on clinical bacterial isolates

Isolates	Extracts							
	Aqueous(mg/ml)				Ethanol(mg/ml)			
	12.5	25	50	100	12.5	25	50	100
Escherichia coli	+	+	+	-	+	+	-	-
Salmonella typhi	+	+	+	+	+	+	+	-
Pseudomonas aeruginosa	+	+	-	-	+	+	+	-
Staphylococcus aureus	+	+	-	-	+	+	-	-
Positive control	+	+	+	+	+	+	+	+
Negative control	-	-	-	-	-	-	-	-

Key: + = Growth. - = No growth

Discussion

The findings of this study revealed that *Carica papaya* seeds contain some bioactive agents, namely: alkaloids, carbohydrates, proteins, flavonoids, tannins, glycosides, phenolic compounds, saponins, vitamin C, and steroids. The antibacterial activity of papaya seed extracts is attributed to the synergistic effects of these phytochemicals (Sharma *et al*., 2022). Alkaloids have been reported to intercalate with DNA, disrupting replication and transcription processes (Kaminskyy *et al*., 2006; Wink, 2020). Flavonoids and tannins can form complexes with bacterial cell walls and extracellular proteins, leading to cell wall disruption and inhibition of essential enzymes (Donadio *et al*., 2021). Saponins are known to interact with membrane sterols, increasing cell permeability and causing leakage of intracellular contents (Böttger *et al*., 2012). These combined actions result in bacteriostatic or bactericidal effects against a broad spectrum of pathogens (Doughari *et al*., 2007; Prasetya *et al*., 2018).

The bacteria used in this study—*Escherichia coli*, *Salmonella typhi*, *Pseudomonas aeruginosa* (Gram-negative), and *Staphylococcus aureus* (Gram-positive)—were tested for susceptibility to both aqueous and ethanol extracts of *C. papaya* seeds. The results confirmed antibacterial activity against both Gram-negative and Gram-positive bacteria. Ethanol extract was significantly more effective, which aligns with previous studies showing ethanol as a better solvent for extracting a broader range of bioactive compounds (Awah *et al*., 2017; Al-Hajj, 2021; Oboh, 2023). The efficacy of the ethanol extract, particularly against Gram-negative bacteria, is attributed to its ability to dissolve and extract non-polar compounds such as alkaloids and phenolics, which interfere with bacterial cell membranes and inhibit metabolic processes (Ezeifeka *et al*., 2004). For example, the greater inhibition zone for *Pseudomonas aeruginosa* in the ethanol extract supports research showing these phytochemicals target specific components of Gram-negative bacterial structures.

On the other hand, the aqueous extract displayed higher activity against *Staphylococcus aureus* (Gram-positive) than the Gram-negative strains, with a zone of inhibition of 12.9 ± 0.7 mm. This suggests that water effectively extracts polar compounds, such as tannins and flavonoids, which are particularly active against Gram-positive bacteria due to their less complex cell wall (Álvarez-Martínez *et al*., 2020). Notably, the aqueous extract produced a better inhibitory effect against *S. aureus* (12.92 ± 0.7 mm) when compared to the ethanol extract (10.70 ± 0.6 mm), indicating isolate-specific responsiveness.

The results of the inhibitory effects further revealed that the ethanol extract consistently outperformed the aqueous extract against *Escherichia coli*, *Samonella typhi*, and *Pseudomonas aeruginosa*. For instance, the inhibitory effect of the ethanol extract against *Escherichia coli* was 11.61 ± 3.9 mm when compared to 7.81 ± 0.9 mm for aqueous extract; the aqueous extract could not inhibit the growth of *Salmonella typhi* but the bacterium growth was inhibited by ethanol extract at 3.34 ± 0.2 mm. In comparison with ciprofloxacin (standard antibiotic,, which produced inhibition zones of 17.41 ± 0.4 mm (*E. coli*), 10.34 ± 0.3 mm (*S. typhi*), 12.14 ± 0.2 mm (*P. aeruginosa*), and 18.34 ± 0.5 mm (*S. aureus*), both plant extracts showed reasonable efficacy overall. However, the potency of the ethanol extract was comparably close to that of ciprofloxacin, especially against *E. coli* and *S. aureus*, suggesting its potential for development as a natural antibacterial agent. According to CLSI interpretative standards, *Salmonella typhi* and *Pseudomonas aeruginosa* showed resistance to ciprofloxacin, highlighting the urgent need for alternative antibacterial and reinforcing the need for natural product screening.

MIC and MBC analyses further substantiated the better performance of ethanol extract.. Both extracts exhibited an MIC of 50 mg/ml for *E. coli*, but only the ethanol extract inhibited *Salmonella typhi* at 100 mg/ml. The aqueous extract failed to inhibit *Salmonella typhi* even at that concentration. Similarly, the MBC for *S. typhi* was >100 mg/ml for the aqueous extract, while it was achieved at 100 mg/ml with the ethanol extract. These findings demonstrate that the ethanol extract not only inhibits bacterial growth but also exhibits bactericidal activity at moderate concentrations—a property not observed in the aqueous extract for certain resistant strains.

Conclusion

This study showed that *Carica papaya* seeds contain bioactive phytochemicals that inhibit the growth of the selected bacteria isolates. In addition, ethanol was a better solvent for extracting the bioactive phytochemicals in papaya seeds. Furthermore, this study reveals that *C. papaya* seeds could be a source of broad-spectrum antimicrobial agents effective against gastrointestinal infections, which could be used as an alternative to conventional antibiotics with environmental sustainability; such advancements have the potential to address the growing threat of drug-resistant bacteria.

Conflict of interest statement

There are no conflicts of interest associated with this publication.

References

Al-Hajj D: *In vitro* evaluation of antimicrobial and antioxidant activity of *Carica papaya* l. Seeds grown in the republic of Yemen. Electron J Univ Aden Basic Appl Sci, 2(3):93-102. 2021.

Álvarez-Martínez FJ, Barrajón-Catalán E, Encinar JA, Rodríguez-Díaz JC, Micol V: Antimicrobial capacity of plant polyphenols against gram-positive bacteria: A comprehensive review. Curr Med Chem, 27(15):2576-2606.2020.

Awah NS, Agu KC, Ikedinma JC, Uzoechi AN, Eneite HC, Victor-Aduloju AT, Umeoduagu ND, Onwuatuegwu JTC, Ilikannu SO: Antibacterial activities of the aqueous and ethanolic extracts of the male and female *Carica papaya* leaves on some pathogenic bacteria. J Biosci Bioeng, 5:25-29. 2017.

Böttger S, Hofmann K, Melzig MF: Saponins can perturb biologic membranes and reduce the surface tension of aqueous solutions: a correlation? Bioorg Med Chem, 20(9):2822–2828. 2012.

Dagne E, Dobo B, Bedewi Z: Antibacterial activity of papaya (*Carica papaya*) leaf and seed extracts against some selected Gram-positive and Gram-negative bacteria. Pharmacog J, 13 (6):1727-1733. 2021.

Donadio G, Mensitieri F, Santoro V, Parisi V, Bellone ML, De Tommasi N, Izzo V, Dal Piaz F: Interactions with microbial proteins driving the antibacterial activity of flavonoids. Pharmaceutics, 13(5): 660. 2021.

Doughari JH, Elmahmood AM, Manzara S: Studies on the antibacterial activity of root extracts of *Carica papaya*. L. Afr J Microbiol Res, 22: 37 – 41. 2007.

Ezeifeka GO, Owor CI, Nwachukwu E Okoye FBC: Antibacterial activity of different solvent extracts of *Carica papaya* and Parquetina nigrescens on three clinical isolates of bacteria. Afr J Biotech, 3:300–302. 2004.

Jubair N, Rajagopal M, Chinnappan S, Abdullah NB, Fatima A: Review on the antibacterial mechanism of plant-derived compounds against multidrug-resistant bacteria (MDR). Evid Based Complement Alternat Med, 3663315. 2021.

Kadeřábková N, Mahmood AJS, Mavridou DAI. Antibiotic susceptibility testing using minimum inhibitory concentration (MIC) assays. NPJ Antimicrob Resist, 2(1):37. 2024.

Kaminskyy V, Lootsik M, Stoika R: Correlation of the cytotoxic activity of four different alkaloids, from Chelidonium majus (greater celandine), with their DNA intercalating properties and ability to induce breaks in the DNA of NK/Ly murine lymphoma cells. Cen Euro J Biol, 1:2-15. 2006.

Khan S, Arshad S, Amin Z, Abbas S, Ahmad M, Tanveer R, Latif A, Shahid A: *Carica papaya* therapeutic properties in disease management: a review. Plant Cell Biotech Mol Biol, 1-14. 2022.

Laxminarayan R, Duse A, Wattal C, Zaidi AK, Wertheim HF, Sumpradit N, Vlieghe E, Hara GL, Gould IM, Goossens H, Greko C, So AD, Bigdeli M, Tomson G, Woodhouse W, Ombaka E, Peralta AQ, Qamar FN, Mir F, Kariuki S, Bhutta ZA, Coates A, Bergstrom R, Wright GD, Brown ED, Cars O: Antibiotic resistance-the need for global solutions. Lancet Infect Dis, 13(12):1057-98. 2013.

Lestari AR, Syahfitri SA, Cahyo ST, Wardaniati I, Herli MA: Aktivitas antibakteri seduhan biji pepaya (*Carica papaya* l) terhadap *Escherichia coli*, *Salmonella typhi* and *Staphlycocus aureus*. J Pharm Sci, 1(2): 39-45. 2018.

Mancuso G, Midiri A, Gerace E, Biondo C: Bacterial antibiotic resistance: The most critical pathogens. Pathogens (Basel, Switzerland), 10(10): 1310. 2021.

Mittal AK, Bhardwaj R, Mishra P, Rajput SK: Antimicrobials misuse/overuse: Adverse effect, mechanism, challenges and strategies to combat resistance. The Open Biotech, J 14: 107-112. 2020.

Muhamad SAS, Jamilah B, Russly AR: The antibacterial activities and chemical composition of extracts from *Carica papaya* cv. Sekaki/Hong Kong seed. Int Food Res J, 24(2): 810-818. 2017.

Oboh E: Investigating the astonishing antimicrobial potential of papaya seeds against *Salmonella* spp and *Candida albicans*. Int J Trad Comp Med Res, 4(1):26-30. 2023.

Ogunjobi AA, Ogunjobi TE: Comparative Study of antibacterial activities of ethanol extracts of the bark and seeds of *Garcinia kola* and *Carica papaya*. Afr J Biomed Res, 14 (2): 147 – 152. 2011.

Parveen M, Some S: Antimicrobial activity of medicinal plants: a weapon to combat multi-drug resistant pathogens. Int J Plant Environ, 7: 133-142. 2021.

Pokharel S, Raut S, Adhikari B: Tackling antimicrobial resistance in low-income and middle-income countries. BMJ Glob Health, 4(6): e002104. 2019.

Prasetya AT, Mursiti S, Maryan S, Jati NK: Isolation and identification of active compounds from papaya plants and activities as antimicrobial. IOP Conf Ser: Mater Sci Eng, 349: 012007. 2018.

Sharma A, Sharma R, Sharma M, Kumar M, Barbhai MD, Lorenzo JM, Sharma S, Samota MK, Atanassova M, Caruso G, Naushad M, Radha, Chandran D, Prakash P, Hasan M, Rais N, Dey A, Mahato DK, Dhumal S, Singh S, Senapathy M, Rajalingam S, Visvanathan M, Saleena LAK, Mekhemar M: *Carica papaya* L. leaves: Deciphering its antioxidant bioactives, biological activities, innovative products, and safety aspects. Oxid Med Cell Longev, 2451733. 2022.

Tang WC, Eisenbrand G: Chinese drugs of plant origin: Chemistry, pharmacology and use in traditional and modern medicine. Springer, Berlin Heidelberg, pp. 849-854. 1992.

Urooj F, Sammia S: Pharmacological activities of *Carica papaya* Linn. J Basic Appl Sci, 14:210-216. 2018.

Wink M: Potential of DNA intercalating alkaloids and other plant secondary metabolites against SARS-CoV-2 causing COVID-19. Diversity, 12: 175. 2020.