https://dx.doi.org/10.4314/dujopas.v12i2c.32
ISSN (Print): 2476-8316
ISSN (Online): 2635-3490
Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol.12 No. 2c June 2026*

Microwave-Assisted Extraction and Bioactivity Evaluation of *Morinda lucida* Stem Bark

Nicholas Omatule Ugbenyo[*1,3], Muluh Emmanuel Khan[2], Jonathan Ilemona Achika[3], Larayetan Rotimi Abisoye[4], Friday Attah[5], Abdulrahman Monday Abdulazeez[1,3], Ekundayo Timi Areh[1], Patience Anazuo Evinemi[1], Abdulgafar Omeiza Zubair [1] and David Adeniran Adedapo[1]

[1]Department of Chemistry,
Faculty of Science,
Confluence University of Science and Technology (CUSTECH),
Osara,
Kogi State,
Nigeria

[2]Department of Chemistry,
Faculty of Science Federal University of Agriculture Mubi,
Adamawa State,
Nigeria

[3]Department of Chemistry,
Faculty of Science Federal University Lokoja,
Kogi State,
Nigeria

[4]Department of Chemistry,
Faculty of Science,
Prince Abubakar Audu University,
Anyigba,
Kogi State,
Nigeria

[5]Department of Microbiology,
Faculty of Science Confluence University of Science and Technology (CUSTECH),
Osara,
Kogi State,
Nigeria

Email: ugbenyonicholas@gmail.com

Abstract

Morinda lucida is widely utilized in ethnopharmacological applications for the management of bacteria-related infectious diseases and oxidative stress-related disorders; however, the validation of its phytochemical profile and bioactivity using microwave-assisted extraction (MAE) remains limited. In this study, MAE was used to obtain ethyl acetate stem bark extract of Morinda lucida (ML-E) which was evaluated for its phytochemical composition, antimicrobial and antioxidant potentials. Extraction of 200 g of the plant material yielded 6.90 g (3.45 %) of extract, dominated by flavonoids (210.99 ± 0.31 mg/ 100 g), anthraquinones (132.43 ± 0.10 mg/ 100 g), triterpenoids (101.97 ± 0.40 mg/ 100 g) and phenolics (65.29 ± 0.00 mg/ 100 g). ML-E exhibited selective activity against methicillin-resistant

*Author for Correspondence

Staphylococcus aureus (21.33 ± 0.58 mm), Staphylococcus aureus (23.67 ± 0.58 mm), vancomycin-resistant enterococci (26.00 ± 1.00 mm), Klebsiella pneumoniae (22.35 ± 0.58 mm) and Candida albicans (23.67 ± 0.58 mm), with minimum inhibitory concentration of 2.5 mg/mL for all the sensitive organisms except Klebsiella pneumoniae (1.25 mg/mL) and Candida albicans (5.00 mg/mL). Minimum bactericidal/fungicidal concentration ranged from 5.00 mg/mL to 10.00 mg/mL for both bacteria and fungi. ML-E demonstrated concentration-dependent DPPH radical scavenging activity (69.99 % at 500 µg/mL; IC_{50} = 287.50 µg/mL). Overall, MAE protocol yielded an extract containing measurable bioactive compounds, notable antioxidant potential and selective efficacy against drug-resistant pathogens, supporting its folkloric usage and its potential as a therapeutic precursor.

Keywords: Antimicrobial, Antioxidant, Microwave-assisted extraction, Morinda lucida, Phytochemical screening

INTRODUCTION

The separation of active ingredients in medicinal plants from the plant matrix is a necessary and crucial step in the isolation of bioactive compounds from plants. This all-important step is known as extraction (Abubakar and Hacque, 2020). Whether for use in herbal medical practice or for the purpose of research, extraction plays a very important role in the processing or analysis of plants with medicinal values. Owing to the fact that extraction remains a very vital step in natural products research, significant effort is being channeled towards the application of innovative extraction techniques which require lesser operational time, minimal solvent and energy consumption, and which offer higher yield with a good quality of extract; Microwave – assisted extraction (MAE) is one of such innovative techniques.

MAE is known for its ability to extract compounds of interest with improved yield at a shorter time, lesser energy and solvent consumption (Saifullah *et al*., 2021). Exploring the potential of this innovative and green extraction method in the study of the bioactivity of *Morinda lucida* holds a great potential for improved quality of extract with better bioactivity compared to extract from the conventional method of extraction.

Plants have played a major role as natural antioxidants in the fight against free radicals due to the presence of phytochemicals such as polyphenols, flavonoids and carotenoids in them (Gonfa *et al*., 2020). Many life-threatening diseases such as cancer and diabetes are in one way or the other connected with oxidative stress (Adam *et al*., 2019). Therefore, the search for natural antioxidants obtained through extraction techniques that guarantee improved yields and quality of extract cannot be overemphasized.

MAE has been used in some studies on plant species that are closely related to *Morinda lucida*. In a study on *Morinda critifolia*, MAE was reported as an efficient extraction method for the recovery of anthraquinones and flavonoids (Suktham *et al*., 2021). They reported that the use of MAE correlated with improved extraction yield of antioxidants more than the traditional extraction techniques. Similarly, Al Kausar *et al*. (2026) reported that the use of MAE led to increased yield of phytochemicals rich in antioxidant properties.

Most of the studies that revealed the antimicrobial and antioxidant properties of *Morinda lucida* have focused on the conventional extraction techniques, hence the need for the application of MAE for the recovery of bioactive compounds from the plant, particularly the stem bark

This study evaluated the phytochemical composition, antimicrobial activity, and antioxidant potential of *Morinda lucida* stem bark extract obtained using MAE; thereby exploring the potential of the extraction method to yield good quality of extract that can serve as natural antimicrobial and antioxidant agent in the fight against antimicrobial resistance and oxidative stress.

MATERIALS AND METHODS

Collection of Plant Sample: Fresh stem bark of *Morinda lucida* was harvested from Ibaji Local Government Area (7° 30′ N, 6° 45′ E) of Kogi State, North-Central, Nigeria during the early dry season in November 2023. Authentication of the plant material was carried out by Dr. Namadi Sanusi of the Department of Biological Science, ABU, Zaria (VN: ABU0992). The plant sample was washed thoroughly with distilled water to remove impurities, after which it was dried under shade for three weeks, and pulverized in a stainless-steel hammer-mill (Retsch SK-100, 1 mm screen) and stored in plastic bags at room temperature until needed for extraction.

Microwave-Assisted Extraction: Microwave-assisted extraction was carried out in line with the procedure given by Chan *et al.* (2014), Saifullah *et al*. (2021), Nour *et al*. (2021) and Ugbenyo *et al*. (2025). The plant material was first irradiated using hexane to remove some fatty components of the plant material. The plant material (200 g) was placed in a glass vessel and mixed with hexane (2000 mL) after which the vessel was capped tightly and irradiated at 70 watts for a total of 30 minutes (3 minutes at a time, with a cooling interval of 30 minutes). After extraction, the glass vessel was allowed to cool to room temperature after mixture was filtered using filter paper (Watchmann No. 1) and was concentrated at room temperature to obtain the extract. The process was repeated, using ethyl acetate as a solvent to obtain *Morinda lucida* ethyl acetate extract, ML-E.

Phytochemical Screening: Qualitative phytochemical screening was carried out according to the methods reported by Ukwubile *et al.* (2017), Abubakar and Hacque (2020) and Ugbenyo *et al.* (2025) with some slight modifications in the mass of extract used. Quantitative Phytochemical Analysis followed the methods reported by Ademoye *et al*. (2018), Osuntokun *et al*. (2016), Ayodeji *et al*. (2016), Malik *et al*. (2017), Ojwang *et al*. (2017) and Saeed *et al.* (2017).

Determination of Alkaloids: 10 % of acetic acid in ethanol (200 mL) was added to the pulverized plant material (5 g), kept for 1 hour with intermittent agitation and filtered. The filtrate was concentrated and reacted with ammonium hydroxide and filtered. The residue (precipitates) was further washed with ammonium hydroxide and dried to a constant mass.

Percentage of alkaloids $= \frac{Weight\ of\ precipitate}{Weight\ of\ sample}$ x 100 (Osuntokun *et al*., 2016)

Determination of Flavonoids: The plant sample (2 g) was extracted repeatedly with 80 % ethanol and filtered. The filtrate was evaporated to dryness over water bath and kept in a desiccator until the mass became constant.

Percentage Flavonoid = $\frac{Weight\ of\ flavonoids}{Weight\ of\ sample}$ x100 (Osuntokun *et al*., 2016)

Determination of Saponins: The sample (3 g) was extracted using 20 % ethanol for one hour over a water bath at 55 ^{o}C. The mixture was filtered and the residue was re-extracted. The filtrate was combined and concentrated to about 20 mL over water bath. The concentrate was fractionated with diethyl ether in a separating funnel and the aqueous fraction collected. 20 mL of 1- butanol was added and the aqueous layer was washed thoroughly with NaCl (5 %, 10 mL). The mixture was heated to a constant mass.

Percentage Saponin = $\frac{Weight\ of\ final\ extract}{Weight\ of\ sample}$ x100 (Ayodeji *et al*., 2016)

Determination of Terpenoids: The plant material (3 g) was extracted with 9 % ethanol for 24 h and filtered. The filtrate was fractionated with petroleum ether in a separating funnel. The petroleum ether fraction was evaporated to a constant weight and the percentage terpenoid was calculated as given below:

Percentage Terpenoid = $\frac{Weight\ of\ final\ extract}{Weight\ of\ sample}$ x100 (Malik *et al*., 2017)

Determination of Tannin: This was carried out using Folin-C methodology. The plant extract (0.1 mL) was mixed with distilled water (7.5 mL) and Folin-Ciocalteu phenol reagent in a 10 mL volumetric flask. Sodium carbonate (35 %, 1 mL) was added and made up to 10 mL mark with distilled water. The mixture was vigorously shaken and allowed to stand for 30 minutes at room temperature. Tannic acid was prepared as standard reference at the concentration of 20, 40, 60, 80 and100 µg/mL as described earlier. The measurement of absorbance for the standard and test solutions was carried out on a spectrophotometer at 700 nm. Tannin content was expressed in terms of mg of tannic acid equivalent /g of dried sample (Ojwang *et al*., 2017).

Determination of phenols: The sample (1 mL, 1 mg/mL) was added to Folin–Ciocalteu phenol reagent, followed by $NaCO_{3(aq)}$ (7 %, 10 mL) and distilled water (13 mL) and shaken thoroughly. The mixture was allowed to stand for 1 h 30 minutes at 24 ^{o}C and the absorbance was measured at 750 nm. The extrapolation of the calibration curve which was made by preparing gallic acid solution was used to determine the total phenolic content. Total phenolic content was taken as follows:

Total phenolic content = $\frac{mg\ of\ gallic\ acid\ equivalent}{Mass\ of\ dried\ sample}$ (Saeed *et al*., 2017)

Test Organisms for Antimicrobial Screening

The clinical isolates used for the antimicrobial assay comprised of Gram-positive bacteria, namely Methicillin-resistant *Staphylococcus aureus* (MRSA), *Staphylococcus aureus*, *Bacillus subtilis* and Vancomycin-resistant *Enterococci* (VRE); Gram-negative bacteria, namely *Escherichia coli*, *Klebsiella pneumoniae*, *Salmonella typhi*, *Proteus mirabilis*, *Pseudomonas aeruginosa; as well as fungi, namely Candida albicans* and *Candida tropicalis.* All clinical isolates were obtained from the Department of Medical Microbiology, Ahmadu Bello University Teaching Hospital, Zaria.

Antimicrobial Screening

ML-E was prepared by dissolving the crude extract (0.1 g) in 10 mL of dimethyl sulfoxide (DMSO) to otain a stock concentration of 10 mg/mL. Ciprofloxacin and sparfloxacin served as the reference standards for the antibacterial assay, while fluconazole served as the reference standard for the antifungal assay; and DMSO was used as a negative control. The standards drugs were prepared in the same manner as ML-E.

Antimicrobial screening was carried out using agar well diffusion method in line with the standard procedures by Idris *et al. (*2019), Ugbenyo *et al.* (2021) and Achika *et al.* (2026). Mueller-Hinton agar was used for bacterial cultures while Sabouraud dextrose agar was used for the fungal cultures. All cultures were prepared according to the manufacturer's instructions. Standard microbial inocula equivalent to 0.5 McFarland turbidity (approximately 1.5 x 10^8 CFU/mL) were prepared in sterile normal saline. Each agar plate was seeded with the standard inoculum (0.1 mL) and spread evenly using a sterile swab. Wells

of 6 mm diameter were aseptically bored into the agar plates and 0.1 mL of ML-E (10 mg/mL) was introduced into each well. Plates were incubated at 37 °C for 24 hours for bacteria and 30 °C for seven days for fungi, after which the zones of inhibition were measured in millimetres (mm).

Minimum Inhibitory Concentration (MIC)

The minimum inhibitory concentration (MIC) of ML-E was determined using the broth dilution method. Mueller-Hinton Broth was prepared, sterilized and dispensed into the sterile tubes. Two-fold serial dilutions were carried out to obtain concentrations ranging from 10 mg/mL to 0.625 mg/mL. Standard microbial suspensions were inoculated into each tube and incubated under the condition described earlier. The lowest concentration of ML-E that showed no visible turbidity after incubation was taken as the MIC.

Minimum Bactericidal Concentration (MBC)

Minimum bactericidal concentration (MBC) and minimum fungicidal concentration (MFC) were determined by subculturing aliquots from the tubes that had no visible growth from the MIC test into fresh MHA with incubation carried out as earlier stated. The lowest concentration that yielded no colony growth was recorded as the MBC or MFC respectively.

DPPH Assay: The antioxidant activity of ML-E was investigated using 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging test following the usual standard approach by Ademoye *et al*. (2018), Islam *et al*. (2021), Ugbenyo *et al*. (2025) and Achika *et al*. (2026). Different concentrations of ML-E (100 - 500 µg mL^{-1}) were incubated at 28 °C for 20 minutes with 0.1 mM DPPH in methanol. Ascorbic acid, a standard antioxidant was used as a positive control. The measurement of absorbance was done at 518 nm on a spectrophotometer. Percentage inhibition of DPPH radicals was calculated as follows:

$$Percentage\ Inhibition = \frac{A_{control} - A_{sample}}{A_{control}} \times 100$$

RESULTS

Extraction: The extraction of *Morinda lucida* (200 g) using ethyl acetate (2000 mL) via Microwave-assisted extraction gave crude extract with the description in **Table 1.**

Table1: Extraction Outcome

Extract	Colour	Mass (g)	Percentage yield (%)
Ethyl acetate	Dark brown	6.90	3.45

Phytochemical Analysis Result: The phytochemical analysis of ML-E revealed qualitative and quantitative presence of multiple bioactive compounds (**Table 2**). The results are expressed as mean mass (mg/100 g ± SD, n = 3).

Table 2: Phytochemical Analysis Result

S/N	Phytochemical	Confirmation	Quantity(mg/100g)
1	Anthraquinones	+	132.43 ± 0.10
2	Alkaloids	+	46.15± 0.22
3	Tannins	+	9.09 ± 0.20
4	Saponins	+	0.02± 0.00
5	Glycosides	+	0.21± 0.00
6	Steroids	-	
7	Phenolics	+	65.29± 0.00
8	Coumarins	-	
9	Flavonoids	+	210.99± 0.31
10	Triterpenoids	+	101.97± 0.4
11	Phlobatannins	-	
12	Anthocyanins	+	0.62 ± 0.00

Antimicrobial Assay: The antimicrobial assay of ML-E performed using the agar well diffusion method and compared with standard antimicrobial agents, namely Ciprofloxacin, Sparfloxacin, and Fluconazole demonstrated selective antibacterial activity against both Gram-positive and Gram-negative bacteria and fungi (**Table 3**). The results were expressed as mean zone of inhibition (mm ± SD, n = 3) with notable zones of inhibition recorded for drug-resistant bacteria MRSA and VRE (**Table 3**). The minimum inhibitory concentration was 2.5 mg/mL for all the tested organisms (**Table 4)** while MBC/MFC was 10.00 mg/mL for all the tested organisms except VRE which was 5.00 mg/mL (**Table 4**).

Table 3: Antimicrobial Sensitivity/ Inhibition Zone (mm) of ML-E (at 10 mg/mL) Compared with Ciprofloxacin, Sparfloxacin, and Fluconazole (Mean + SD, n = 3)

Test microorganism	ML-E	Ciprofloxacin	Sparfloxacin	Fluconazole
Methicillin-resistant *Staphylococcus aureus(MRSA)*	S (21.33 ± 0.58)	NS	32.67 ± 1.15	NS
Staphylococcus aureus	S (23.67 ± 0.58)	NS	31.00 ± 1.00	NS
Bacillus subtilis	NS	NS	35.33 ± 1.53	NS
Escherichia coli	NS	S (36.33 ± 1.15)	NS	NS
Klebsiella pneumoniae	S (22.33 ± 0.58)	NS	S (30.33 ± 0.58)	NS
Salmonella typhi	NS	S (41.67 ± 1.53)	NS	NS
Vancomycin-resistant enterococci	S (26.00 ± 1.00)	S (30.00 ± 2.00)	NS	NS
Proteus mirabilis	NS	NS	S (32.33 ± 0.58)	NS
Pseudomonas aeruginosa	NS	NS	S (32.67 ± 1.15)	NS
Candida albicans	S (23.67 ± 0.58)	NS	NS	S (32.67 ± 1.15)
Candida tropicalis	NS	NS	NS	S (33.67 ± 0.58

S = Sensitive, NS = Not Sensitive

Table 4: MIC, MBC/MFC of ML-E against the Test Microorganisms

	ML-E	
Organisms	**MIC (mg/mL)**	**MBC (mg/mL)**
Methicillin-resistant *Staphylococcus aureus*	2.50	10.00
Staphylococcus aureus	2.50	10.00
Bacillus subtilis	NA	NA
Escherichia coli	NA	NA
Klebsiella pneumoniae	1.25	5.00
Salmonella typhi	NA	NA
Vancomycin-resistant enterococci	2.50	5.00
Proteus mirabilis	NA	NA
Pseudomonas aeruginosa	NA	NA
Candida albicans	5.00	10.00
Candida tropicalis	NA	NA

NA = Not applicable

DPPH Radical Scavenging Potential

ML-E demonstrated concentration dependent DPPH radical scavenging potential (**Table 5**)

Table 5: DPPH Inhibition Percentage of ML-E vs Ascorbic Acid

Conc. (µg/mL)	ML-E Percentage Inhibition			Ascorbic acid Percentage Inhibition		
	MEAN	SD	N	MEAN	SD	N
0.00	0.00	0.00	3.00	0.00	0.00	3.00
100.00	21.73	0.25	3.00	86.65	0.16	3.00
200.00	37.67	0.16	3.00	87.77	0.16	3.00
300.00	51.76	0.20	3.00	90.79	0.16	3.00
400.00	68.33	0.41	3.00	91.89	0.32	3.00
500.00	69.99	0.00	3.00	93.91	0.40	3.00
IC50	287.5 µg/mL			<100 µg/mL		

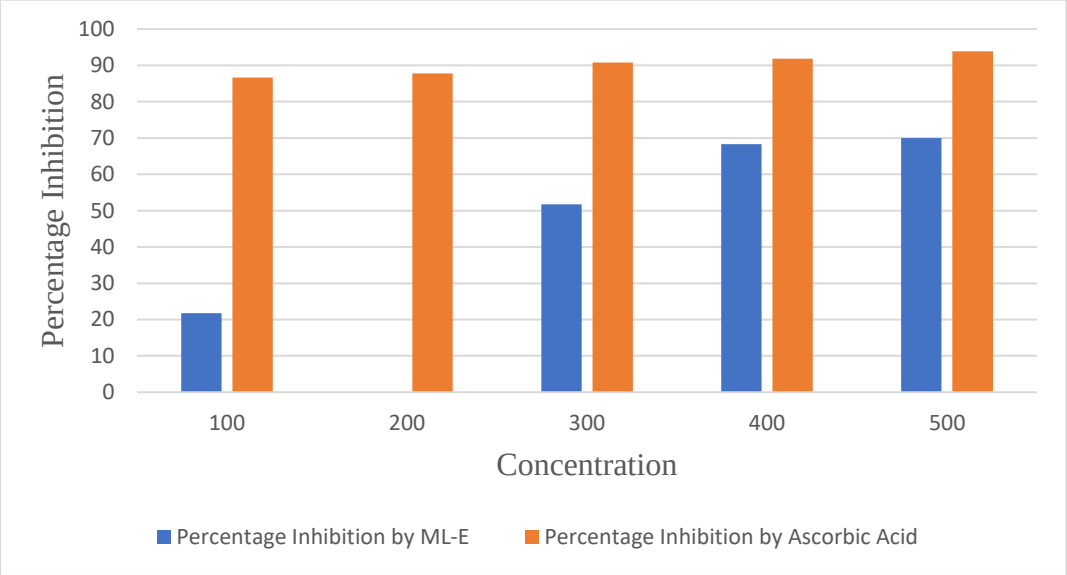

Figure 1: **DPPH Inhibition Percentage of ML-E vs Ascorbic Acid**

DISCUSSION

The phytochemical analysis of ML-E confirmed the presence of multiple bioactive compounds that can exert very important effect on the physiology of humans through metabolic, antioxidant, anti-inflammatory and disease prevention mechanism. These phytochemicals are responsible for protection against diseases and modulation of human biological system. The most abundant of the phytochemicals detected is flavonoids (210.99 ± 0.31 mg/100g). Flavonoids are known for their strong antioxidant and anti-inflammatory effects possible through their ability to scavenge free radicals and the modulation of pathways that are involved in chronic diseases (Li *et al*.,2023, Barreca *et al*., 2023 and Yi, 2023). High flavonoid intake is associated with reduced risk of certain diseases such as cardiovascular diseases, lowered blood pressure, improved endothelial function and decreased cases of Type 2 diabetes (Ahmed 2021). Anthraquinones are known for activities such as laxative effects, antimicrobial and anti-inflammatory effects with potential anticancer properties (Khatoon *et al*., 2024). Their presence in the quantity detected suggests potential biological activity.

Terpenoids have well documented antiviral and anti-inflammatory activities, and are known for their ability to enhance immune responses and provide cardioprotective and hepatoprotective effects by lowering inflammatory and oxidative stress which are associated with the progression of chronic diseases (Devi *et al*., 2024). The presence of phenolics in the measure detected is also suggestive of antioxidant effect. Phenolic compounds are prized for

their antioxidant defense mechanism in which they neutralize reactive oxygen species and inhibit the peroxidation of lipids, leading to reduced risk of cardiovascular diseases and enhanced total antioxidant capacity of ML-E in synergy with flavonoids (Tanase *et al*., 2019). Alkaloids are known for pharmacological effects such as analgesic effects and antimalarial effects. Their presence in ML-E is indicative of the ability of the plant to deliver antimalarial effects. Tannins are known for antimicrobial and gastrointestinal protective effects which can reduce the risks of infection and irritation (Cosme *et al*., 2026). Anthocyanins possess strong antioxidant and anti-inflammatory activities. Dietary intake of anthocyanins can lead to reduced risks of cardiovascular diseases, modulation of glucose metabolism and improved cognitive function (Kalt *et al*., 2020). Saponins and glycosides also have documented important biological activities. Saponins demonstrate antimicrobial activity, cholesterol-lowering effects and immunomodulation, while glycosides are known for important cardiovascular functions (Omole *et al*., 2025). Collectively, the phytochemical composition of ML-E which is dominated by flavonoids, anthraquinones, terpenoids and phenolics confers ML-E with a profile with high antioxidant and anti-inflammatory capacity, which are mechanisms that are central to reducing the risk factors for metabolic disorder, cardiovascular diseases and cancer.

ML-E's phytochemical profile is similar to that of other *Morinda s*pecies, notwithstanding differences in the dominance of particular compounds. Flavonoids, iridoids, alkaloids, and phenolic acids are also abundant in *Morinda citrifolia* (Hou *et al*., 2025). Triterpenoids such ursolic acid coexist with anthraquinones like nordamnacanthal and damnacanthal in *Morinda geminata's* distinctive profile (Sambou *et al*., 2017).

The antimicrobial activity of ML-E which was carried out using the agar well diffusion method and compared with three standard antimicrobial drugs viz Ciprofloxacin, Sparfloxacin and Fluconazole was expressed as mean zone of inhibition (mm ± SD, n=3). ML-E demonstrated selective activity against both Gram-positive and Gram-negative organisms. For the Gram-positive bacteria, notable inhibition was recorded against Methicillin-resistant *Staphylococcus aureus* (MRSA) (21.33 ± 0.58 mm) and *Staphylococcus aureus* (23.67 ± 0.58 mm). Strong activity was observed against Vancomycin-resistant *enterococci* (VRE) (26.00 ± 1.00 mm). However, no activity was observed against *Bacillus subtilis.* For the Gram-negative bacteria, ML-E demonstrated activity against only *Klebsiella pneumoniae* (22.33 ± 0.58 mm). No inhibition was recorded against *Escherichia coli*, *Salmonella typhi*, *Proteus mirabilis* and *Pseudomonas aeruginosa*. For the Fungi, ML-E demonstrated activity against *Candida albicans* (23.67 ± 0.58 mm) but showed no activity against *Candida tropicalis*. Compared with the standard antimicrobial agents used, Sparfloxacin exhibited the highest activity against Gram-positive bacteria except VRE, with inhibition zones ranging from 31.00 ± 1.00 to 35. 33 ± 1.53. Ciprofloxacin showed activity against only VRE (30. 00 ± 2.00). Fluconazole was inactive against the bacteria because it is an antifungal agent. For the Gram – negative bacteria, Ciprofloxacin showed strong activity against *Escherichia coli* (36.33 ± 1.15 mm) and *Salmonella typhi* (41.67 ± 1.53 mm), while Sparfloxacin showed potent inhibition against *Klebsiella pneumoniae, Proteus mirabilis* and *Pseudomonas aeruginosa* (≥ 30 mm). Fluconazole showed strong inhibition against both *Candida albicans* (32.67 ± 1.15 mm) and *Candida Tropicalis* (33.67 ± 0.58 mm), confirming broad spectrum of activity, while Ciprofloxacin and Sparfloxacin showed no activity since they are antibacterial drugs. The overall findings shows that ML-E possesses broad spectrum of activity against Gram-positive bacteria, with significant inhibition of MRSA and VRE (MIC 2.50), suggestive of the presence of bioactive compounds which are capable of overcoming certain antibiotic resistance mechanism. However, it lacked broad spectrum activity against Gram- negative bacteria and fungi when compared to the standards.

According to earlier research, *Morinda lucida* leaf extracts exhibited a 23 mm zone of inhibition against *S. aureus* (Okwute and Ochi, 2023). Further demonstrating the variation in antimicrobial effectiveness among various extract preparations, certain research on *M. lucida* have revealed no action against *C. albicans* (Okwute and Ochi, 2023). The DPPH (2,2 – diphenyl-1-picrylhydrazyl) radical scavenging test demonstrated that ML-E possess moderate but significant antioxidant activity which increased with increase in concentration (**Table 5**). Although ML-E showed less potent radical scavenging activity than ascorbic acid which was used as a standard at all concentrations, it demonstrated moderate to strong antioxidant activity at higher concentrations. At 500 µg/mL, ML-E achieved approximately 70 % radical scavenging, with excellent reproducibility (SD < 0.41). This moderate antioxidant activity of ML-E can be attributed to the presence of flavonoids and phenolic compounds in ML-E which are known for their radical scavenging properties. This result revealed the potential use of the plant as a source of natural antioxidant for application in food and nutraceuticals. Strong DPPH scavenging action has also been demonstrated by *Morinda* species stem bark and fruit extracts, which are frequently associated with their phenolic and flavonoid content (Nascimento Júnior *et al*., 2025).

CONCLUSION

This study showed that MAE is an alternative extraction method for extracting bioactive components from *Morinda lucida* with good extract yield, great phytochemical profile and significant antimicrobial and antioxidant activities. The extract possesses strong antibacterial and antioxidant activity owing to the rich phytochemical profile of ML-E with flavonoids and anthraquinones dominant. However, there are only few studies performed on ML-E, showing that it has a high ability in scavenging DPPH free radicals (70% at 500 µg/mL) and a selective efficiency against multidrug bacteria such as MRSA and VRE. This suggests that this extract deserves further investigation for a possible therapeutic application. This result highlights the ethnopharmacological potential of *Morinda lucida* and supports the potential of the plant as a promising source of natural antimicrobial and antioxidant agent.

REFERENCES

Abubakar, A. R., and Haque, M. (2020). Preparation of medicinal plants: Basic extraction and fractionation procedures for experimental purposes. *Journal of Pharmacy and Bioallied Sciences,* 12(1), pp. 1-10. doi**:** 10.4103/jpbs.JPBS_175_19

Adam, O. A. O., Abadi, R. S. M., and Ayoub, S. M. H. (2019). The effect of extraction method and solvents on yield and antioxidant activity of certain Sudanese medicinal plant extracts. *Journal of Phytopharmacology, 8*(5), pp. 248-252. https://doi.org/10.31254/phyto.2019.8507

Ademoye, M. A., Lajide, L., and Owolabi, B. J. (2018). Phytochemical and antioxidants screening of *Chrysophyllum albidum*, *Mezoneuronbenthamianum*, *Phyllanthus muellerianus* and *Acalypha fimbriata*. *International Journal of Sciences, 7*(11), pp. 8-18 Doi:10.18483/ijSci.1803

Achika, J. I., Atawodi, J. C., Atawodi, S.E, and Ayo, R. G. (2026). Antimicrobial and antioxidant natural products from the ethyl acetate fraction of cold methanolic extract of the aerial parts of *Centaurea perrottetii* L. *Pharmacological Research - Natural Products, 10*, p. 100477. https://doi.org/10.1016/j.prenap.2025.100477

Ahmed, A. (2021). Flavonoids and cardiovascular risk factors: A review. *Pharmadvances*, 3(3), pp. 521-547. https://doi.org/10.36118/pharmadvances.2021.15

Al Kausar, R., Garcia, S., Rahmah, Z., Larasati, R.M., Anisa, D.N., *et al*. (2026). Microwave-assisted extraction and nutritional-pharmacological evaluation of antioxidant-rich

Morinda citrifolia phytochemical capsules, *PharmaNutrition*, 36, p. 100497. https://doi.org/10.1016/j.phanu.2026.100497.

Ayodeji, O. I., Adeleye, O., Dada, O., Adeyemi, O., and Anyaso, G.N. (2016). Phytochemical constituent and antioxidant activity of *Thaumatococcus daniellii* Benn (Benth.) leaves (food wrapper). *International Journal of Pharmacology, Phytochemistry and Ethnomedicine*, 2, pp. 55-61. doi:10.18052/www.scipress.com/IJPPE.2.55

Barreca, M.M., Alessandro, R. and Corrado, C. (2023). Effects of Flavonoids on Cancer, Cardiovascular and Neurodegenerative Diseases: Role of NF-B Signaling Pathway. International *Journal of Molecular Sciences*., 24(11), p. 9236. https://doi.org/10.3390/ijms24119236

Cosme, F., Aires, A., Pinto, T., Oliveira, I., Vilela, A., *et al*. (2025). A comprehensive review of bioactive tannins in foods and beverages: Functional properties, health benefits, and sensory qualities. *Molecules, 30*, p. 800. https://doi.org/10.3390/molecules30040800

Chann, C., Yusoff, R., and Ngoh, G. (2014). Optimization of microwave-assisted extraction based on absorbed microwave power and energy. *Chemical Engineering Science, 111*, pp. 41–47. https://doi.org/10.1016/j.ces.2014.02.011

Devi, M., Bamrah, P. K., Goyal, R., Choudhary, M., and Chopra, H. (2024). Insights on the emerging therapeutic potential of terpenoids as anti-inflammatory agents: A scoping review. *Journal of Bio-X Research, 7*, Article 0006. https://doi.org/10.34133/jbioxresearch.0006

Gonfa,T., Teketle, S. and Kiros, T. (2020). Effect of extraction solvent on qualitative and quantitative analysis of major phyto-constituents and in-vitro antioxidant activity evaluation of *Cadaba rotundifolia* Forssk leaf extracts, *Cogent Food & Agriculture*, 6, p.1853867. https://doi.org/10.1080/23311932.2020.1853867

Nour, H., A., Oluwaseun, R. A., Omer, M. S., Nour, H., A. and Ahmed, N. (2021). Microwave-assisted extraction of bioactive compounds (Review). Microwave Heating - Electromagnetic Fields Causing Thermal and Non-Thermal Effects. *IntechOpen*. https://doi.org/10.5772/intechopen.96092

Hou, S., Ma, D.,Wu, S.; Hui, Q.and Hao, Z. (2025)**.** Morinda citrifolia L.: A Comprehensive Review on Phytochemistry, Pharmacological Effects, and Antioxidant Potential. *Antioxidants*, 14(13), p. 295. https://doi.org/10.3390/antiox14030295

Idris, A., Aliyu, A. B., &Oyewale, A. O. (2019). Phytochemical screening and antibacterial activity of *Centaurea senegalensis* growing in Nigeria. *Journal of Applied Sciences and Environmental Management,23*(6), 1087-1092. https://dx.doi.org/10.4314/jasem.v23i6.14

Islam, M. A., Zaman, S., Biswas, K., Al-Amin, M. Y., Hasan, M. K., *et al.* (2021). Evaluation of cholinesterase inhibitory and antioxidant activity of *Wedelia chinensis* and isolation of apigenin as an active compound. *BMC Complementary Medicine and Therapies, 21*(1), p. 204. https://doi.org/10.1186/s12906-021-03373-4

Kalt, W., Cassidy, A., Howard, L. R., Krikorian, R., Stull, A. J. *et al*. (2020). Recent research on the health benefits of blueberries and their anthocyanins. *Advances in Nutrition,* 11, pp. 224-236. https://doi.org/10.1093/advances/nmz065

Khatoon, M., Dubey, A., and Janhvi, V. K. (2025). Unveiling anthraquinones: Diverse health benefits of an essential secondary metabolite. *Recent Patents on Biotechnology*, 18(3), pp. 179 -197. https://doi.org/10.2174/0118722083301761240628083511

Li, M., Qian, M., Jiang, Q.,Tan, B., Yin, Y. *et al.* (2023). Evidence of flavonoids on disease prevention. *Antioxidants*, 12(2), p. 527. https://doi.org/10.3390/antiox12020527

Malik, S. K., Ahmad, M., and Khan, F. (2017). Qualitative and quantitative estimation of terpenoid contents in some important plants of Punjab, Pakistan. *Pakistan Journal of Science, 69*(2), pp. 150 - 154

Nascimento Júnior, J. A. C., Santos, A. M., Oliveira, A. M. S., Santana Júnior, C. C., Serafini, M. R., Quintans, J. S. S., et al. (2025). Botany, ethnomedicinal uses, biological activities, phytochemistry, and technological applications of *Morinda citrifolia*. *Molecules, 30*, p. 3831. https://doi.org/10.3390/molecules30183831

Ojwang, R. A., Muge, E. K., Mbatia, B., Mwanza, B. and Ogoyi, D.O. (2017). Comparative Analysis of Phytochemical Composition and Antioxidant Activities of Methanolic Extracts of Leaves, Roots and Bark of Jackfruit (Artocapus heterophyllus) from Selected Regions in Kenya and Uganda. *Journal of Advances in Biology & Biotechnology* 16(1), pp. 1-13. doi: 10.9734/JABB/2017/37355

Okwute, S., and Ochi, I. O. (2023). Antimicrobial, antioxidant, anti-inflammatory and acute toxicity screening of leaf extracts of *Morinda lucida*. *Journal of Biomedical Research & Environmental Sciences, 4*, pp. 372-382. https://doi.org/10.37871/jbres1685

Omole, J. G., Udom, G. J., Aturamu, A., Agbana, R. D., Aziakpono, O. M., Oritsemuelebi, B., et al. (2025). Cardiac glycosides: Looking beyond heart failure and atrial fibrillation. *Indian Journal of Pharmacology, 57*(1), pp. 33-47. https://doi.org/10.4103/ijp.ijp_934_24

Osuntokun, T. O., Yusuf-Babatunde, M. A., Ige, O. O., &and Odufuwa, E. A. (2016). Phytochemical Screening and Evaluation of Antioxidant and Proximate Properties of Morinda lucida Ethanolic Extract. *Journal of Advances in Medical and Pharmaceutical Sciences*, *11*(2), pp. 1-11. https://doi.org/10.9734/JAMPS/2016/29997

Saifullah, M., McCullum, R., & Vuong, Q. V. (2021). Optimization of microwave-assisted extraction of polyphenols from lemon myrtle. *Processes, 9*, p. 2212. https://doi.org/10.3390/pr9122212

Saeed, N., Khan, M. R., & Shabbir, M. (2012). Antioxidant activity, total phenolic and total flavonoid contents of whole plant extracts of *Torilisleptophylla*. *BMC Complementary and Alternative Medicine, 12*, p. 22. https://doi.org/10.1186/1472-6882-12-221

Suktham, K., Daisuk, P. and Shotipruk, A. (2021) 'Microwave-assisted extraction of antioxidative anthraquinones from roots of *Morinda citrifolia* L. (Rubiaceae): Errata and review of technological development and prospects', *Separation and Purification Technology*, 256, p. 17844. https://doi.org/10.1016/j.seppur.2020.117844

Sambou, O., Gassama, A., Karé, M., Gambe, D., Rivard, M., *et al.* (2017). Antimicrobial anthraquinones and triterpenoid isolated from *Morinda geminata DC* (Rubiaceae). *Mediterranean Journal of Chemistry* 2017, 6(5), pp. 191-195
DOI: http://dx.doi.org/10.13171/mjc65/01710131601-gassama

Tanase, C., Coşarcă, S. and Muntean, D.-L. (2019). A critical review of phenolic compounds extracted from the bark of woody vascular plants and their potential biological activity. *Molecules*, 24(6), p.1182. https://doi.org/10.3390/molecules24061182

Ugbenyo, N. O., Anyam, J. N., Yahaya, M. K., Habib, L. O., & Abdulsalam, S. (2021). Microwave-assisted extraction, phytochemical and antimicrobial evaluation of ethyl acetate extracts of *Ficus exasperata*. *Journal of Applied Sciences and Environmental Management, 25*(9), pp. 1569-1573.

Ugbenyo, N. O., Itodo, A. U., Apeh, D. O. and Abdulazeez, A. M. (2025) Avocado Seed Extracts as Natural Antimicrobial and Antioxidant: Phytochemical Analysis and Bioactivity Studies. *Confluence University Journal of Science and Technology*, 2 (2), pp. 6-13. doi:10.5455/CUJOSTECH.251006

Ukwubile, C. A., Oise, I. E., and Nyiayem, J. T. (2017). Preliminary phytochemical screening and antibacterial activity of *Thaumatococcus daniellii* leaf extract. *Journal of Bacteriology & Mycology: Open Access,* 4(2), pp. 53-57. DOI: 10.15406/jbmoa.2017.04.00086

Yi, Y.-S. (2023). Regulatory Roles of Flavonoids in Caspase-11 Non-Canonical Inflammasome-Mediated Inflammatory Responses and Diseases. International *Journal of Molecular Sciences*, 24 (12), p. 10402. https://doi.org/10.3390/ijms241210402