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COMPARATIVE PHYTOCHEMICAL AND *IN VITRO* ANTIMICROBIAL STUDIES OF AQUEOUS LEAVES EXTRACTS OF *COLOCASIA ESCULENTA*, *AZADIRACHTA INDICA* AND *MORINGA OLEIFERA*

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ABSTRACT

The growing resistance of pathogenic microorganisms to synthetic antibiotics has necessitated renewed interest in medicinal plants as potential sources of novel antimicrobial agents. This study comparatively evaluates the phytochemical composition and antimicrobial activities of aqueous leaves extracts of *Colocasia esculenta*, *Azadirachta indica*, and *Moringa oleifera*. Standard phytochemical screening revealed the presence of alkaloids, flavonoids, saponins, tannins, terpenoids, steroids, glycosides, and phenolics in varying concentrations across the three species. Quantitative analysis indicated that *Moringa oleifera* exhibited the highest total phenolic and flavonoids contents (82.46 mg GAE/g and 59.23 mg QE/g) respectively. *Colocasia esculenta* showed significantly higher saponins (10.36 mg/g) and terpenoid, while *Azadirachta indica* recorded the highest terpenoids concentration (11.84 mg/g). Antimicrobial activity was determined using the disc method against *Aspergillus niger, Aspergillus flavus, Botryodiplodia theobromae, Fussarium oxysporum* and *Myrothecium verrucaria* as well as *Klebsiella oxytoca, Serratia marcescens, Pseudomonas aeruginosa*, *Escherichia coli* and *Erwinia carotovora*. *M. oleifera* demonstrated the highest inhibitory zones, followed by *A. indica* and *C. esculenta*. Among the test organisms, *Erwinia carotovora* and *Escherichia coli* were the more susceptible isolates. A Minimum Inhibition Concentration (MIC) of 12.50 mg/mL was recorded for *Moringa oleifera* and 25.00 mg/mL against *Azadirachta indica* and *Colocaisa esculenta*. The results suggest that these plants possess broad-spectrum antimicrobial potential, with *M. oleifera* showing the greatest potency. The findings support the ethnomedicinal use of these plants and potential application in the development of plant-based antimicrobials.

KEYWORDS: Phytochemicals, Antimicrobial activity, *Colocasia esculenta*, *Azadirachta indica*, *Moringa oleifera*, aqueous extract.

1.0 INTRODUCTION

Medicinal plants remain indispensable source for novel antimicrobials and low-cost therapeutics in traditional healthcare systems and continue to be a rich source of bioactive compounds used in modern pharmacology especially in regions where access to conventional antibiotics is limited. Again, the rise in multidrug-resistant microorganisms has renewed interest in plant-derived antimicrobials as safer, cost-effective alternatives. Their antimicrobial properties, in particular, have gained renewed attention in the face of escalating antibiotic resistance (Edeoga et al., 2023; WHO, 2024; Birlutiu et al., 2025). Among such plants, *Colocasia esculenta* (taro), *Azadirachta indica* (neem), and *Moringa oleifera* (drumstick tree) have been widely recognized for their diverse therapeutic benefits and phytochemical richness as documented by many researchers (Terngu et al., 2024; Ugosor & Shausu, 2025; Ugosor & Ornguga, 2025; Ugosor & Wada, 2025). Recent systematic and experimental reports (Oboh &

Akomolafe, 2022; Wylie, 2022; Veerendrakumar et al., 2023; Setyani et al., 2023; Singh & Patel, 2024; Ugosor et al., 2025) indicate abundant phenolics/flavonoids, alkaloids, saponins, tannins, terpenoids and reproducible antibacterial activity for *M. oleifera*, broad antimicrobial capacity for *A. indica*, and emerging phytochemical catalogues for *C. esculenta*, but cross-study comparability is limited by diverse extraction and assay methods, hence the present study bridges this gap by comparative evaluation of their phytochemical profiles and antimicrobial potency to help prioritize plants for development of cost-effective antimicrobial agents for the treatment and management of multi-drug resistant variants of microorganisms and inform community use.

Colocasia esculenta is known for its antioxidant and antimicrobial constituents, particularly phenolics and flavonoids, which play key roles in its pharmacological activity (Kumar et al., 2023; Pareek et al., 2023; El-Sherbiny et al., 2024; Lawal & Rotimi, 2025).

Azadirachta indica is a well-documented medicinal plant containing limonoids, azadirachtin, nimbin, and quercetin, compounds known for antibacterial (Arogba & Etok, 2022), antifungal (Saidu et al., 2024), and antiviral effects (Al-Kaf, 2019; Bashir & Adamu, 2020; Khan et al., 2023; Singh & Patel, 2024).

Moringa oleifera is rich in vitamins, minerals (Anwar et al., 2021), and secondary metabolites such as alkaloids, tannins, saponins, and terpenoids that contribute to its broad-spectrum antimicrobial activity (Adebayo & Ogundipe, 2021; Deepali et al., 2025; Setyani et al., 2023; Ugosor & Wada, 2025; Ugosor & Ornguga, 2025; Ugosor et al., 2025).

Despite extensive studies on the individual species, comparative evaluations of these plants under similar extraction and assay conditions are limited. Therefore, this study investigates and compares the phytochemical constituents and antimicrobial efficacy of aqueous extracts of C. *esculenta*, *A. indica*, and *M. oleifera* leaves, to elucidate their relative therapeutic potentials.

2.0 MATERIALS AND METHODS

2.1 Collection and Preparation of Plant Samples

Fresh leaves of *C. esculenta*, *A. indica*, and *M. oleifera* were collected from the Botanical Garden of Rev. Fr. Moses Orshio Adasu University, Makurdi, Nigeria, and authenticated at the Department of Botany by a plant taxonomist. The leaves were washed, shade-dried for two weeks at room temperature (28 °C), pulverized using a sterile electric blender, and stored in airtight containers until extraction.

2.2 Aqueous Extraction

The powdered leaves were extracted by method of Harbone (1998) with slight modifications. Hundred grammes (100 g) of each powdered sample were soaked separately in 500 mL of distilled water for 48 hours with intermittent stirring. The extracts were filtered through Whatman No. 1 filter paper and concentrated at 40 °C using a rotary evaporator to yield semi-solid residues, which were stored at 4 °C for further analysis.

2.3 Phytochemical Screening

Qualitative tests for alkaloids, flavonoids, tannins, phenolics, saponins, glycosides, and terpenoids were performed using standard methods (Harborne, 1998); Trease and Evans (2009); Alam et al (2024) and Farooq & Saeed (2024). Quantitative estimation of Total Phenolic content (TPC) and Total Flavonoid Content (TFC) were performed gravimetrically and spectrophotometrically using UV-Vis methods described by Edeoga et al (2023) and Farooq & Saeed (2024) with results expressed as mg gallic acid equivalent (GAE)/g and mg quercetin equivalent (QE)/g of extract. Alkaloids, saponnins, and terpenoids contents were determined gravimetrically and expressed as %. Folin-Denis or Vanillin-HCl method was used to determine tannin content, expressed as mg Tannic Acid Equivalent (TAE)/g extract. Steroids content was determined spectrophotometically at 420 nm and expressed as mg cholesterol equivalent per gramme. Glycosides was determined by Anthrone method expressed as mg GE/g as described by Ugosor & Apeyuan (2025).

2.4 Antimicrobial Assay

Antimicrobial activity was assessed using the disc method as described by CLSI (2023) and El-Sherbint et al (2024). The test microorganisms included *Aspergillus niger*, *Aspergillus flavus*, *Botryodiplodia theobromae*, *Fussarium oxysporum* and *Myrothecium verrucaria* as well as *Klebsiella oxytoca*, *Serratia marcescens*, *Pseudomonas aeruginosa*, *Escherichia coli* and *Erwinia carotovora*, obtained from the Department of Biology, Rev, Fr. Moses Orshio Adasu University, Makurdi. Mueller-Hinton agar was used for bacterial cultures, while Sabouraud Dextrose agar was used for fungal isolates. The pure isolates were individually inoculated on the appropriate media and 5 mm discs containing 100 mg/mL, 75 mg/mL, 50 mg/mL, and 25 mg/mL *C. esculenta*, *M. indica* and *M. oleifera* extract respectively were applied on the cultured plates and incubated at 37 ^{o}C for 24 h (bacteria) and 7 days (fungi). Triplicates samples were prepared. The controls consisted of 1 mL 100 % Voriconazole (200 mg) and 100 % of 1 mL Gatifloxacin (400 mg) tablets for fungi and bacteria respectively. Zone of inhibition (mm) where present was recorded with a transparent plastic ruler after the incubation period and the percentage inhibition zone calculated as follows:

$$\% \text{ Inhibition Zone (\% IZ)} = \frac{\text{Average diametre of pathogen colony}}{\text{Average diametre of pathogen in control}} \text{ X } 100\ \%$$

MICs were determined by broth microdilution, with concentrations ranging from 3.13 mg/mL to 25 mg/mL (Terngu et al., 2024; Ugosor & Apeyuan, 2025).

2.5 Statistical Analysis

All experiments were performed in triplicate. Results were expressed as mean ± standard deviation (SD). Data were analyzed using one-way ANOVA followed by Duncan's multiple range test at a 95% confidence level using SPSS version 26.0.

3.0 RESULTS

3.1 Qualitative Phytochemical Composition

Table 1: Qualitative Phytochemical Composition Result

Phytochemical	*Colocasia esculenta*	*Azadirachta indica*	*Moringa oleifera*
Alkaloids	++	+	+
Flavonoids	++	+++	++++
Phenolics	++	+++	++++
Tannins	+++	++	++
Saponins	++	+++	+
Glycosides	+	++	++
Terpenoids	++	+++	+

Key: +: slight: ++: moderate; +++: abundant; ++++: very abundant.

Table 2: Quantitative Phytochemical Analysis Result.

Parameter	*Colocasia esculenta*	*Azadirachta indica*	*Moringa oleifera*
Total Phenolic Content, TPC (mg GAE/g)	46.58	74.12	82.46
Total Flavonoid Content, TFC (mg QE/g)	28.35	52.23	59.23
Saponins (mg/g)	9.13	13.72	6.30
Terpenoids (mg/g)	4.25	11.84	4.81
Tannin (mg/g)	10.36	9.41	3.52
Steroids (mg GE/g)	0.59	0.68	0.75
Alkaloids (%)	3.53	1.50	1.12
Glycosides (mg GE/g)	4.78	5.70	5.10

Moringa oleifera exhibited the highest diversity and concentration of phytochemicals, consistent with published studies (El-Sherbiny et al., 2024; Mishra et al., 2023; Farooq & Saeed, 2024). These data align with prior qualitative and quantitative studies where *Moringa oleifera* and neem aqueous leaves extracts showed higher phenolics and flavonoids contents (Setyani et al., 2023; Lawal & Rotimi, 2025).

Table 3: Antimicrobial Sensitivity Test Result for *Azadirachta indica* Leaves Extract.

Concentration (mg/mL)					
	100	75	50	**25**	**100 (Control)**
Test Organisms					
Fungi					
A. niger	$4.54^{b} \pm 0.01$	$3.72^{c} \pm 0.01$	$2.24^{d} \pm 0.01$	$1.56^{e} \pm 0.13$	$7.90^{a} \pm 0.01$
A. flavus	$11.59^{b} \pm 0.32$	$9.30^{c} \pm 0.07$	$7.49^{d} \pm 0.05$	$5.42^{e} \pm 0.01$	$20.07^{a} \pm 0.03$
B. theobromae	$6.37^{b} \pm 0.02$	$5.29^{c} \pm 0.06$	$4.47^{d} \pm 0.01$	$3.88^{e} \pm 0.01$	$12.29^{a} \pm 0.01$
F. oxysporum	$4.90^{b} \pm 0.01$	$3.84^{c} \pm 0.02$	$1.29^{d} \pm 0.01$	$0.39^{e} \pm 0.01$	$8.99^{a} \pm 0.08$
M.verrucaria	$13.52^{b} \pm 0.02$	$11.82^{c} \pm 0.02$	$9.10^{d} \pm 0.03$	$7.54^{e} \pm 0.01$	$25.15^{a} \pm 0.01$
Bacteria					
K. oxytoca	$9.85^{b} \pm 0.04$	$7.12^{c} \pm 0.40$	$5.75^{d} \pm 0.08$	$4.62^{e} \pm 0.01$	$20.25^{a} \pm 2.20$
S. marcescens	$7.50^{b} \pm 0.30$	$5.04^{c} \pm 0.09$	$3.52^{d} \pm 0.01$	$1.63^{e} \pm 0.01$	$21.32^{a} \pm 0.04$
P. aeruginosa	$5.94^{b} \pm 0.01$	$3.97^{c} \pm 0.01$	$2.90^{d} \pm 0.02$	$1.62^{e} \pm 0.01$	$24.97^{a} \pm 0.04$
E. coli	$21.96^{b} \pm 0.02$	$18.10^{c} \pm 0.03$	$15.56^{d} \pm 0.03$	$12.78^{e} \pm 0.02$	$27.37^{a} \pm 0.02$
E. carotovora	$13.59^{b} \pm 0.03$	$10.96^{c} \pm 0.02$	$9.22^{d} \pm 0.02$	$7.91^{e} \pm 0.03$	$20.25^{a} \pm 0.02$

N = 5, values expressed as Mean ± SD. Values in the same row with different alphabetical letters (superscript) are statistically significant at $p < 0.05$.

Table 4: Antimicrobial Sensitivity Test Result for *Colocasia esculenta* Leaves Extract

Concentration (mg/mL)					
	100	75	50	**25**	**100 (Control)**
Test Organisms					
Fungi					
A. niger	$3.67^{b} \pm 0.01$	$2.45^{c} \pm 0.01$	$1.95^{d} \pm 0.01$	$0.79^{e} \pm 0.13$	$7.90^{a} \pm 0.01$
A. flavus	$7.53^{b} \pm 0.32$	$6.30^{c} \pm 0.07$	$5.49^{d} \pm 0.05$	$3.42^{e} \pm 0.01$	$20.07^{a} \pm 0.03$
B. theobromae	$4.45^{b} \pm 0.02$	$2.28^{c} \pm 0.06$	$1.56^{d} \pm 0.01$	$0.98^{e} \pm 0.01$	$12.29^{a} \pm 0.01$
F. oxysporum	$3.90^{b} \pm 0.01$	$1.86^{c} \pm 0.02$	$1.20^{d} \pm 0.01$	$0.67^{e} \pm 0.01$	$8.99^{a} \pm 0.08$
M.verrucaria	$8.56^{b} \pm 0.02$	$6.26^{c} \pm 0.02$	$4.15^{d} \pm 0.03$	$3.67^{e} \pm 0.01$	$25.15^{a} \pm 0.01$
Bacteria					
K. oxytoca	$7.89^{b} \pm 0.04$	$5.32^{c} \pm 0.40$	$3.51^{d} \pm 0.08$	$1.45^{e} \pm 0.01$	$20.25^{a} \pm 2.20$
S. marcescens	$3.57^{b} \pm 0.30$	$2.45^{c} \pm 0.09$	$1.68^{d} \pm 0.01$	$0.93^{e} \pm 0.01$	$21.32^{a} \pm 0.04$
P. aeruginosa	$4.63^{b} \pm 0.01$	$3.18^{c} \pm 0.01$	$2.10^{d} \pm 0.02$	$1.22^{e} \pm 0.01$	$24.97^{a} \pm 0.04$
E. coli	$18.87^{b} \pm 0.02$	$15.34^{c} \pm 0.03$	$12.89^{d} \pm 0.03$	$9.81^{e} \pm 0.02$	$27.37^{a} \pm 0.02$
E. carotovora	$10.57^{b} \pm 0.03$	$7.76^{c} \pm 0.02$	$5.51^{d} \pm 0.02$	$3.59^{e} \pm 0.03$	$20.25^{a} \pm 0.02$

N = 5, values expressed as Mean ± SD. Values in the same row with different alphabetical letters (superscript) are statistically significant at $p < 0.05$.

Table 5: Antimicrobial Sensitivity Test Result for *Moringa oleifera* Leaves Extract.

Concentration (mg/mL)					
	100	75	50	**25**	**100 (Control)**
Test Organisms					
Fungi					
A. niger	$6.54^{b} \pm 0.01$	$4.70^{c} \pm 0.01$	$2.24^{d} \pm 0.01$	$1.94^{e} \pm 0.13$	$7.90^{a} \pm 0.01$
A. flavus	$15.59^{b} \pm 0.32$	$12.30^{c} \pm 0.07$	$10.49^{d} \pm 0.05$	$8.42^{e} \pm 0.01$	$20.07^{a} \pm 0.03$
B. theobromae	$9.37^{b} \pm 0.02$	$7.29^{c} \pm 0.06$	$5.47^{d} \pm 0.01$	$3.88^{e} \pm 0.01$	$12.29^{a} \pm 0.01$
F. oxysporum	$5.90^{b} \pm 0.01$	$3.84^{c} \pm 0.02$	$1.29^{d} \pm 0.01$	$0.80^{e} \pm 0.01$	$8.99^{a} \pm 0.08$
M.verrucaria	$21.52^{b} \pm 0.02$	$17.82^{c} \pm 0.02$	$15.10^{d} \pm 0.03$	$13.54^{e} \pm 0.01$	$25.15^{a} \pm 0.01$
Bacteria					
K. oxytoca	$11.85^{b} \pm 0.04$	$9.12^{c} \pm 0.40$	$7.75^{d} \pm 0.08$	$5.62^{e} \pm 0.01$	$20.25^{a} \pm 2.20$
S. marcescens	$9.50^{b} \pm 0.30$	$7.04^{c} \pm 0.09$	$5.52^{d} \pm 0.01$	$3.63^{e} \pm 0.01$	$21.32^{a} \pm 0.04$
P. aeruginosa	$7.94^{b} \pm 0.01$	$5.97^{c} \pm 0.01$	$3.90^{d} \pm 0.02$	$1.62^{e} \pm 0.01$	$24.97^{a} \pm 0.04$
E. coli	$23.96^{b} \pm 0.02$	$19.10^{c} \pm 0.03$	$15.56^{d} \pm 0.03$	$10.78^{e} \pm 0.02$	$27.37^{a} \pm 0.02$
E. carotovora	$17.59^{b} \pm 0.03$	$12.96^{c} \pm 0.02$	$15.22^{d} \pm 0.02$	$10.91^{e} \pm 0.03$	$20.25^{a} \pm 0.02$

N = 5, values expressed as Mean ± SD. Values in the same row with different alphabetical letters (superscript) are statistically significant at $p < 0.05$.

Table 6: MIC, MFC, and MBC of *Colocasia esculenta* leaves extract.

Concentration (mg/mL)					
	25.00	**12.50**	**6.25**	**3.13**	**MIC**
Test Organisms					
Fungi					
Aspergilus niger	-	+	++	++	25.00
Aspergilus flavus	-	+	++	+++	25.00
Botryodioplodia theobromae	-	+	++	++	25.00
Fussarium oxysporum	-	+	++	+++	25.00
Myrothecium verrucaria	-	+	++	++	25.00
Bacteria					
Klebsiella oxytoca	-	+	++	+++	25.00
Serratia marcescens	-	+	++	+++	25.00
Pseudomonas aeruginosa	-	+	++	+++	25.00
Esherichia coli	-	+	++	+++	25.00
Erwinia carotovora	-	+	++	+++	25.00

Key: - = No growth; + = Growth; ++ = Moderate growth: +++ = Significant growth

Table 7: MIC, MFC, and MBC of the *Azadirachta indica* Leaves Extract.

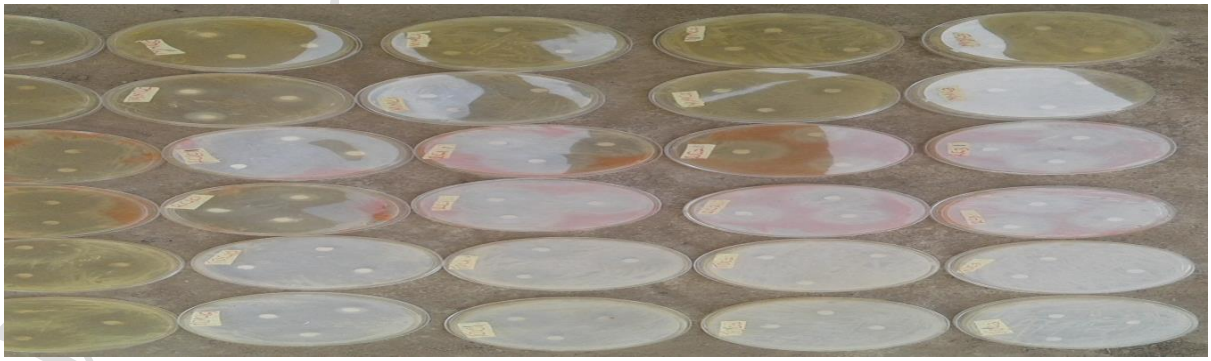
Concentration (mg/mL)					
	25.00	**12.50**	**6.25**	**3.13**	**MIC**
Test Organisms **Fungi**					
Aspergilus niger	-	+	++	+++	25.00
Aspergilus flavus	-	+	++	+++	25.00
Botryodioplodia theobromae	-	+	++	+++	25.00
Fussarium oxysporum	-	+	++	+++	25.00
Myrothecium verrucaria	-	+	++	+++	25.00
Bacteria					
Klebsiella oxytoca	-	+	++	+++	25.00
Serratia marcescens	-	+	++	+++	25.00
Pseudomonas aeruginosa	-	+	++	+++	25.00
Esherichia coli	-	+	++	+++	25.00
Erwinia carotovora	-	+	++	+++	25.00

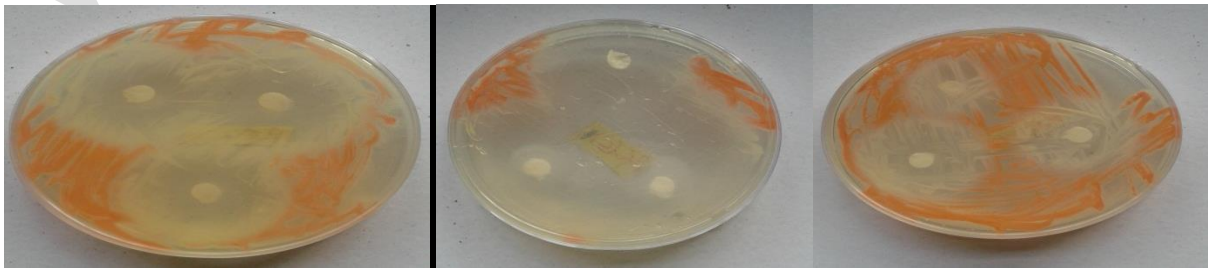
Key: - = No growth; + = Growth; ++ = Moderate growth: +++ = Significant growth

Table 8: MIC, MFC, and MBC of the *Moringa oleifera* Leaves Extract.

Concentration (mg/mL)					
	25.0	**12.50**	**6.25**	**3.13**	**MIC**
Test Organisms **Fungi**					
Aspergilus niger	-	-	+	++	12.50
Aspergilus flavus	-	-	++	+++	12.50
Botryodioplodia theobromae	-	-	+	++	12.50
Fussarium oxysporum	-	-	+	++	12.50
Myrothecium verrucaria	-	-	+	++	12.50
Bacteria					
Klebsiella oxytoca	-	-	+	++	12.50
Serratia marcescens	-	-	+	++	12.50
Pseudomonas aeruginosa	-	-	+	+++	12.50
Esherichia coli	-	-	+	++	12.50
Erwinia carotovora	-	-	+	++	12.50

Key: - = No growth; + = Growth; ++ = Moderate growth: +++ = Significant growth





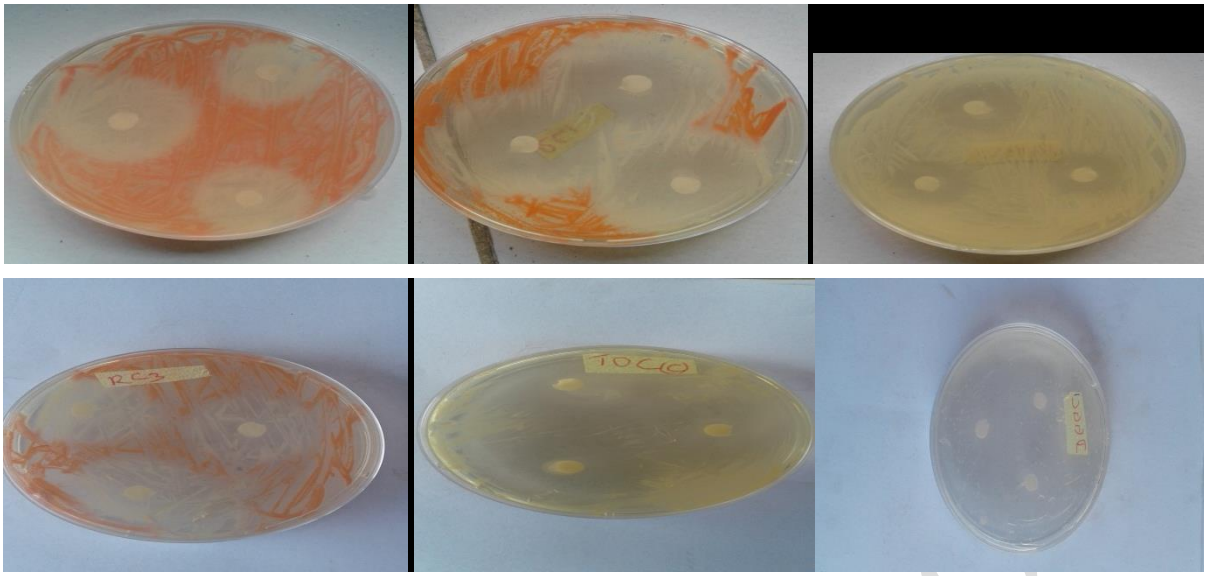


Figure 1: Some antimicrobial sensitivity test plates.

4.0 DISCUSSION

Quantitative evaluation showed alkaloids, terpenoids, phenolics, flavonoids, steroids, saponins, tannins, and glycosides in varying proportions. The result indicates that *M. oleifera* had the highest total phenolic content (82.46 mg GAE/g) and flavonoid content (59.23 QE/g), while *A. indica* recorded the highest saponin (13.72 mg/g). *Colocasia esculenta* exhibited moderate amounts of these phytochemicals but a higher tannin concentration (10.36 mg/g). The observed differences in phytochemical concentrations reflect the unique biosynthetic capacities of each plant species, which are influenced by genetic and environmental factors (Deepali et al., 2025; Ugosor & Shausu, 2025). The high phenolic and flavonoid levels in *M. oleifera* and *A. indica* are consistent with their strong antimicrobial potential, as these compounds can disrupt microbial membranes and inhibit nucleic acid synthesis (Setyani et al., 2023). Similarly, saponins and terpenoids may enhance permeability of microbial cell walls, leading to cell lysis (Ogbuewu et al., 2024; Ugosor & Apeyuan, 2025).

Table 3, 4, and 5 represent the antimicrobial sensitivity test result for *Colocasia esculenta*, *Azadirachta indica*, and *Moringa oleifera* leaves extracts respectively, while table 5, 7, and 8 shows MIC for *Colocasia esculenta*, *Azadirachta indica*, and *Moringa oleifera* leaves extracts accordingly. The result showed that the inhibitory effect of the extracts against the test microorganisms increased with extract concentration, with the highest activity observed at 100 mg/mL, while the control exhibited the strongest inhibition overall. The result indicates that antimicrobial potency is concentration-dependent.

Moringa oleifera showed the largest inhibition zones across all test organisms, particularly against *M. verrucaria* (21.52 mm) and *E. coli* (23.96 mm), followed by *Azadirachta indica* (*M. verrucaria*: 13.52 mm) and *E. coli*: 21.96 mm) and *Colocasia esculenta* (*M. verrucaria*: 8.56 mm and *E. coli*: 18.87 mm) at 100 mg/mL of extracts. The result revealed that among the test organisms, *M. verrucaria* (fungi) and *E. coli* (bacteria) were the most susceptible to the extracts.

The largest inhibition zones and lowest MIC value (12.50 mg/mL) of *Moringa oleifera*, compared to lower inhibition zones and higher MIC values (25.00 mg/mL) of *Colocasia esculenta* and *Azadirachta indica* corroborate with recent findings by Farooq & Saeed (2024); El-Sherbiny et al (2024); Terngu et al (2024), and Ugosor & Apeyuan (2025). Comparative MICs and inhibition zone sizes however, vary by extraction method, plant provenance and assay conditions. The higher TPC and TFC observed in *M. oleifera* correspond to its stronger antimicrobial activity, supporting the notion that phenolic and flavonoid compounds contribute to bacterial cell wall disruption and protein denaturation (Mishra et al., 2023; Khan et al., 2023, and Setyani et al., 2023). *C. esculenta* exhibited moderate antimicrobial effects, aligning with reports that its aqueous extract contains fewer potent antimicrobial constituents (Al-Kaf, 2019; Alam et al., 2024). *Azadirachta indica* antimicrobial activity is likely due to its terpenoids and limonoids such as azadirachtin and nimbin (Wylie, 2022).

The variation in efficacy among the plants can also be attributed to differences in extraction yield, phytochemical solubility, and microbial susceptibility (Arogba & Etok, 2022). These findings affirm the synergistic roles of multiple phytochemicals in mediating antimicrobial efficacy.

The antimicrobial profiles corroborate previous findings that *A. indica*, *M. oleifera*, and *C. esculenta* possess broad-spectrum activity against both Gram-positive and Gram-negative bacteria (Kashyap et al., 2023; Terngu et al., 2024; Ugosor & Shausu, 2025; Ugosor & Apeyuan, 2025; Ugosor & Ornguga, 2025). The high inhibition observed in the extracts support their supplementary

roles in traditional medicine but suggests that its aqueous extract may require concentration optimization or combination with other extracts for enhanced antimicrobial efficacy.

5.0 CONCLUSION

This comparative study confirms that *Colocasia esculenta, Azadirachta indica,* and *Moringa oleifera* aqueous leaves extracts contain diverse bioactive compounds responsible for notable *in vitro* antimicrobial activities. Among the extracts, *Moringa oleifera* demonstrated the highest total phenolic and flavonoid content and the strongest antimicrobial potency, followed by *A. indica* and *C. esculenta*. In addition, *Moringa oleifera* recorded the highest inhibition zones and lower MIC value, compared to lower inhibition zones and higher MIC values of *Colocasia esculenta* and *Azadirachta indica*. These findings support their ethnopharmacological relevance and suggest *M. oleifera* as a leading candidate for potential use in developing natural antimicrobial formulations.

Further research is recommended to standardize extraction processes so as to develop quality control measures to ensure consistency in phytochemical compositions, isolate and identify the specific phytochemical compounds, conduct toxicological studies to evaluate safety and identify potential side effects, carry out *in vivo* and clinical trials, develop formulations (e.g. Creams, ointments, tablets) and evaluate their stability and efficacy as well as pharmacological evaluation (e.g. bioavailability, pharmacokinetics) to fully explore the therapeutic potentials of the extracts and develop them into alternative or complementary therapies for multi-drug resistant variants of microorganisms and other infections.

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Competing Interests

Authors have declared that no competing interests exist.

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