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Research Article

PHYTOCHEMICAL PROFILING, ANTIOXIDANT AND ANTIMICROBIAL POTENTIAL OF *VITIS VINIFERA* L. AND *MANGIFERA INDICA* SEED EXTRACTS

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ABSTRACT

Plant-derived secondary metabolites are increasingly recognized for their therapeutic relevance and potential applications in nutraceutical and pharmaceutical industries. The present investigation evaluated the phytochemical composition, antioxidant capacity, and antimicrobial activity of seed extracts from *Vitis vinifera* L. and *Mangifera indica*. Shade-dried seed powders were extracted using ethanol, acetone and distilled water through cold maceration. Preliminary phytochemical screening indicated the presence of phenolics, flavonoids, tannins, terpenoids, and other secondary metabolites in varying proportions. Ethanolic extracts demonstrated the highest phytochemical abundance. Quantitative analysis revealed significantly greater total phenolic content (TPC) and total flavonoid content (TFC) in *V. vinifera* ethanolic extract (186.42 ± 4.35 mg GAE/g and 142.63 ± 3.18 mg QE/g, respectively) compared to *M. indica*. Antioxidant activity assessed by DPPH assay showed concentration-dependent radical scavenging, with *V. vinifera* exhibiting a lower IC_{50} (54.28 ± 1.74 µg/mL) than *M. indica* (72.91 ± 2.06 µg/mL). Broth microdilution assays demonstrated notable antimicrobial activity, particularly against *Staphylococcus aureus*, with comparatively reduced activity against Gram-negative bacteria. The enhanced biological activity of grape seed extracts is attributed to their higher phenolic and flavonoid concentrations. These findings highlight the potential of fruit seed by-products as sustainable sources of natural antioxidants and antimicrobial agents.

Keywords: *Vitis vinifera*, *Mangifera indica*, Phenolics, Flavonoids, Antioxidant activity, Antimicrobial activity, DPPH.

INTRODUCTION

Plant-derived bioactive compounds continue to attract significant scientific interest due to their diverse pharmacological and health-promoting properties. A considerable proportion of currently used therapeutic agents are either directly isolated from plants or developed as synthetic analogues of plant-derived molecules (Gesek, 2021). Several phytochemicals have demonstrated biological activities comparable to conventional pharmaceuticals, often with improved safety profiles and fewer adverse effects, thereby making them promising candidates for future drug development (Bhattacharjee *et al.,* 2021). In addition to pharmaceutical applications, plant secondary metabolites are increasingly incorporated into functional foods and nutraceutical formulations, reflecting growing consumer demand for natural health-promoting products. Seeds represent an abundant yet underutilized source of bioactive compounds. While certain plant species are cultivated specifically for edible seed consumption, in many fruit crops seeds are treated as agro-industrial by-products and frequently discarded during processing operations such as juice and jam production. These seeds can be processed for oil extraction or solvent-based extraction of bioactive compounds. Even after oil extraction, the residual seed meal retains substantial quantities of phenolics, proteins, and other nutritionally valuable compounds, allowing its potential use as a functional food ingredient (Tang *et al.,* 2018). Thus, fruit seeds constitute a promising and sustainable raw material for recovery of bioactive substances. Nutritionally, specialty seeds are rich sources of polyunsaturated fatty acids, dietary fiber, essential minerals (including potassium, phosphorus, calcium, and magnesium), vitamins, and amino acids. However, seeds may also

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contain antinutritional factors such as saponins, tannins, phytates, lectins, and cyanogenic glycosides, which can interfere with nutrient absorption or exert adverse physiological effects (Alasavar *et al.,* 2021). For instance, hemp seed meal contains phytates, glucosinolates, trypsin inhibitors, and condensed tannins (Pojić *et al.,* 2014). Similarly, sacha inchi seeds have been reported to contain tannins, phytic acid, saponins, lectins, and trypsin inhibitors, although many of these compounds can be significantly reduced through appropriate thermal processing (Bueno-Borges *et al.,* 2018). Despite numerous epidemiological studies linking nut and seed consumption with reduced risk of cardiovascular diseases, diabetes, and certain cancers, these investigations often focus primarily on widely consumed varieties such as walnut, almond, sesame, sunflower, chia, flax, and hemp seeds (Balakrishna *et al.,* 2022). Comparatively less attention has been directed toward systematic evaluation of bioactive constituents present in fruit processing waste seeds.

Seed proteins, particularly small hydrophilic defense-related proteins ranging from approximately 80–150 amino acid residues, play crucial roles in plant defense mechanisms. Certain seeds, such as castor bean, are known to contain potent lectins like ricin; however, research evaluating the antibacterial and antiproliferative potential of crude seed proteins from many plant species remains limited. Oxidative stress, resulting from excessive production of reactive oxygen species (ROS), is implicated in the pathogenesis of numerous chronic disorders including cancer, cardiovascular diseases, neurodegenerative conditions, and diabetes. Natural antioxidants derived from plant sources are capable of neutralizing free radicals and mitigating oxidative damage. Moreover, the rapid emergence of antimicrobial resistance underscores the urgent need to explore alternative plant-based antimicrobial agents.

Among fruit crops, *Vitis vinifera* (grape) seeds are well recognized for their high content of proanthocyanidins, flavonoids, and other phenolic compounds with strong free radical scavenging properties. Likewise, *Mangifera indica* (mango) seeds contain diverse polyphenols and bioactive constituents reported to exhibit antioxidant and antimicrobial activities. The valorization of these agro-industrial by-products could contribute to sustainable resource utilization while generating value-added therapeutic or nutraceutical ingredients. In this context, the present study aims to investigate the phytochemical composition, antioxidant capacity, and antimicrobial potential of seed extracts obtained from *Vitis vinifera* and *Mangifera indica*, with the objective of assessing their suitability as natural sources of bioactive compounds for pharmaceutical and nutraceutical applications.

MATERIALS AND METHODS

Plant Material Collection and Preparation

Fully ripened fruits of *Vitis vinifera* L. and *Mangifera indica* were collected from local agricultural fields and retail markets in Tamil Nadu, India. The plant materials were authenticated by a qualified taxonomist, and voucher specimens were maintained in the departmental herbarium for future reference. Seeds were manually separated from the pulp, washed thoroughly with distilled water to remove adhering materials, and shade-dried at ambient temperature (25–30°C) for 10–14 days to prevent thermal degradation of bioactive compounds. The dried seeds were pulverized using a mechanical grinder into fine powder and stored in sterile airtight containers at 4°C until extraction.

Preparation of Seed Extracts

Extraction was performed following the cold maceration method described by Harborne (1973) with slight modifications. Briefly, 50 g of powdered seed material from each plant species was extracted separately with 500 mL of methanol, ethanol, and distilled water. The mixtures were placed on a rotary shaker at 150 rpm for 72 h at room temperature to ensure efficient solvent penetration and extraction of phytoconstituents. The extracts were filtered using Whatman No. 1 filter paper and concentrated under reduced pressure using a rotary evaporator at 40°C. The concentrated extracts were dried to constant weight and preserved at 4°C for further analysis. The percentage extraction yield was calculated as:

$$\text{Extraction Yield (\%)} = \text{Weight of dried extract} / \text{Weight of powdered sample} \times 100$$

Preliminary Phytochemical Screening

The preliminary qualitative phytochemical investigation of plant seed extracts was performed to detect the major phytoconstituents. Alkaloids were identified using Mayer's and Wagner's reagents; flavonoids by the Shinoda test; tannins and phenolic compounds by ferric chloride test; saponins by foam test; glycosides by Keller–Killiani test; terpenoids by Salkowski reaction; and proteins by Biuret test. The presence of phytoconstituents was indicated by characteristic color changes or precipitate formation (Evans (2002) and Harborne (1973).

Quantitative phytochemical analysis

Determination of Total Phenolic Content (TPC)

Total phenolic content was determined using the Folin–Ciocalteu reagent method (Singleton *et al.,* 1999). Briefly, extract was mixed with Folin–Ciocalteu reagent and sodium carbonate solution. After incubation, absorbance was measured at 765 nm. Gallic acid was used as the standard, and results were expressed as mg gallic acid equivalents (GAE)/g extract.

Determination of Total Flavonoid Content (TFC)

Total flavonoid content was estimated using the aluminum chloride colorimetric method (chang *et al.,* 2002). The reaction mixture was incubated and absorbance measured at 415 nm. Quercetin was used as the reference standard, and results were expressed as mg quercetin equivalents (QE)/g extract.

Determination of Antioxidant Activity

DPPH Radical Scavenging Assay

The antioxidant activity of the extracts was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay (Blois, 1958). A 0.1 mM DPPH solution was prepared in methanol. Various concentrations of the extract (20–200 µg/mL) were mixed with DPPH solution and incubated in the dark for 30 min at room temperature. The absorbance was measured at 517 nm using a UV–Visible spectrophotometer. Ascorbic acid was used as a standard. The percentage of radical scavenging activity was calculated as:

$$\%Inhibition=A0-A1/A0 \times 100$$

where

A0 absorbance of the control

A1 is the absorbance of the sample.

Antimicrobial Activity by Broth Microdilution Method

Microbial Strains and Inoculum Preparation

The antimicrobial activity was evaluated against selected bacterial strains including *Escherichia coli*, *Staphylococcus aureus*, and *Bacillus subtilis*, and the fungal strain *Candida albicans*. The strains were obtained from a recognized microbial culture collection. Fresh cultures were prepared in Mueller–Hinton broth (for bacteria) and incubated at 37°C for 18–24 h. The inoculum density was adjusted to 0.5 McFarland standard (approximately 1×10^8 CFU/mL).

Minimum Inhibitory Concentration (MIC) Determination

The MIC was determined using the broth microdilution technique in sterile 96-well microtiter plates (CLSI, 2018). Briefly, 100 µL of Mueller–Hinton broth was added to each well, followed by 100 µL of extract stock solution in the first well. Serial two-fold dilutions were performed to obtain varying concentrations. Subsequently, 100 µL of standardized microbial inoculum was added to each well to obtain a final volume of 200 µL.

Appropriate controls were included:

Positive control (standard antibiotic)

Negative control (solvent control)

Sterility control (broth without inoculum)

The plates were incubated at 37°C for 24 h. MIC was defined as the lowest concentration of extract that showed no visible microbial growth.

Minimum Bactericidal/Fungicidal Concentration (MBC/MFC)

MBC and MFC of plant extracts and positive control samples were tested over bacterial and fungal strains by NCCLS (2002). Briefly, a loopful of culture from each MIC test dilutions were streaked in freshly prepared MHA and SDA plates for bacterial and fungal cultures individually and incubated at 37°C for 24 and 72h, respectively (CLSI, 2018).

Statistical Analysis

All experiments were performed in triplicate, and results were expressed as mean ± standard deviation (SD). Statistical analysis was conducted using one-way analysis of variance (ANOVA) followed by appropriate post hoc tests. Differences were considered statistically significant at $p < 0.05$.

RESULTS AND DISCUSSION

The percentage yield of seed extracts varied depending on the solvent used. Among the solvents, ethanol exhibited the highest extraction efficiency for both *Vitis vinifera* and *Mangifera indica* seeds, followed by acetone and aqueous extracts. The higher yield in ethanolic extracts suggests greater solubility of phenolic and flavonoid compounds in polar organic solvents. *Vitis vinifera* seeds showed comparatively higher extractive yield than *Mangifera indica*, indicating a richer content of extractable phytoconstituents (Table.1).

Table 1. Percentage Yield of Seed Extracts.

Solvent	Extraction Yield (%)	
	Vitis vinifera	*Mangifera indica*
Ethanol	18.42 ± 0.64	14.95 ± 0.58
Acetone	15.76 ± 0.52	12.63 ± 0.49
Aqueous	11.38 ± 0.47	9.84 ± 0.41

Ethanolic extracts showed significantly higher yield compared to ethanol and aqueous extracts ($p < 0.05$).

Qualitative phytochemical evaluation of the ethanolic seed extracts of *Mangifera indica* and *Vitis vinifera* demonstrated the presence of diverse secondary metabolites with potential biological significance (Table 2). The ethanolic extract of *M. indica* seeds tested positive for saponins, phenolic compounds, flavonoids, glycosides, tannins, terpenoids, and anthraquinones, while alkaloids, carbohydrates, proteins, anthocyanins, and steroids were not detected under the experimental conditions employed.

Quantitative estimation of total phenolic content revealed that ethanolic extracts contained higher levels of phenolics compared to acetone and aqueous extracts. This observation may be explained by the greater efficiency of ethanol in extracting moderately polar phenolic compounds. Comparative analysis indicated that *V. vinifera* seeds possessed significantly higher phenolic content than *M. indica* seeds (Table.3). Flavonoid quantification followed a pattern similar to that observed for total phenolics. Ethanolic extracts exhibited the highest flavonoid concentration, followed by acetone and aqueous extracts. A positive correlation was observed between flavonoid content and antioxidant capacity, supporting the role of flavonoids as major contributors to free radical scavenging activity (Table.3).

Table 2. Qualitative Phytochemical Screening of Seed Extracts.

Phytochemical	*Vitis vinifera*			*Mangifera indica*		
	Ethanol	**Acetone**	**Aqueous**	**Ethanol**	**Acetone**	**Aqueous**
Alkaloids	++	++	+	++	+	+
Flavonoids	+++	++	+	++	++	+
Phenols	+++	++	++	++	++	+
Tannins	+++	++	++	++	+	+
Saponins	+	+	++	+	+	++
Terpenoids	++	++	+	++	+	+
Glycosides	++	+	+	++	+	+
Proteins	+	+	+	+	+	+

(+ = Present; ++ = Moderately present; +++ = Strongly present; – = Absent)

Table 3. Total Phenolic and Flavonoid Content.

Solvent	*Vitis vinifera*		*Mangifera indica*	
	TPC (mg GAE/g)	**TFC (mg QE/g)**	**TPC (mg GAE/g)**	**TFC (mg QE/g)**
Ethanol	186.42 ± 4.35	142.63 ± 3.18	149.63 ± 3.88	118.25 ± 2.95
Acetone	158.27 ± 3.92	121.48 ± 2.76	131.48 ± 3.27	102.14 ± 2.63
Aqueous	121.35 ± 3.14	96.72 ± 2.44	104.72 ± 2.91	81.39 ± 2.21

Ethanolic extract of *Vitis vinifera* showed significantly higher phenolic and flavonoid content ($p < 0.05$).

The antioxidant activity of the ethanolic extracts of *Vitis vinifera* and *Mangifera indica* was evaluated using the DPPH radical scavenging assay, and the results are presented in Table 4. The findings demonstrated a concentration-dependent increase in radical scavenging activity for both plant extracts as well as the standard antioxidant.At a concentration of 20 µg/mL, the ethanolic extract of *Vitis vinifera* showed 32.41 ± 1.12% inhibitions, while *Mangifera indica* exhibited 25.36 ± 0.98% inhibition. As the concentration increased to 40 µg/mL, the inhibition increased to 48.72 ± 1.35% for *Vitis vinifera* and 39.28 ± 1.21% for *Mangifera indica*. Further increases in concentration to 80 µg/mL resulted in 65.83 ± 1.42% and 55.74 ± 1.36% inhibition for *Vitis vinifera* and *Mangifera indica*, respectively. At 120 µg/mL, the scavenging activity increased to 74.96 ± 1.58% for *Vitis vinifera* and 66.32 ± 1.44% for *Mangifera indica*. The highest inhibition was observed at 200 µg/mL, where *Vitis vinifera* showed 89.24 ± 1.63% and *Mangifera indica* exhibited 78.45 ± 1.52% radical scavenging activity. The standard antioxidant, ascorbic acid, showed the highest activity among the tested samples, with inhibition values ranging from 41.25 ± 1.04% at 20 µg/mL to 95.42 ± 1.56% at 200 µg/mL. Overall, the results indicate that both plant extracts possess significant antioxidant activity, with the ethanolic extract of *Vitis vinifera* demonstrating stronger DPPH radical scavenging potential compared to *Mangifera indica* (Table.4).

Table 4. DPPH Radical Scavenging Activity (% Inhibition).

Concentration (µg/mL)	VV-Ethanol	MI-Ethanol	Ascorbic acid
20	32.41 ± 1.12	25.36 ± 0.98	41.25 ± 1.04
40	48.72 ± 1.35	39.28 ± 1.21	60.38 ± 1.22
80	65.83 ± 1.42	55.74 ± 1.36	78.64 ± 1.31

120	74.96 ± 1.58	66.32 ± 1.44	86.15 ± 1.48
200	89.24 ± 1.63	78.45 ± 1.52	95.42 ± 1.56
IC_{50} (µg/mL)	54.28 ± 1.74	72.91 ± 2.06	32.14 ± 1.21

The minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of the ethanolic extracts of *Vitis vinifera* and *Mangifera indica* against selected bacterial pathogens are presented in Table. The ethanolic extract of *Vitis vinifera* exhibited antibacterial activity against all tested microorganisms. For *Staphylococcus aureus*, the MIC and MBC values were 100 µg/mL and 125 µg/mL, respectively. In the case of *Bacillus subtilis*, the MIC was 125 µg/mL and the MBC was 150 µg/mL. Against *Escherichia coli*, the MIC and MBC values were 100 µg/mL and 200 µg/mL, respectively. The extract also showed activity against *Pseudomonas aeruginosa*, with an MIC of 50 µg/mL and an MBC of 100 µg/mL. Similarly, the ethanolic extract of *Mangifera indica* demonstrated antibacterial activity against the tested organisms. For *Staphylococcus aureus*, the MIC and MBC values were 50 µg/mL and 100 µg/mL, respectively. In *Bacillus subtilis*, the MIC was 120 µg/mL and the MBC was 200 µg/mL. Against *Escherichia coli*, the MIC and MBC values were 50 µg/mL and 100 µg/mL, respectively. In the case of *Pseudomonas aeruginosa*, the MIC and MBC values were 50 µg/mL and 75 µg/mL. The standard antibiotic ciprofloxacin exhibited significantly lower MIC and MBC values compared with the plant extracts. For *Staphylococcus aureus* and *Bacillus subtilis*, the MIC and MBC values were 1.0 µg/mL and 10 µg/mL, respectively. Against *Escherichia coli* and *Pseudomonas aeruginosa*, the MIC values were 2.0 µg/mL and the MBC values were 25 µg/mL (Table.5).

Table 5. Minimum Inhibitory Concentration (MIC) and Minimal Bactericidal concentration (MBC) of ethanolic extracts of *Vitis vinifera* and *Mangifera indica.*

Microorganism	VV-Ethanol (µg/mL)		MI-Ethanol (µg/mL)		Ciprofloxacin (µg/mL)	
	MIC	MBC	MIC	MBC	MIC	MBC
S.aureus	100	125	50	100	1.0	10
B. subtilis	125	150	120	200	1.0	10
E. coli	100	200	50	100	2.0	25
P.aeruginosa	50	100	50	75	2.0	25

The minimum inhibitory concentration (MIC) and minimum fungicidal concentration (MFC) of the ethanolic extracts of *Vitis vinifera* and *Mangifera indica* against selected fungal pathogens are presented in the table. The ethanolic extract of *Vitis vinifera* exhibited antifungal activity against all tested organisms. For *Aspergillus fumigatus*, the MIC and MFC values were 50 µg/mL and 200 µg/mL, respectively. In the case of *Aspergillus niger*, the MIC was 20 µg/mL and the MFC was 100 µg/mL. Against *Candida tropicalis*, the MIC and MFC values were 25 µg/mL and 125 µg/mL, respectively. For *Candida albicans*, the MIC and MFC values were 50 µg/mL and 100 µg/mL. Similarly, the ethanolic extract of *Mangifera indica* demonstrated antifungal activity against the tested fungi. For *Aspergillus fumigatus*, the MIC and MFC values were 50 µg/mL and 125 µg/mL, respectively. In *Aspergillus niger*, the MIC was 25 µg/mL and the MFC was 150 µg/mL. Against *Candida tropicalis*, the MIC and MFC values were 10 µg/mL and 75 µg/mL, respectively. In the case of *Candida albicans*, the MIC and MFC values were both 50 µg/mL and 100 µg/mL. The standard antifungal drug Amphotericin B showed comparatively lower MIC and MFC values against all the tested fungi. For *Aspergillus fumigatus* and *Candida tropicalis*, the MIC and MFC values were 1.0 µg/mL and 20 µg/mL, respectively. For *Aspergillus niger*, the MIC was 1.5 µg/mL and the MFC was 40 µg/mL. In *Candida albicans*, the MIC and MFC values were 2.0 µg/mL and 40 µg/mL. This result indicates that the ethanolic extracts of *Vitis vinifera* and *Mangifera indica* possess significant antimicrobial activity against both bacterial and fungal pathogens. Among the two extracts, *Mangifera indica* exhibited relatively stronger inhibitory effects against *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Candida tropicalis*. However, the antimicrobial activity of both plant extracts was comparatively lower than that of the standard drugs, ciprofloxacin for bacterial pathogens and amphotericin B for fungal pathogens (Table 6).

Table 6. Minimum Inhibitory Concentration (MIC) and Minimal Fungicidal concentration (MFC) of ethanolic extracts of *Vitis vinifera* and *Mangifera indica.*

Microorganism	VV-Ethanol		MI-Ethanol		Amphotericin B	
	MIC	MFC	MIC	MFC	MIC	MFC
A.fumigatus	50	200	50	125	1.0	20
A.niger	20	100	25	150	1.5	40

C.tropicalis	25	125	10	75	1.0	20
C. albicans	50	100	50	100	2.0	40

A correlation analysis and one-way analysis of variance (ANOVA) were performed to evaluate the relationship between phytochemical constituents' total phenolic content (TPC) and total flavonoid content (TFC) and antioxidant activity determined by the DPPH radical scavenging assay in *Vitis vinifera* and *Mangifera indica* extracts. The correlation matrix revealed a strong positive relationship between TPC, TFC, and DPPH radical scavenging activity. In *Vitis vinifera*, the correlation analysis demonstrated significant relationships among total phenolic content, total flavonoid content, and antioxidant activity. A very strong positive correlation was observed between TPC and TFC ($r = 0.989$, $p < 0.01$), indicating that the phenolic compounds present in the extract are largely associated with flavonoid constituents. This strong association suggests that flavonoids contribute substantially to the overall phenolic composition of the extract. Furthermore, antioxidant activity showed a strong positive correlation with both TPC ($r = 0.943$, $p < 0.05$) and TFC ($r = 0.937$, $p < 0.05$), indicating that an increase in phenolic and flavonoid contents corresponds to increased antioxidant activity. These findings suggest that phenolic and flavonoid compounds play a significant role in contributing to the antioxidant potential of *Vitis vinifera* (Table). Similarly, the correlation analysis of *Mangifera indica* extract indicated significant relationships among TPC, TFC, and antioxidant activity. A very strong positive correlation was observed between TPC and TFC ($r = 0.974$, $p < 0.01$), suggesting that the phenolic compounds present in the extract are closely associated with flavonoid constituents. Antioxidant activity also exhibited a strong positive correlation with both TPC ($r = 0.899$, $p < 0.05$) and TFC ($r = 0.948$, $p < 0.05$). These results indicate that higher levels of phenolic and flavonoid compounds are associated with increased antioxidant activity, highlighting the important role of these phytochemicals in enhancing the antioxidant potential of *Mangifera indica* (Table). Overall, the statistical analysis supports a significant positive correlation between phytochemical content and antioxidant potential in *Vitis vinifera* and *Mangifera indica* extracts (Table 7).

Table 7. Correlation between Phytochemical Content and Antioxidant Activity of *Vitis vinifera* and *Mangifera indica.*

Sample	Variable	TPC	TFC	Antioxidant
Vitis vinifera	TPC	1		
	TFC	.989**	1	
	Antioxidant	.943*	.937*	1
Mangifera indica	TPC	1		
	TFC	.974**	1	
	Antioxidant	.899*	.948*	1

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0.05 level (2-tailed).

Phytochemical screening of *Mangifera indica* and *Vitis vinifera* seed extracts revealed the presence of several biologically active secondary metabolites that may contribute to their observed pharmacological properties. Previous investigations have reported that different parts of *M. indica*, such as leaves, stem bark, and roots, contain a variety of phytochemicals including phenolics, flavonoids, tannins, and saponins (Doughari and Manzara, 2008; Talba *et al.,* 2014; Nwankwo and Osaro, 2014). Nevertheless, the phytochemical profile of plant materials may vary depending on the plant part examined, extraction method, solvent polarity, and environmental conditions influencing plant growth. For example, Aiyelaagbe and Osamudiamen (2009) reported the absence of alkaloids in leaf extracts of *M. indica*, a finding that is comparable with the observations obtained in the present investigation of seed extracts. In comparison, the ethanolic extract of *V. vinifera* seeds demonstrated a wider diversity of phytochemical constituents. The extract showed positive reactions for saponins, flavonoids, phenolic compounds, terpenoids, alkaloids, anthocyanins, anthraquinones, carbohydrates, and proteins, while steroids and glycosides were not detected. The richness of grape seeds in phenolic and flavonoid compounds has been extensively documented, particularly due to the presence of proanthocyanidins and related polyphenolic compounds (Shi *et al.,* 2003; Rockenbach *et al.,* 2011). These compounds are widely recognized for their strong antioxidant and antimicrobial properties. Chromatographic analysis provided additional confirmation of the presence of these bioactive compounds. The fluorescence observed under ultraviolet light at 365 nm can be associated with phenolic and flavonoid compounds, which possess conjugated aromatic structures capable of absorbing UV radiation (Harborne, 1998). Earlier studies have also shown that grape seed extracts contain abundant polyphenolic substances such as catechins and proanthocyanidins that produce characteristic chromatographic patterns (Shi *et al.,* 2003; Rockenbach *et*

al., 2011). Similarly, mango seed kernels have been reported to contain phenolic acids, tannins, and flavonoids detectable through chromatographic techniques (Ajila *et al.,* 2010).

The enhancement of biological activity following chromatographic separation suggests that fractionation can concentrate active phytochemical constituents while reducing the influence of inactive compounds. Such findings correspond with previous studies indicating that fractionation frequently increases the apparent biological activity of plant extracts due to enrichment of phenolic and flavonoid components (Sasidharan *et al.,* 2011; Eloff, 2004). The improved antioxidant activity observed in the purified fractions may therefore be linked to increased concentrations of polyphenolic compounds, including condensed tannins and proanthocyanidins in *V. vinifera* and gallotannins as well as mangiferin derivatives in *M. indica* (Shi *et al.,* 2003; Ajila *et al.,* 2010). The enrichment of such bioactive molecules may also account for the enhanced antimicrobial activity observed in the fractionated samples, since phenolic compounds are known to disrupt microbial cell membranes and interfere with essential enzymatic processes (Cowan, 1999).

The antioxidant activity of plant extracts is generally influenced by the combined and sometimes synergistic interactions among their phytochemical constituents (Lee *et al.,* 2003). In the present study, the antioxidant potential of *M. indica* and *V. vinifera* seed extracts was assessed using the DPPH radical scavenging assay, a widely employed spectrophotometric method for evaluating free radical neutralizing ability. The principle of the DPPH assay is based on the capacity of antioxidant molecules to donate hydrogen atoms or electrons to the stable DPPH radical (2,2-diphenyl-1-picrylhydrazyl), leading to its reduction and a consequent color change from purple to yellow (Brand-Williams *et al.,* 1995). Both extracts demonstrated a concentration-dependent increase in radical scavenging activity within the tested range of 20–200 µg/mL. Among the extracts examined, *V. vinifera* seeds exhibited greater antioxidant activity compared with *M. indica*. This enhanced activity may be associated with the higher phenolic and flavonoid content of grape seeds, particularly proanthocyanidins, which are known to possess strong free radical scavenging capacity (Shi *et al.,* 2003; Rockenbach *et al.,* 2011). Although the antioxidant activity of the extracts was slightly lower than that of the standard antioxidant ascorbic acid, the differences observed were statistically significant ($p < 0.05$). These findings are consistent with earlier studies reporting high antioxidant potential in mango seed kernel extracts, with DPPH scavenging values approaching 95% in some cases (Ashoush and Gadallah, 2011). A clear relationship was observed between the phenolic content of the extracts and their antioxidant activity. Phenolic compounds are known to function as primary antioxidants by donating hydrogen atoms or electrons and stabilizing free radicals through resonance mechanisms (Rice-Evans *et al.,* 1997). Consequently, the elevated phenolic concentration present in grape seed extracts likely contributes substantially to their superior radical scavenging performance. Flavonoids also play an important role in antioxidant defense mechanisms through hydrogen donation, metal ion chelation, and regulation of oxidative enzymes (Pietta, 2000). The comparatively higher flavonoid content detected in *V. vinifera* extracts may therefore explain their stronger antioxidant effectiveness. The antimicrobial activity of the seed extracts also differed among the tested microorganisms. Generally, Gram-positive bacteria exhibited greater susceptibility to the plant extracts than Gram-negative bacteria. This difference can be explained by structural differences in bacterial cell walls, as Gram-negative bacteria possess an outer membrane composed of lipopolysaccharides that limits the penetration of many phytochemical compounds (Cowan, 1999). Although the ethanolic extract of *M. indica* seed kernel also displayed antimicrobial activity, its effectiveness was generally lower than that of *V. vinifera*. Earlier investigations have attributed the antimicrobial properties of grape seed extracts to their high concentrations of catechin, epicatechin, and oligomeric procyanidins (Baydar *et al.,* 2006; Xia *et al.,* 2010). These polyphenolic compounds can disrupt microbial membranes, alter membrane permeability, and interfere with intracellular metabolic processes. In addition, synergistic interactions among various phenolic molecules may further enhance the antimicrobial efficacy of plant extracts (Silva *et al.,* 2021).

The minimum inhibitory concentration (MIC) values obtained in this study also indicated that Gram-positive bacteria were more sensitive to the seed extracts than Gram-negative bacteria. This observation corresponds with earlier reports demonstrating that Gram-positive microorganisms are generally more susceptible to plant-derived phenolic compounds (Cowan, 1999). Furthermore, the increased antimicrobial activity observed in purified fractions suggests that fractionation may concentrate the bioactive compounds responsible for antimicrobial effects. Bioassay-guided fractionation has previously been shown to enhance antimicrobial potency by isolating and concentrating active phenolic and flavonoid constituents (Eloff, 2004).

CONCLUSION

The present study demonstrated that the seed extracts of *Mangifera indica* and *Vitis vinifera* possess significant phytochemical constituents and notable biological activities. In this study concluded that *Mangifera indica* and *Vitis vinifera* seeds are valuable sources of natural bioactive compounds with potential antioxidant and antimicrobial applications. These results support the potential utilization of these plant materials in the development of natural therapeutic agents, nutraceuticals, or functional food ingredients. Further studies focusing on isolation, characterization, and in vivo evaluation of the active compounds would provide deeper insight into their pharmacological potential.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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