J Herbmed Pharmacol. 2024; 13(3): 381-389.

http://www.herbmedpharmacol.com doi: 10.34172/jhp.2024.44481

Journal of Herbmed Pharmacology

Investigation of the phytochemical content, antioxidant activities, and antimicrobial properties of the selected South African medicinal plants

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ARTICLE INFO

Article Type:
Original Article

Article History:
Received: 27 June 2022
Accepted: 25 October 2023

Keywords:
Phytotherapy
Plant extract
Ethnopharmacology
Pharmacognosy
Herbal therapy

ABSTRACT

Introduction: The increase in antimicrobial resistance has necessitated the screening of medicinal plants as potential agents for the treatment of microbial infections. The aim of the research was to explore antimicrobial activities of identified local plants, namely: *Kigelia africana*, *Maytenus chasei*, *Ximenia caffra*, and *Schrebera alata*.

Methods: The powdered leaves of the selected plants were extracted using ethanol, hexane, ethyl acetate, methanol, and water as solvents, and phytochemical contents were determined. DPPH (1,1-diphenyl-2-picrylhydrazyl) assay was used to determine the antioxidant activities of the extracts. Plant extracts were tested against bacterial ATCC strains for their antimicrobial properties.

Results: Hexane and water extracts of *K. africana* showed the highest percentage yield (16.15% and 8.85%, respectively). The highest phenolic content was found in water extracts of *S. alata* (14.07 ± 4.8 mg/g) and ethanol extracts of *M. chasei* (8.6 ± 1.53 mg/g), while the highest flavonoid content was found in the ethyl acetate extract of *M. chasei* (997.34 ± 52.04 mg/g). For all the tested plant extracts, the ethanol extract of *M. chasei* showed the best IC_{50} value of ± 4.71 µg/mL against DPPH compared to other plant extracts. The water extracts of all the tested plants also showed high antioxidant activities. Extracts of *X. caffra* and *S. alata* showed comparable inhibitions to ciprofloxacin ($P > 0.05$) against all tested organisms.

Conclusion: The findings of the study suggest that the compounds in the plant extracts contained both antioxidant and antibacterial activities and these plants might be considered for the treatment of bacterial infections.

Implication for health policy/practice/research/medical education:
The article reports the phytochemicals and pharmacological properties of the selected South African medicinal plants. The findings of this study will be useful when exploring potential alternative treatments for infectious diseases.

Please cite this paper as: Makhubele EM, Odeyemi SW, Masebe TM, Lebelo SL. Investigation of the phytochemical content, antioxidant activities, and antimicrobial properties of the selected South African medicinal plants. J Herbmed Pharmacol. 2024;13(3):381-389. doi: 10.34172/jhp.2024.44481.

Introduction

The use of medicinal plants dates back many decades ago, and they have proven their value as a source of products and molecules with therapeutic potential (1-3). This practice is set to continue in the coming years and with the attention they get, there will be an improvement in medicinal plant use practices, especially in the potency, safety, and efficacy of these plants (4,5). Medicinal plant parts such as barks, stems, leaves, acorns, and roots are used for the treatment of various ailments, such as hypertension, diabetes, male infertility, and bacterial infections (6,7).

According to the World Health Organization (WHO), 70% of the global population relies on medicinal flora for primary healthcare and the treatment of many ailments. About 35 000 to 70 000 plant species are used to cure bacteria caused diseases. Most African healthcare facilities have limited modern medical treatments, and they rely on medicinal plant use because of lower costs, ease of access, and fewer adverse side effects (4,7). Many South Africans depend on traditionally used plants to cure bacteria caused

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diseases and these practices occur in many communities of various settings. This has prompted the increased exploration of medicinal plants as potential alternative treatment sources for human infectious diseases and other ailments (8,9). Medicinal plants are potential agents in combating microorganisms that cause diseases and to decrease resistance resulting from antibiotic usage (10-12). Historically, ethnomedicine has been used for the prevention and treatment of various diseases and most of the plants have shown different bioactivities ranging from antioxidants, antibacterial, and hypoglycemic activities (13,14).

Kigelia africana, *Maytenus chasei*, *Ximenia caffra*, and *Schrebera alata* are commonly used by the traditional healers in southern Africa. The ethnomedicinal usage of these plants has also been reported. The traditional usage of *K. Africana* and *M. chasei* include treatment of skin disorders, malaria, hemorrhoids, cancer and gynecological complaints (15,16). The leaves and root of *X. caffra* is used for the treatment of wounds, infections, fever, infertility, and diarrhea (17). The stem bark, root, leaves of *S. alata* are used for the treatment of cardiovascular diseases and their associated risk factors (18). Generally medicinal plants are considered safe to use with less side effects, however they can be toxic when taken in high doses, or uncontrolled usage for a significantly long duration (5), or when taken with synthetic antibiotics (12). This necessitates the need for the scientific investigation of these plants to determine their safety, bioactive ingredients, and bioactivities. Hence, the aim of this present study is to investigate the phytochemical contents, antioxidants activities and antimicrobial properties of *K. africana*, *M. chasei*, *X. caffra*, and *S. alata*. These plants were selected based on their common use by traditional healers and communities in rural areas in South Africa.

Recent report suggests that *K. africana* inhibits cell proliferation and induced cell death in neuroblastoma cell lines (19). The seed oils of *K. Africana* and *X. caffra* have also been reported to possess anti-proliferative effects on hormone-dependent (MCF-7) and cytotoxic effects on hormone-independent (MDA-MB-231) breast cancer cells (20). However, there is limited data in the literature on the scientific investigation on *M. chasei*. Plant extracts have been reported to be effective on against gram-positive bacteria than on gram-negative ones. This is due to the lipopolysaccharide barrier in the outer membrane of gram-negative bacteria which disallows the entrance of various molecules. Also, gram-negative bacteria possess innate resistance because of systems like the release of specific enzymes, porin loss and bacterial transport proteins, which are involved in extruding substrates, which gram-positive do not possess, hence permitting easier entry of phytochemicals through the bacterial cell membrane (21,22). With the presented evidence on the efficacy of some medicinal plants in curing various ailments, it is prudent to explore these plants for therapeutic use, especially on bacteria caused diseases that affect many people globally (10). This study aimed to explore the antibacterial activities of some South African plants, namely: *K. africana*, *M. chasei*, *X. caffra*, and *S. alata*.

Materials and Methods

Plant materials

The leaves of the *K. africana* (44/1977, 106/1970, 106/1972), *M. chasei* (0816720), *X. caffra* (204/1985, 24/1969), and *S. alata* (568/1968) plant species were all collected in the summer from labeled trees in December 2019 from the Lowveld Botanical Garden, Mbombela, Mpumalanga province, South Africa. The place of deposition was at the Lowveld Botanical Garden. All the plant materials were cleaned with distilled water and air-dried. The plant materials were then ground into powder using a laboratory electric grinder and stored in air-tight containers until further use.

Plant material extraction

About 20 g of each plant powder was weighed and mixed with ethanol (Merck, Germany), ethyl acetate, hexane, methanol (Sigma Aldrich, Germany), and water, then shaken for 24 hours at an ambient temperature of 25 °C in a YIHPER LM-600RD orbital shaker incubator and set at 120 rpm (Thermofisher, UK). Each extract was then filtered into a 50 mL bottle using 100 mm Whatman No 1 filter paper (Sigma Aldrich, Germany). Aqueous extracts were then frozen at -80 °C for 48 hours and further processed through freeze drying machine. Ethanol, methanol, ethyl acetate, and hexane solvents in the extracts were completely removed by a rotary evaporation at 50 °C, then the dried powder was stored at room temperature in labeled vials for use in subsequent experiments.

Determination of the phytochemical contents

Total phenolics

A total phenolic content (TPC) test was done to determine the amount of phenolic content in the plant extract. Phenolic compounds have redox properties, and these properties allow them to act as antioxidants (23). The phenolic contents were determined using the 96 well plates as described by (24) with some modifications. Folin-Ciocalteu (Sigma Aldrich, Germany) reagent was prepared by adding 20 mL of the solvent into 20 mL of distilled water, 25 µL of the solution was then added into tannic acid solution (1 mg/mL) of different volumes (2-10 µg/mL) prepared in distilled water, then followed by the addition of 125 µL of $NaCO_3$ (15 g of $NaCO_3$ into 50 mL of distilled water) into the mixture; These were then used to prepare the standard calibration curve. The absorbance was recorded at a wavelength of 725 nm.

The plant extracts (20 µL) were mixed with 100 µL of Folin-Ciocalteu, followed by 80 µL of $NaCO_3$ resulting in a volume of 200 µL. The mixture was then put in the dark

for 30 minutes to prevent phenols from reacting with light and the absorbance was recorded at 725 nm. The phenolic constituent was calculated using the following equation: phenolic constituent was computed with the use of the equation below:

Y= 0.004x,
R^2 = 0.99, as tannic acid equivalents (TAE)/100 g of the extract, Y is the absorbance and x is the TAE (µg/mL). Then, the TPC was computed with the use of the equation below:

TPC = TAE × V/W.

which V is the extract volume in the reacting solution (mL); and W is the weight of the extract (g).

Total flavonoid content

This method described by Odeyemi et al, was used to quantify flavonoids in the plant extracts. Flavonoids are of importance in human health due to their free radical scavenging activities, inhibiting hydrolytic and oxidative enzymes, and anti-inflammatory activities (23). The flavonoid content was determined using 96 well plates as described by Odeyemi and Afolayan (24). A total of 1 g of 2% aluminum trichloride ($AlCl_3$) (Sigma Aldrich, Germany) was prepared by adding to 50 mL methanol; the mixture was mixed with Quercetin (Sigma Aldrich, South Africa) (100 µg/mL), the standard or the plant extract (2, 4, 6, 8, 10 µL), followed by distilled water in different volumes (40, 42, 44, 46, 48, 50 µL). The absorbance was recorded at a wavelength of 415 nm.

The equation Y= 0.0025x (R2 = 0.9743) was used for the calibration curve and the results were expressed as grams of quercetin equivalent (QE)/100 g of the extract, where Y = absorbance and x = catechin equivalent (µg/g).

The total flavonoid content was calculated as QE/100 g by the following equation:

$TFC = C \times V_T/W$

Where TFC = flavonoid content of the extract; C = concentration of Quercetin from the calibration curve (µg/g); V_T = volume of the extract in the reacting solution (mL); and W = weight of the extract (g)

Determination of antioxidant activity

The antioxidant activity of extracts was measured using the DPPH free radical scavenging reaction. This free radical is stable at room temperature and is reduced in the presence of an antioxidant molecule resulting in a colorless methanol solution (25). The DPPH activity was determined using a 96-well microtiter plate as previously described (26) with some modifications. About 25 µL of methanol was added to all the wells, then 4-20 µL of the plant extracts (100 µg/mL) and methanol were used as a blank solution. Ascorbic acid (100 µg/mL) (Sigma Aldrich, South Africa) was used as a positive control. The test was done in triplicates. Water was also added in each well in a decreasing sequence from–80-100 µL, followed by 50 µL of 0.135 Mm DPPH solution (Sigma Aldrich, South Africa) in each well. The solutions were then vortexed and incubated at room temperature for 30 minutes in the dark to prevent DPPH from reacting with the sun; the absorbance was recorded at 517 nm. The decrease in absorbance was measured against the control, followed by the calculations of the scavenging ability of the plants. The antioxidant activities of the plants and the half-maximal inhibitory concentration (IC_{50}) of the samples were calculated. The percentage of inhibition was calculated as follows:

$$\text{DPPH \% scavenging activity} = ([Abs_{control} - Abs_{sample}]/Abs_{control}) \times 100$$

where $Abs_{control}$ is the absorbance of DPPH with methanol and Abs_{sample} is the absorbance of DPPH with sample (or standard).

Determination of the minimum inhibition concentration (MIC) values

To determine the lowest concentration of *K. africana*, *M. chasei*, *X. caffra*, and *S. alata* effective against bacterial ATCC strains, *E. coli* (ATCC 25922), *Pseudomonas aeruginosa* (ATCC 27853), *Klebsiella pneumoniae* (ATCC 13883), *Enterococcus faecalis* (ATCC 29212) (Anatech Analytical technology, South Africa), the minimum inhibitory concentration (MIC) test was done on 96 well microtiter plates (27). Bacterial ATCC strains cultured on nutrient agar (Sigma Aldrich, South Africa) was incubated overnight at 37°C and diluted (1.5×10^8 CFU/mL of bacterial cells) with saline broth. About 100 µL of each extract (500 µg/mL in 5% DMSO) was added to a 96-well plate containing 100 µL of freshly prepared broth and serially diluted. Ciprofloxacin was used as the control. After 24 hours incubation at 37 °C, about 40 µL of 0.2 mg/mL iodonitrotetrazolium chloride (Sigma Aldrich, Germany) was added to each well and incubated for 30 minutes at 37 °C.

Statistical analysis

All the tests were performed in triplicate. The data were presented as mean ± standard deviation (SD). Regression was performed using the Microsoft Excel program. The significant difference was $P < 0.05$.

Results

The percentage yield of crude extracts

The subsequent percentage yields of the plants were determined after extraction preparation using water, ethanol, methanol, hexane, and ethyl acetate (Table 1). Hexane extract of *K. africana* had the highest percentage yield for all crude extracts, followed by water extract; the least was hexane extract of *X. caffra*.

Total phenolic and flavonoid contents

The total phenolic and flavonoid contents of different extracts are presented in Table 2 and Table 3, respectively. The highest phenolic content was found in the *S. alata* water extract (14.07 ± 4.8 mg TAE/g), followed by *M. chasei* ethanol extract (8.6 ± 1.53 mg TAE/g), methanol extract (7.93 ± 1.33152 mg TAE/g), and water extract (6.32 ± 0.76 mg TAE/g), respectively. The aqueous solvent extracted more phenolics than other solvents except in *K. africana* and *M. chasei*, which were lower than the ones of ethanol and methanol solvents. The contents of flavonoids found in all the extracts were higher compared to their phenolic contents; the values were in the range of 21.76 ± 5.24 to 997.34 ± 52.04 mg QE/g. Hence, the *M. chasei* ethyl acetate extract (997.34 ± 52.04 mg QE/g) showed the highest flavonoid contents followed by *K. africana* ethyl acetate extract (871.5 ± 46.66 mg QE/g), *S. alata* ethanol extract (558.25 ± 69.4 mg QE/g), and *M. chasei* methanol extract (417.55 ± 31.03 mg QE/g), respectively. The ethyl acetate, ethanol, and methanol extracts showed higher flavonoid contents in all the plants except the ethyl acetate; lower flavonoid content was observed in *X. caffra*.

Antioxidant activity

The ability of the extracts to reduce DPPH radicals showed an increase in the percentage inhibition with increasing concentrations (Figure 1). The half maximum inhibition showed that the ethanolic extract of *M. chasei* (13.66 ± 4.71 µg/mL) had the best activity compared to all the investigated samples and control (Table 4). There was no clear pattern in the effect of the solvent extraction on the activities. The water extract of *X. caffra* (73.1 ± 1.3 µg/mL), methanol extract of *S. alata* (52.96 ± 1.97 µg/mL), water and methanol extracts of *K. africana* (66.64 ± 1.67 and 67.34 ± 2.08 µg/mL), and ethanol extract of *M. chasei* (13.66 ± 4.71 µg/mL) showed better activities compared to different extractions of each plant.

Antibacterial activity

The MIC was used to determine the antibacterial activities of the plant extracts on selected gram-negative and gram-positive bacteria. The values of MIC ranged from 0.25 mg/mL to 0.5 mg/mL. The highest activities were by *X. caffra* and *S. alata* extracts against *P. aeruginosa*, *E. coli*, and *K. pneumoniae,* which were comparable to ciprofloxacin

Table 1. Percentage yield (%) of crude extracts of the selected plant species using water, ethanol, methanol, hexane, and ethyl acetate as solvents

Plant species	Yield (%)				
	Water	Ethanol	Methanol	Hexane	Ethyl acetate
Ximenia caffra	2.95	4.50	7.25	0.75	1.50
Schrebera alata	2.85	2.80	4.05	1.25	1.80
Maytenus chasei	1.06	5.70	6.20	2.45	1.25
Kigelia africana	8.85	1.70	2.45	16.15	1.70

Table 2. Total phenolic contents of selected plant extracts

Plant species	Total phenolic content				
	Water	Ethanol	Methanol	Hexane	Ethyl acetate
Ximenia caffra	3.71 ± 0.6	-	0.84 ± 0.67	-	-
Schrebera alata	14.07 ± 4.8	1.15 ± 0.14	1.45 ± 0.08	-	-
Maytenus chasei	6.32 ± 0.76	8.6 ± 1.53	7.93 ± 1.33	-	-
Kigelia africana	0.63 ± 0.46	4.33 ± 0.14	3.17 ± 1.00	-	0.53 ± 0.02

All values are represented as mean ± SD; Tannic acid equivalent per gram of sample mgTAE/g; - : not determined.

Table 3. Total flavonoid contents of selected plant extracts

Solvent used	Total flavonoid content			
	Ximenia caffra	*Schrebera alata*	*Kigelia africana*	*Maytenus chasei*
Hexane	21.76 ± 5.24	416.34 ± 36.72	56.64 ± 13.52	243.55 ± 57.76
Ethyl acetate	33.94 ± 5.92	381.42 ± 70.82	871.5 ± 46.66	997.34 ± 52.04
Ethanol	257.09 ± 39.67	558.25 ± 69.4	334.29 ± 76.02	323.28 ± 78.35
Methanol	286.33 ± 75.47	212.23 ± 64.5	272.37 ± 23.03	417.55 ± 31.03
Water	76.44 ± 8.94	132.55 ± 3.00	311.04 ± 40.55	46.10 ± 2.49

All values are represented as mean ± SD; Quercetin equivalent per gram of sample (QE/g).

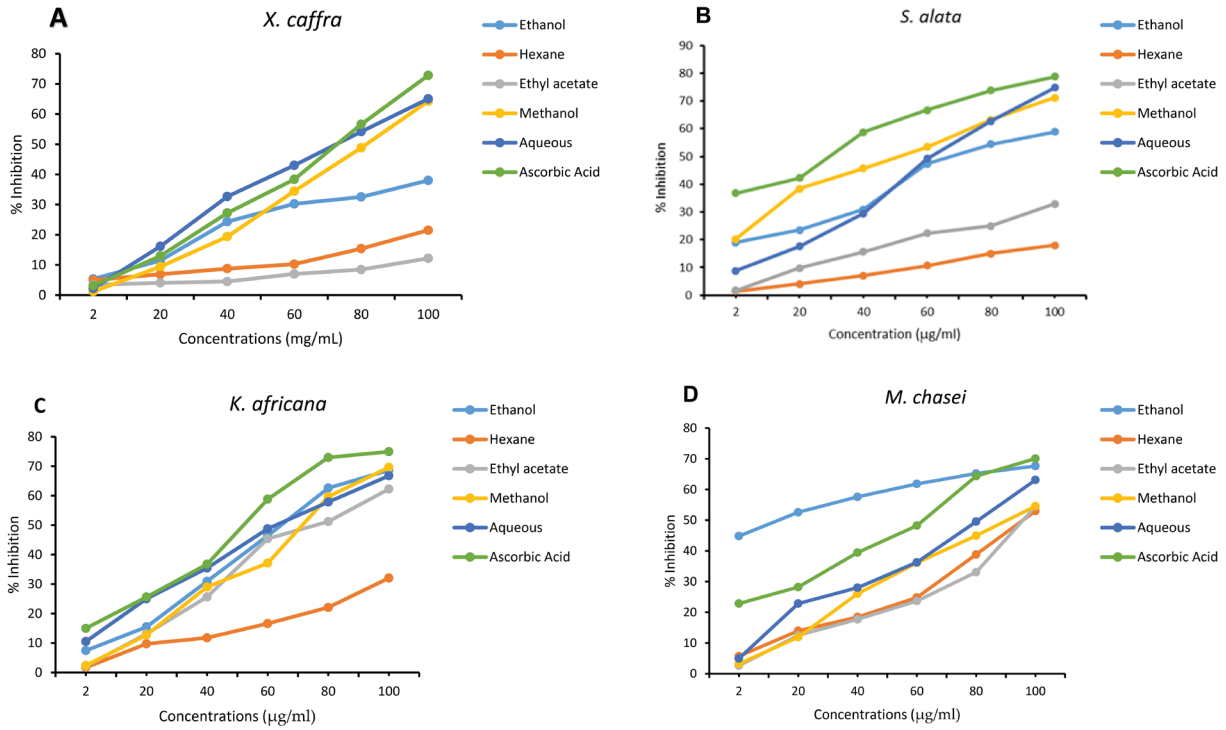

Figure 1: Graphical illustration of DPPH (1,1-diphenyl-2-picrylhydrazyl) scavenging activity of ethanol, hexane, ethyl acetate, methanol, and water extracts of the selected plant extracts. A: *Ximenia caffra*; B: *Schrebera alata;* C: *Kigelia africana;* D: *Maytenus chasei* and ascorbic acid. Values are expressed as DPPH % inhibition and concentration of extracts in µg/mL.

Table 4. Half maximal inhibitory concentrations (IC_50 µg/mL) of four selected plant extracts

Solvents	*Ximenia caffra*	*Schrebera alata*	*Kigelia africana*	*Maytenus chasei*
Hexane	293.24 ± 1.09	285.07 ± 0.66	172.69 ± 1.41	102.89 ± 2.06
Ethyl acetate	550.92 ± 5.78	156.67 ± 1.34	76.85 ± 0.32	105.10 ± 2.89
Ethanol	128.65 ± 1.05	74.84 ± 1.72	67.34 ± 2.08	13.66 ± 4.71
Methanol	81.67 ± 1.33	52.96 ± 1.97	71.03 ± 1.17	89.05 ± 1.49
Water	73.10 ± 1.3	63.88 ± 1.15	66.64 ± 1.67	79.27 ± 2.05
Ascorbic acid	71.159 ± 2.08	29.27 ± 1.04	54.28 ± 1.08	59.05 ± 2.00

(Table 5). The ethanol, ethyl acetate, hexane, methanol, and water extracts of *X. caffra* and *S. alata* showed better inhibition against all tested organisms except *E. faecalis,* comparable to ciprofloxacin, which was used as a positive control.

Discussion

The screening for phytochemicals and antioxidant activity remains vital in determining the presence and levels of phytochemical concentration in different plants. The different extraction yields in this study suggest the importance of the polarity of the solvents in the extraction of phytochemicals. This could also be attributed to the nature of the compounds present in the plant samples (25).

Polyphenolics are important secondary metabolites in plants that have been reported to possess therapeutic uses such as antioxidant, antidiabetic, anticarcinogenic, and antimutagenic activities (26). The two plants with the highest polyphenolics (*S. alata* and *M. chasei*) had their highest yields with ethanol, methanol, and aqueous solvents. This is similar to previous reports that aqueous and methanolic extracts contained abundant polyphenols; these solvents are suitable for the isolation of polyphenols (24,27). The higher phenolic content of the aqueous extract of *S. alata* (14.07 ± 4.8 mg TAE/g) compared to ethanol (1.15 ± 0.14 mg TAE/g) and methanol (1.45 ± 0.08 mg TAE/g) used as extracting solvents was similar to a previous report on *S. alata* (28). The polyphenolic contents of *K. africana* observed in this study corroborated with previous reports and have been linked with the major pharmacological activities of this plant (29,30). There are a lot of strategies currently used to rapidly determine plant extracts' antioxidant activities *in vitro* (31). One of

Table 5. The minimum inhibitory concentrations (mg/mL) of different extracts against the selected gram-positive and gram-negative bacteria

		Ximenia caffra	*Schrebera alata*	*Kigelia africana*	*Maytenus chasei*	Ciprofloxacin
Pseudomonas aeruginosa	Ethanol	0.25	0.25	>0.5	>0.5	0.25
	Methanol	0.25	0.25	>0.5	>0.5	0.25
	Hexane	0.25	0.25	>0.5	>0.5	0.25
	Water	0.25	0.25	>0.5	>0.5	0.25
	Ethyl acetate	0.25	0.25	>0.5	>0.5	0.25
Escherichia coli	Ethanol	0.25	0.25	>0.5	>0.5	0.25
	Methanol	0.25	0.25	>0.5	>0.5	0.25
	Hexane	0.25	0.25	>0.5	>0.5	0.25
	Water	0.25	0.25	>0.5	>0.5	0.25
	Ethyl acetate	0.25	0.25	>0.5	>0.5	0.25
Klebsiella pneumoniae	Ethanol	0.25	0.25	>0.5	>0.5	0.25
	Methanol	0.25	0.25	>0.5	>0.5	0.25
	Hexane	0.25	0.25	>0.5	>0.5	0.25
	Water	0.25	0.25	>0.5	>0.5	0.25
	Ethyl acetate	0.25	>0.5	>0.5	>0.5	0.25
Enterococcus faecalis	Ethanol	>0.5	>0.5	>0.5	>0.5	0.25
	Methanol	>0.5	>0.5	>0.5	>0.5	0.25
	Hexane	>0.5	>0.5	>0.5	>0.5	0.25
	Water	0.5	>0.5	0.5	0.5	0.25
	Ethyl acetate	0.5	>0.5	>0.5	>0.5	0.25

the techniques used is the measurement of the electron donation ability of medicinal plants to reduce DPPH which is evident by the decolorization of the purple-colored solution. Antioxidants fight against free radicals and are involved in the prevention of various diseases. They exert their actions either by scavenging the reactive oxygen species or protecting the antioxidant defense mechanisms (32).

The DPPH antioxidant assay was chosen based on previous reports suggesting the structural interactions between both the bioactive compounds in the samples and the antioxidant constituents of DPPH (24,33). The plant extracts that showed good antioxidant activities might contain some antioxidative phenolic compounds. There is a strong relationship between phenolic contents and antioxidant activity (34). The antioxidant activity of a plant extract plays an important role in its therapeutic benefits, and this is attributed to the presence of phenolics and flavonoids in the extract (35). Flavonoids can scavenge free radicals showing oxidative properties (36). The presence of high oxidant compounds and free radical-reducing abilities of plants justifies the importance of plants for medical purposes (37).

In the present study, among all the samples investigated, *M. chasei* ethanol extract showed significantly higher scavenging activity with the IC_{50} of 13.66 ± 4.71 µg/mL, followed by methanol extract of *S. alata* with the IC_{50} of 52.96 ± 1.97 µg/mL. Also, the higher antioxidant activity of *M. chasei* ethanol extract observed in this study correlated positively with its TPC. In sum, it is evident from this study that higher polyphenolic contents correlate with higher antioxidant activity. The high antioxidant activity of the plant extracts observed in this study was also related to the solvent of extraction and the presence of phenolic compounds. Previous reports have also suggested the correlation between the phenolic contents of plant extracts and their antioxidant activities (26,38,39).

The use of medicinal plants for the treatment of bacterial infections is largely due to their widespread availability, less drug resistance, and few or no side effects (40). The present study corroborates with previous reports on the antibacterial activities of *X. caffra* and *S. alata* and suggests broad-spectrum antimicrobial activities against these pathogens (41-43).

Medicinal plants that are used in traditional medicine with MICs <8 mg/mL may have some antimicrobial activity and are suitable for the treatment of infections (44). Therefore, the MICs of *X. caffra* and *S. alata* suggest their potent antimicrobial activities and the observed activities might be due to the presence of broad-spectrum antibiotic compounds present in the plant extracts (45).

The observed antibacterial activities of *K. africana* and *M. chasei* extracts were contrary to their phenolic and flavonoid contents. The report suggests that the MIC of

the leaf extract of *K. africana* was between 2.5–7.5 mg/mL, which probably justified the poor MIC reported in this study (40). There is a paucity of data on the antimicrobial activity of *M. chasei;* however, the activity of other plants in the *Maytenus* genus such as *M. senegalensis* has been reported to have antimicrobial activity against a wide range of microorganisms. These plants have been used by traditional healers in the treatment of different ailments such as arthritis, skin tumors, eye infection, rheumatism, influenza, and plasmodial infections (46,47).

Conclusion

The findings demonstrated the effects of extracting solvents on the yield, phytochemical contents, and some bioactivities of plant extracts. The high antioxidant activity of the ethanolic extract of *M. chasei* and the good antibacterial activities observed in all extracts of *X. caffra* and *S. alata,* justify the continuous use of these plants in traditional medicine. Therefore, this study emphasizes the need to further investigate the compounds isolated for their potential therapeutic agents. Further studies should include the determination of the active compounds and structural characterization of the plant extracts from these plants.

Acknowledgment

The authors would like to thank the University of South Africa for providing their facilities to perform this research.

Authors' contribution

Conceptualization: Sogolo Lucky Lebelo, Mulalo Emelda Makhubele
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Writing–original draft: Samuel Wale Odeyemi, Mulalo Emelda Makhubele.
Writing–review & editing: Samuel Wale Odeyemi, Sogolo Lucky Lebelo, Tracy Madimabi Masebe.

Conflict of interests

The authors do not have any conflict of interest.

Ethical considerations

Ethical clearance was approved by the College of Agriculture and Environmental Sciences Research Ethics Committee of the University of South Africa (UNISA) with the ethics number: 2018/CAES/076. Permission to collect medicinal plants was obtained from the South Africa National Biodiversity Institute (SANBI).

Funding/Support

The study had no funding.

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