

Effect of *Tamarindus indica* L. and *Manihot esculenta* Extracts on Antibiotic-resistant Bacteria

Zenon Machado Lima¹, Lenilson Santos da Trindade¹, Genelane Cruz Santana², Francine Ferreira Padilha¹, Marcelo da Costa Mendonça¹, Luiz Pereira da Costa^{1,3}, Jorge A. López¹, Maria Lucila Hernández Macedo¹

¹Program in Industrial Biotechnology- Tiradentes University/ Institute of Technology and Research, ²Material Science and Engineering- Federal University of Sergipe, ³Biomaterials and Nanotechnology Laboratory- Technological Institute and Research of the Sergipe State, Aracaju-SE, Brazil

ABSTRACT

Background: The chemical composition of plants used in traditional medicine exhibits biologically active compounds, such as tannins, flavonoids, and alkaloids and becomes a promising approach to treat microbial infections, mainly with drug-resistant bacteria. **Objective:** The aim of the present study was to evaluate the hydroethanolic leaf extracts of *Tamarindus indica* (tamarind) and *Manihot esculenta* (cassava) as antimicrobial potential against *Pseudomonas aeruginosa* clinical isolated and Methicillin-resistant *Staphylococcus aureus*. **Materials and Methods:** Hydroethanolic leaf extracts were prepared and characterized by high-performance liquid chromatography/diode array detection, Fourier transform infrared, 1,1-diphenyl-2-picrylhydrazyl, and ultraviolet-visible methods. The antimicrobial activity against four strains of clinical relevance was evaluated by the microdilution method at minimum inhibitory concentrations. **Results:** Phenolic compounds such as flavonoids were detected in the plant extracts. *T. indica* extract at 500 µg/mL showed antimicrobial activity against *S. aureus* and *P. aeruginosa*; however, *M. esculenta* showed only activity against *P. aeruginosa* in this concentration. **Conclusions:** Our results suggested that polyphenols and flavonoids present in *T. indica* leaf extracts are a potential source of antimicrobial compound. The *T. indica* extract showed antibacterial activity against *S. aureus* and *P. aeruginosa* while *M. esculenta* had effect only on *P. aeruginosa* meropenem resistant.

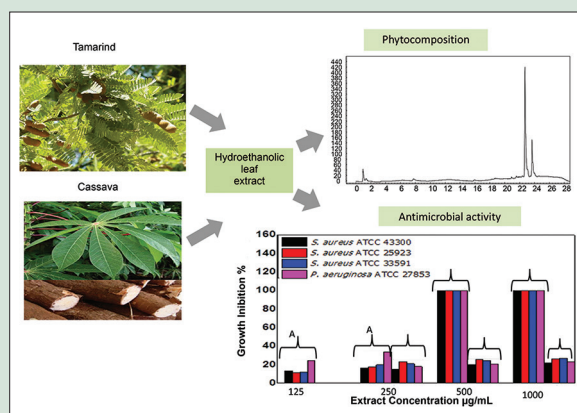
Key words: Antibiotic-resistant bacteria, antimicrobial, plant extract

SUMMARY

- Antibacterial effect of *T. indica* and *M. esculenta* leaf extract was evaluated.
- *T. indica* extract displayed activity against *S. aureus* and *P. aeruginosa* strains.
- *M. esculenta* showed effect on *P. aeruginosa* meropenem resistant.

Abbreviations Used: BHI: Agar brain heart infusion, CAPES: Coordination for the improvement of higher education personnel, DPPH: 1,1-diphenyl-

2-picrylhydrazyl, FAPITEC/SE: Foundation for support to research and technological innovation of the state of sergipe, FTIR: Fourier transform infrared spectroscopy, HPLC: High-performance liquid chromatography, KBr: Potassium bromide, MIC: Minimum inhibitory concentration, MRSA: Methicillin-resistant *Staphylococcus aureus*, RSC: Radical scavenging capacity, UV-vis: Ultraviolet-visible.



Access this article online

Website: www.phcogres.com

Quick Response Code:



Correspondence:

Dr. Maria Lucila Hernández Macedo,
Tiradentes University, Institute of Technology and
Research, Av. Murilo Dantas, 300, Bairro Farolândia,
CEP: 49032-490, Aracaju/SE, Brazil.
E-mail: lucyherma@gmail.com
DOI: 10.4103/0974-8490.204648

INTRODUCTION

Ethnobotanical and experimental evidence supports the use of plants due to their wide variety of secondary metabolites, such as tannins, terpenoids, alkaloids, and flavonoids, which have been found to have antimicrobial activity,^[1-4] displaying even synergistic effects with existing antimicrobial drugs.^[5]

Thus, due to the growing problem of antibiotic resistance of *Pseudomonas aeruginosa* and *Staphylococcus aureus*, there is a great interest in plants considering their phytochemicals as potential therapeutic agents.^[6,7] In this context, *Tamarindus indica* L. and *Manihot esculenta* have significant importance in traditional medicine for different medicinal purposes.^[8-12]

The *T. indica* L. and *M. esculenta* phytochemical studies have correlated their antimicrobial activities to several metabolites. *T. indica* leaf extract revealed the presence of many compounds such as ascorbic acid, β-carotene, polyphenols, and flavonoids (e.g., apigenin, catechin, epicatechin, and naringenin).^[13]

Regarding *M. esculenta* leaf phytochemical composition, it indicated the flavonoids, tannins, ascorbic acid, alkaloids, and saponins presence,^[14] which display antimicrobial, antioxidant, and anti-inflammatory effects.^[15]

Overall, phenolic compounds display a structural diversity which could be used for therapeutic intervention due to their biological broad spectrum.^[16,17] These bioactivities are attributed to polyphenol

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

Cite this article as: Lima ZM, da Trindade LS, Santana GC, Padilha FF, da Costa Mendonça M, da Costa LP, López JA, Macedo ML. Effect of *Tamarindus indica* L. and *Manihot esculenta* extracts on antibiotic-resistant bacteria. Phcog Res 2017;9:195-9.

interactions with proteins, lipids, and carbohydrates. These interaction induced cell permeability, causing membrane disruption.^[18]

Therefore, the chemical composition of *T. indica* L. and *M. esculenta* leaf extracts was evaluated, as well as their antimicrobial activity against *P. aeruginosa* clinical isolated and Methicillin-resistant *S. aureus* (MRSA).

MATERIALS AND METHODS

Plant material and leaf extract preparation

T. indica L. and *M. esculenta* were collected in Porto da Folha, Sergipe, Brazil. The plants species were identified by Prof. Marla Ibrahim Uehbe de Oliveira and deposited in the Tiradentes University herbarium as AJU154 and AJU155, respectively. The leaves were previously oven-dried at 65°C for 2 days and powdered before extract preparation according to Sultana *et al.*^[19] In brief, 10 g of each dried leaves was mixed with 100 mL of hydro-alcohol (20:80) and ultra-sounded for 1 h. Then, the obtained aqueous phases were concentrated and lyophilized. The dried crude concentrated extracts were stored at -4°C, until used for analyses.

Determination of total phenolic compounds

Total phenolic extract content was determined by Folin-Ciocalteu method.^[20] The absorbance was measured in triplicate at 745 nm (DR 5000™ ultraviolet-visible [UV-vis] Spectrophotometer) and results expressed as mg of gallic acid equivalents per 100 mg of extract.

Scavenging activity of 1,1-diphenyl-2-picrylhydrazyl radicals

The extract for antioxidant activity was evaluated by 1,1-diphenyl-2-picrylhydrazyl (DPPH) method. Experiments were carried out according to Shaker *et al.*^[21] with some modification. Briefly, 3 mL of each hydroethanolic extract (50–250 µg/mL) was mixed with 750 µL of ethanolic solution of DPPH 400 mM. The reaction mixture was shaken thoroughly and incubated in the dark at room temperature for 15 min. The absorbance was measured in triplicate at 517 nm (DR 5000™ UV-vis Spectrophotometer). The free radicals percentage inhibition was calculated using the following formula: % RSC = $(A_0 - A)/A \times 100$, where RSC = radical scavenging capacity (%), A_0 = absorbance of control sample ($t = 0$ h), and A = absorbance of a tested sample at the end of the reaction ($t = 1$ h).

Qualitative phytochemical characterization

High-performance liquid chromatography/diode array detection

The hydroethanolic leaf extract composition was performed by reversed phase high performance liquid chromatography according to Aznar *et al.*^[22] Dry leaves extract samples (5 mg/mL) were dissolved in methanol and 9 µL was injected into the HPLC (Varian ProStar HPLC system, Walnut Creek, Au). The samples were eluted using 0.1% formic acid and acetonitrile as mobile phase for gradient elution (flow rate = 1 mL/min) through the column Phenomenex C18 (4.6 mm × 100 mm, 2.6 µ particle size, Torrance, CA, USA). The peaks were detected at 280 nm. The compounds identification was done by comparison of their retention's time and UV absorption spectrum with those of the standards.

Ultraviolet-visible and fourier transform infrared

To detect *T. indica* and *M. esculenta* phenolic compounds, the plant extracts were scanned by UV-vis in the wavelength ranging from 200 to 800 nm using a LAMBDA™ 45 UV-vis Perkin Elmer spectrophotometer. Fourier transform infrared (FTIR) analysis was performed using 10 mg of dried powder of each plant extracts, encapsulated in 100 mg of KBr, and loaded in FTIR spectroscope (Spectrum BX, Perkin Elmer), with a scan range from 400 to 4000 cm⁻¹ with a resolution of 4 cm⁻¹.

Microorganisms

Microorganism strains (*P. aeruginosa* ATCC 27853, *S. aureus* [MRSA] ATCC 25923, *S. aureus* [MRSA] ATCC 33591, and *S. aureus* [MRSA] ATCC 43300) were supplied by the National Institute for Quality Control in Health (INCQS) from the Oswaldo Cruz Foundation (FIOCRUZ). The bacteria maintenance was carried out on Agar Brain Heart Infusion (BHI) (stationary culture) for 37°C at 24 h.

Minimum inhibitory concentration Determination

The microdilution method was used to estimate the minimum inhibitory concentration (MIC).^[23] Briefly, 96-well microplate was coated with 100 µL BHI, 100 µL leaves extract (0, 1 g/mL), and 20 µL of microorganisms suspensions previously diluted at 0.5 McFarland turbidity standard. The microplates were incubated at 37°C for 24 h and microbial growth inhibition was determined at 595 nm (Microplate Reader Model 550, Bio Rad, USA). Vancomycin and meropenem were used as standard positive drug against *S. aureus* and *P. aeruginosa*, respectively. Experiments were done in triplicate.

Statistical analysis

All experimental results were centered using three parallel measurements of the mean ± standard deviation. Analysis of variance was performed followed by Tukey's test as applicable, using the statistical software R (R Development Core Team, 2008). $P < 0.05$ was considered statistically significant.

RESULTS

Phenolic content and antioxidant activity of the extracts

The total phenolic content of *T. indica* and *M. esculenta* extracts showed 132.85 ± 1.43 µg/100 mg and 121.64 ± 1.71 µg/100 mg of phenolic compounds, respectively, expressed as gallic acid equivalents.

The RSC evaluated by DPPH method is presented in Figure 1. Both extracts were able to reduce the DPPH in a concentration-dependent manner; however, *T. indica* showed better antioxidant capacity than *M. esculenta* compared to silymarin control, ranged from 18% to 75% of RSC.

Qualitative phytochemical composition

The chromatographic profiles of *M. esculenta* leaf extract showed two major peaks whose absorption spectrum matching to 353 nm (band I) and 256 nm (band II) and for *T. indica* 212 and 269 nm [Figures 2 and 3].

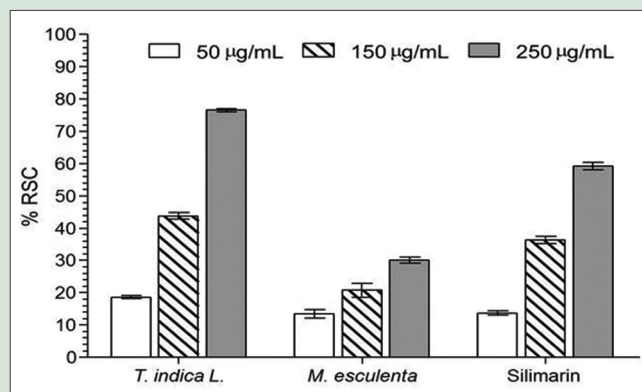


Figure 1: 1,1-diphenyl-2-picrylhydrazyl radical scavenging activity of the *Tamarindus indica* and *Manihot esculenta* extracts. Values are means ± standard deviation ($n = 3$). RSC: Radical scavenging capacity

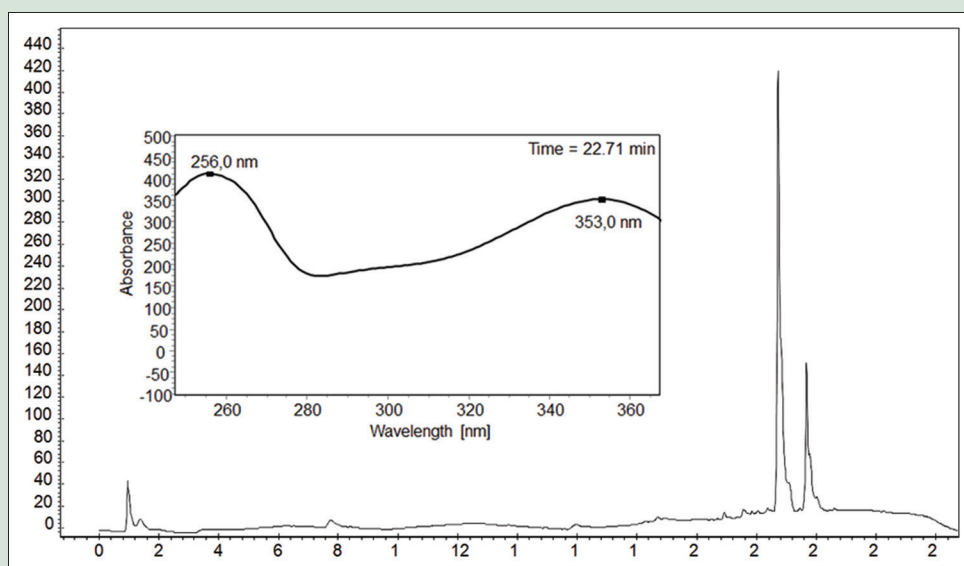


Figure 2: Chromatographic profile of *Manihot esculenta* leaf extract used to investigate the qualitative content of polyphenols

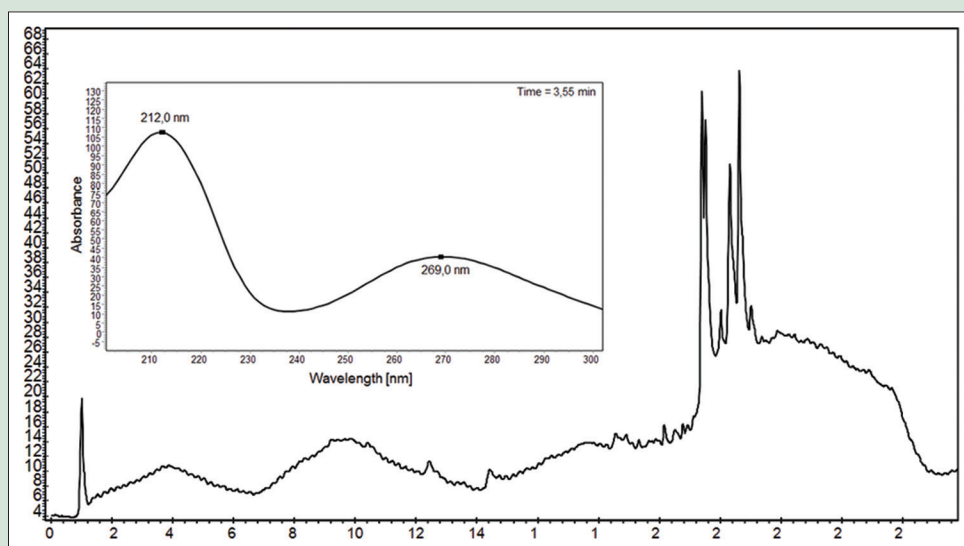


Figure 3: Chromatogram of the extract of leaves of *Tamarindus indica* used to investigate the presence of flavonoids

Ultraviolet-visible and fourier transform infrared analysis

With respect to UV-vis analyses, the extracts showed bands at 283 and 327–328 nm for *T. indica*, whereas bands at 286 and 309–321 nm were observed for *M. esculenta* extract [Figure 4].

On the other hand, the FTIR spectra obtained from *T. indica* and *M. esculenta* extracts showed bands between 3.500 and 3.000 cm^{-1} assigned to OH group stretching vibration (alcohol and water), and also bands ranged from 2.950 to 2800 cm^{-1} indicating CH groups vibrations (methyl and methylene) were observed. The peak obtained at 1.680–1.630 cm^{-1} showed stretching vibration of the C=O (carbonyl) groups while bands between 1.150–1.050 cm^{-1} and 900–1.300 cm^{-1} corresponding to C-OH and CH groups, respectively [Figure 5].

Antimicrobial activity

The antibacterial activity of the plant extracts is shown in Table 1. The results indicated that extracts showed antibacterial activities at variable degrees

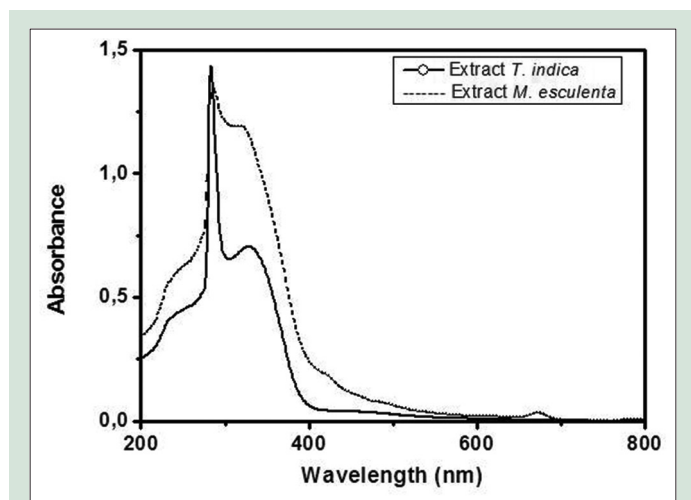
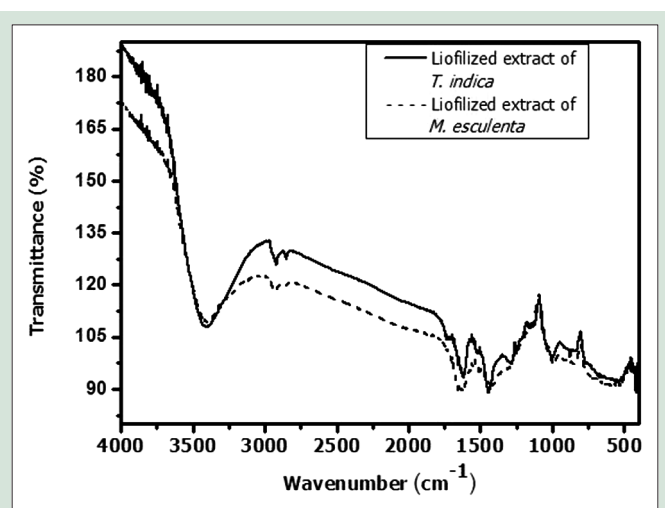
against clinical isolates (*P. aeruginosa*) and MRSA bacteria, with MICs values varying from 125 to 1000 $\mu\text{g/mL}$. *T. indica* extracts displayed the most important spectrum of activity at 500 and 1000 $\mu\text{g/mL}$, by inhibiting 100% growth of all microorganisms, whereas *M. esculenta* at 500 $\mu\text{g/mL}$ had satisfactory antibacterial activity only against *P. aeruginosa*. Vancomycin at 1.95 $\mu\text{g/mL}$ inhibited the *S. aureus* growth while meropenem had no activity against *P. aeruginosa* at 500 $\mu\text{g/mL}$ (data not shown).

DISCUSSION

Total phenolic content in plant extracts and their antioxidant activity are strongly related. Phenols have ability of eliminating free radicals due to its hydroxyl groups; therefore, the presence of these compounds in plants may directly contribute to their antioxidant and antimicrobial actions.^[24–27] In this study, the phenolic content of *T. indica* leaf extract was high than in *M. esculenta*. Although the presence of polyphenols in *M. esculenta* was observed, its antioxidant activity is decreased due to glycosides substitutions in their molecular structure, interfering

Table 1: Minimal inhibitory concentration of *Tamarindus indica* and *Manihot esculenta* extract against *Pseudomonas aeruginosa* and *Staphylococcus aureus*. (–) No inhibition

Leaves extract Concentration (µg/mL)	MIC mean±SD (%)							
	<i>S. aureus</i> 43300		<i>S. aureus</i> 25923		<i>S. aureus</i> 33591		<i>P. aeruginosa</i> 27853	
	<i>T. indica</i>	<i>M. esculenta</i>	<i>T. indica</i>	<i>M. esculenta</i>	<i>T. indica</i>	<i>M. esculenta</i>	<i>T. indica</i>	<i>M. esculenta</i>
125	17	–	15	–	16	–	24	–
250	18	17	19	22	20	21	37	20
500	100	23	100	26	100	27	100	100
1000	100	30	100	31	100	33	100	100

**Figure 4:** Ultraviolet-visible spectrum of *Tamarindus indica* and *Manihot esculenta* leaf extract**Figure 5:** Fourier transform infrared of *Tamarindus indica* and *Manihot esculenta* extract

in this activity.^[28] This may explain the lower value of the DPPH with *M. esculenta* extract despite its phenols content. Similar results were obtained by Rahiman *et al.*^[29] by analyzing the antioxidant activity and total phenolic content of plants used as home remedies.

Thus, the better antioxidant capacity of *T. indica* extract can be explained by a variety of flavonoids and phenolic compounds presence, which act as reducing agents, stabilizing the free radical DPPH.^[21]

The extract UV-vis spectra revealed two bands at 310–350 and 250–290 nm, indicating the presence of flavones and flavonols, respectively.^[30,31] This result is relevant considering the antimicrobial activity of these compounds.

UV-vis and FTIR data are supported by chromatographic profiles of *M. esculenta* and *T. indica* leaf extracts that indicated the phenolic compounds and flavonoids presence, suggested by two typical bands of flavonoids structure and functional groups present (e.g., acids, carbonyl, alcohols, aldehydes, alkanes, and ethers) in these compounds; this is consistent with several data described in scientific literature.^[15,32]

According to Jakobek,^[18] the detected flavonoids and phenolic compounds in plant extracts act as antimicrobial agents against various human pathogens. The polyphenols mechanism of action on microorganisms are still poorly understood, and some authors suggest that polyphenol acts by reducing the iron availability, inhibiting protein expression, changing the cell membrane permeability, and fluidity.^[33–35]

Although antimicrobial compounds present in *T. indica* leaves are not well elucidated, our results are in line with Cuban and Puerto Rican plant extract studies from the same species, which showed antimicrobial potential probably due to the presence of phenolic compounds.^[36,37]

T. indica extract inhibited the *S. aureus* and *P. aeruginosa* growth at 500 and 1000 µg/mL. MIC values between 50 and 500 µg/mL indicate

strong activity while 600–1500 µg/mL values denote a moderate antimicrobial action,^[38] showing that *T. indica* extract has activity against the bacteria studied.

Although literature reports that Gram-negative bacteria are more resistant than Gram-positive to polyphenols due to the cell wall chemical composition,^[39] this resistance was not observed in our results, since the *T. indica* extract showed an inhibitory capacity against *P. aeruginosa*.

On the other hand, *M. esculenta* extract has inhibition at 500 µg/mL only against *P. aeruginosa* meropenem resistant, evidencing the antimicrobial potential of the extract. The low inhibitory effect of *M. esculenta* on *S. aureus* is probably due to attachment of carbohydrates in polyphenols and flavonoids compounds that decreased their antioxidant and antimicrobial activities.^[18,33,40]

CONCLUSIONS

In the present study, two plant extracts (*T. indica* L. and *M. esculenta*) were studied and their antioxidant and antimicrobial capacities were evaluated. Biomolecules such as polyphenols and flavonoids present in leaf extracts exhibited antimicrobial activity on drug-resistant bacteria. The *T. indica* extract showed antibacterial effect against Gram-positive and Gram-negative bacteria, while *M. esculenta* had activity only on *P. aeruginosa* meropenem resistant. Therefore, results suggest that both extracts are an affordable antioxidants source and have antimicrobial effects.

Acknowledgement

Authors are thankful to CAPES and Fapitec/SE for the financial support and fellowship. We also would like to thank Embrapa Coastal Tablelands, the National Laboratory Sincrontron Light and Sergipe Federal University for technical supports.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Upadhyay A, Upadhyaya I, Kollanoor-Johny A, Venkitanarayanan K. Combating pathogenic microorganisms using plant-derived antimicrobials: A minireview of the mechanistic basis. *Biomed Res Int* 2014;2014:761741.
- Singh M, Khatoon S, Singh S, Kumar V, Rawat AK, Mehrotra S. Antimicrobial screening of ethnobotanically important stem bark of medicinal plants. *Pharmacognosy Res* 2010;2:254-7.
- Roumy V, Gutierrez-Choquevilca AL, Lopez Mesia JP, Ruiz L, Ruiz Macedo JC, Abedini A, *et al.* *In vitro* antimicrobial activity of traditional plant used in mestizo shamanism from the Peruvian amazon in case of infectious diseases. *Pharmacogn Mag* 2015;11 Suppl 4:S625-33.
- Kali A. Antibiotics and bioactive natural products in treatment of methicillin resistant *Staphylococcus aureus*: A brief review. *Pharmacogn Rev* 2015;9:29-34.
- Brahim MA, Fadli M, Hassani L, Boulay B, Markouk M, Bekkouche K, *et al.* *Chenopodium ambrosioides* var. *ambrosioides* used in Moroccan traditional medicine can enhance the antimicrobial activity of conventional antibiotics. *Ind Crops Prod* 2015;71:37-43.
- Dharmaprakash A, Thandavarayan R, Joseph I, Thomas S. Development of broad-spectrum antibiofilm drugs: strategies and challenges. *Future Microbiol* 2015;10:1035-48.
- Al-Azzawi A, Alguboori A, Hachim MY, Najat M, Al Shaimaa A, Sad M. Preliminary phytochemical and antibacterial screening of *Sesuvium portulacastrum* in the United Arab Emirates. *Pharmacognosy Res* 2012;4:219-24.
- Dewprashad B, Zakia S, Katayama S, Hendrix R. Antibacterial effects of the sauce from cassava. *J Med Plants Res* 2009;3:880-2.
- Goyal B, Alok S, Jain SK, Verma A. Evaluation of analgesic activity of ethanolic extract of *Tamarindus indica* leaves on experimental animal model. *Int J Pharm Sci Res* 2013;4:1994-7.
- Kuru P. *Tamarindus indica* and its health related effects. *Asian Pac J Trop Biomed* 2014;4: 676-81.
- Bhadoriya SS, Ganeshpurkar A, Narwaria J, Rai G, Jain AP. *Tamarindus indica*: Extent of explored potential. *Pharmacogn Rev* 2011;5:73-81.
- Nwodo UU, Obiyeke GE, Chigor VN, Okoh AI. Assessment of *Tamarindus indica* extracts for antibacterial activity. *Int J Mol Sci* 2011;12:6385-96.
- Samina KK, Shaikh W, Shahzadi S, Kazi TG, Usmanghani K, Kabir A, *et al.* Chemical constituents of *Tamarindus indica* L. medicinal plant in Sindh. *Pak J Bot* 2008;40:2553-9.
- Blagbrough IS, Bayoumi SA, Rowan MG, Beeching JR. Cassava: An appraisal of its phytochemistry and its biotechnological prospects. *Phytochemistry* 2010;71:1940-51.
- Raimi MM, Oyekanmi AM, Farombi AG. Proximate and phytochemical composition of leaves of *Ceiba pentandra*, *Manihot esculentus* and *Abelmoschus esculentus* in Southwestern Nigeria. *Sci Res J* 2014;2:30-4.
- Tsao R. Chemistry and biochemistry of dietary polyphenols. *Nutrients* 2010;2:1231-46.
- Asowata-Ayodele AM, Otunola GA, Afolayan AJ. Assessment of the polyphenolic content, free radical scavenging, anti-inflammatory, and antimicrobial activities of acetone and aqueous extracts of *Lippia javanica* (Burm. F.) spreng. *Pharmacogn Mag* 2016;12:353-62.
- Jakobek L. Interactions of polyphenols with carbohydrates, lipids and proteins. *Food Chem* 2015;175:556-67.
- Sultana B, Anwar F, Ashraf M. Effect of extraction solvent/technique on the antioxidant activity of selected medicinal plant extracts. *Molecules* 2009;14:2167-80.
- Slinkard K, Singleton VL. Total phenol analyses: Automation and comparison with manual methods. *Am J Enol Vitic* 1977;28:49-55.
- Shaker E, Mahmoud H, Mnaa S. Silymarin, the antioxidant component and *Silybum marianum* extracts prevent liver damage. *Food Chem Toxicol* 2010;48:803-6.
- Aznar O, Checa A, Oliver R, Hernández-Cassou S, Saurina J. Determination of polyphenols in wines by liquid chromatography with UV spectrophotometric detection. *J Sep Sci* 2011;34:527-35.
- Manual Clinical and Laboratory Standards Institute (CLSI). National Committee for Clinical Laboratory Standards. Reference Method for Dilution Antimicrobial Susceptibility Tests for Bacteria That Grow Aerobically; Approved Standard-Ninth Edition: CLSI document M07-A9. Wayne, PA: Clinical and Laboratory Standards Institute; 2015.
- Mamta, Mehrotra S, Amitabh, Kirar V, Vats P, Nandi SP, *et al.* Phytochemical and antimicrobial activities of Himalayan *Cordyceps sinensis* (Berk.) Sacc. *Indian J Exp Biol* 2015;53:36-43.
- Rekha K, Sivasubramanian C, Thiruvengadam M. Evaluation of polyphenol composition and biological activities of two samples from summer and winter seasons of *Ligularia fischeri* var. *Spiciformis* Nakai. *Acta Biol Hung* 2015;66:179-91.
- D'Sousa Costa CO, Ribeiro PR, Loureiro MB, Simões RC, de Castro RD, Fernandez LG. Phytochemical screening, antioxidant and antibacterial activities of extracts prepared from different tissues of *Schinus terebinthifolius* Raddi that occurs in the coast of Bahia, Brazil. *Pharmacogn Mag* 2015;11:607-14.
- Pochapski MT, Fosquiera EC, Esmerino LA, Dos Santos EB, Farago PV, Santos FA, *et al.* Phytochemical screening, antioxidant, and antimicrobial activities of the crude leaves' extract from *Ipomoea batatas* (L.) Lam. *Pharmacogn Mag* 2011;7:165-70.
- Prawat H, Mahidol C, Ruchirawat S, Prawat U, Tuntiwachwut-tikul P, Tooptakong U, *et al.* Cyanogenic and non-cyanogenic glycosides from *Manihot esculenta*. *Phytochemistry* 1995;40:1167-73.
- Rahiman S, Tantry BA, Kumar A. Variation of antioxidant activity and phenolic content of some common home remedies with storage time. *Afr J Tradit Complement Altern Med* 2012;10:124-7.
- Markham RK, Mitchell KA, Wilkins AL, Daldy JA, Lu Y. HPLC and GC-MS identification of the major organic constituents in New Zealand propolis. *Photochemistry* 1996;42:205-11.
- Tsimogiannis D, Samiotaki M, Panayotou G, Oreopoulou V. Characterization of flavonoid subgroups and hydroxy substitution by HPLC-MS/MS. *Molecules* 2007;12:593-606.
- Naseem B, Shah SW, Hasan A, Sakhawat Shah S. Interaction of flavonoids, the naturally occurring antioxidants with different media: A UV-visible spectroscopic study. *Spectrochim Acta A Mol Biomol Spectrosc* 2010;75:1341-6.
- Daglia M. Polyphenols as antimicrobial agents. *Curr Opin Biotechnol* 2012;23:174-81.
- Mila I, Scalbert A, Expert D. Iron withholding by plant polyphenols and resistance to pathogens and rots. *Phytochemistry* 1996;42:1551-5.
- Petti S, Scully C. Polyphenols, oral health and disease: A review. *J Dent* 2009;37:413-23.
- Escalona-Arranz JC, Pérez-Roses R, Urdaneta-Laffita I, Camacho-Pozo MI, Rodríguez-Amado J, Licea-Jiménez I. Antimicrobial activity of extracts from *Tamarindus indica* L. leaves. *Pharmacogn Mag* 2010;6:242-7.
- Meléndez PA, Capriles VA. Antibacterial properties of tropical plants from Puerto Rico. *Phytomedicine* 2006;13:272-6.
- Aliogiannis N, Kalpoutzakis E, Mitaku S, Chinou IB. Composition and antimicrobial activity of the essential oils of two *Origanum* species. *J Agric Food Chem* 2001;49:4168-70.
- Nakamura K, Ishiyama K, Sheng H, Ikai H, Kanno T, Niwano Y. Bactericidal activity and mechanism of photoirradiated polyphenols against Gram-positive and -negative *Bacteria*. *J Agric Food Chem* 2015;63:7707-13.
- Abd Aziz SM, Low CN, Chai LC, Abd Razak SS, Selamat J, Son R, *et al.* Screening of selected Malaysian plants against several food borne pathogen bacteria. *Int Food Res J* 2011;18:1195-201.