ORIGINAL ARTICLE

Organic leaf extracts of *Garcinia mangostana* grown in ivory coast inhibit the growth of pathogenic bacterial strains

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Abstract

Introduction: *Garcinia mangostana* is a plant tree used in traditional medicine in Africa and South-Asia. Its tropical fruit is an important source of xanthones as well as other bioactive substances identified in many studies. The purpose of this study is to investigate the potential of organic leaf extracts of *G. mangostana* grown in Ivory Coast as a novel source of antimicrobial agents. **Materials and Methods:** A phytochemical screening of the plant leaf was established by various colorimetric assays protocols. Three organic leaf extracts were tested, the dichloromethane leaf extract (GMLD), the methanol leaf extract (GMLM), and the n-hexane leaf extract (GMLH). The antibacterial activity was tested against four reference bacterial strains *Escherichia coli*, *Staphylococcus aureus*, *Listeria monocytogenes*, and *Pseudomonas aeruginosa* using well diffusion method and microdilution assays. **Results:** Phytochemical analysis showed the presence of all chemical groups tested such as tannins, alkaloids, and flavonoids. The inhibitory activity of dichloromethane, n-hexane, and methanol extracts was remarkable (inhibition zone ≥14 mm) against the four strains. However, GMLD showed the lowest inhibition capacity. The values of minimum inhibitory concentration and minimal bactericidal concentration have ranged from 0.25 to >4 mg/ml. **Conclusion:** This study is a first-time investigation on the pharmacological potential of *G. mangostana* leaves against main pathogenic bacterial strains which are more resistant to antibiotics. Our results proved that *G. mangostana* leave extracts can be used to treat diseases caused by bacterial infections.

Key words: Antimicrobial activity, *Garcinia mangostana*, leaf extracts, phytochemical screening

INTRODUCTION

Through centuries, bacterial infections have always taken a primary place as major causes of morbidity and mortality in poor as well as in developed countries.[1] They constitute a worldwide health problem. Nowadays, the lack of functional treatments against these bacterial infections is alarming. Antibiotics and synthetic molecules currently used to fight microbial diseases have almost reached their limits.[2] Indeed, the emergence and spread of antibiotic resistances of most bacterial strains increase year after year and becomes a real issue to global public health.[3] In West African countries like Ivory Coast, pathologies such as respiratory infections, bacterial meningitis, diarrhea, and other infectious diseases are endemic and caused an increase in antibiotic consumption for both symptomatic and prophylactic treatment. These circumstances increase the propagation of bacterial resistance.[4] Therefore, medicinal plants used in traditional therapies appear to be precious sources for local treatment of diseases and showed high antibacterial activities.[5] However, scientific evidence is needed to insure a better use of these plants, some with a high curative potential on various pathologies.[6]

Garcinia mangostana is a small tree commonly cultivated in gardens mostly in Asian and African countries. The whole

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tree as a long history in traditional medicine over the world.[7] Indeed, all parts of the plant are used in traditional healing practices inventoried particularly in Thai, Indian, Philippine, and Malaysian folk medicines.[8-10] Mode of preparation, route of administration, and treated diseases are summarized in Table 1. Several experimental studies showed that various extracts, mainly of the fruit, had various biological activities.[11-17] The growing number of mangosteen trees in Ivory Coast and the results of scientific research on his antimicrobial activity led us to select this plant for experimental purpose. Therefore, the present study proposes a preliminary phytochemical screening of extracts from its leaves and the determination of the antibacterial effects of organic extracts against the main bacterial strains.

MATERIALS AND METHODS

Chemicals

N-hexane, methanol, dichloromethane Dragendorff's reagent, FeCl, Potassium ferrocyanide, reagent Acid Chlorydric reagent, magnesium, chloroform, sulfuric acide, and resazurin were purchased from Sigma-Aldrich (USA) and Honeywell Riedel-de Haën (Germany). All culture mediums were purchased from Biokar Diagnostics (France).

Plant Material

G. mangostana used in this study for the collection of the plant material was grown in Anyama, Abidjan province, Ivory Coast (N5°29'59.148 W4°3'9.853). Leaves were collected in September 2017 [Figure 1: *G. mangostana*'s tree. A: Photography of the tree. B: Photography of a little part of the branch with young leaves]. The plant material was identified by the Ivorian National Center for Agricultural Research (CNRA) and was deposited at their Herbarium, but no reference number was needed. Samples are sorted alphabetically.

Organic Extractions

The leaves were air dried at room temperature under shade and then powdered and weighed (100 g). They were consecutively extracted with 1 L of each organic solvent n-hexane, methanol and dichloromethane using Soxhlet and then filtered (Whatman 10347673 Quantitative-filter-paper, England). The obtained filtrates were concentrated in a rotary evaporator (HeidolphTyp VV 1-Germany). The crude extracts are named GMLH (hexane extract), GMLM (methanol extract), and GMLD (dichloromethane extract) and stored at 4°C for further uses.

Phytochemical Screening

G. mangostana dried powder and crude extract were subjected to qualitative phytochemical analysis for the presence of various groups of chemical molecules part of the secondary metabolism of plants using standard protocols, as shown in Table 2. The color intensity or the precipitate formation was used as analytical responses to these tests.

Figure 1: G. mangostana's tree. A: Photography of the tree. B: Photography of a little part of the branch with young leaves

Determination of the Antibacterial Activity

Bacteria strains

The antibacterial activity of extracts was tested against *Escherichia coli* K12 (MTCC-1302) (*E. coli*) (Laboratory of Food Microbiology, UCL, Belgium: MBLA), *Pseudomonas aeruginosa* (MTCC-1034) (Institute of hygiene, Rabat, Morocco: IH), *Staphylococcus aureus* CECT 976 (*S. aureus*) (MTCC-1144), and *L. monocytogenes* serovar 4b CECT 4032 (Spanish Type Culture Collection: CECT) (MTCC-1143). Strains were maintained on an inclined agar medium at 4°C. The bacteria were revived by two subcultures in an appropriate culture medium: Luria-Bertoni (LB) broth at 37°C for 18–24 h. For the test, final inoculums concentrations were about 10^6 CFU/ml.

Agar-well diffusion assay

To determine the diameter of inhibition of the extracts against the four bacteria strains, we used the well diffusion method.[23] 10 ml of Muller–Hinton Agar medium are poured in empty sterile Petri dishes. After gelling the medium, sterile cylindrical wells having a diameter of 8 mm are placed in the boxes. A tube containing 6 ml of LB medium (LB), supplemented with 0.8% agar, is inoculated with the bacteria strains to be studied. The final concentration of the bacteria is about 10^6 CFU/ml. The LB agar is then poured gently into the Petri dishes. The cylinders are removed after solidification of the medium creating wells which will be

Table 1: Traditional uses of all the part of *Garcinia mangostana* in South-Asian folk medicines

Partused	Mode of preparation	Route of administration	Ethno-medicinal uses	Reference
Bark Stem/root	Decoction	Oral	Amoebic dysentery	
	Decoction	Oral	Affection of genito-urinary tracts	
	Decoction	External	Aphtha or thrush	
	Decoction	Oral	Dysmenorrhea	
Leaf	Decoction	External	Aphtha or thrush	
	Decoction	Oral	Fever	
	Infusion	External	Wound infections and inflammation	
	Decoction	Oral	Urinary disorder	[8-10]
Peel/Rind	Rubbing	External	Skin infection	
	Decoction	Oral	Dysentery	
	Maceration	Oral	Diarrhea	
	Ointment	External	Eczema	
	Decoction	External	Cystitis	
	Decoction	External	Gonorrhea	
Pericarp	Decoction	Oral	Intestinal Catarrh	
	Decoction	Oral	Dysentery	
	Infusion	Oral	Respiration disorders	
	Rubbing	External	Skin affection	
	Maceration	Oral	Diarrhea	
	Fresh	External	Arthritis	
Fruit hulls	Decoction	External	Skin infection	
	Infusion	External	Wound infections	
	Maceration	Oral	Diarrhea	
	Maceration	Oral	Chronic ulcer	
	Decoction	External	Abdominal pain	
	Decoction	Oral	Dysentery	
	Decoction	External	Suppuration	

Table 2: Preliminary chemical screening of *Garcinia mangostana's* leaf

Phytochemical molecules	Name of the test	Status
Alkaloids flavonoids tannins saponines terpenoids anthraquinones Anthocyanins	Dragendorff's reagent[18]	+
	Shinoda'stest[19]	+
	FeCl, Potassium ferrocyanide reagent[20]	+
	FeCl, Potassium ferrocyanide reagent[20]	++
	Salkowski's test[21]	++
	Borntrager's test[22]	++
	Acid chlorydric reagent[22]	+

filled with 50 µL (2.5 mg/ml) of extract to be tested. Finally, the dishes are incubated at 37°C for 24 h. The results are read by measuring the diameter of the zone of inhibition around the wells. Each assay was carried in triplicated. The inhibition diameter, which reflects the antibacterial extract activity, can be observed by the appearance of transparent circular inhibition zones around the wells.

Determination of the minimum inhibitory concentration (MIC)

The MICs were determined by the microdilution method as previously described.[24] This technique involves inoculating decreasing concentration range of extracts. After incubation, observation of the range makes it possible to determine the MICs, which corresponds to the lowest concentration of extract capable of inhibiting bacterial growth. This experimental protocol was performed on a sterile microdilution plate containing 96 wells. Series of dilutions of extract were prepared in LB agar medium at 0.15%. Then to each well 50 µl of LB medium, 0.15% agar

is added and inoculated from a bacterial culture exponential growth phase (106 CFU/ml). Control wells do not contain extract. The plates are then incubated at 37°C for growth of the bacterium for 18h. Afterward, resazurin (10 µL) is added to facilitate the reading of the MICs by a change of color which results in bacterial growth. When resazurin retains its color, it corresponds to the MICs. All experiments were performed in triplicate.

Determination of minimal bactericidal concentration (MBC)

The MBCs correspond to the lowest concentration of extract that can kill more than 99.9% of the initial bacterial inoculum (<0.01% of survivors). It defines the bactericidal effect of a test substance. The MBC was determined on solid medium. Briefly, 10 µL are taken from wells, which have not undergone any resazurin color transformation to be spread in Petri dishes containing PCA medium, and the dishes are incubated at room temperature for 24 h. The MBC (µg/ml) corresponds to the lowest concentration that gives no bacterial subculture, so the MBC of an extract is deduced from the first well exempt of bacteria.[24] All experiments were performed in triplicates.

Statistical analysis

Data were expressed as mean ± standard deviation (SD) of three determinations. Comparisons between means of different groups were carried out using one-way analysis of variance followed by least significant difference test, using SPSS statistical software (version 15). Differences were considered statistically significant at * $P < 0.05$ and ** $P < 0.001$.

RESULTS

Phytochemical Screening

The phytochemical analysis of leaf extract of *G. mangostana* indicated the presence of the phytochemicals tested in this study, which constitute the major classes of chemicals belonging to the secondary metabolism of plants [Table 2]. The results showed that leaves are rich in metabolites but contains more saponins (++), Terpenoids (++) and anthraquinones (++). Alkaloids were revealed with the appearance of an orange precipitate using the Dragendorff reagent. The presence of terpenoids was confirmed by a red-brown coloration in the interphase between chloroform and sulfuric acid. For anthraquinones, the Bornträger reaction showed a high positive red color. After de addition of a ferric chloride solution, the black colored precipitate shows the existence of tannins. Saponins were confirmed by a residual foam formation. In a basic solution, the appearance of a blue color revealed the presence of anthocyanins. Flavonoids gave a purple coloration adding magnesium chips to an ethanolic solution.

Antibacterial Activity

The antibacterial activity of the medicinal plant *G. mangostana* organic leaf extracts was investigated by the agar-well diffusion assay against four bacterial strains; two Gram-positive (*Listeria monocytogenes* and *S. aureus*) and two Gram-negative (*E. coli* and *P. aeruginosa*). Results are expressed in term of diameter (mm) of inhibition [Table 3]. As presented in the table, all the extracts showed important inhibition zones particularly against *E. coli* and L. *Monocytogenes*. In fact, the n-hexane extract had the highest inhibition values against *E. coli* (32 ± 2.5 mm) and L. *Monocytogenes* (33 ± 2.2 mm). However, *P. aeruginosa* was the most resistant strain to the organic extracts. The dichloromethane extract showed lowest values. The determination of the MIC and MBC was assessed by the microdilution method and results are reported in Table 4. The methanol and n-hexane extracts had the lowest MIC values particularly against S. *aureus* (CMI=0.25 mg/ml). In addition, methanol extract also showed a MIC value of 0.25 mg/ml against *L. Monocytogenes*. When the values of MIC are equals to MBC, the bactericidal effect of extract is obtained at the minimal inhibitory concentration. In contrary to the result of the well diffusion method, with the microdilution assay n-hexane and methanol leaf extracts attempted to inhibit *P. aeruginosa* with a bactericidal action, while *E. coli* was the most resistant to the action of all extracts.

DISCUSSION

There are many medicinal plants used in all regions of the world to treat pathologies in traditional medicine and therapeutic. This finding has led to a growing interest in the study of plants. They are rich in various metabolites.[25] The vegetal metabolism is subdivided in two parts; the first one is the primary metabolism, which synthesized metabolites that are essentials to the survival of the plant. They are involved in construction, operation, and storage mechanisms, these metabolites usually have low bioactivity. The second one is the secondary metabolism also call specialized metabolism, involved in the protection, communication, and adaptation of the plant to its environment, they present a wide structural diversity. This chemodiversity gives them their bioactivity.[26] They are sometimes specific to species and are synthesized in low quantities. The major groups are alkaloids, polyphenols, and terpenoids.

With a preliminary phytochemical screening of *G. mangostana's* leaf extract, we demonstrate the presence of alkaloids, flavonoids, tannins, anthocyanin, and saponins with a higher amount of anthraquinones and terpenoids. In fact, anthraquinones includes a large spectrum of different molecules specifically structured. Indeed, biological effects of these molecules depend on their structure, nature, and quantity. Many studies demonstrated the biological activities of anthraquinones as an anti-oxidant, anti-bacterial, anti-viral, anti- leishmanial, and anti-malarial.[27-29] Terpenoids

Table 3: Antibacterial activity of organic extracts (GMLD, GMLM, and GMLH) and reference antibiotics (Erythromycin and Chloramphenicol) against four bacterial strains

Inhibition zone diameters (mm)	*Escherichia coli*	*Staphylococcus aureus*	*Pseudomonas aeruginosa*	*Listeria monocytogenes*
GMLD	18±5.84**	14±1.5**	na	29±1.6*
GMLM	31±4.7*	19±0.5**	18±0.8**	31±1.2*
GMLH	32±2.5*	20±1.0**	11±1.2**	33±2.2*
Erythromycin C	21±2.5	26±3.0	na	24±1.66
Chloramphenicol	33±0.5	29±1.75	24±1.66	27±2.33

Results are the means±standard deviations (SD) of triplicate determinations (n=3). (*P<0.05 and **P<0.001. na: Not active.
GMLD: *G. mangostana* leaf dichloromethane extract, GMLM: *G. mangostana* leaf methanol extract, GMLH: *G. mangostana* leaf n-hexane extract

Table 4: Minimal inhibitory concentration and minimal bactericidal concentration of the organic leaf extracts against the four bacterial strains

Concentrations (mg/ml)	*Escherichia coli*		*Staphylococcus aureus*		*Pseudomonas aeruginosa*		*Listeria monocytogenes*	
	MIC	MBC	MIC	MBC	MIC	MBC	MIC	MBC
GMLD	>4	>4	1	1	4	4	2	>4
GMLM	1	2	0.25	0.5	0.5	0.5	0.25	0.5
GMLH	1	2	0.25	0.25	0.5	0.5	0.5	2

All values are means of three assays, GMLD: *G. mangostana* leaf dichloromethane extract, GMLM: *G. mangostana* leaf methanol extract, GMLH: *G. mangostana* leaf n-hexane extract, MIC: Minimum inhibitory concentration, MBC: Minimal bactericidal concentration

Table 5: Highlight on the antibacterial activity of the different parts of *G. mangostana* in various studies

Plant part	Type of extract	Bacterial strains	Experimental methods	Inhibition zone diameter (mm)	References
Leaf	Dichloromethane Methanol Hexane	*E. coli* *S. Aureus*	Agar well diffusion method	18±5.84 31±4.7 32±2.5 14±1.5 19±0.5 20±1.0	Present study
Pericarp	Methanol	*S. aureus* *B. subtilis* *S. aureus* *S. faecalis*	Disc diffusion test Filter-paper disk-agar diffusion technique	4.50±0.19 20.60±0.75 16.62±0.93 17.11±0.51	[37,38]
Peel/ Rind	Ethanol	*E. coli*	Total plate count method	15±1	[39]
Pulp	Methanol	*S. aureus*	Disc diffusion test	2.31±0.47	[37]
Seed	Methanol	*S. aureus*	Disc diffusion test	9.00±1.16	[37]
Bark	Methanol	*E. coli* *B. subtilis*	Agar well diffusion method	Inhibition zone ≥ 10	[32]
Whole fruit	Methanol	*S. aureus*	Agar diffusion test	5.00±0.05	[40]

E. coli: Escherichia coli, S. aureus: Staphylococcus aureus, P. aeruginosa: Pseudomonas aeruginosa, B. subtilis: Bacillus subtilis, S. faecalis: Streptococcus faecalis

constitute also a large class of compounds known for their anti-bacterial, anti-inflammatory, and cytotoxic activities.[30-32] This evidence suggests that *G. mangostana* leaves grown in Ivory Coast may have a strong antimicrobial activity with the abundance of terpenoids and anthraquinones.

Moreover, traditional uses of this plant summarized in Table 1 showed that all parts are used for traditional healing of various endemic diseases. Although anti-inflammatory, anti-parasitic, and antipyretic activities could be possible effects of treatments with *G. mangostana*, we noticed that illnesses implicating bacterial infections are the most treated by this plant. This evidence led us to focus on this biological capacity. In fact, quantitative experiments should give a better global appreciation. Thereby, in this study, we investigated the anti-microbial activity of three organic leaf extracts

of *G. mangostana*. Bacterial infections are predominant in industrialized countries but even more in sub-saharian African countries like Ivory Coast. Many recent researches data described multidrug-resistant and antibiotic-resistant bacteria, which is the main cause of failures of treatment of these diseases.[33,34] Type and degree of resistance depend on various factors such as the host, environment, and the pathogen. Synthetic molecules, used to treat infections, were tested toxic to the human cells.[35] Then, finding new molecules or new natural therapeutic approaches is necessary to face further antimicrobial infection. All organic extracts tested in our study (n-hexane, methanol, and dichloromethane) have a concrete antibacterial activity according to the two *in vitro* method used, although the hexane extract generally showed better pathogen inhibition. This activity could be explained by the chemical composition of leaves. In the first method, agar-well diffusion assay, results reveal the potential of extracts against *E. coli,* while, with the microdilution assay, these bacteria were quite resistant. In fact, diffusion technique is a qualitative analyses method and microdilution liquid method is quantitative. Moreover, it was demonstrated that the antibacterial activity of extracts depends on the method used to access this biological parameter. Methanol and n-hexane extracts succeeded to the inhibition of *P. aeruginosa* (MIC=MBC=0.5). This antimicrobial activity is even more interesting because *P. aeruginosa* is one of the most resistant strain to antibiotics often associated to opportunistic immunodeficient diseases and nosocomial infection.[36,37] The results suggest that there are molecules present in organic extracts who had specific actions against the bacteria. As shown in Table 5, comparing to results obtained with other part of *G. mangostana*, at lower concentration, leaf extracts had higher inhibition zone diameters. Thereby, leaves can be most valuable candidate to replace actual antibiotics.

Studies conducted on the antibacterial potential of *G. mangostana* leaf extracts with ethanol as solvent confirmed our results.[40] Moreover, results obtained in our experiments confirmed the antibacterial activity of this medicinal plant used in traditional medicine against bacterial infections and suggest that n-hexane and methanol leaf extract of this plant have a better specify activity on bacterial strains particularly against *P. aeruginosa*. In fact, antimicrobial activities of Garcinia whole fruit rind, bark, pericarp, and isolated or modified molecules showed lower pathogenic effects.[41] The biological activity of leaves can be due to the interaction of many components present in extracts.

CONCLUSION

This *in vitro* study demonstrated that while the fruits of *G. mangostana* are widely studied for their biological activities due to the abundance of xanthone identified and isolated, leaves also represent an available source of potential curative compounds. Antimicrobial activity of organic leaf extracts could be a precious and natural alternative to solve the problem of resistance encounter against several bacterial strains. Actual medication to treat bacterial infection used pharmaceutical based on a single molecule, which sometimes causes side effects.

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REFERENCES

1. Rossolini GM, Mantengoli E. Antimicrobial resistance in Europe and its potential impact on empirical therapy. Clin Microbiol Infect 2008;14:2-8.
2. Aminov RI. A brief history of the antibiotic era: Lessons learned and challenges for the future. Front Microbiol 2010;1:134.
3. Tacconelli E, Carrara E, Savoldi A, Harbarth S, Mendelson M, Monnet DL, *et al*. Discovery, research, and development of new antibiotics: The WHO priority list of antibiotic-resistant bacteria and tuberculosis. Lancet Infect Dis 2018;18:318-27.
4. Ouedraogo AS, Pierre HJ, Banuls AL, Ouédraogo R, Godreuil S. Émergence et diffusion de la résistance aux antibiotiques en Afrique de l'Ouest: Facteurs favorisants et évaluation de la menace. Méd Santé Trop 2017;27:147-54.
5. Gurib-Fakim A. Medicinal plants: Traditions of yesterday and drugs of tomorrow. Mol Aspects Med 2006;27:1-93.
6. Barwick M, Van der Schans A, Claudy JB. Tropical and Subtropical Trees: A Worldwide Encyclopaedic Guide. United Kingdom: Thames and Hudson; 2004.
7. Jain SK, Srivastava S. Traditional uses of some Indian plants among islanders of the Indian Ocean. Indian J Tradit Knowl 2005;4:345-7.
8. Lim TK. Edible Medicinal and Non-medicinal Plants. Germany: Springer; 2012.
9. Osman MB, Milan AR. Fruits for the Future 9: Mangosteen *Garcinia mangostana*. Malaysia: Crops for the Future; 2006.
10. Pedraza-Chaverri J, Cárdenas-Rodríguez N, Orozco-Ibarra M, Pérez-Rojas JM. Medicinal properties of mangosteen (*Garcinia mangostana*). Food Chem Toxicol 2008;46:3227-39.
11. Chew YL, Lim YY. Evaluation and comparison of antioxidant activity of leaves, pericarps and pulps of three *Garcinia* species in Malaysia. Free Radic Antioxid 2018;8:130-4.
12. Mohamed GA, Al-Abd AM, El-Halawany AM, Abdallah HM, Ibrahim SR. New xanthones and cytotoxic constituents from *Garcinia mangostana* fruit hulls against human hepatocellular, breast, and colorectal cancer cell lines. J Ethnopharmacol 2017;198:302-12.

13. Chae HS, Oh SR, Lee HK, Joo SH, Chin YW. Mangosteen xanthones, α-and γ-mangostins, inhibit allergic mediators in bone marrow-derived mast cell. Food Chem 2012;134:397-400.
14. Fu Y, Zhou H, Wang M, Cen J, Wei Q. Immune regulation and anti-inflammatory effects of isogarcinol extracted from *Garcinia mangostana* L. against collagen-induced arthritis. J Agric Food Chem 2014;62:4127-34.
15. Tadtong S, Viriyaroj A, Vorarat S, Nimkulrat S, Suksamrarn S. Antityrosinase and antibacterial activities of mangosteen pericarp extract. J Health Res 2009;23:99-102.
16. Dharmana E. Effect of Mangosteen (*Garcinia mangostana*) peel extract towards CD4+ lymphocytes and IL-2 level in HIV patients with antiretroviral therapy. Adv Sci Lett 2017;23:6677-80.
17. Obolskiy D, Pischel I, Siriwatanametanon N, Heinrich M. *Garcinia mangostana* L: A phytochemical and pharmacological review. Phytother Res 2009;23:1047-65.
18. Bouyahya A, Abrini J, Bakri Y, Dakka N. Screening phytochimique et évaluation de l'activité antioxydante et antibactérienne des extraits d'Origanum compactum. Phytothérapie 2017;15:379-83.
19. Et-Touys A, Fellah H, Mniouil M, Bouyahya A, Dakka N, Abdennebi EH, *et al*. Screening of antioxidant, antibacterial and antileishmanial activities of *Salvia officinalis* L. extracts from Morocco. Br Microbiol Res J 2016;16:1-10.
20. Bouyahya A, Abrini J, El-Baabou A, Bakri Y, Dakka N. Determination of phenol content and antibacterial activity of five medicinal plants ethanolic extracts from North-West of Morocco. J Plant Pathol Microbiol 2016;7:4.
21. Trease GE, Evans WC. A Text-book of Parmacognosy. London: Bailliere Tinall Ltd.; 1989. p. 53.
22. Edeoga HO, Okwu DE, Mbaebie BO. Phytochemical constituents of some Nigerian medicinal plants. Afr J Biotechnol 2005;4:685-8.
23. Hussein AR, Ali EM, Hamid E. Antibacterial activity of alcoholic and aqueous extracts of *Agaricus bisporus* against food borne bacterial pathogens. Al-Nahrain J Sci 2018;21:111-4.
24. Khan IA, Aziz A, Sattar M, Munawar SH, Manzoor Z, Raza MA, *et al*. Evaluation of wound healing potential of *Rumex vesicarius* L. Leaf extract and fractions in rabbit. Afr J Tradit Complement Altern Med 2015;12:60-4.
25. Sharangi AB. Secondary metabolites in spices and medicinal plants: An overview. In: Plant Secondary Metabolites, Three-Volume Set. New Jersey: Apple Academic Press; 2017. p. 163-88.
26. Wink M. Modes of action of herbal medicines and plant secondary metabolites. Medicines 2015;2:251-86.
27. Duval J, Pecher V, Poujol M, Lesellier E. Research advances for the extraction, analysis and uses of anthraquinones: A review. Ind Crops Prod 2016;94:812-33.
28. Semple SJ, Pyke SM, Reynolds GD, Flower RL. *In vitro* antiviral activity of the anthraquinone chrysophanic acid against poliovirus. Antiviral Res 2001;49:169-78.
29. Sittie AA, Lemmich E, Olsen CE, Hviid L, Kharazmi A, Nkrumah FK, *et al*. Structure-activity studies: *In vitro* antileishmanial and antimalarial activities of anthraquinones from *Morinda lucida*. Planta Med 1999;65:259-61.
30. Eguchi Y, Widiastuti A, Odani H, Chinta YD, Shinohara M, Misu H, *et al*. Identification of terpenoids volatilized from *Thymus vulgaris* L. by heat treatment and their *in vitro* antimicrobial activity. Physiol Mol Plant Pathol 2016;94:83-9.
31. Souza MT, Almeida JR, Araujo AA, Duarte MC, Gelain DP, Moreira JC, *et al*. Structure-activity relationship of terpenes with anti-inflammatory profile-a systematic review. Basic Clin Pharmacol Toxicol 2014;115:244-56.
32. Biradi M, Hullatti K. Bioactivity guided isolation of cytotoxic terpenoids and steroids from *Premna serratifolia*. Pharm Biol 2017;55:1375-9.
33. Guessennd NK, Ouattara MB, Ouattara ND, Nevry RK, Gbanon V, Tiekoura KB, *et al*. Study of multi-resistant bacteria in hospital effluents from a university hospital (CHU) in the city of Abidjan (Ivory Coast). J Appl Biosci 2013;69:5456-64.
34. Chang HH, Cohen T, Grad YH, Hanage WP, O'Brien TF, Lipsitch M. Origin and proliferation of multiple-drug resistance in bacterial pathogens. Microbiol Mol Biol Rev 2015;79:101-16.
35. Wang L, Hu C, Shao L. The antimicrobial activity of nanoparticles: Present situation and prospects for the future. Int J Nanomedicine 2017;12:1227-49.
36. Micek ST, Wunderink RG, Kollef MH, Chen C, Rello J, Chastre J, *et al*. An international multicenter retrospective study of *Pseudomonas aeruginosa* nosocomial pneumonia: Impact of multidrug resistance. Crit Care 2015;19:219.
37. Lim YS, Lee SH, Tan BC. Antioxidant capacity and antibacterial activity of different parts of mangosteen (*Garcinia mangostana* Linn.) extracts. Fruits 2013;68:483-9.
38. Fernando K, Dasanayaka PN. Antibacterial activity of extracts of pericarp of *Garcinia mangostana*. Vidyodaya J Sci 2006;3:99-107.
39. Soetikno JS, Handayani R, Rahayu RD. Assay for antimicrobial activity of mangosteen rind extracts. J Innov Pharm Biol Sci 2016;3:54-60.
40. Cunha BL, França JP, Moraes AA, Chaves AL, Gaiba S, Fontana R, *et al*. Evaluation of antimicrobial and antitumoral activity of *Garcinia mangostana* L. (mangosteen) grown in Southeast Brazil. Acta Cir Bras 2014;29:21-8.
41. Al-Massarani SM, El Gamal AA, Al-Musayeib NM, Mothana RA, Basudan OA, Al-Rehaily AJ, *et al*. Phytochemical, antimicrobial and antiprotozoal evaluation of *Garcinia mangostana* Pericarp and α-mangostin, its major xanthone derivative. Molecules 2013;18:10599-608.

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