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BIOACTIVE CONSTITUENTS FROM BARK OF *PELTOPHORUM PTEROCARPUM* BAKER EX K. HEYNE

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Abstract– *In vitro* antimicrobial and antioxidant activities of sequential bark extracts of *Peltophorum pterocarpum* Baker ex K. Heyne,was tested against four Gram negative, two Gram-positive bacteria and five fungal isolates. Antioxidant profile was investigated using 2, 2-Diphenyl-1-picryl-hydrazyl and reduction capability by ferric ion reducing antioxidant potentials method. Bark ethyl acetate extract showed significant activity against *B. subtilis* and *P. aruginosa* (IZ 18.33 ± 0.33 mm and 18.33 ± 0.57 mm with MIC of 62.5 and 31.25 µg/ml, respectively) similarly, higher antioxidant potentials with lower IC_{50}value (5 µg/ml; % inhibition of 97.08 at 80 µg/ml), whereas in FRAP method, methanol extract (1463.33 ± 3.33 AAE/mg dw antioxidant potential) show better activity. Further, GC-MS analysis of the ethyl acetate extract confirmed 33 compounds. The main identified constituent was 1,2-benzenedicarboxylic acid, bis(2-ethylhexyl) ester with 48.9% availability.

INTRODUCTION

Antibiotic resistance is a type of drug resistance where a microorganism develops ability to survive in exposure of an antibiotic. Genes and evolutionary stress such as exposure to antibiotics selects its resistant trait, greater the duration of exposure, greater the risk of the resistance development (D'Costa *et al.,* 2011). Some of the common resistant pathogens are *Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli*, *Bacillus subtilis* and *Candida albicans.* Resistance of these pathogenic strains increasing worldwide causing pneumonia, bacteremia, meningitis, sinusitis, peritonitis, food poisoning and arthritis. These problem demands renewed effort to seek new antibacterial agents, effective against pathogenic microorganisms resistant to current antibiotics (Donadio *et al.,* 2010).

Antioxidants are the substances that delay the oxidation process, inhibiting free radicals, initiated chain polymerization and other subsequent oxidizing reactions (Cespedes *et al.,* 2008), these are widely used in food, cosmetic and pharmaceutical industries (Al-Duais *et al.,* 2009). Antioxidants play an important role in biological systems because they defend against oxidative damage and participate in the major signaling pathways of cells (Kumar *et al.,* 2008; Gulcin *et al.,* 2009; Wang *et al.,* 2009).

Plants have limitless ability to synthesize aromatic substances, most of which are phenols or their oxygen-substituted derivatives such as tannins. These substances serve as plant defense mechanisms against predation of microorganisms, insects and herbivores. Since long time, traditional healers using plants as medicaments to cure infectious conditions (Lu *et al.,* 2007; Mbwambo *et al.,* 2007). Many of these plants have been investigated for their antimicrobial and antioxidant activities where large number of plant products significantly inhibited growth of pathogenic bacteria and having antioxidant potentials (Senatore *et al.,* 2007; Singh *et al.,* 2007).

Peltophorum pterocarpum Baker ex K. Heyne is a semi-arid tree of 50 feet in height and grows in many part of India as an ornamental tree. Bark of the plant is used in dysentery, as a constituent of gargle, tooth powder, lotions, in eye trouble, muscular pain and sores (Deshaprabhu, 1966). On phytochemical investigation flavonoids from whole plant (Rahman *et al.,* 1969; Varshney and Dubey, 1969); berginin from flowers (Sulochana *et al.,* 1970); peltophorin, leucocyanidin, quercetin from bark, leaves, fruits and wood (Sastry *et al.,* 1977); tannins from roots and essential oils were reported from pod extracts (Badami and Daulatabad, 1969; Menon *et al.,* 1982).

Pharmacologically antimicrobial (Ahmad and Sultana, 2003; Duraipandiyan *et al.,* 2006), antiinflammatory (Menon *et al.,* 1982; Swarnlakshmi *et al.,* 1984), enterohaemorrhagic effect (Voravuthikunchai *et al.,* 2004) have been documented earlier.

This paper describes bioeffecacies of *P. pterocarpum* successive extracts with its chemical investigation via GC-MS analysis.

MATERIALS AND METHODS

All the chemicals and solvents used in this study were of analytical grade and obtained from HiMedia Chemicals Mumbai, India.

Plant material

Arial parts of *P. pterocarpum* were collected at full flowering stage from the campus, University of Rajasthan, Jaipur, in the months of July-Aug 2010 and authenticated from the Herbarium of the Department itself. Voucher specimen have been deposited (Herbarium Sheet No. 20707) in the Herbarium and Laboratory for further reference. For experiment, bark of *P. pterocarpum* collected in the months of July-August, shade-dried and powdered. The powdered plant material was extracted separately in pet. ether, dichloromethane (DCM), ethyl acetate and methanol successively. These extracts were concentrated using vacuum desiccator and stored at 4 ^{0}C for further use.

Antimicrobial activity

In *In vitro* preliminary analysis, successive extracts were dissolved in DMSO (4 mg/mL concentration). Muller-Hinton agar for antimicrobial and Sabourod Dextrose agar were used for antifungal activities. Pure cultures of Gram +ve bacteria (*Bacillus subtilis,* MTCC 441; *Staphylococcus aureus,* MTCC 740), Gram -ve bacteria (*Escherichia coli,* MTCC 443; *Pseudomonas aeruginosa,* MTCC 741; *Enterobacter aerogenes,* MTCC 111; *Raoultella planticola,* MTCC 530) and fungal strains (*Aspergillus flavus* ATCC 16870; *A. niger* ATCC 322, *Candida albicans* ATCC 4718, *Penicillium chrysogenum* ATCC 5476 and *Tricophyton rubrum* ATCC 2327) were obtained from Institute of Microbial Technology, Chandigarh. These cultures were grown and maintained on Nutrient broth (NB) at 37 °C for 24 h in case of bacteria and Sabouraud Dextrose Broth (SDB) medium at 24 °C for 48 h in case of fungi. Agar well diffusion method (Boyanova *et al.,* 2005) was used for antimicrobial potentials. Briefly, the surface of the agar medium was punched using a sterile cork borer (diameter 6 mm). A 40 µl of extract was dropped into the wells and kept in incubator for 24 h. Following incubation, the inhibition zone in all well was read and diameter expressed in mm. Gentamycin (10 µg/ml) in case of bacteria and ketoconozole (100 units/ml) in case of fungi, were used as positive control. DMSO used as a negative control. Minimum Inhibitory Concentration (MIC) was defined as the lowest concentration of the extract resulted in complete inhibition of visible growth of tested microbes in inoculated plates. Agar well diffusion method was used for MIC determination

Antioxidant activity

1,1-Diphenyl-2-picrylhydrazyl radical scavenging assay

The scavenging effect of the different fractions on the DPPH radical was measured using a modified version of the method (Fogliano *et al.,* 1999). In brief, the extract solution in methanol at different concentrations (80, 60, 40, 20, 10 µg/ml) were added to 2.5 ml of 0.02 % (w/v) solution of DPPH in methanol. The scavenging activities on DPPH radical were determined by measuring the absorbance at 517 nm after 30 min of incubation. The DPPH radical scavenging activity % inhibition was calculated using the following formula:

% Inhibition= (ODControl–OD Sample) /OD Control) ×100

Where OD Control is the absorbance of the blank (containing all reagents except the extract solution) and OD Sample is the absorbance of the test sample. The DPPH radical scavenging activity of quercetin was also assayed for comparison. All tests were performed in triplicate.

Reducing power assay

Reducing power was determined according to the method of Yen and Chen (1995). Each of the extract (1000, 500, 250, 125, 62.5 µg/ml, 1ml) in ethanol was mixed with 2.5 ml of 0.2 M phosphate buffer (pH 6.6) and 2.5 ml of 1% potassium ferricyanide (Sigma) and the mixture was incubated at 50 °C for 20 min. After incubation, 2.5 ml of 10% trichloroacetic acid was added. The upper layer of 2.5 mL was mixed with 2.5 ml deionized water and 0.1% ferric chloride (0.5 ml). Optical density was measured at 700 nm. A higher absorbance indicates a greater reducing

power. Ascorbic acid used aspositive control.

Statistical analysis

All data were subjected to one-way analysis of variance in a statistical analysis system. Duncan's multiple range tests was performed to compare significant differences (P <0.05) in variables between groups. Each set of experiments were conducted in triplicate.

Gas chromatography-Mass spectrophotometry analysis

Ethyl acetate extract was used for Gas chromatography-Mass spectrophotometry (GC-MS) analysis due toits higher phenolic contents (higher intensities on $FeCl_3$ spray). GC-MS (Model; QP_{2010} series, Shimadzu, Tokyo, Japan) equipped with a VF-5ms fused silica capillary column of 30 cm length, 0.25 mm diameter and 0.25μm film thickness was use for the analysis. For detection, an electron ionization system with ionization energy of 70eV was used. Helium gas (99.99%) was used as a carrier gas at a constant flow rate of 1.51 ml/min. injector and mass transfer line temperature were set at 200 and 240 °C respectively. The oven temperature was programmed from 70 to 220 °C at 10 °C/min, held isothermal for 1min and finally raised to 300 °C at 10 °C/min. 2 ml of respective diluted samples was manually injected in the split less mode, with split ratio of 1:40 and with mass scan of 50-600 amu. Total running time of GC-MS is 35 min. The relative percentage of the each extract constituents was expressed as percentage with peak area normalisation.

The identity of the components in the extracts was assigned by the comparison of their retention indices and mass spectra fragmentation patterns with those stored on the computer library and also with published literatures. NIST08.LIB [9], WILEY8.LIB [10], PESTEI_3.LIB, and FA_ME.LIB library sources were used for matching the identified components from the plant material.

RESULTS AND DISCUSSION

Antimicrobial activity

Antimicrobial activity and MIC of the extracts was measured using agar well diffusion method (Table 1). Bark extract was active against most of the tested extracts. The extract exhibits higher to moderate activity towards *B. subtilis, P. aruginosa, R. planticola* with inhibition zone of 18.33 ± 0.33, 18.33 ± 0.57 and 16.00 ± 0.57 mm and MIC of 62.5, 31.25 μg/ml in last two cases respectively. Further dichloromethane extract also exhibited appreciable activity against *B. subtilis, E.coli* and *P. aeruginosa* (IZ of 19.33 ± 0.88, 16.00 ± 0.57 and 18.00 ± 0.57 mm respectively with MIC 125, 15.62 and 125 μg/ml respectively). The result reveled that ethyl acetate extract exhibited potentials similar to positive control.

Antioxidant activity

1,1-Diphenyl-2-picrylhydrazyl radical scavenging assay

ROS are formed as natural byproducts of normal metabolism and have important role in cell signaling. The effects of ROS on the cell metabolism have been well documented in variety of species (Osawa and Namiki, 1981; Dorman *et al.*, 2003).

The DPPH radical is a stable free radical, which has been widely accepted as a tool for estimating free radical scavenging activities of antioxidants (Sanchez-Moreno, 2002). When DPPH radicals are scavenged, the color of reaction mixture changes from purple to yellow and absorbance at 517 nm decreases. Ethyl acetate extract demonstrated lower IC_{50} value i.e. 5 μg/ml with % inhibition of 97.08 at 80 μg/ml concentration followed by methanol extract (IC_{50} 5.5 μg/ml; % inhibition 96.06) (Table 2).

Reducing power assay

The reduction of Fe (III) ions is often used as a indicator of electron donating activity, which is an important mechanism of the phenolic antioxidant action, and strongly correlated with other antioxidant properties. Among the tested extracts, methanol extract showed appreciable reduction with 1463.33 ± 3.33 AAE/mg dw antioxidant potential (Table 3). Another potential extract was ethyl acetate extract (895.33 ± 3.78 AAE/mg dw), indicating similar reductive potentials to standard ascorbic acid.

On the basis of activities ethyl acetate extracts were analyzed for GC-MS analysis where, 49 distinct peaks were identified through the NIST08 L. database (Table 4). The major compound present in the extract was 1,2-benzenedicarboxylic acid, bis(2-ethylhexyl) ester with RT: 25.28, area 48.47 % (molecular formula: $C_{24}H_{38}O_4$, MW: 390). Other major components were β-caryophyllene (RT: 10.51, area 5.80%), cedryl methyl ester (RT: 12.85, area 5.80%) 9-octadecenoic acid (Area 6.65%), ethyl docosonate(3.81%), hexadecanoic acid (Area 3.24%),

Table 1. Antibacterial activity of *P. pterocarpum* bark.

Microorganisms		Nature of extract			
		Pet. ether	DCM*	Ethyl acetate	Methanol
B. subtilis	IZ[a]	17.66± 0.33	19.33 ± 0.88	18.33 ± 0.33	15.00 ± 0.57
	MIC[b]	125	125	62.5	125
	AI[c]	0.80	0.87	0.83	0.68
E. aerogenes	IZ	13.00 ± 0.00	14.33 ± 0.33	13.00 ± 0.57	13.33 ± 0.66
	MIC	250	250	62.5	250
	AI	0.92	1.02	0.92	0.95
E. coli	IZ	15.00 ± 0.57	16.00 ± 0.57	15.66 ± 0.33	14.00 ± 0.57
	MIC	125	15.62	31.25	31.25
	AI	0.78	0.72	0.71	0.84
P. aruginosa	IZ	15.33 ± 0.33	18.00 ± 0.57	18.33 ± 0.33	15.66 ± 0.33
	MIC	250	125	31.25	31.25
	AI	0.76	0.90	0.91	0.78
R. planticola	IZ	15.33 ± 0.66	15.00 ± 0.57	16.00 ± 0.57	15.00 ± 0.57
	MIC	125	125	31.25	250
	AI	0.69	0.68	0.72	0.68
S. aureus	IZ	14.66 ± 0.33	15.33 ± 0.33	14.66 ± 0.70	13.33 ± 0.88
	MIC	500	125	250	125
	AI	0.69	0.73	0.69	0.63
A. flavus	IZ	14.00 ± 0.57	13.33 ± 0.67	-	12.84 ± 0.56
	MIC	250	250	-	250
	AI	0.51	0.49	-	0.46
A. niger	IZ	10.33 ± 0.33	12.33 ± 0.33	11.00 ± 0.66	11.00 ± 1.00
	MIC	250	500	62.5	125
	AI	0.45	0.45	0.40	0.40
C. albicans	IZ	13.66 ± 0.66	14.66 ± 0.88	15.66 ± 0.88	12.66 ± 0.66
	MIC	250	62.5	500	1000
	AI	0.50	0.66	0.71	0.57
P. chrysogenum	IZ	13.33 ± 0.66	13.33 ± 0.66	15.33 ± 0.33	12.66 ± 0.66
	MIC	125	250	250	62.5
	AI	0.63	0.63	0.73	0.60
T. rubrum	IZ	13.33 ± 0.33	12.66 ± 0.33	14.33 ± 0.33	12.66 ± 0.66
	MIC	250	250	62.50	500
	AI	0.45	0.45	0.49	0.43

Test samples 4 mg/well. Standard test drugs: Gentamycin for bacteria, Ketonocozole for fungi (10 mcg/disc). DCM*=Dichloromethane.
IZ[a]=Inhibition zone (in mm) including the diameter of well (6 mm). MIC[b]= Minimum inhibitory concentration in µg/ml.
AI[c] = Activity index = Inhibition zone of the sample/Inhibition zone of the standard.

Table 2. Antioxidant activity of *P. pterocarpum* bark by DPPH method.

Nature of extract		[a]% Inhibition (concentration in µg/ml)				
	IC_{50}	10	20	40	60	80
Pet. ether	6.5	78.07 ± 2.80	90.62 ± 1.95	93.81 ± 0.76	94.58 ± 0.28	94.88 ± 0.68
DCM	6	84.10 ± 0.39	85.99 ± 0.06	89.59 ± 0.10	91.13 ± 0.28	94.63 ± 0.11
Ethyl acetate	5	96.26 ± 0.19	96.57 ± 0.08	96.93 ± 0.18	96.95 ± 0.26	97.08 ± 0.31
Methanol	5.5	86.54 ± 0.30	93.48 ± 0.76	95.80 ± 0.09	96.01 ± 0.06	96.06 ± 0.11
Quercetin	4	62.42	80.58	93.38	93.82	94.71

s[a]% Inhibition = 1-(Absorbance of the sample/Absorbance of the control) × 100

Table 3. Antioxidant activity of *P. pterocarpum* bark by FRAP method.

Nature of extract	Antioxidant activity in [b]AAE /mg dw (concentration in µg/ml)				
	62.5	125	250	500	1000
Pet. ether	37.00 ± 3.00	151.00 ± 0.00	176.66 ± 13.97	408.33 ± 10.14	864.66 ± 17.72
DCM	41.66 ± 4.41	47.00 ± 3.51	121.66 ± 10.48	306.66 ± 12.02	726.00 ± 6.69
Ethyl acetate	85.00 ± 5.78	179.00 ± 10.11	301.66 ± 1.66	573.00 ± 14.23	895.45 ± 3.78
Methanol	113.33 ± 7.27	160.00 ± 15.29	268.66 ± 7.82	630.00 ± 16.09	1463.33 ± 3.33
Ascorbic acid	62.5	125	250	500	1000

[b]AAE/g = Ascorbic acid equivalent/ mg extract

Gas chromatography-Mass spectrophotometry analysis

Table 4. GC-MS spectra of bark ethyl acetate extract of *P. pterocarpum.*

Peak	R.Time	Area%	Name	Properties known
1.	10.517	5.80	β-caryophyllene	Anti-inflammatory
2.	10.952	2.57	α-humulene, α-caryophyllene	Antitumor, antimicrobial
3.	12.023	0.71	Elemol	Neruropharmacological properties
4.	12.854	5.80	Cedryl methyl ester	Flavor, antitumor, insecticidal
5.	14.055	1.10	Benzene, ethylphenoxy- ar-ethylphenyl phenyl ether	-
6.	14.732	0.26	2-phenyldodecane	Anti-carcinoma
7.	14.909	0.35	6-Phenyltridecane	"
8.	14.986	0.23	Heptadecane	Antimicrobial
9.	15.534	0.37	Nonadecane	Antimicrobial, antiradical, spasmolytic
10.	15.789	2.81	2-Phenyltridecane	-
11.	16.272	2.96	Hexadecanoic acid	Antioxidant, hypocholesterol emicnematicide, pesticide, lubricant, antiandrogenic, flavor
12.	16.827	0.41	(1-methylnonadecyl) benzene	-
13.	17.668	0.17	9-Octadecenoic acid	Fungicidal, reduce muscular tension in cardiac muscle
14.	18.730	0.68	Octadecane	Antimicrobial
15.	20.415	0.20	10-12-Pentacosadiynoic acid	Antiviral
16.	21.056	0.26	abieta-9(11),8(14),12-trien-12-ol	-
17.	22.690	1.62	2,4-bis(1-phenylethyl)phenol	Molting hormone
18.	25.287	48.47	1,2-benzenedicarboxylic acid	Antimicrobial, antitick, allelopathic
19.	26.054	0.51	Ethyl docosanoate	Antibody production
20.	28.109	0.40	Tetracontane	Antibacterial, antioxidant
21.	28.630	0.38	Tetracosanoic acid methyl ester	-
22.	29.501	1.05	Ethyl docosanoate	Antibody production
23.	30.009	0.47	Squalene, Spinacene	Antioxidant, antitumor
24.	30.823	0.27	Tetratriacontane	Antioxidant, antimicrobial
25.	30.907	0.23	1-Eicosanol	Antidiabetic, antioxidant, anticholinesterase
26.	33.242	1.97	2,4,6-Tris-(1-phenylethyl)-phenol	Pesticide
27.	33.500	2.45	Acetic acid, 7-isopropyl-3a,3b,9b-trimethyl-2-phenyl-dodecahydro-6-oxa-cyclopenta[a]phenanthren-3-yl ester	-
28.	34.439	0.83	β-Sitosterol	Antimicrobial, anti-inflammatory, analgesic, antipyretic
29.	37.496	0.28	Stigmasta-5,22-dien-3-ol	Antitumor, anti-inflammatory, Antioxidant
30.	38.761	0.19	Stigmast-5-en-3-ol	Insecticidal, fungicidal, antioxidant
31.	40.308	0.24	Lupeol	Antibacterial, Antioxidant, Antitumor
32.	42.209	0.23	Stigmast-4-en-3-one	Antioxidant
33.	43.463	0.40	3-Hydroxy-6-isopropenyl-4,8a-dimethyl-octahydro-2-naphthalenyl acetate	
		100.00		

benzene, 2-phenyltridecane (RT: 15.78, area 2.81%), tricontane (1.35%), β–sitosterol (0.83%), heptadecane (0.76%), tricosane (0.68%) and octacosane (0.60%). Further, properties of identified compounds have been given in Table 4.

Several plants reported elevated antimicrobial potentials due to presence of long chain (C6 to C10) alcohols and aldehydes like hepadecane, nonadecane, hexadecanoic acid, tricosane and triacontane (30). Hydrophobicity enables these compounds to partition the lipids of the bacterial cell membrane, disturbing the cell structures and rendering them more permeable (Sikkema *et al.*, 1994). Extensive leakage from bacterial cells or the exit of critical molecules and ion will lead to death (Denyer and Hugo, 1991). Long chain (C6 to C10) alcohols were particularly active against Gram-positive bacteria (Delaquis *et al.*, 2002), the antimicrobial properties of alcohols were known to increase with molecular weight (Morton, 1983). Further purification and bioactivities are in active progress.

New antimicrobial agents against bacterium are very valuable, especially in multidrug resistant strain. Present investigation for antibacterial, antioxidant and chemical investigation supports traditional use of bark infusion as therapeutic agent. Further, the plant can be used as antibacterial supplement in the developing countries towards the development of new drug of natural origin. Additional *in vivo* studies and clinical trials will also be needed to justify the potentials of ethyl acetate extract in topical and oral applications.

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REFERENCES

Ahmad, K.F. and Sultana, N. 2003. Studies on Bioassay Directed Antifungal Activity of Medicinal Plants *Calotropis procera, Skimmia laureola, Peltophorum pterocarpum* and two pure Natural compounds ulopterol and 4-methoxy-l-methyl- 3-(2 'S-hydroxy-3 '-ene butyl)-2-quinolone. *J. Chem. Soc. Pakistan*. 25: 328-330.

Al-Duais, M., Muller, L., Bohm, V. and Jetschke, G. 2009. Antioxidant capacity and total phenolics of *Cyphostemma digitatum* before and after processing: Use of different assays. *European Food Res. Technol*. 228: 813-21.

Badami, R.C. and Daulatabad, C.D. 1969. Component acids of *Tamarindus indica, Peltophorum ferrugineum* and *Albizzia ulibrassian. J. Karnataka Univ.* 14: 204.

Boyanova, L., Gergova, G., Nikolov, R., Derejian, S., Lazarova, Katsarov, N., Mitov, I. and Krastev, Z. 2005. Activity of Bulgarian propalis against 94 *Helicobacter pylori* strains *in vitro* by agar well diffusion, agar dilution and disc diffusion methods. *J. Med. Microbiol.* 54: 481-3.

Cespedes, C.L., El-Hafidi, M., Pavon, N. and Alarcon, J. 2008. Antioxidant and cardioprotective activities of phenolic extracts from fruits of Chilean Blackberry *Aristotelia chilensis* (Elaeocarpaceae), Maqui. *Food Chem.* 107 : 820-829.

D'Costa, V., King, C., Kalan, L., Morar, M., Sung, W., Schwartz, C., Froese, D., Zazula, G., Calmels, F., Debruyne, R., Golding, G.B., Poinar, H.N. and Wright, G.D. 2011. Antibiotic resistance is ancient. *Nature*. 477: 457–461.

Delaquis, P.J., Stanich, K., Girard, B. and Mazza, G. 2002. Antimicrobial activity of individual and mixed fractions of dill, cilantro, coriander and eucalyptus essential oils. *Int. J. Food Microbiol.* 74 : 101–109.

Denyer, S.P. and Hugo, W.B. 1999. Biocide-induced damage to the bacterial cytoplasmic membrane. In: Denyer, S.P. and Hugo, W.B. (Eds.) *Mechanisms of Action of Chemical Biocides*. Oxford Blackwell Scientific Publication. Oxford. Pp171-88.

Deshaprabhu, S.B. (Ed.). 1966. The Wealth of India-*An Encyclopedia of India's Raw Material Resources*. Vol. VII, CSIR, New Delhi, India. Pp291.

Donadio, S., Maffioli, S., Monciardini, P., Sosio, M. and Jabes, D. 2010. Antibiotic discovery in the twenty-first century: Current trends and future perspectives. *J. Antibiotics.* 63: 423–430.

Dorman, H.J.D., Peltoketo, A., Hiltunen, R. and Tikkanen, M.J. 2003. Characterization of the antioxidant properties of de-odourised aqueous extracts from selected Lamiaceae herbs. *Food Chem.* 83 : 255–262.

Duraipandiyan, V., Ayyanar, M. and Ignacimuthu, S. 2006. Antimicrobial activity of some ethnomedicinal plants used by Paliyar tribe from Tamilnadu, India. *BMC Complement Altern. Med.* 17 : 35-42.

Fogliano, V., Verde, V., Randazzo, G. and Ritieni, A. 1999. A method for measuring antioxidant activity and its application to monitoring the antioxidant capacity of wines. *J. Agric. Food Chem.* 47 : 1035-1040.

Gulcin, I., Elias, R., Gepdiremen, A., Taoubi, K. and Koksal, E. 2009. Antioxidant secoiridoids from fringe tree (*Chionanthus virginicus* L.). *Wood Sci. Technol.* 43 : 195-212.

Huhtanen, C.N. 1980. Inhibition of *Clostridium botulinum* by spice extracts and aliphatic alcohols. *J. Food Prot.* 43 : 195-196.

Kumar, K.S., Ganesan, K. and Subba Rao, P.V. 2008. Antioxidant potential of solvent extracts of *Kappaphycus alvarezii* (Doty) Doty-an edible seaweed. *Food Chem.* 107 : 289-295.

Lu, Y., Zhao, Y.P., Wang, Z.C., Chen, S.Y. and Fu, C.X. 2007. Composition and antimicrobial activity of the essential oil of *Actinidia macrosperma* from China. *Nat. Prod Res.* 21 : 227-233.

Mbwambo, Z.H., Moshi, M.J., Masimba, P.J., Kapingu, M.C. and Nondo, R.S. 2007. Antimicrobial activity and brine shrimp toxicity of extracts of *Terminalia brownie* roots and stem. *BMC Complement Altern. Med*. **7:** 9-13.

Menon, P.S., Gangabai, G., Swarnalakshmi, T., Sulochana, N. and Amala, B. 1982. Chemical and pharmacological studies on *Peltophorum pterocarpum. Indian Drugs*. 19 : 345-7.

Morton, H.E.1983. Alcohols. In: Block SS (Eds.) *Disinfection, Sterilization and Preservation*. Lea and Febiger, Philadelphia, USA. 225– 239.

Osawa, T. and Namiki, M. 1981. A novel type of antioxidant isolated from leaf wax of eucalyptus leaves. *Agric. Biol. Chem.* 45 : 735–739.

Rahman, W., Ilyas, M. and Hameed, M.N. 1969. Flower pigment flavonoids glycosides from *Peltophorum inermis. J. Indian Chem. Soc.* 46 : 278.

Sanchez-Moreno, C. 2002. Reviews: methods used to evaluate the free radical scavenging activity in foods and biological systems. *Food Sci. Technol. Int.* 8 : 121–137.

Sastry, K.N.S., Sulochana, V., Rao, V.S.S. and Reddy, K.K. 1977. Studies on Iyal Vagai (*Peltophorum ferrugineum)* tannins. Part III. Identification of plant acids, polyols and amino acids in different parts of *Iyal Vagai*. *Leather Sci.* 24: 394-396.

Senatore, F., Rigano, D., Formisano, C., Grassia, A., Basile, A. and Sorbo, S. 2007. Phytogrowth-inhibitory and antibacterial activity of *Verbascum sinuatum*. *Fitoterapia.* 78 : 244-247.

Sikkema, J., De Bont, J.A.M. and Poolman, B. Interactions of cyclic hydrocarbons with biological membranes.*J. Biol. Chem.* 269 : 8022-8028.

Singh, G., Maurya, S., Delampasona, M.P. and Catalan, C.A**.** 2007. A comparison of chemical, antioxidant and antimicrobial studies of cinnamon leaf and bark volatile oils, oleoresins and their constituents. *Food Chem. Toxico.* 45 : 1650-1661.

Sulochana, V., Sastry, K.N.S., Rao, V.S.S. and Reddy, K.K. 1970. Isolation of berginin from *Peltophorum ferrugineum*. *Leather Sci.* 17: 327.

Swarnlakshmi, T., Sethuraman, M.G., Sulochana, N. and Arivudainambi. R. 1984. A note on the anti-inflammatory activity of berginin. *Curr. Sci.* 53 : 917-919.

Varshney, I.P. and Dubey, N.K. 1969. Chemical examination of flowers of *Peltophorum inermis* Roxb. *J. Indian Chem. Soc.* 46 : 805-806.

Voravuthikunchai, S., Lortheeranuwat, A., Jeeju, W., Sririrak, T., Phongpaichit, S. and Supawita, T. 2004. Effective medicinal plants against enterohaemorrhagic *E. coli* 0157:H7. *J. Ethnopharmacol.* 94 : 49-54.

Wang, J., Yuan, X., Sun, B., Tian, Y. and Cao, Y. 2009. Scavenging activity of enzymatic hydrolysates from wheat bran. *Food Technol. Biotechnol.* 47 : 39-46.

Yen, G.C. and Chen, H.Y. 1995. Antioxidant activity of various tea extracts in relation to their antimutagenicity. *J. Agric. Food Chem.* 43 : 27-32.