Phytochemicals and Metabolites as Antimicrobial Agents from Medicinal Plants of Bangladesh: A Review

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ABSTRACT

Microbial infection and contamination have become major concern during last few decades. A vast array of microorganisms is responsible for devastating consequences like- human and other animal infection, food poisoning, resource contamination etc. Beyond this, antimicrobial resistance against many natural, synthetic and semi synthetic compounds has raised our concern about the possible way to get rid of such complication. All classes of people are not accessible to the commercially available antimicrobials due to their expensiveness. Moreover, commercially available antimicrobials are not preferable to everyone due to their toxicity and other side effects. Many phytochemicals and secondary metabolites from plants such as, flavonoids, tannins, terpenoids, essential oil, saponins have been shown to have *in vitro* antimicrobial activities with less toxicity and side effects. Many of these compounds are even effective against a range of resistant strains. Bangladesh is an agricultural country and tremendous variety of medicinal plants with antimicrobial property is available here. This study has been designed to find out the medicinal plants from Bangladesh with antimicrobial activity, their effective antimicrobial bioactive compounds and the range of microorganisms upon which these compounds are active. Hopefully, this study will raise research interest among researchers about the active antimicrobial agents from medicinal plants.

Keywords: Antimicrobial, Bioactive compounds, Bangladesh, Medicinal plants, Phytochemicals, Secondary metabolites

INTRODUCTION

Medicinal plants are the natural sources of many bioactive compounds which trigger different functions in human body. Wide variety of medicinal plants is being used for the treatment of multiple diseases from ancient time by the people in rural areas around the world (Newman et al., 2000). Numerous plants among them have predominant antimicrobial activities against different pathogenic and non pathogenic microbes (Srivastava et al., 1996). Effective bioactive compounds with antimicrobial activities found in these plants include phytochemicals and many secondary metabolites of pharmaceutical value. Although *in vitro* screening of many phytochemicals has already been done, potentiality of many compounds is still to be explored (Cowman, 1999). This review article comprises the effectiveness of multiple (50) medicinal plants with antimicrobial activity found in Bangladesh. However, further research study may be required to find out the best possible antimicrobial agent from medicinal plant.

PROBABLE MECHANISM OF ANTIMICROBIAL ACTION OF PLANT DERIVED COMPOUNDS

Different plant derived compounds follow different modes of action to exhibit their antimicrobial property. And different plants are effective against different types and strains of microorganisms such as- gram positive and gram negative bacteria and fungi. For example, Saponins usually exhibit antimicrobial property by pore formation in the fungal cytoplasmic membrane. Allicin interacts with the thiol (-SH) group of many enzymes and disrupt their function. Alongside this, Apigenin and Quercetin interrupt the DNA replication process of microorganisms. Yet another types of plant metabolites such as, Resveratrol and Solenopsin A have been shown to exhibit antimicrobial activity by interfering with the cellular communication between

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multiple microorganisms. A range of other metabolites have been shown to coagulate the intracellular components of microorganisms. Thus the probable mechanisms of antimicrobial activity of plant derived metabolites can be attributed to 5 possible routes- (1) the disruption of membrane function and structure, (2) interruption of DNA/RNA synthesis and function, (3) interference with intermediary metabolism, (4) induction of coagulation of cytoplasmic constituents and (5) interruption of normal cell communication (Radulovic et al., 2013)

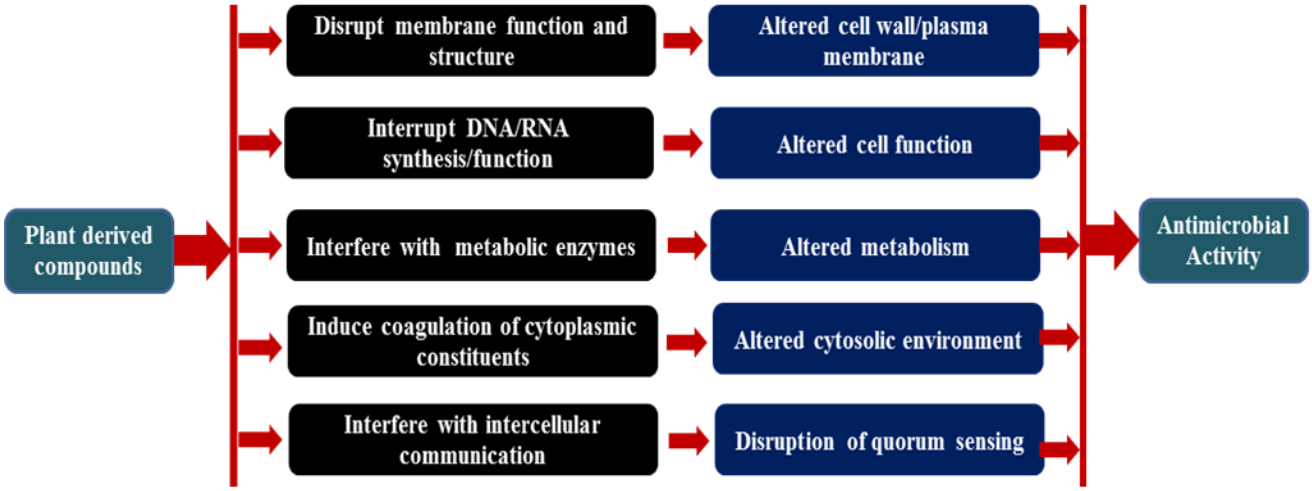

Figure 1: Probable mechanisms of antimicrobial action of plant derived compounds. (Modified from Radulovic et al., 2013)

Medicinal Plants of Bangladesh with Antimicrobial Activity

Bangladesh is an excellent repository of medicinal plants and different plants belonging to different family have been used in Ayurvedic and Unani formulation from long period of time (Rahman et al., 2001). Table 1 listed some medicinal plants of Bangladesh with antimicrobial activity and other information.

Table 1: Medicinal plants with antimicrobial activity, their effective compounds and range of target microorganisms.

Sl. No.	Species	Family	Common Name (English, Bengali)	Effective Plant Part(s) Used	Antimicrobial Bioactive Compound(s)	Effective Against	Ref.
01.	*Acorus calamus*	Acoraceae	Sweet flag, Bach	Rhizome	β-asarone	*Staphylococcus aureus, Bacillus subtilis, Staphylococcus aureus*	(McGaw et al., 2002)
02.	*Adhatoda vasica*	Acanthaceae	Malabur nut, bashok	Leaf	vasicine, vasicinone, vasicine acetate, 2-acetyl benzyl amine, vasicinolone	*Salmonella paratyphi, Candida albicans, Proteus vulgaris*	(Singh and Sharma, 2013; Karthikeyan *et al.* 2009)
03.	*Aegle marmelos*	Rutaceae	Wood Apple, Bael	Whole Plant	Cardiac Glycosides, Terpenoids, Saponins, Tannins, Flavonoids,	*Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus, Bacillus subtilis*	(Venkatesan et al., 2009)

					Steroids		
04.	*Allium cepa*	Amaryllidaceae	Onion, Peyaj	Bulb	Essential oil containing methyl 5-methylfuryl sulfide, methyl 3,4-dimethyl-2-thienyl disulfide, 1-propenyl propyl disulfide	*Escherichia col,i Bacillus subtilis, Staphylococcus aureus, Rhodotorula glutinis, Aspergillus niger, Aspergillus terreus*	(Ye et al., 2013)
05.	*Allium sativum*	Amaryllidaceae	Garlic, Rashun	Bulb	Ajoene, Allicin	*Staphylococcus aurcus, Streptococcus viridians, Bacillus subtilis Bacillus typhimurium, Vibrio cholerae*	(Ledezma and Apitz-Castro, 2006; Cavalitto and Bailey, 1944)
06.	*Aloe vera*	Asphodelaceae	True aloe/Indian aloe, Gritkumari	Leaf	Pyrocatechol, Cinnamic acid, *p*-coumaric acid, Ascorbic acid	*Bacilluscereus, Salmonella typhi, Sterptococcus pyogenes*	(Lawrence et al., 2009)
07.	*Ananus comosus*	Bromeliads	Pineapple, Anaras	Fruit	Bromelain	*Bacillus subtilis, Staphylococcus aureus, Eshcherichia coli, Candida albicans*	(Dutta and Bhattacharyya , 2013)
08.	*Andographis paniculate*	Acanthaceae	Green chirayta, Kalomegh	Whole plant	Andrographolide, 14-deoxy-11-oxoandrographolide, 14-deoxy-11,12-didehydroandrographolide and neoandrographolide	*Pseudomonas aeruginosa, Candida albicans, Bacillus subtilis*	(Singha et al., 2003)
09.	*Bacopa monnieri*	Plantaginaceae	Water hyssop, Brahmishak	Aerial plant part	Betulinic acid, wogonin, oroxindin	*Alternaria Alternate, Fusarium fusiformis*	(Chaudhuri et al., 2004)
10.	*Boerhaavia diffusa*	Nyctaginaceae	Red spiderling, punarnava	Leaf	Quinones, furanoids, sterols, glycosides etc.	*Klebsiella pneumonia, Serratia marcescens, Shigella flexneri, Micrococcus luteus*	(Umamaheswari *et al.* 2010)
11.	*Brassica oleracea*	Brassicaceae	Cabbage, Badha-kopi	Leaves	Glucosinolate-derived isothiocyanates	*Enterococcus faecalis, Listeria monocytogenes, Salmonella*	(Brandi et al., 2006)

						enterica	
12.	*Calotropis gigantea*	Apocynaceae	Gigantic swallow wort, Akand	Leaves	3-O-rutinosides, kaempferol, isorhamnetin, 5-hydroxy-3,7-dimethoxyflavone-40-O-b-glucopyranoside	*Candida albicans, Salmonella enteritidis, Staphylococcus aureus*	(Nenaah, 2013)
13.	*Camellia sinensis*	Theaceae	Tea, Cha	Leaf	Theaflavin, Polyphenon 60	*Shigella dysenteriae, Shigella flexneri*	(Vijaya, 1995)
14.	*Capsicum annuum*	Solanaceae	Red chili, Lal morich	Fruit	Capsaicin	*Vibrio cholera, Pseudomonas solanacearum, Bacillus subtilis*	(Omolo *et al.* 2014; Molina-Torres*et al.* 1999)
15.	*Carica papya*	Caricaceae	Pawpaw, Pepe	Leaf, Fruit	Saponins, Tannins, Glycosides, Phenols	*Shigella flexneri, Pseudomonas aeruginosa, Proteus mirabilis*	(Doughari, 2007)
16.	*Cassia alata*	Fabaceae	Candle bush, dad-mardan	Leaf	Rhein, emodol, 4,5-dihydroxy-1-hydroxy-methylanthrone etc.	*Yeast, Aspergillus flavus, Mucor spp.,Rhizopus spp.*	(Phongpaichit *et al.* 2004)
17.	*Cassia fistula*	*Caesalpiniaceae*	Golden shower, badar lati	Various parts	5-Nonatetracontanone, 2-hentriacontanone, triacontane etc.	*Klebsiella sp., Bacillus mycoides, Mycobacterium smegmatis*	(Misra *et al.* 1996; Panda *et al.* 2011)
18.	*Cassia occidentalis*	Fabaceae	Coffee senna, Kalkashundi	Root	Emodin	*Bacillus subtilis, Staphylococcus aureus*	(Chukwujekwu*et al.* 2006)
19.	*Centella asiatica*	Apiaceae	Centella, thankuni	Aerial part of the plant	Terpenoids including asiaticoside, centelloside,	*Staphylococcus aureus, Proteus vulgaris, Aspergillus niger*	(James and Dubery, 2009; Dash *et al.* 2011)

					brahmoside, thankuniside etc.		
20.	*Citrus aurantium*	Rutaceae	Bitter orange, kumla lebu	Flower	Limonene, E-nerolidol, α-terpineol etc.	*Enterococcus faecalis, Micrococcus luteus, Fusarium oxysporum, Alternaria alternata*	(Hsouna *et al.* 2013)
21.	*Citrus limon*	Rutaceae	Lemon, lebu	Fruit peel	Protopine, lactons, acyclic sesquiterpenes , hypericin etc.	*Salmonella typhimurium, Micrococcus aureus*	(Dhanavade *et al.* 2011)
22.	*Coccinia grandis*	Cucurbits	Ivy gourd, Telakuch	Leaves	Protease inhibitor	*Klebsiella pneumoniae,Proteus vulgaris, Aspergillus flavus*	(Satheesh and Murugan, 2011)
23.	*Curcuma longa*	Zingiberaceae	Turmeric, Holud	Rhizome	Cucurmin & curcuminoids	*Staphylococcus epidermidis, Aeromonas hydrophila, Streptococcus agalactiae, Bacillus subtilis*	(Zorofchian Moghadamtousi*et al.* 2014)
24.	*Datura metel*	Solanaceae	Datura, Dhutra	Leaf, fruit	5,7- dimethyl 6– hydroxy 3, phenyl 3 α - amine β - yne sitosterol 1	*Pseudomonas aeruginosa, Proteus mirabis, Solmonella typhi, Bacillus subtilis*	(Okwu and Igara, 2009)
25.	*Diospyros blancoi*	Ebenaceae	Velvet apple, bilati gab	Leaf	Isoarborinol methyl ether, β-amyrin palmitoleate etc.	*Escherichia coli, Trichophyton mentagrophytes, Candida albicans, Bacillus subtilis*	(Ragasa*et al.* 2009)
26.	*Excoecaria agallocha*	Euphorbiaceae	Blinding Tree, Gewa	Leaves	2, 3-secoatisane type diterpene, 3, 4, 5-trihydroxy methyl benzoate	*Aeromonas hydrophila, Pseudomonas aeruginosa, Vibrio harveyi*	(Raja et al., 2010)
27.	*Ficus carica*	Moraceae	Fig , Dumur	Leaf	Flavonoids like rutin & luteolin, phenolic acids like ferrulic acid	*Streptococcus anginosus, Prevotella intermedia , Porphyromonas gingivalis*	(Jeong*et al.* 2009)
28.	*Gloriosa superba*	Colchicaceae	Flame lily, ulatchandal	Root tuber	Colchicine and its derivatives	*Proteus vulgaris, Salmonella typhi, Rhizopus oryzae, Mucor sp.*	(Hemaiswarya *et al.* 2009)

29.	*Glycyrrhiza glabra*	Fabaceae	Licorice, Yashthimadhu	Root	Glabridin	*Helicobacter pylori, Bacillus megaterium, Micrococcus luteus, Staphylococcus aureus*	(Gupta*et al.* 2008; Ates and Erdogrul, 2003)
30.	*Hibiscus rosa-sinensis*	Malvaceae	Chinese hibiscus, Jaba	Leaf, flower	Cyanidin, hentriacontane, calcium oxalate, thiamine, niacin, n-Hexacosa-3-one-20,21-diol; N Triacontane etc.	*Citrobacter sp., Staphylococcus aureus, Pseudomonas aeruginosa*	(Uddin*et al.* 2010; Siddiqui *et al.* 2006)
31.	*Jatropha curcas*	Euphorbiaceae	Barbados nut, bagh verenda	Seed kernel	2-(Hydroxymethyl)-2 nitro-1,3-propanediol, β-sitosterol, 2-furancarboxaldehyde, 5-(hydroxymethy), acetic acid	*Proteus vulgaris, Pseudomonas aeruginosa and Acinetobacter baumannii*	(Oskoueian *et al.* 2011)
32.	*Mangifera indica*	Anacardiaceae	Mango, Aam	Kernel, stem bark	Gallotannin, mangiferin	*Bacillus pumilus, Trichoderma reesei,* Clostridium botulinum,Campylobacter jejuni	(Engels*et al.* 2011; Shah *et al.* 2010)
33.	*Momordica charantia*	Cucurbits	Bitter gourd, Karola	Leaves	β- sitosterol	*Pseudomonas aeruginosa, Staphylococcus aureus, Klebsiella pneumoniae*	(Sen et al., 2012)
34.	*Nigella sativa*	Ranunculaceae	Black cumin, kalojira	Seeds	Thymoquinone, thymohydroquinone, thymol	*Staphylococcus epidermidis, Streptococcus pyogenes, Staphylococcus aureus*	(Salman*et al.* 2008)
35.	*Ocimum sanctum*	Lamiaceae	Holy basil, tulsi	Seeds	linolenic acid	*Staphylococcus aureus, Micrococcus luteus, Staphylococcus epidennidis, Bacillus pumilus*	(Singh*et al.* 2005)
36.	*Phyllanthus emblica*	Phyllanthaceae	Indian gooseberry, Amlaki	Fruit	beta-caryophyllene, beta-bourbonene, thymol, methyleugenol	*Shigella boydii, Vibrio mimicus, Vibrio parahemolyticus*	(Rahman*et al.* 2009; Liu *et al.* 2009)

37.	*Plumbago zeylanica*	Plumbaginaceae	Doctorbush, Chita	Root	Plumbagin	*Serratia marcescens, Proteus vulgaris, Klebsiella pneumonia, Salmonella typhi*	(Jeyachandran *et al.* 2009)
38.	*Psidium guajava*	Myrtaceae	Guava, Peyara	Leaf	Morin-3-O-a-L-lyxopyranoside andmorin-3-O-a-L-arabopyranoside, guaijavarin etc.	*Salmonella enteritidis, Bacillus stearothermophilus, Brochothrix thermosphacta, Listeria monocytogenes*	(Arima and Danno, 2002; Rattanachaikunsopon and Phumkhachorn, 2010)
39.	*Punica granatum*	Lythraceae	Pomegrante, Dalim	Fruit juice	Gallagic acid, punicalins, punicalagins	*Cryptococcus neoformans, Mycobacterium intracellulare, Candida albicans, Pseudomonas aeruginosa*	(Reddy*et al.* 2007)
40.	*Ricinus communis*	Euphorbiaceae	Castor oil plant, reri	Fruit	sodium ricinoleate from castor oil	*Candida glabrata,* Streptococcus mutans,Candida albicans	(Salles*et al.* 2015)
41	*Saracaasoca*	Fabaceae	Ashoka tree, ashok	Various plant parts	Catechins	*Pseudomonas aeruginosa, Staphylococcus aureus, Klebsiella pneumoniae*	(Shirolkar*et al.* 2013)
42.	*Syzygium aromaticum*	Myrtaceae	Clove, Labanga	Fruit	Eugenol	*Candida albicans, Aspergillus flavus, Microsporum gypseum, Aspergillus niger*	(Pinto*et al.* 2009)
43.	*Tagetes erecta*	Asteraceae	Marigold, Gendaphul	Leaf	Thiophenes	*Acinetobacter baumannii, Enterococcus faecalis, Alcaligen faecalis, Salmonella enteriditis*	(Dasgupta*et al.* 2012)
44.	*Tamarindus indica*	Fabaceae	Tamarind, tetul	Stem bark, leaf, pulp	Phlobatamins, anthraquinone, saponin etc.	*Proteus mirabilis, Shigella flexnerri, Salmonella paratyphi, Pseudomonas aerugenosa*	(Doughari 2006; Abukakar *et al.* 2008)
45.	*Terminalia arjuna*	Combretaceae	Arjun tree, Arjun	Bark	Phytosterols, Lactones, Tannins, Glycosides	*Streptococcus mutans, Staphylococcus aureus, Klebsiella pneumoniae*	(Mandal et al., 2013)
46.	*Terminalia chebula*	Combretaceae	Chebulic myrobalan,	Fruiting bodies	Gallic acid, gallate esters	*Staphylococcus aureus, Bacillus*	(Sato *et al.* 1997)

			Haritaki			*cereus*	
47.	*Vitex negundo*	Lamiaceae	Horseshoe vitex, Nisinda	Leaves and Twigs	Flavone glycosides	*Trichophyton mentagrophytes, Cryptococcus neoformans, Aspergillus fumigatus*	(Sathiamoorthy et al., 2007)
48.	*Withania somnifera*	Solanaceae	Indian ginseng, ashwagandha	Root	Withanolide (WS-1)	*Salmonella typhi, Pseudomonas aeruginosa, Klebsiela pneumonia*	(Kharel *et al.* 2011)
49.	*Xanthium sibiricum*	Asteraceae	Common cocklebur, Ghagra	Leaf	Sesquiterpene lactone	*Staphylococcus aureus, Staphylococcus epidermidis, Klebsiella pneumonia, Salmonella typhi*	(Sato *et al.* 1997)
50.	*Zingiber officinale*	Zingiberaceae	Ginger, Ada	Rhizome	camphene, 1,8-cineol and α-pinene, β-phellandrene and 1,8-cineol	*Fusarium sp. , Bacillus nutto, Pseudomonas aerugenosa*	(Sa-Nguanpuag *et al.* 2011)

DISCUSSION

Variety of medicinal plants possesses different types of secondary metabolites and other phytochemicals which exhibit significant antimicrobial property against variety of microorganisms. Scientists from different field are interested in finding new agent from plant for the use as antimicrobial due to less toxicity and inexpensiveness. Hopefully newly formulated antimicrobials from medicinal plants will be more effective or at least it will be used effectively in combination with commercially available antimicrobials against resistant strains.

CONCLUSION

A well directed *in vitro* study may be required to find the best possible antimicrobial from the medicinal plants. It will be advantageous for the people of all classes to use the less expensive form of medication to treat infection and diseases.

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