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WORLD WIDE USED TRADITIONAL MEDICINAL PLANTS AGAINST *Staphylococcus aureus* STRAINS. A REVIEW

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Abstract

Staphylococcus aureus is an extraordinarily adaptable pathogen with a proven ability to develop resistance. It is notorious for its ability to become resistant to antibiotics. Infections that are caused by antibiotic-resistant strains often occur in epidemic waves that are initiated by one or a few successful clones. Also, it is a virulent pathogen that is currently the most common cause of infections in hospitalized patients. S. aureus infection can involve any organ system. The success of S. aureus as a pathogen and its ability to cause such a wide range of infections are the result of its extensive virulence factors. It is well-known that from ancient times the herbal world was the answer for many bacterial diseases. Throughout the years numerous investigations concerning the inhibition of S. aureus by spices, herbs, their extracts, essential oils and various constituents have been reported. Many of these plant extracts possess significant antimicrobial activity, which in many cases is due primarily to a particular constituent: polyphenols, flavonoids, alkaloids. Interpretation and results comparison of various studies is complicated by variations in the methodology used for the determination of antimicrobial activity.

***Key words**: plant extracts, S. aureus, antimicrobial activity.*

INTRODUCTION

Humans are dependent upon plants. Directly or indirectly, plants provide food, clothing, fuel, shelter, and many other necessities of life.
Ever since ancient times, in search for rescue for their disease, the people looked for drugs in nature (Petrovska, 2012). Nature has bestowed on us a very rich botanical wealth and a large number of diverse types of plants grow in different parts of the world.
Since time immemorial people have tried to find medications to alleviate pain and cure different illnesses. In every period, every successive century from the development of humankind and advanced civilizations, the healing properties of certain medicinal plants were identified, noted, and conveyed to the successive generations. The benefits of one society were passed on to another, which upgraded the old properties, discovered new ones, till present days. The continuous and perpetual people's interest in medicinal plants has brought about today's modern and sophisticated fashion of their processing and usage (Petrovska, 2012).
Approved by nature, extracted by science and confirmed by scientists, aromatic and medicinal plants have been used as traditional treatments for numerous human diseases for thousands of years and in many parts of the world. *Staphylococcus* is part of the human indigenous microflora and is carried asymptomatically in a number of body sites. Transmission from these sites causes both endemic and epidemic diseases. *Staphylococcus aureus*, a member of the *Staphylococcaceae* family, appears as Gram-positive cocci in clusters. *S. aureus* infection is a major cause of skin, soft-tissue, respiratory, bone, joint, and endovascular disorders. Many strains of *S. aureus* are developing resistance to available antibacterial

agents, creating a serious problem in medical microbiology. The ß-lactam antibiotics are the drugs of choice for the treatment of *S.aureus* infections. Resistance to ß-lactam compounds has been reported for methicillin, oxacillin, nafcillin, cloxacillin, and dicloxacillin. Methicillin resistant *S. aureus* (MRSA) infections can cause abroad range of symptoms depending on parts of the body that are infected. These may include surgical wounds, burns, catheter sites, eyes, skin and blood. Infections often result in redness, swelling and tender-ness at the site of infection and possibly progress to severe diseases. Methicillin resistance is most commonly mediated by the *mecA* gene, which encodes for a single additional penicillin binding protein, PBP2a, with low affinity for all ß-lactams. *S. aureus* is also resistant to other commonly used antimicrobial agents including aminoglycosides, macrolides, chloramphenicol, tetracycline, and fluoroquinolones.

Medicinal plants have been used as remedies for infectious diseases in many tropical countries, providing a rationale for investigating natural products for the treatment of MRSA infection.

The uncertainty evolving around micro- and macrolevel determinants influencing antimicrobial resistance makes long-term prediction challenging. Although simulation studies may provide guidance about short-term trends, long-term predictions about the future of antimicrobial resistance are fraught with difficulties, as shown by a look back in history. When the antimicrobial drug era began, scientists were impressed by the milestones of antimicrobial agent discovery and issued predictions about the future of antimicrobial resistance that seem overly optimistic today. (Harbarth and Samore, 2005).

This bibliographic study aims to present a brief review of the most important scientific findings about medicinal herbs that possess antimicrobial activity against *S. aureus* (MRSA).

The study is focused on the medicinal plants from four continents, two of them considered developed (Australia and North America) and others developing-countries (Africa, Asia) and it shows the interest for traditional medicine offered by nature itself.

ANTIBACTERIAL CHARACTERISTICS OF ACTIVE COMPOUNDS FOUND IN PLANT EXTRACTS

The natural products derived from medicinal plants have proved to be an abundant source of biologically active compounds, many of them being the basis for the development of new chemicals for pharmaceuticals. With respect to diseases caused by microorganisms, the increasing resistance in many common pathogens to currently used therapeutic agents, such as antibiotics and antiviral agents, has led to renewed interest in the discovery of novel anti-infective compounds (Palombo and Semple, 2002).

In nature there are a large number of different types of antimicrobial compounds (phytoalexins) that play an important role in the natural defence of all kinds of living organisms. This research is focused on phenolic phytoalexins, such as e.g. flavonoids.

The flavonoids constitute a large group of secondary plant metabolites that are ubiquitous among higherplants.

They are polyphenolic compounds which generally occur as glycosylated derivatives. As dietary compounds, they are widely known antioxidants that inhibit the oxidation of low-density lipoproteins and reduce thrombotic tendencies (Hertog et al., 1993). Attention has also been paid to their antimicrobial activity, but no dramatic evidence of their effectiveness has been reported (Mori et al., 1987; Barnabas and Nagarajan, 1988; Tsuchiya et al., 1996; Rauha et al., 2000). Plant extracts have the ability to hamper the growth of a diverse range of pathogens because of the presence of natural compounds produced by the plant organs. The result of phytochemical screening revealed the presence of flavonoids and tannins in all extracts. Flavonoids and tannins have been reported to possess antimicrobial activity, the antimicrobial activity of flavonoids is due to their ability to complex with extracellular and soluble protein and to complex with bacterial cell wall while that of tannins may be related to their ability to inactivate microbial adhesions, enzymes and cell envelop proteins (Cowan, 1999).

When comparing data obtained in different studies, most publications provide generalizations about whether or not a plant oil or extract possesses activity against Gram-positive and Gram-negative bacteria and fungi. However, not all of the studies provide details about the extent or spectrum of this activity.

Some publications also show the relative activity of plant oils and extracts by comparing results from different oils tested against the same organism(s).

Due to the large amount of extraction methods and techniques used by different authors in their studies, the comparation of the results is problematic, with previously published results is problematic. First, the composition of plant oils and extracts is known to vary according to local climatic and environmental conditions (Janssen et al. 1987; Sivropoulou et al., 1995). Furthermore, some oils with the same common name may be derived from different plant species (Windholz et al. 1983; Reynolds 1996; Hammer et al., 1999).

Secondly, the method used to assess antimicrobial activity, and the choice of test organism(s), varies between publications (Janssen et al., 1987).

A method frequently used to screen plant extracts for antimicrobial activity is the agar disc diffusion technique (Morris et al., 1979; Smith-Palmer et al., 1998; Yuniati et al., 2018; Chew et al., 2018).

The usefulness of this method is limited to the generation of preliminary, qualitative data only, as the hydrophobic nature of most essential oils and plant extracts prevents the uniform diffusion of these substances through the agar medium (Janssen et al., 1987; Rios et al., 1988). Agar and broth dilution methods are also commonly used.

The results obtained by each of these methods may differ as many factors vary between assays (Janssen et al., 1987; Hili et al., 1997).

These include differences in microbial growth, exposure of micro-organisms to plant oil, the solubility of oil or oil components, and the use and quantity of an emulsifier.

Table 1. Chemical composition of certain plant extracts and their antibacterial activity against *S. aureus* strains

Africa

Herbs – plant origin (country)	**Plant source**	**Extraction method**	**Active phytochemicals**	***S.aureus* strains**
Nigeria				
(Okigbo & Mmeka, 2008) *Vernonia amygdalina* *Garcinia kola* *Cymbopogon citratus*	leaves seeds leaves	ethanol cold water hot water	- not determined and specified	*S. aureus*
(Akinyemi et al., 2005) *Terminalia avicennioides* Guill & Perr. *Phylantus discoideus* Müll. Arg. *Ocimum gratissimum* Linn. *Acalypha wilkesiana* Müll. Arg.	barks barks leaves leaves	ethanol water	alkaloids, tannins, saponins, anthraquinone flavonoids, reducing and non-reducing carbohydrates	MRSA
(Aliyu et al., 2008) *Acacia albida* Del. *Anchomanes difformis* Engl. *Boscia senegalensis* (PERS) Lam. *Moringa oleifera* Lam. *Momordica basalmina* Linn *Pavetta crassipes* K. Schum. *Phyllanthus amarus* Schumach & Thonn. *Vernonia blumeoides* Hook. f.	stem bark roots roots leaves whole plants leaves whole plants aerial parts	methanol ethanol	alkaloids, anthraquinone flavonoids, cardiac glycosides, tannins, saponins,	MRSA
South Africa				
(Eloff, 1998) *Combretum molle* R. Br. ex G. Don (Combretaceae)	leaves	acetone	not determined and not specified	*S. aureus* ATCC 29213
(Aiyegoro et al., 2009) *Helichrysum pedunculatum*	leaves	methanol	not determined and not specified	*S. aureus* ATCC 6538

Asia

China				
(Zuo et al., 2008) *Anemone rivalry* Buch.-Ham. *Biota orientalis* (L.) Endl. *Conyza blinii* Levl. *Dendrobenthamia capitata* (Wall.) Hutch. *Dichrocephala chrysanthemifolia* (Bl.) DC. *Duchesnea indica* (Arulr.) Forke *Elsholtzia blanda* Benth. *Elsholtzia rugulosa* Hemsl. *Gaultheria yurmaneiisis* (Fr.) Rehd. *Geranium strictipes* K. Kunth *Keineckea carnea* (Andr.) Kunth. *Physalis alkekengi* L. *Polygonum multiflorum* Thunb. *Potentilla fulgens* Wall. *Rosa laevigata* Michx. *Rubia cordifolia* L. *Schizandra spaeraridra* Stapf. *Senecio scandens* Buch.-Ham. *Tetrastigma hypoglaucum* PI.	rhizomes aerial parts aerial parts aerial parts whole plants whole plants aerial parts whole plants whole plants roots whole plants fruits rhizomes fruits rhizomes whole plants aerial parts whole plants roots	ethanol	not determined and not specified	MRSA
Iran				
(Tohidpour et al., 2010) *Thymus vulgaris* *Eucalyptus globulus*	aerial parts	essential oils	thymol, ρ-Cymene, γ-Terpinene, Eucalyptol, (+) Spathulenol, α-Pinene,	MRSA ATCC 33592 *S. aureus* ATCC 25922 14 MRSA strains
(Mansouri, 2008) *Menta viridis* L. *Myrtus communis* L. *Glycyrrhiza glabra* L. *Eucalyptus globolus* Labill. *Satureia hortensis* L. *Teucrium polium* L. *Achillea santolina* L.	leaves leaves rhizomes leaves leaves flowers flowers	ethanol	not determined and not specified	*S. aureus* ATCC 25923 *S. aureus* ATCC 9144 *S. aureus* ATCC 29737 *S. aureus* ATCC 12596 *S. aureus* Bristol A 9596 489 *S. aureus* strains
Palestine				
(Abu-Shanab et al., 2004) *Syzyium aromaticum* (Myrtaceae) *Cinnamomum cassia* (Lauraceae) *Salvia officinalis* (Lamiaceaea) *Thymus vulgaris* (Lamiaceaea) *Rosmarinus officinalis* (Labiatae)	seeds barks leaves leaves leaves	hot water ethanol methanol	not determined and not specified	MRSA
(G. Adwan & Mhanna, 2008) *Psidium guajava* *Rosmarinus officinalis* *Salvia fruticose*	leaves leaves leaves			

Majorana syriaca *Ocimum basilucum* *Rosa damascene* *Laurus nobilis* *Syzygium aromaticum*	leaves leaves flowers leaves dried flowerbuds	hot water	not determined and not specified	4 MSSA MRSA
(Abu - Shanab et al. , 2006) *Althaea officinalis* *Mentha longifolia* *Melissa officinalis* *Rosa damascene*	aerial parts aerial parts aerial parts flowers	hot water ethanol	corilagin, tellimagrandin	MRSA
(Jarrar et al., 2010) *Rosmarinus officinalis*	leaves	ethanol	flavonoids, phenolic acids (caffeic, chorogenic and rosmarinic), essencial oils (camphor and cineole), diterpenes (carnosol)	5 MRSA strains *S. aureus* ATCC 25923
(Adwan et al., 2008) *Rhus coriaria* *Psidium guajava* *Lawsonia inermis* *Sacropoterium spinosum*	leaves leaves leaves seeds	ethanol water	not determined and not specified	4 MRSA strains
Thailand				
(Chomnawang et al., 2009) *Barleria lupulina* *Eupatorium odoratum* *Garciniaman gostana* *Hibiscus sabdariffa* *Lawsonia inermis* *Psidium guajava* *Senna alata* *Tagetes erecta*	fruit hulls	ethanol	α- mangostin	*S. aureus* ATCC 25923 MRSA strain
(Voravuthikunchai & Kitpipit, 2005) *Acacia catechu* *Garcinia mangostana* *Impatiens balsamina* *Peltophorum pterocarpum* *Psidium guajava* *Punica granatum* *Quercus infectoria* *Uncaria gambir* *Walsura robusta*	not specified	water ethanol	Tannins	*S. aureus* ATCC 25923 MRSA strain
Turkey				
(Özkan et al., 2004) *Rosa damascene* Mill.	flowers	methanol	phenolic compounds, essential oil	S. *aureus* Cowan 1
(Erdoğrul, 2002) *Artemisia absinthium* (Compositae/Asteraceae) *Rosmarinus officinalis* L. (Labiatae/Lamiaceae)	whole plants leaves	ethyl acetate methanol chlorofor m acetone	essential oil: α-fenchene, β-myrcene, *endo*-bornyl acetate, and β-pinene essential oil: α-pinene, borneol, 1,8-cineol, camphor, α-terpineol, camphene, and β-pinene	*S. aureus* ATCC 25923
Bangladesh				
(Alam et al., 2009) *Swertia chirata*	leaves and stems	ethanol	flavonoids, xanthones, terpenoids, iridoid and secoiridoid glycosides	*S. aureus*
India				
(Anas et al., 2008) *Psidium guajava* Linn.	leaves	acetone methanol -water	Tannins	Multi drug resistant *S. aureus*
(Parekh & Chanda, 2008)			cellogenamide-a cyclic	

Celosia argentea L. *Vernonia anthelmintica* (L.) Willd. *Balanites aegyptiaca* (L.) Del. *Spathodea campanulata* Beauv. *Cassia fistula* L. *Beta vulgaris* L. *Rourea santaloides* (Vahl.) Wight &. Arnott *Cressa cretica* L. *Lepidium sativum* L. *Lagenaria vulgaris* Seringe *Momordica charantia* L. *Mukiamadera spatana* (L.) M. Roem. *Cyperus scarious* R. Br. *Cordia dichotoma* Forst. *Ricinus communis* L. *Arachis hypogaea* L. *Vigna radiata* L. *Fumaria indica* (Haussk.) Pugsley. *Mesua ferra* Linn. *Ocimum kilimanjaricum* L. *Cinnamom umtamala* Nees & Ebern. *Wood for diafruticosa* Kurz. *Thespesia populnea* (L.) Sol ex Correa. *Artocarpus hetrophyllus* Lam. *Gardenia resinifera* Roth. *Manilkara hexandra* (Roxb.) Dubard.	whole plants whole plants whole plants aerial parts leaves leaves roots roots seeds fruits fruits aerial parts seeds leaves leaves leaves whole plants seeds seeds whole plants leaves flowers leaves whole plants gum exudate leaves	water methanol ethanol	peptide, phenols, flavonoids, resin, essential oil, saponin, argenic acid, mucilage, sugar,fatty acids, glucosides, phenols, tannins, anthraquinone derivatives, gluten, sugar, gum, betin, rourinoside, rouremin, alpha-tocopherol, ascorbic acid, benzyl-isothiocyanate, beta-sitosterol, iodine, niacin, linoleic acid, fixed oils, saponins, vitamins, minerals, 5-hydroxytryptamine, alkaloids, ascorbic acid, beta-carotene, citrulline, cryptoxanthine, diosgenin, lanoscharantin, cryptoxanthin, lutein, lycopene, momordicin, niacin, stigmasterol, zeaxanthin, zeinoxanthin, spinasterol, dihydrospinasterolglucoside, fatty acids, myristic,stearic acid, b-selinne, cyperenone, catharin, gum ash, ricin, ricin oil, palmitin, sterine, palmitic acid, oleic acid, protein, vitamin B1, B2, B6 and containslecithin, proteins, arachidic acid, arginine, ascorbic acid, genstein, shikimic acid, mesuanic acid, mesuaferol, mesuaferrone-A&B, β-sitosterol, xanthones, coumarins, methyl cinamate, camphor, eugenol, terpene, cinnamic aldehyde oil saffral, naturally acquired yeast microflora, gossypol, herbacetin, kaempferol, gyanomacloin, starch, ash fibre, resinous gum called dikamali,	*S. aureus* ATCC 25923
(Aqil et al., 2005) *Allium sativum(Liliaceae)* *Camellia sinensis (Theaceae)* *Citrus sinensis (Rutaceae)* *Delonix regia (Leguminosae)* *Holarrhena antidysenterica (Apocyanaceae)* *Lawsonia inermis (Lythraceae)* *Ocimum sanctum (Labiatae)* *Punica granatum (Punicaceae)* *Terminalia belerica (Combretaceae)* *Terminalia chebula (Combretaceae)*	bulbs leaves rinds flowers barks leaves leaves rinds fruits fruits	ethanol	phenols, glycosides, saponins, alkaloids, phenols, flavonoids	MRSA MSSA
(Jahan et al., 2011) *Syzygium cumini* (Jamun) *Lawsonia inermis* (Mehndi) *Zizyphus mauritiana* (Ber) *Ocimum sanctum* (Tulsi) *Ficus religiosa* (Peepal)	leaves	ethanol	flavanoids, tannins, alkaloids, anthocyanin, phenols, xanthoproteins, carboxylic acid, coumarins, sterols, saponins, glycosides	MRSA MSSA

(Duraipandiyan et al., 2006) *Acalypha fruticosa* Forsskal Euphorbiaceae *Albizia procera* Benth. Mimosaceae *Cassia alata* L. Caesalpiniaceae *Cassia auriculata* L. Caesalpiniaceae *Cassia auriculata* L. Caesalpiniaceae *Peltophorum pterocarpum* (DC.) Backorex. K. Heyne. Fabaceae *Punica granatum* L. Punicaceae *Syzygium cumini* Skeels. Myrtaceae *Syzygium lineare* Wall. Myrtaceae *Toddalia asiatica* Pers. Solanaceae	aerial parts stem barks leaves leaves flowers flowers roots seeds leaves leaves	hexane methanol	tannins, essential oils	*S. aureus* ATCC 25923
(Mehrotra et al., 2010) *Emblica officinalis* *Azadirachta indica* *Aloe vera* *Camellia sinensisassamica* *Syzygium aromaticum*	fruits leaves leaves leaves buds	ethanol	not determined and not specified	MRSA
(Thosar et al., 2013) *Melaleuca alternifolia* *Lavandula officianalis L. angustifolia* or *L. vera -Labiatae/Lamiaceae* *Thymus* spp., *T. citriodorits, T. vulgaris - Labiatae/Lamiaceae* *Mentha piperita -Lamiaceae/Labiatae* *Eugenia caryophyllata*	whole plants flowers leaves + flowers leaves buds, stems, weeds	essential oils	terpinen-4-ol, α-terpineol and 1,8-, monoterpens, oxides,linalyl, geranyle esters, geraniol, linalool, thymol and carvacrol with borneol, cineol, linalool, menthone, B-cymene, pinene and triterpenic acid, monoterpenic alcohols-menthol, ketones-menthones, tannin complex, gum, resin, glucosides of sterols, eugenol (4-allyl-2-methoxyphenol), acetyleugenol, gallic acid, sesquiterpenes, furfural, vanillin, methyl-n-amyl ketone, flavonoids, carbohydrates, lipids, oleanolicacid, rhamnetin and vitamins	*S. aureus* ATCC 25923

Australia

(Hammer et al., 1999) *Anibaros aeodora* *Apium graveolens* *Boswellia carterii* *Cananga odorata* *Cedrus atlantica* *Citrus aurantifolia* *Citrus aurantium* *Citrus aurantium var. bergamia* *Citrus limon* *Citrus x paradisi* *Citrus reticulate var.madurensis* *Commiphora myrrha* *Coriandrum sativum* *Cucurbita pepo* *Cupressus sempervirens* *Cymbopogon citratus* *Cymbopogon martini* *Cymbopogon nardus* *Daucus carota* *Eucalyptus polybractea* *Foeniculum vulgare*	woods seeds resins flowers woods fruits peels, leaves and twigs peels peels peels peels resins seeds seeds leaves and twigs leaves leaves leaves seeds leaves and twigs seeds			

Gaultheria procumbens	herbs			
Juniperus communis	berries			
Lavandula angustifolia	flowers	essential	not determined	*S. aureus*
Macadamia integrifolia	nuts	oils	and not specified	NCTC
Melaleuca alternifolia	leaves and twigs	fixed oils		6571
Melaleuca cajuputi	leaves and twigs			
Melaleuca quinquenervia	leaves and twigs			
Mentha x piperita	herbs			
Mentha spicata	herbs			
Ocimum basilicum	herbs			
Oenotherabiennis	seeds			
Origanum majorana	herbs			
Origanum vulgare	herbs			
Pelargonium graveolens	herbs			
Pimpinella anisum	seeds			
Pimenta racemosa	leaves			
Pinus sylvestris	needles			
Piper nigrum	berries			
Pogostemon patchouli	leaves			
Prunus armeniaca	seeds			
Prunus dulcis	seeds			
Rosmarinus officinalis	herbs			
Salvia officinalis	herbs			
Salvia sclarea	herbs			
Santalum album	woods			
Syzygium aromaticum	buds			
Thymus vulgaris	herbs			
Vetiveria zizanioides	leaves			
Zingiber officinale	rhizomes			
(Palombo & Semple, 2002)				M67638
Amyema quandang (Loranthaceae)	leaves			M67783
Eremophila alternifolia (Myoporaceae)	leaves			M99320
Eremophila duttonii (Myoporaceae)	leaves	ethanol	not determined	M173525
Lepidosperma viscidum (Cyperaceae)	stem bases		and not specified	M180920
				M183909
				S. aureus
				ATCC
				12600

North America

Canada				
(Omar et al., 2000)		1.	7.	13.
Acer rubrum L.		2.	8.	14.
Acer saccharum L.		3.	9.	15.
Betula papyrifera Marsh.		4.	10.	16.
Carya cordiformis K.		5.	11.	17.
Carya ovata K.		6.		18.
Fagus grandifolia Ehrh.	barks and woods	ethanol	not determined	MSSA
Juglans cinerea L.			and not specified	
Prunus serotina Ehrh.			12.	
Populus sp.				
Quercus rubra L.				
Tilia americana L.				
Ulmus americana L.				
(McCutcheon et al., 1994)				
Rhus glabra	barks			
Oplopa naxhorridum	inner barks			
Asarum caudatum	whole plants			
Mahonia aquifolium	roots			
Alnus rubra	barks			
Alnur rubra	catkins			
Betula papyrifera	branches			

Lonicera ciliosa	branches			
Sambucus caerulea	branches			
Sambucus racemosa ssp. *pubens*	barks			
Symphoricarpos albus var. *laevigatus*	branches			
Achillea millefolium ssp. *lanulosa* var. *lanulosa*	whole plants			
Ambrosia chamissonis	aerial parts			
Antennario microphyila	whole plants	methanol	not determined and not specified	MSSAP00017 MRSAP00017
Arnico sororia	aerial parts			
Artemisia ludoviciana var. *latiloba*	aerial parts			
Artemisia michauxiana	aerial parts			
Artemisia tridentata ssp. *tridentata*	branches			
Balsamorhiza sagittata	aerial parts			
Balsamorhiza sagittata	roots			
Chaenactis douglasii	whole plants			
Chrysothamnus nauseous var. *abicaulis*	branches			
Erigeron filifolius	aerial parts			
Gailiardia aristata	aerial parts			
Conocephalum conicum	thalluses			
Cornus canadensis	aerial parts			
Capsella bursa-pastoris	whole plants			
Cardamine angulata	roots			
Juniperus communis	branches			
Empetrum nigrum	branches			
Arctostaphylosuva-ursi	branches			
Arctostaphylosuva-ursi	roots			
Kalmia microphylla ssp. *occidentalis*	branches			
Ledum groenlandicum	branches			
Moneses uniflora	aerial parts			
Monotropauniflora	whole plants			
Ribes sanguineum	branches			
Philadelphus lewisii	branches			
Hypericum perforatum	aerial parts			
Lupinussericeus var. *sericeus*	aerial parts			
Lycopodium clavatum	branches			
Fauria crista-galli	aerial parts			
Nuphar polysepalum	roots			
Nuphar polysepalum	rhizomes			
Epilobium minutum	whole plants			
Larix occidentalis	branches			
Pinuscontorta var. *contorta*	branches			
Pinus ponderosa	branches			
Plantago major	whole plants			
Eriogonum heracleoides	aerial parts			
Eriogonum heracleoides	roots			
Polystichum munitum	rhizomes			
Delphinium nuttallianum var. *nuttallianum*	whole plants			
Ceanothus velutinus	branches			
Amelanchieral nifolia var. *humptulipensis*	branches			
Aruncus sylvester	branches			
Crataegus douglasii	branches			
Fragaria chiloensis	leaves			
Fragaria vesca	leaves			
Geum macrophyllum	roots			
Holodiscus discolor	branches			
Potentilla arguta	roots			
Potentilla pacifica	branches			
Prunus virginiana var. *demissa*	branches			
Prunus virginiana var. *virginiana*	branches			
Rubus parviflorus	branches			
Spiraea pyramidata	branches			
Heuchera cylindrica	roots			
Penstemon fruticosus	branches			
Verbas cumthapsus	leaves			

Glehnialittoralis ssp. *leiocarpa* *Heracleum lanatum* *Heracleum lanatum* *Lomattum dissectum* var. *multifidum* *Osmorhiza purpurea*	roots aerial parts roots roots roots			
United States of America				
(Frey & Meyers, 2010) *Achillea millefolium* *Hieracium pilosella* *Ipomoea pandurata* *Solida gocanadensis* *Silene virginica*	flowers flowers and leaves flowers and leaves leaves leaves	water	not determined and not specified	*S. aureus* [Presque Isle No.4651]

NEW ERA: NEW SYNTHETIC DRUGS, MORE RESISTANT BACTERIAL STRAINS

While the intense selective pressure of antimicrobial drug use has been an important factor in the emergence of resistance, the inconsistent application of infection control guidelines by hospital personnel largely accounts for the dissemination of resistance in the healthcare setting.

Infection control measures to limit the spread of antimicrobial resistance are being increasingly well defined. Despite the increase in the prevalence of resistance of several important pathogens, there has been some success in controlling its clinical impact. Several countries have recently reported a stabilization or decrease in infection rates due to multidrug-resistant *Staphylococcus aureus* (Schrijnemakers et al., 2004).

Novel anti-MRSA modalities of plant antimicrobials such as alteration in efflux pump, inhibition of pyruvate kinase, and disturbance of quorum sensing in MRSA are also summarized which may be promising alternatives to antibacterial drug development in future(Li et al., 2018).

MRSA, a virulent and difficult-to-treat "superbug," can optimize its gene content and expression to create new strains with augmented virulence and colonization capabilities. Being an extraordinarily adaptable pathogen with the proven ability to develop resistance, MRSA is considered an urgent threat to public health (Lakhundi and Zhang, 2018).

CONCLUSIONS

Herbal plants are an important source of new chemical substances with medicinal potential uses.

The increased interest on plant medicines in today's world is from the belief that green medicine is safe and dependable, compared with costly synthetic chemicals that have different adverse effects (Nair and Chanda, 2006).

The present study suggests that plant extracts certainly possess some chemical constituents with antimicrobial properties and these findings are very important in discovering new drugs for the therapy of infectious diseases.

However, further studies are required to isolate and characterize the active constituents responsible for the antimicrobial property of all the plants studied.

So far plants could be the ideal potential sources to explore novel antibacterial drugs even against antibiotic-resistant bacterial strains (Davidson, 2001; Ceylan and Fung, 2004; Tayel et al., 2018).

Also, the resurgence of interest in natural therapies and increasing consumer demand for effective and safe natural products, meaning that quantitative data on plant oils and extracts are required.

In summary, this study confirms that many essential oils and plant extracts possess *in vitro* antibacterial activity against *S. aureus.* However, if plant oils and extracts will be used for food preservation or medicinal purposes, safety and toxicity studies both *in vitro* and *in vivo*, must be made.

REFERENCES

Abu-Shanab, B., Adwan, G., Jarrar, N., Adwan, K. (n.d.). *Antibacterial Activities of Some Plant Extracts Utilized in Popular Medicine in Palestine*.

Adwan, G.M., Abu-Shanab, B.A., Adwan, K.M. (2008). In vitro activity of certain drugs in combination with plant extracts against *Staphylococcus aureus* infections. *Pakistan Journal of Medical Sciences*.

Adwan, G., Mhanna, M. (2008). Synergistic Effects of Plant Extracts and Antibiotics on *Staphylococcus aureus* Strains Isolated from Clinical Specimens. *Middle-East Journal of Scientific Research*, *3*(3), 134–139.

Aiyegoro, O.A, Afolayan, A.J. (2009). Synergestic interaction of Helichrysum pedunculatum leaf extracts with antibiotics against wound infection associated bacteria. *Biological Research*, *42*, 327–338.

Akinyemi, K.O., Oladapo, O., Okwara, C.E., Ibe, C.C., Fasure, K.A. (2005). Screening of crude extracts of six medicinal plants used in South-West Nigerian unorthodox medicine for anti-methicillin resistant Staphylococcus aureus activity. *BMC Complementary and Alternative Medicine*, *5*(1), 6.

Alam, K.D., Ali, M.S., Parvin, S., Mahjabeen, S., Akbar, M.A.A.R. (2009). In vitro Antimocrobial activities of Different Fractions of *Swertia chirata* Ethanolic Extract. *Pakistan Journal of Biological Sciences*, *12*(19), 1334–1337.

Aliyu, A.B., Musa, A.M., Abdullahi, M.S., Oyewale, A. O., Gwarzo, U.S. (2008). Activity of plant extractsused in Northern Nigerian traditional medicine against methicillin-resistant *Staphylococcus aureus* (MRSA). *Nigerian Journal of Pharmaceutical Sciences*, *7*(1), 189–823.

Anas, K., Jayasree, P.R., Vijayakumar, T., Kumar, P.R. M. (2008). In vitro antibacterial activity of Psidium guajava Linn. leaf extract on clinical isolates of multidrug resistant *Staphylococcus aureus*. *Indian Journal of Experimental Biology*, *46*(1), 41–46.

Aqil, F., Khan, M.S.A., Owais, M., Ahmad, I. (2005). Effect of certain bioactive plant extracts on clinical isolates of β-lactamase producing methicillin resistant *Staphylococcus aureus*. *Journal of Basic Microbiology*.

Bassam, Abu-Shanab, Ghaleb, Advin, Naser, Jarrar, Awni, Abu-Hijleh, K.A. (2006). Antibacterial Activity of Four Plant Extracts Used in Palestine in Folkloric Medicine against Methicillin-Resistant *Staphylococcus aureus*. *Turkish Journal of Biology*, *30*, 195–198.

Barnabas, C.G., Nagarajan, S. (1988). Antimicrobial activity of flavonoids of some medicinal plants. *Fitoterapia*, 3, 508-510.

Chew, Y.L., Mahadi, A.M., Wong, K.M., Goh, J.K. (2018). Anti-methicillin-resistance Staphylococcus aureus (MRSA) compounds from Bauhinia kockiana Korth. And their mechanism of antibacterial activity. *BMC Complementary and Alternative Medicine*, *18*(1), 1–9.

Chomnawang, M.T., Surassmo, S., Wongsariya, K., Bunyapraphatsara, N. (2009). Antibacterial Activity of Thai Medicinal Plants against Methicillin-resistant *Staphylococcus aureus*. *Fitoterapia*.

Cowan, M.M. (1999). Plant Products as Antimicrobial Agents. *Clinical Microbiology* Reviews, *12*(4), 564–582.

Davidson, P.M. (2001). Chemical preservatives and naturally antimicrobial compounds. In: Beuchat, M.P., Montville, L.R. (Eds.), *Food Microbiology: Fundamentals and Frontiers*, second ed. ASM Press, Washington DC, pp. 593–628.

Duraipandiyan, V., Ayyanar, M., Ignacimuthu, S. (2006). Antimicrobial activity of some ethnomedicinal plants used by Paliyar tribe from Tamil Nadu, India. *BMC Complementary and Alternative Medicine*.

Eloff, J.N. (1998). A sensitive and quick microplate method to determine the minimal inhibitory concentration of plant extracts for bacteria. *Planta Medica*.

Erdoğrul, Ö.T. (2002). Antibacterial Activity of Some Plant Extracts Used in Folk Medicine. *Journal of Herbal Pharmacotherapy*, *40*(4), 269–273.

Frey, F.M., Meyers, R. (2010). Antibacterial activity of traditional medicinal plants used by Haudenosaunee peoples of New York State. *BMC Complementary and Alternative Medicine*, *10*.

Hammer, K.A., Carson, C.F., Riley, T.V. (1999). Antimicrobial activity of essential oils and other plant extracts. Journal *of Applied Microbiology*.

Harbarth, S., Samore, M.H. (2005). Diagnostic Uncertainty and Progress in Laboratory Detection. *Emerging Infectious Diseases*, *11*(6).

Hili, P., Evans, C.S., Veness, R.G. (1997). Antimicrobial action of essential oils: the effect of dimethylsulfoxide on the activity of cinnamon oil. *Letters in Applied Microbiology,* 24, 269–275.

Jahan, F., Lawrence, R., Kumar, V., Junaid, M. (2011). Evaluation of antimicrobial activity of plant extracts on antibioticsusceptible and resistant *Staphylococcus aureus* strains. *Journal of Chemical and Pharmaceutical Research*, *4*(3), 777–789.

Janssen, A.M., Scheffer, J.J.C., Baerheim Svendsen, A. (1987). Antimicrobial activity of essential oils: a 1976–86 literaturere view. Aspects of the test methods. *Planta Medica,* 53, 395–398.

Jarrar, N., Abu-Hijleh, A., Adwan, K. (2010). Antibacterial activity of *Rosmarinus officinalis* L. alone and in combination with cefuroxime against methicillin-resistant *Staphylococcus aureus*. *Asian Pacific Journal of Tropical Medicine*, *3*(2), 121–123.

Lakhundi, S., Zhang, K. (2018). Methicillin-resistant *Staphylococcus aureus*: molecular characterization, evolution, and epidemiology. *Clinical microbiology reviews*, 31(4), e00020-18.

Li, J., Liu, D., Tian, X., Koseki, S., Chen, S., Ye, X., Ding, T. (2018). Novel antibacterial modalities against methicillin resistant *Staphylococcus aureus* derived from plants. *Critical Reviews in Food Science and Nutrition*, 1–9.

Mansouri, S. (2008). Pharmaceutical Biology Inhibition of Staphylococcus Aureus Mediated by Extracts from Iranian Plants. *Pharmaceutical Biology*.

McCutcheon, A.R., Ellis, S.M., Hancock, R.E.W., Towers, G.H.N. (1994). Antifungal screening of

medicinal plants of British Columbian native peoples. *Journal of Ethnopharmacology*, *44*(3), 157–169.
Mehrotra, S., Srivastava, A.K., Nandi, S.P. (2010). Comparative antimicrobial activities of Neem, Amla, Aloe, Assam Tea and Clove extracts against Vibrio cholerae, Staphylococcus aureus and Pseudomonas aeruginosa. *Journal of Medicinal Plants Research*, *4*(18), 2473–2478.
Michael, G.L., *Hertog*, E.J.M., Feskens, P.C.H., Hollman, M.B., Katan, D.K. (1993). The surface gene promoter of the human hepatitis B virus displays a preference for differentiated hepatocytes. *The Lancet*, *342*, 1007–1011.
Mori, S., Nishizawa, N. (1987). Methionine as a Dominant Precursor of Phytosiderophores in Graminaceae Plants, *Plant and Cell Physiology*, 28 (6), 1081–1092
Morris, J.A., Khettry, A., Seitz, E.W. (1979) Antimicrobialactivity of aroma chemicals and essential oils. *Journal of the American Oil Chemists Society,* 56, 595–603.
Nair, R., Chanda., S. (2006).Activity of some medicinal plants against *certain* pathogenic bacterial strains. *Indian J Pharmacol*., 38, 142-144.
Okigbo, R.N., Mmeka, E.C. (2008). Antimicrobial effects of three tropical plant extracts on *staphylococcus* aureus, escherichia coli and candida albicans. *J. Trad. CAM*, *5*(3), 226–229.
Omar, S., Lemonnier, B., Jones, N., Ficker, C., Smith, M., Neema, C., Arnason, J. (2000). Antimicrobial activity of extracts of *eastern* North American hardwood trees and relation to traditional medicine. *Journal of Ethnopharmacology*, *73*(1–2), 161–170.
Özkan, G., Sağdiç, O., Baydar, N.G., Baydar, H. (2004). Note: *Antioxidant* and antibacterial activities of Rosa damascena flower extracts. *Food Science and Technology International*, *10*(4), 277–281.
Palombo, E.A., Semple, S.J. (2002). Antibacterial activity of Australian plant extracts against methicillin-*resistant* Staphylococcus aureus (MRSA) and vancomycin-resistant enterococci (VRE). *Journal of Basic Microbiology*.
Parekh, J., Chanda, S.V. (2008). Antibacterial activity of aqueous and alcoholic extracts of 34 Indian medicinal plants against some Staphylococcus species. *Turkish Journal of Biology*.
Petrovska, B. (2012). Historical review of medicinal plants usage. *Pharmacognosy Reviews*, *6*(11), 1.
Rauha, J.P., Remes, S., Heinonen, M., Hopia, A., Kähkönen, M., Kujala, T., Vuorela, P. (2000). Antimicrobial effects of Finnish plant extracts containing flavonoids and other phenolic compounds. *International Journal of Food Microbiology*, *56*(1), 3–12.
Reynolds, J.E.F. (1996). Martindale – the Extra Pharmacopoeia31stedn. London: Royal Pharmaceutical Society of Great Britain
Rios, J.L., Recio, M.C., Villar, A. (1988) Screening methodsfor natural products with antimicrobial activity: a review of theliterature. *Journal of Ethnopharmacology,* 23, 127–149.
Schrijnemakers, P., Bruinsma, N., Monen, J., Witte, W., Grundmann, H. (2004). *Staphylococcus aureus* in Europe, 1999 – 2002. *Emerging Infectious Diseases*, *10*(9), 1999–2002.
Sivropoulou, A., Kokkini, S., Lanaras, T., Arsenakis, M. (1995). Antimicrobial activity of mint essential oils. *Journal of Agricultural and Food Chemistry*, *43*(9), 2384–2388.
Smith-Palmer, A., Stewart, J., Fyfe, L. (1998). Antimicrobialproperties of plant essential oils and essences against five impor-tant food-borne pathogens. *Letters in Applied Microbiology,* 26,118–122.
Tayel, A.A., Shaban, S.M., Moussa, S.H., Elguindy, N.M., Diab, A.M., Mazrou, K.E., El-Sabbagh, S.M. (2018). Bioactivity and application of plant seeds extracts to fight resistant strains of Staphylococcus aureus. *Annals of Agricultural Sciences*, 63(1), 47-53.
Thosar, N., Basak, S., Bahadure, R. N., Rajurkar, M. (2013). Antimicrobial efficacy of five essential oils against oral pathogens: An in vitro study. *European Journal of Dentistry*, *7*(5 SUPPL.), 71–77.
Tohidpour, A., Sattari, M., Omidbaigi, R., Yadegar, A., Nazemi, J. (2010). Antibacterial effect of essential oils from two medicinal plants against Methicillin-resistant Staphylococcus aureus (MRSA). *Phytomedicine*.
Tsuchiya, H., Sato, M., Miyazaki, T., Fujiwara, S., Tanigaki, S., Ohyama, M., Iinuma, M. (1996). Comparative study on the antibacterial activity of phytochemical flavanones against methicillin-resistant *Staphylococcus aureus*. *Journal of Ethnopharmacology*, *50*(1), 27–34.
Voravuthikunchai, S.P., Kitpipit, L. (2005). Activity of medicinal plant extracts against hospital isolates of methicillin-resistant *Staphylococcus aureus*. *Clinical Microbiology and Infection*.
Windholz, M., Budavari, S., Blumetti, R.F., Otterbein, E.S. (1983). The Merck Index, an Encyclopedia of Chemicals, Drugs and Biologicals 10th edn. Rahway, NJ: Merck and Co. Inc.
Yuniati, Y., Hasanah, N., Ismail, S., Anitasari, S., Paramita, S. (2018). Antibacterial activity of dracontomelon dao extracts on methicillin-resistant S. Aureus (MRSA) and E. Coli multiple drug resistance (MDR). *African Journal of Infectious Diseases*, *12*(Special Issue 1), 62–67.
Zuo, G.Y., Wang, G.C., Zhao, Y.B., Xu, G.L., Hao, X.Y., Han, J., Zhao, Q. (2008). Screening of Chinese medicinal plants for inhibition against clinical isolates of methicillin-resistant Staphylococcus aureus (MRSA). *Journal of Ethnopharmacology*, *120*(2), 287–290.