

PLANT-BASED ADJUNCTS FOR ANTIBIOTIC RESISTANCE: FOCUS ON MENTHA ESSENTIAL OILS

Saiqa Ishtiaq^{*1}, Atif Rasool¹, Zahra Akbar¹, Rashida Manzoor², Maida Asghar¹, Saoud Athar¹, Muhammad Gulfam¹, Saim Abdullah³

^{1,2,3,5,6,7}Punjab University College of Pharmacy, University of the Punjab, Lahore, Pakistan.

⁴Government College and University, Faisalabad, Pakistan

⁸University College of Conventional Medicine, The Islamia University of Bahawalpur, Pakistan

^{*1}saiqa.pharmacy@edu.pk

DOI: <https://doi.org/10.5281/zenodo.17103932>

Keywords

Essential Oils, Genus Mentha, Mechanism of resistance, Adjuvants, MRSA

Article History

Received: 19 June 2025

Accepted: 29 August 2025

Published: 12 September 2025

Copyright @Author

Corresponding Author: *

Saiqa Ishtiaq

Abstract

Antimicrobial resistance is the domain of more concerns in health care system because it is leading to the failure of chemotherapy. Resistant bacteria have been reported as high priority pathogen by world Health Organization in 2017 A.D. The worldwide prevalence of resistant is touching significant number in countries along Indian and Atlantic Ocean. The basic mechanism to develop resistance against antibiotics is genetic mutation that enables bacteria to produce proteins such as penicillinase to destroy antibiotics or activation of efflux pump and biofilm formation. Flora has been pioneer source of medicine since evolution of life. Whenever, there is new pathological condition in the world, secondary metabolites and essential oils of plants have played crucial role either in the domain of anti-microbes or receptor's agonist and antagonists. In the area of antimicrobial resistance, secondary metabolites or essential oils are potent adjuvants for antibiotics. Essential oils are more effective against gram positive as compare to negative bacterium because these allow the passage of lipophilic substance in to cytoplasm while negative bacteria do not allow the passage of lipophilic substance due to presence of extra lyophilic layer. Essential oils and secondary metabolites reduce the minimum inhibitory concentration of antibiotics and overcome the adaptive mechanism of resistance. In this paper we will discuss genus Mentha as source of adjuvants of antibiotics to overcome antimicrobial resistance.

INTRODUCTION

Antimicrobial resistance is one of the major health challenges faced by the health care system today. Around 10 million deaths per annum have been forecasted by experts by the year 2050 A.D (Huang et al., 2021). Increasing microbial resistance is attracting attention due to its severity, and the challenges it poses to healthcare system soon. It gears up the interest of scientists to find a novel antimicrobial agent either from natural or synthetic source. The

global prevalence of methicillin resistant bacteria is rising significantly and approaching to threatening number in the developing as well as in developed countries. The mortality rate caused by resistant bacteria especially from methicillin is 14% (Moreno Cardenas and Çiçek, 2023). Methicillin resistant bacteria reported as high priority pathogen in the report of 2017 by World Health Organization.

The global burden of antimicrobial resistance is alarming situation for the chemotherapy. MRSA prevalence across different countries has been

presented in Figure 1 (Moreno Cardenas and Çiçek, 2023).

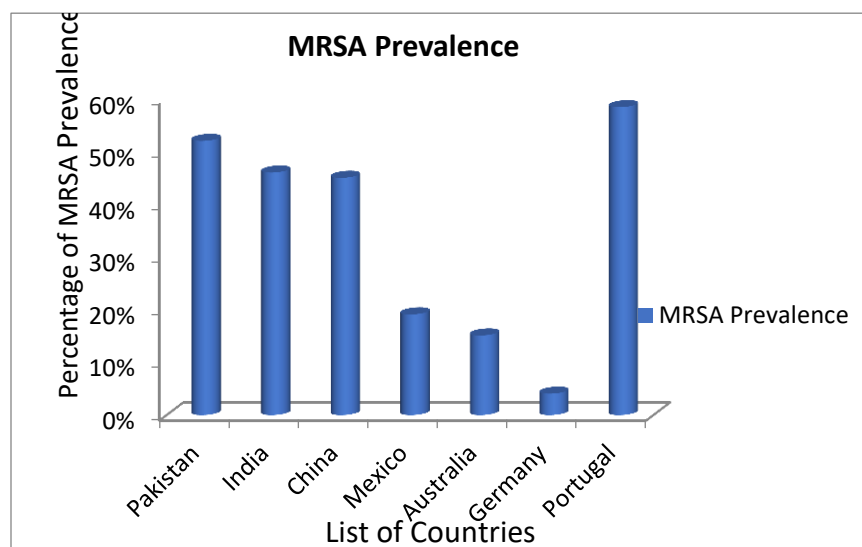


Figure 1. The Global Prevalence of MRSA

The antimicrobial resistance has been reported against all type of antibiotics but it is prominent in the case of beta lactam antibiotics. It is due to the presence of beta lactamase enzyme in the bacterial cytoplasm. Beta lactam ring which is responsible for the action of antibiotics. The ring is ultimately is affected by beta lactamase enzyme and it leads to alterations in specific structure of antibiotics due to which it becomes unable to perform its specific action (Askarinia *et al.*, 2019). *Staphylococcus aureus* (Gram-positive bacterium) leading pathogen among of antimicrobial resistance. First MRSA resistant strain was reported in Europe (Jevons). There are two major Methicillin resistant strains that have been reported. One is HMRSA (Hospital acquired methicillin resistant) and second one is community acquired infections resistant (Khosravi *et al.*, 2012),(Cheung and Otto, 2012). The main mechanism to develop resistance is mutation in its genetic makeup (Rodríguez-Noriega *et al.*, 2010). Multi-drug resistance phenomenon is adapted by the bacteria by two ways first one is activation of efflux pump (Andersson *et al.*, 2016). Second is the formation of biofilm (Huang *et al.*, 2021).

Although there have been advancements in medical technology, bacteria are persistent in developing resistance. However, multiple antibiotics have been

developed in to overcome this hurdle. Although all antibiotics have different mechanisms to overcome the bacterial resistance, but there are several cases where only specific antibiotics work and preferred. Nevertheless, the purpose of using them remains same which is to revert resistance phase and ultimately to kill bacteria. A good example of this is Vancomycin which is specifically prescribed to kill the MRSA. Vancomycin once incorporated into the body it attaches with precursor of bacterial cell wall which is D-alanyl-D-alanine leading to inhibition of formation of cell wall of bacteria (Howden Benjamin *et al.*, 2010). But unfortunately, VISA and hVISA developed resistance against vancomycin by increasing thickness of cell wall ,it reduced glycopeptide cross-linking pins-down and seized vancomycin that ultimately effected its action (Okwu *et al.*, 2019). This may be because of change in composition of peptidoglycan due to increase D-ala-D-ala residues, these residues have greater affinity for vancomycin and don't allow it to reach at its target site.

Plants have been an important source of drug discovery since evolution of medical domain. So, Plants are expected the most feasible source of novel antibiotics. Some of these are actively acting as antibiotics, some as adjuvants, showing their effects

synergistically and cost effective also (Ke *et al.*, 2012). The activity of allicin against large number pathogenic bacteria mimics the activity of antibiotics (Sheppard *et al.*, 2018). Genus *Mentha* might be a potent source to overcome the microbial resistance. The constituents of genus *Mentha* have shown potency to decrease the minimum inhibitory concentration of several antibiotics and these may be exploited as direct antibiotics or adjuvants of a antibiotics in the near future (Yousefian *et al.*, 2023).

Mentha

Origin of term Mentha:

The term *Mentha* refers to a specific genus that is also called Mints, was purposed by Greek philosopher (Theophrastus) on the base of Greek character called Minthe. The word Minthe represents the Greek mythology probably indicates different ancient contents. According to book *Didactic Epic of Halieutika* (On Fishing), She was a Goddess and wife of Aidoneus (Yousefian *et al.*, 2023), (Mair, 1928).

Taxonomical Classification

Taxonomical classification of genus *Mentha* firstly was described by French botanist Antoine-Laurent de Jussieu, in 1789AD. He proposed the family Lamiaceae (flowering plant family) comprises of 7000 species and these were arranged into 260 genera (Brahmi *et al.*, 2017). Umbrella of Lamiaceae family comprises of 10 subfamilies. Thar are Lamioideae, Nepetoideae, Ajugoideae, Symphorematoideae, Prostantheroideae Scutellarioideae Viticoideae, Cymarioideae, Peronematoideae, Premnoideae (Li *et al.*, 2016).

Morphology of different Species

Representative plants of each species have their own characteristic morphology. Peculiar appearance of leaves and stems makes difference between the different species of genus mints. Some major differences are presented in Table 1 (Yousefian *et al.*, 2023).

Table 1. Comparative characteristic features of some major *Mentha* species

Mentha species	Morphology
<i>M. spicata</i> L.	Stem: Hair may be present or not, Leaves: contrasting arrangements, ovoid tapered in appearance and light green in color, often hairless on both sides, serrated margins.
<i>M. arvensis</i> L.	Stem: straight-rising branched stem Leaves: contrast arrangement, scarcely hairy, shortly sessile, elliptic ovate or egg shaped, light green color, sharp margins.
<i>M. longifolia</i> L.	Stems: stems with branches, the stems are straight upward 0.5–1 m height and delicate hair cover stems Leaves: Pale white hairs are present, round or ovoid shaped in with protruding edges and color is in the shade of green
<i>M. piperita</i>	Stems: Tetra sided, pastel purple, upward branching, negligible hair Leaves: opposite, peculiar petiolate are there, fin and regular overlapping, pale green color
<i>M. Mozaffarianii</i> Jamzad	Stems: 4 angled, epidermis (surface) bear hair Leaves: Hairs are present on the surface

Family Nepetoideae:

Different studies have reported different number of species of family Nepetoideae of genus *Mentha* (Yousefian *et al.*, 2023). It comprises of 18 to 30 parent and 15 hybrid species of Genus *Mentha* have been reported but 5 species are of prime importance due to their active components against microbes including *Mentha spicata*, *Mentha*

aquatic, *Mentha arvensis*, *Mentha longifolia*, *Mentha suaveolens* (Kapp, 2015), (Silva, 2020). Hybrid species come in to existence due to combinations of different parent species (Yousefian *et al.*, 2023). As it is presented in Table 2.

Table 2. Taxonomic overview of Parent and Hybrid species within genus *Mentha* L.

Parent and Hybrid species of the genus <i>Mentha</i> L.	
Hybrid	Parent species
<i>M. × carinthiaca</i> Host	<i>Mentha arvensis</i> L. × <i>Mentha suaveolens</i> Ehrh.
<i>M. × dalmatica</i> Tausch	<i>Mentha arvensis</i> L. × <i>Mentha longifolia</i> (L.) L.
<i>M. × dumetorum</i> Schultes	<i>Mentha aquatica</i> L. × <i>Mentha longifolia</i> (L.) L.
<i>M. × gracilis</i> Sole	<i>Mentha arvensis</i> L. × <i>Mentha spicata</i> L.
<i>M. × maximiliana</i> F. W. Schults	<i>Mentha aquatic</i> L. × <i>Mentha suaveolens</i> Ehrh.
<i>M. × piperita</i> L.	<i>Mentha aquatica</i> L. × <i>Mentha spicata</i> L.
<i>M. × rotundifolia</i> (L.) Huds.	<i>Mentha longifolia</i> (L.) L. × <i>Mentha suaveolens</i> Ehrh.
<i>M. × smithiana</i> R. Graham	<i>Mentha aquatic</i> L. × <i>Mentha arvensis</i> L. × <i>M. spicata</i>
<i>M. × verticillata</i> L.	<i>Mentha aquatica</i> L. × <i>Mentha arvensis</i> L.
<i>M. × villosa</i> Huds.	<i>Mentha spicata</i> L. × <i>Mentha suaveolens</i> Ehrh.
<i>M. × villosa-nervata</i> Opiz	<i>Mentha longifolia</i> (L.) L. × <i>Mentha spicata</i> L.

Optimum conditions to grow

Damp environment is the most feasible situation for growth of plant that are related to Genus *Mentha* such as at the banks of river and other natural water resources. In contrast, some species require temperate zone (Silva, 2020). These are herbaceous aromatic perennial plants, that grow underground as well as over ground (Yousefian *et al.*, 2023). They have ability to endure the climatic conditions that makes them feasible for cultivation in the world for economical as well as industrial or medicinal interests (Yousefian *et al.*, 2023).

General uses

Essential oils are economically and industrially valuable and have tremendous applications in field of medical science (Zhao *et al.*, 2023). In book

Canon of Medicine by Ibn Sinna, importance of Mints for medical purposing has been described (Hajar, 2013). The records have been found which indicate the use of aromatic herbs for medicinal uses in old ages (Silva, 2020). Traditionally, Mints have been used because of their properties like anti-oxidant (phenolic acid, flavonoids, vitamin C (Ascorbic acid), carotenoids, free radical scavengers), anti-bacterial, analgesic, anti-viral, anti-cancer (Yousefian *et al.*, 2023), (Silva, 2020). These different activities of *Mentha* have been reported of different species in different type of solvent that had been used during extraction. The activity of these varies as the concentration or nature of solvent changes (Eftekhari *et al.*, 2021). The general uses of genus *Mentha* has been enlisted in Figure 2.

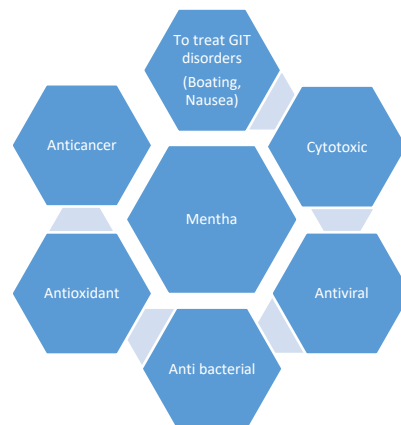


Figure 2. General use of genus *Mentha*

The medicinal properties of different extracts of different species are depends upon the type of solvents that are used during extraction. These are commonly used in series from non-polar to polar. In this almost components are present in extract either they are polar or non-polar. So, we are able to find

out all the possible numbers of activity. Table 3 represents the specific activity of extract with reference to solvent (Yousefian *et al.*, 2023), (Eftekhari *et al.*, 2021).

Table 3. Various therapeutic effects reported for *Mentha* species

Therapeutic effects	Mentha species	Solvent for Extraction/ Oil
Analgesic	<i>M. spicata</i>	Methanol
	<i>M. piperita</i>	Methanol
Antioxidant	<i>M. spicata</i>	Methanol
		Ethanol
		Water
	<i>M. pulegium</i>	Essential oil
	<i>M. piperita</i> L.	Water
Antibacterial	<i>M. spicata</i>	Volatile oil
	<i>M. arvensis</i>	Ethanolic extract
	<i>M. pulegium</i>	Essential oil
	<i>M. piperita</i>	Essential oil
	<i>M. aquatica</i>	Essential oil
Antiviral	<i>M. spicata</i>	Essential oil
	<i>M. piperita</i>	Essential oil
Cytotoxic	<i>M. piperita</i>	Essential oil
Anticancer	<i>M. piperita</i>	Methanol
	<i>M. arvensis</i>	Methanol
	<i>M. longifolia</i>	Menthol
	<i>M. spicata</i>	Menthol
	<i>M. viridis</i>	

The medical significance of essential oils cannot be denied. This is stated on grounds of their use in the medical therapy that has been in historical records during ancient civilization (Silva, 2020). Volatile or essential oils are produced by the plants as a defensive mechanism against herbivores. These possesses different physical properties. Except camphor, all essential oils are colorless liquids and have low density (except cinnamon oil and clove oil). They are extracted by the crushing and distillation of the plant parts. Chemically, essential oils are terpenes (α -pinene, limonene, carvone), monoterpenes (linalool, carvacol, geraniol), and sesquiterpenes (caryophyllene, farnesol, humulene). Throughout the development of resistance, the bacterial genome is always beneficial for bacteria.

The rapid adaptation by change in genetic makeup to given environment helps bacteria to develop resistance. Bacteria always develop resistance after the exposure of a certain chemical or antibiotics. For example, in the case of vancomycin, same principal has been adopted by bacteria. Vancomycin attaches with the precursor of bacterial cell wall which is D-alanyl-D-alanine that results into inhibition of formation of cell wall of bacteria (Howden Benjamin *et al.*, 2010). The complex of vancomycin contains many hydrogen bonds that are present between the peptide component of vancomycin and D-Ala-D-Ala residue (Conly and Johnston, 2002). It prevents biosynthesis of late-stage peptidoglycan which results into accumulation of UDP-linked Mur NAC-pentapeptide precursor. But unfortunately, when

vancomycin was used recurrently against MRSA, it causes mutation in *walkR*, *vrasR*, *rpoB*(ribosomal)genes and *yyqF/vraSR* system which causes the production of vancomycin-intermediate *staphylococcus aureus* (VISA) (Conly and Johnston, 2002).

Mechanism of Action

The antibiotic activities of multiple essential oils have been reported in the past depending upon the different chemical constituents, each one carrying an evident mechanism of action. However, here we will classify the antimicrobial activity of oils on the basis of different bacterial stains Gram positive and Gram negative. In former bacteria, the essentials oils take over the movement of hydrogen (H^+) ions which affected the proton concentration. This ultimately resulted in the decrease of synthesis of Adenosine triphosphate (ATP). The ATP concentration within the cell decreases causing lower intracellular ATP. This reduction in the ATP, increases the permeability of the cell wall followed by the leakage of the cellular contents (Burt, 2004).

Later bacteria is comparatively much more resistant than Gram positive due to the presence of an additional outer layer which is hydrophilic in nature and inhibits the penetration of lipophilic substances such as the essential oils (Zaika, 1988). Although essential oils have significant antimicrobial action but theses cannot be used as alternatives to

antibiotics since they only intensify and strengthen the effects of the antibiotics (Horváth and Koščová, 2017). Normally bacteria develop resistance by mutation in genetic makeup. The gene that is responsible for mutation is called Meca gene on the Staphylococcal Cassette Chromosome that expresses in the form of Penicillin Binding Protein (Arora *et al.*, 2010), (Rathawongjirakul and Thongkerd, 2016). These proteins are attached to beta lactam ring of antibiotics and cause degradation of antibiotics (Askarinia *et al.*, 2019).

There is a plant extract that can be used for the prevention of formation of biofilm i.e trans-cinnamaldehyde that has prominent effect against the biofilm formation of ureo-spathogenic *E. coli*. L-menthone and menthol are the two antimicrobial active components present in peppermint oil (*Mentha piperita*) (Roy *et al.*, 2018, Huang *et al.*, 2021). L-menthone and menthol have been previously reported for the antimicrobial activities they possess strong antimicrobial action (Zhao *et al.*, 2023), (Horváth and Koščová, 2017). The activity spectrum against several species of bacteria represents the specificity of *Mentha* species extracts against specific bacteria (Eftekhari *et al.*, 2021). Selective antibacterial activity of *Mentha* species extracts Against target Bacterial strains has been listed in Table

4.

Table 4: Antibacterial specificity of *Mentha* species extracts against specific bacterial strains

<i>Mentha</i> spp.	Indicator pathogens
<i>M. spicata</i>	<i>Escherichia coli</i> <i>Proteus mirabilis</i> <i>Proteus aeruginosa</i> , <i>Salmonella typhimurium</i>
<i>M. piperita</i>	<i>Escherichia coli</i> <i>Klebsiella pneumoniae</i> , <i>Proteus vulgaris</i> Herpes simplex virus AIDs virus
<i>M. arvensis</i>	<i>Escherichia coli</i> <i>Klebsiella pneumoniae</i> <i>Staphylococcus aureus</i>
<i>M. pulegium</i>	<i>Escherichia coli</i> <i>Proteus aeruginosa</i> <i>Staphylococcus aureus</i>

Menthone is a majorly active component of peppermint (*Mentha piperita*) that has shown antimicrobial activity against Methicillin resistant *Staphylococcus aureus* (MRSA). It is used as adjuvant with other antibiotics to enhance their actions (Zhao *et al.*, 2023), (Horváth and Koščová, 2017). An integrated approach of microbiology and lipidomics has been adopted to describe the antimicrobial activity of menthone. It alters the integrity of the membrane potential and also causes a disruption in

the bacterial biofilm. The lipophilic sites of MRSA were the primary targets for menthone. This investigation has been authenticated by various techniques such as the Ultra High Performance Liquid Chromatography (UHPLC) and Mass spectrometry. Three species (peppermint oil, spearmint oil and cornmint oil) were put under investigation to figure out their effects on MRSA from which the peppermint oil proved to be the most effective of all (Zhao *et al.*, 2023).

Change in Lipid Composition of Methicillin-Resistant *Staphylococcus aureus* (MRSA)

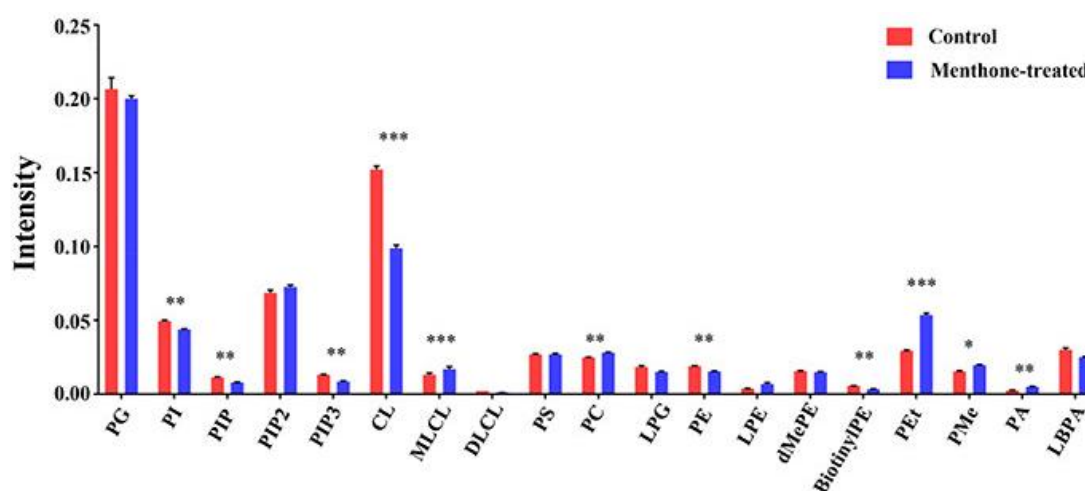


Figure 3. Lipid profile of cell membrane

Experimental studies have been carried out to find out the Minimum Inhibitory Concentration (MIC) which is the minimum concentration of a sample able to prevent the further division of a pathogen while causing minimum side effects, and the Minimum Bactericidal Concentration (MBC) which is an antibacterial agent in the lowest concentration having the ability to kill a specific bacterium. To become able to find these values for menthone, the standard broth dilution method (CLSI M07-A8) was used. The concentrations of 0.25µL/m were prepared and applied. 0.1% dimethyl sulfoxide was used as the negative control. Results manifested that the MIC and MBC values were 3340µg/ml and 7080µg/ml respectively. Lipidomic of the MRSA were also affected by menthone (Zhao *et al.*, 2023).

The concentration of menthone in peppermint oil was reported to be 23.4% which was the highest among all of the other species under consideration which may indicate that antimicrobial activity of *Mentha piperita* is primarily contributed by menthone . (Horváth and Koščová, 2017). Under the considerations of all of these studies, we may confer that the high concentration of menthone in peppermint is the causative factor for most of its effective antimicrobial activity as compared to other species. However, further studies are required to evaluate the given hypothesis. Table 5 elucidating the different species along with the concentrations of different antimicrobial active ingredients is presented (Horváth and Koščová, 2017).

Table No 5: Mentha species and concentrations of antimicrobial active ingredients

Oil	Species	L-Menthol (%)	Menthone (%)	Carvone (%)	Limonene (%)
Peppermint	<i>Mentha piperita</i>	40.7	23.4	–	–
Spearmint	<i>Mentha spicata</i>	–	–	70	10
Carmint	<i>Mentha arvensis</i>	28.8-34.7	16.3	–	–

Conclusion

Antimicrobial resistance is major challenge in the field of chemotherapy. Methicillin resistant strains are posing threat to health care system. If it is not fixed at this stage, it will lead catastrophic situation ultimately to complete failure of chemotherapy. Natural products have the potential to show their antimicrobial activity especially essential oils. Genus *Mentha*'s plant are the leading members of group of plants having antimicrobial activities. The major site of bacteria that has been targeted by the components of essential oils of Genus *Mentha* is cell wall. Integrity of cell wall has been compromised and leads to leakage of cellular contents. Antimicrobial activity of Genus *Mentha* against gram negative bacteria is comparatively low due to presence of hydrophilic layer that prevents the attachment of essential oils on the bacterial surface. In short, we can conclude that natural products can be used as adjuvants with antibiotics to overcome the antimicrobial resistance but these cannot substitute antibiotic therapy.

Authors' contributions

SI (co-author) supervised the reviewing process and manuscript editing. AR performed searching data and contributed as team leader. ZA and MA helped the preparation of the manuscript. SA and MG helped the editing and formatting. All authors read and confirmed the final version of the manuscript for publication.

Conflict of interests

The authors declare no conflict of interest.

Ethical consideration

Ethical issues have been observed by the authors.

Funding/ Support

This research is the assignment of the Undergraduate program of Doctor of Pharmacy. It was self-supporting.

References

- Andersson, DI, D Hughes and JZ Kubicek-Sutherland (2016). Mechanisms and consequences of bacterial resistance to antimicrobial peptides. *Drug Resist Updat.*, **26**: 43-57.
- Arora, S, P Devi, U Arora and B Devi (2010). Prevalence of methicillin-resistant staphylococcus aureus (mrsa) in a tertiary care hospital in northern india. *J Lab Physicians.*, **2**: 78-81.
- Askarinia, M, A Ganji, F Jadidi-Niaragh, S Hasanzadeh, B Mohammadi, F Ghalamfarsa, G Ghalamfarsa and H Mahmoudi (2019). A review on medicinal plant extracts and their active ingredients against methicillin-resistant and methicillin-sensitive staphylococcus aureus. *Journal of Herbmed Pharmacology.*, **8**: 173-184.
- Brahmi, F, M Khodir, C Mohamed and D Pierre (2017). Chemical composition and biological activities of mentha species. Aromatic and medicinal plants-back to nature., IntechOpen.
- Burt, S (2004). Essential oils: Their antibacterial properties and potential applications in foods—a review. *International journal of food microbiology.*, **94**: 223-253.
- Cheung, GY and M Otto (2012). The potential use of toxin antibodies as a strategy for controlling acute staphylococcus aureus infections., *Expert Opin Ther Targets.*, **16**: 601-612.
- Conly, JM and BL Johnston (2002). Visa, hetero-visa and vrsa: The end of the vancomycin era? *Can J Infect Dis.*, **13**: 282-284.
- Eftekhari, A, A Khushro, E Ahmadian, SM Dizaj, A Hasanzadeh and M Cucchiariini (2021). Phytochemical and nutra-pharmaceutical attributes of mentha spp.: A comprehensive review., *Arabian Journal of Chemistry.*, **14**: 103106.

- Hajar, R (2013). The air of history (part v) ibn sina (avicenna): The great physician and philosopher. *Heart views.*, **14**: 196-201.
- Horváth, P and J Koščová (2017). In vitro antibacterial activity of mentha essential oils against staphylococcus aureus. *Folia Vet.*, **61**: 71-77.
- Howden Benjamin, P, K Davies John, DR Johnson Paul, P Stinear Timothy and ML Grayson (2010). Reduced vancomycin susceptibility in staphylococcus aureus, including vancomycin-intermediate and heterogeneous vancomycin-intermediate strains: Resistance mechanisms, laboratory detection, and clinical implications. *Clinical Microbiology Reviews.*, **23**: 99-139.
- Huang, L, S Ahmed, Y Gu, J Huang, B An, C Wu, Y Zhou and G Cheng (2021). The effects of natural products and environmental conditions on antimicrobial resistance. *Molecules.*, **26**: 4277.
- Jevons, MP "Celbenin" - resistant staphylococci, Br Med J. 1961 Jan 14;1(5219):124-5.
- Kapp, K (2015). Polyphenolic and essential oil composition of mentha and their antimicrobial effect. *Academic Dissertation. Faculty of Pharmacy of the University of Helsinki.*
- Ke, F, PK Yadav and LZ Ju (2012). Herbal medicine in the treatment of ulcerative colitis. *Saudi J Gastroenterol.*, **18**: 3-10.
- Khosravi, AD, H Hoveizavi and Z Farshadzadeh (2012). The prevalence of genes encoding leukocidins in staphylococcus aureus strains resistant and sensitive to methicillin isolated from burn patients in taleghani hospital, ahvaz, iran. *Burns.*, **38**: 247-251.
- Li, B, PD Cantino, RG Olmstead, GL Bramley, C-L Xiang, Z-H Ma, Y-H Tan and D-X Zhang (2016). A large-scale chloroplast phylogeny of the lamiaceae sheds new light on its subfamilial classification. *Scientific reports.*, **6**: 34343.
- Mair, AW (1928). Oppian, colluthus, tryphiodorus, Loeb Classical Library.
- Moreno Cardenas, C and SS Çiçek (2023). Structure-dependent activity of plant natural products against methicillin-resistant staphylococcus aureus. *Frontiers in microbiology.*, **14**: 1234115.
- Okwu, MU, M Olley, AO Akpoka and OE Izevbuwa (2019). Methicillin-resistant staphylococcus aureus (mrsa) and anti-mrsa activities of extracts of some medicinal plants: A brief review. *AIMS Microbiol.*, **5**: 117-137.
- Ratthawongjirakul, P and V Thongkerd (2016). Fresh garlic extract inhibits staphylococcus aureus biofilm formation under chemopreventive and chemotherapeutic conditions. *Songklanakarin Journal of Science & Technology.*, **38**.
- Rodríguez-Noriega, E, C Seas, M Guzmán-Blanco, C Mejía, C Alvarez, L Bavestrello, J Zurita, J Labarca, CM Luna, MJ Salles and E Gotuzzo (2010). Evolution of methicillin-resistant staphylococcus aureus clones in latin america. *Int J Infect Dis.*, **14**: e560-566.
- Roy, R, T Monalisa, D Gianfranco and V and Tiwari (2018). Strategies for combating bacterial biofilms: A focus on anti-biofilm agents and their mechanisms of action. *Virulence.*, **9**: 522-554.
- Sheppard, JG, JP McAleer, P Saralkar, WJ Geldenhuys and TE Long (2018). Allicin-inspired pyridyl disulfides as antimicrobial agents for multidrug-resistant staphylococcus aureus. *European journal of medicinal chemistry.*, **143**: 1185-1195.
- Silva, H (2020). A descriptive overview of the medical uses given to mentha aromatic herbs throughout history. *Biology.*, **9**: 484.
- Yousefian, S, F Esmaili and T Lohrasebi (2023). A comprehensive review of the key characteristics of the genus mentha, natural compounds and biotechnological approaches for the production of secondary metabolites. *Iranian Journal of Biotechnology.*, **21**: e3605.

Zaika, LL (1988). Spices and herbs: Their antimicrobial activity and its determination 1. *Journal of food safety.*, **9**: 97-118.

Zhao, W, C Yang, N Zhang, Y Peng, Y Ma, K Gu, X Liu, X Liu, X Liu and Y Liu (2023). Menthone exerts its antimicrobial activity against methicillin resistant staphylococcus aureus by affecting cell membrane properties and lipid profile. *Drug Design, Development and Therapy.*, 219-236.

