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A current review on disrupting the sessile microbial army

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Abstract
The sessile army of microbes enclosed in an extracellular polymeric substance (EPS) is known as the Biofilm. Biofilm formation is commonly seen in bacteria and some fungi. The high tolerance of these sessile army to exogenous stress and other cidal agents poses as a major problem in many fields ranging from industrial biofouling to chronic infections in humans hence researchers all around the globe are testing effective ways to prevent and control the biofilm formation. Chemical intervention of these are found to be unsatisfactory due to various reasons like resistance and toxicity hence in this current review the use of natural products like medicinal plants and its bioactive compounds to combat the formation resistant microbial communities with least toxicity and utmost efficacy is studied. This can be a useful data and guidance for future antibiofilm studies.

Keywords: anti-bio film, plant extracts, essential oil, bioactive compound, secondary metabolites

Introduction
The sessile microbial army enclosed within a extracellular polymeric substance is known as the Biofilm. It's a complex habitat for not just one kind of cells but is a diverse range of community irreversibly attached to a biotic or a abiotic surface [22]. It is hostile environment composed of matrix of polysaccharides, proteins, lipids, nucleic acids and other chemical materials. Biofilm resistance can be attributed to various factors like the reduced permeability of chemicals into the thick matrix, expression of the multidrug efflux pumps, environmental stress, differences in physiological property, bacteriophages and phage particles helps in releasing eDNA helping in the development of antibiotic tolerant colonies, quorum sensing defense, horizontal gene transfer, secretion of antibiotic modifying enzymes and the type IV secretion systems [4]. Hence the go to treatment for Biofilms has been combination of antibacterial agents at high doses which has eventually resulted in the development of multi drug resistant strains [6].

This concern has forced many to investigate alternative anti bio film agent with least side effects. The development of novel therapeutic measures which rely on inhibiting the biofilm formation rather than killing the pathogen using plant based products seems to be a promising approach. The aim of this review is to summarize the effectiveness of various plant based products like solvent extracts, secondary metabolites, bioactive compounds, and essential oils which have proven to have potent anti-bio film activity.

Bio film Formation
The planktonic cells enter the sessile phase of life to form a resistant army by firstly Pre- conditioning the biotic or abiotic substratum followed by the attachment. The cells then rapidly grow and divide, producing extracellular polysaccharides through quorum sensing resulting in the formation of a mature biofilm army composed of various different organisms. This is a reversibly association where the planktonic cells can get detached to form a new attachment [3, 19, 5].

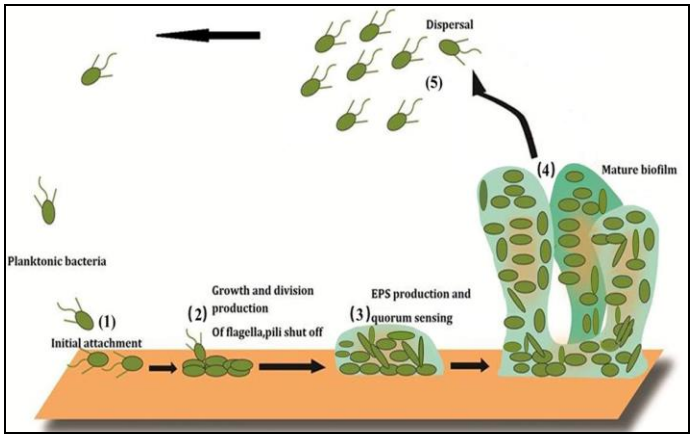

Fig 1

Bio film threat

Biofilms are ubiquitous, they are not only a threat at medical and industrial level but can be a serious problem at our very own houses colonizing a variety of surfaces like the kitchen slabs, toilet seats, sinks, chopping boards, bathrooms, Ac vents and even the toys. The sessile army is a daily challenge in food industry as they can be the potent source of contamination and spoilage of food products [32, 37]. In medical they are responsible for dental plaque to serious chronic illness, nosocomial infections and even the life threatening infections like bacterial endocarditis, Otitis media, cystic fibrosis, lung infections, urinary tract infections etc. Their major concern lies in the implantable devices and prosthetics. Key factors such as surface charge, surface texture, surface hydrophobicity, energy and biomaterial composition plays a critical role in colonizing implants during or any time post-surgery [1]. Marine fouling is also caused by the aggregation of microbial biofilm on ship hulls, metal corrosion, blockage of pipes contamination of water and reduced efficacy of purification are some of the numerous problems associated with biofilms in the water and sewage treatment plants [2].

Plants as Anti bio film agents

Nature has been a source of medicinal agents for thousands of years with a number of modern drugs isolated from natural sources on the basis of their use in traditional medicine. A number of plants derived products or drugs have been used for the treatment of various infections for centuries [13]. Plants produce a diverse range of bioactive molecules, making them a rich source of therapeutic agents and contribute towards human health and well-being. Plant based natural constituents can be derived from any part of the plant like bark, leaves, roots, fruits, seeds, fruit rind, etc. that may contain active components. The antimicrobial property of the plants is attributed to the secondary metabolites like tannins, terpenoids, alkaloids and flavonoids produced by the plants as a means of defense against pathogens or due to environmental stress [7, 20, 36] Due to the relatively lower side effects in comparison with modern synthetic drugs, coupled with reduced cost, plants play an important role in the development of novel drugs.

Most of the phytochemicals are not highly effective as antimicrobial agents but they possess anti-pathogenic or anti-virulence properties, which are neither bactericidal nor bacteriostatic as these phytochemical compounds attenuate the expression of genes responsible for pathogenesis or virulence. This property of herbal constituents eliminates the development of resistance among the microorganisms [15].

Plant extracts as Bio film inhibitors

A number of research findings show the effectiveness of plants and its products in controlling and preventing the formation of the biofilm but most of these studies are *in-vitro.* The review is tabularized for the ease of understanding. The section bellow from Table 1 lists outs the potent natural biofilm inhibitors of plant kingdom.

Table 1: List of plant based potent Antibiofilm inhibitors

Sl. No.	Plant species/ bioactive compound	Material used	Solvent	Effective against	Reference
1.	*Salvadora persica*	Chewing sticks	Methanol	*Streptoccocus mutans*	[10]
2.	*Piper betle*	Leaf	Ethanol	*Streptoccocus mutans* *A actinomycetemcomitans*	[3]
3.	*C robusta*	Beans	Aqueous	*Streptoccocus mutans*	[11]
4.	*Peganum harmala*	Whole plant	Ethanol	*C albicans*	[12]
5.	*P nigrum* *A indica* *P betle* *M indica*	Leaf	Aqueous	*Enterococcus faecalis* *Staphylococcus aureus*	[13]
6.	*Trachyspermum ammi*	Seed	Aqueous Petroleum ether	*Streptoccocus mutans*	[14]
7.	*Dioscorea altissima* *Annona hypogauca*	Aerial organs Flowers	Aqueous	*Streptoccocus mutans*	[15]
8.	*Citrus limonum* *Zingiber officinale*	Essential oil	-	*Klebsiella ornithinolytica* *K. oxytoca* *K. terrigena*	[16]
9.	*Semecarpus anacardium, Glochidion lanceolarium, and Bridelia retusa*	Silver nanoparticles from leaf	-	*Pseudomonas aeruginosa,* *Escherichia coli* *Staphylococcus aureus.*	[17]
10.	Myrtle Pomegranate	Leaf Fruit peel	Polyphenolic	*Streptococcus mutans* *Streptococcus oralis* *Streptococcus mitis* *Rothia dentoca*	[18]
11.	Umbelliferone	-	Methanol	*MRSE*	[19]
12.	Curcumin	-	Methanol	*Acinetobacter baumannii*	[20]

Table 2

Sl. No.	Plant species/ bioactive compound	Material used	Solvent	Effective against	Reference
13.	*Eugenia natalitia* *Eugenia woodii* *Evan Wyk* *Eugenia zeyheri* *Syzygium legatii*	Leaf	Acetone	*Bacillus cereus* *Enterococcus faecalis* *Staphylococcus aureus* *Escherichia coli* *Pseudomonas aeruginosa*	[21]

	Syzygium masukuense			*Salmonella Typhimurium*	
14.	*Adiantum philippense*	Whole plant	Methanol	*S. flexneri* *S. aureus* *P. aeruginosa* *Escherichia coli*	[22]
15.	*Plectranthus barbatus*	Essential oil	-	*Pseudomonas aeruginosa*	[23]
16.	Grape fruit	Seed	Aqueous	*Staphylococcus aureus* *Escherichia coli*	[24]
17.	Grape fruit	Seed	Aqueous	*Candida albicans*	[25]
18.	N-cerotoyltryptamine Asimicin ent-19-carbomethoxykauran -17-oic acid	*Annona senegalensis* seed	Methanol	*Staphylococcus aureus* *Escherichia coli* *Candida albicans*	[26]
19.	*Opuntia ficus-indica*	Cladodes	Polyphenolic	*Staphylococcus aureus*	[27]
20.	*Coriandrum sativum* L. *Mentha* × *piperita* L. *Pimpinella anisum* L	Plant extracts and essential oil	Methanol	*Staphylococcus aureus* *Escherichia coli*	[28]
21.	*Malva parviflora*	Leaf	Ethanol	*Staphylococcus aureus* *Escherichia coli* *Klebsiella pneumonia*	[29]
22.	Cinnamon Eucalyptus Garlic Pomegranate, Tea Tree	Essential oil	-	*Proteus* *Aeromonas* *Pseudomonas*	[30]
23.	Chelerythrine Sanguinarine DiHydroxyBenzoFuran-proAnthocyanidin A2-phosphatidylCholine	Bioactive compound	-	*Staphylococcus aureus* *Staphylococcus epidermidis*	[31]
24.	Phenylpropanoids	Bioactive compound	-	*Candida albicans*	[32]
25.	*C. pumila* ε-Viniferin	Whole plant Bioactive compound	Ethanol	*Pseudomonas aeruginosa* *Escherichia coli*	[33]

Table 3

Sl. No.	Plant species/ bioactive compound	Material used	Solvent	Effective against	Reference
26.	Terpenoids	Bioactive compound	Dimethyl sulphoxide	*Candida albicans*	[34]
27.	NiO nanoparticles	*Eucalyptus globulus* leaf	-	*Pseudomonas aeruginosa* *Escherichia coli* *MRSA*	[35]
28.	Thyme	Essential oil	-	*Acinetobacter* *Sphingomonas* *Stenotrophomonas*	[37]
29.	*Coriandrum sativum L.*	Essential oil	-	*Candida albicans*	[38]
30.	Thyme	Essential oil	-	*Bacillus cereus*	[39]
31.	Pure oregano Thymol Cavacrol	Essential oil	-	*Salmonella* *Escherichia coli*	[40]
32.	Tea tree oil Bergamot oil Basil oil	Essential oil sophorolipids	-	*Vibrio cholerae*	[41]
33.	*Trigonella foenum*	Seed	Methanol	*Pseudomonas aeruginosa* *Aeromonas hydrophila*	[42]
34.	*Achyranthes aspera L.*	Stem	Methanol Benzene Petroleum Ether Aqueous	*Streptoccocus mutans*	[43]
35.	*Capparis spinosa*	Fruit	Methanol	*Escherichia coli Proteus mirabilis Serratia marcescens Pseudomonas aeruginosa*	[44]
36.	*Salvadora persica L*	Fruit	Methanol	*Staphylococcus sp*	[45]
37.	Naringenin Quercetin Sinensetin Apigenin	Citrus flavonoids	Dimethyl sulphoxide	*Escherichia coli* *Vibrio harveyi*	[46]
38.	Embelin Piperine	Bioactive compounds	Dimethyl sulphoxide	*Streptoccocus mutans*	[47]

39.	Casbane Diterpene from *Croton nepetaefolius*	Bark	Ethanol	Oral *Streptococcus*	[48]
40.	Reserpine	Bioactive compound	Dimethyl sulphoxide	*Klebsiella pneumoniae*	[49]
41.	Thyme peppermint	Essential oil	-	*Klebsiella pneumoniae*	[50]

Conclusion

An attempt has been made to review the potential of plant and its products as a promising agent to control and prevent the microbial biofilm formation and as a source for the development of therapeutic agents to combat biofilm induced infections.

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