Nanotherapeutic drug synthesized by way of a microbial pathway targeting *Staphylococcus aureus*

Abstract:

Staphylococcus aureus (*S. aureus*) is one of the most common human pathogens causing various infectious diseases. Further, its ability to form biofilm and the emergence of antibiotic resistance strains has made it difficult to treat the infection. A nanoparticle-based therapeutic approach is an emerging area to treat *S. aureus* infection. Among the different methods to synthesize nanoparticles (NPs), the use of microorganisms to fabricate metal nanoparticles with the antibacterial property against *S. aureus* has been investigated by several studies. The microbial approach is cost-effective, eco-friendly, and devoid of toxic byproducts produced in other methods of nanoparticles formation. The review details the use of bacteria, fungi, yeast, algae, and lichens for producing nanoparticles of various metals, such as silver, gold, zinc, copper, iron, cerium, etc., of varying sizes and shapes and their effective use against *S. aureus*. The present review focuses on the reports of microbial-fabricated nanoparticles as therapeutic agents for treating *S. aureus* infection.

Keywords: *Staphylococcus aureus*, microbial synthesis, nanoparticles, antibacterial

Abbreviations: S. aureus: *Staphylococcus aureus,* **NPs:** Nanoparticles, **MRSA:** Methicillin-resistant *Staphylococcus aureus,* **VISA:** Vancomycin-intermediate *Staphylococcus aureus*, **VRSA:** Vancomycin-resistant *Staphylococcus aureus*, **SeNPs:** Selenium nanoparticles, **Cds:** Cadmium sulfide, **ZnS:** Zinc sulfide, **CdS NPS:** Cadmium sulfide nanoparticles,

Introduction

Due to pathogenic microorganisms and related infectious diseases, the modern world faces a difficult situation. *Staphylococcus aureus*, a Gram-positive bacteria belonging to the genus *Staphylococcus*, is one of the most aggressive and commonly found human pathogens (Tong et al., 2015). Although the substantial population infected with *S. aureus* generally remain asymptomatic, with bacteria commonly present on the skin or mucosal surface (Sakr et al., 2018), it can gain access to the bloodstream through any cut present in the skin surface (McCaig et al., 2006) and consequently can cause debilitating infections like necrotizing fasciitis, impetigo, pyomyositis, *S. aureus* bacteremia, mediastinitis, osteomyelitis, septic arthritis, meningitis, infective endocarditis, etc. and thus affecting various tissues like blood, muscle, and skin and vital internal organs like bone, brain, lungs, hearts, etc. (David and Daum, 2017; Lowy, 1998; Tong et al., 2015). The problem is further made complicated by the emergence of drug-resistant strains of *S. aureus*, such as Methicillin-resistant *Staphylococcus aureus* (MRSA) that is resistant to the beta-lactam class of antibiotics, for example, methicillin, oxacillin, carbapenems, nafcillin, and cephalosporins (Rao et al., 2019; VanEperen and Segreti, 2016). The MRSA can be classified based on genotypic characteristics into either hospital-acquired MRSA (HA-MRSA), isolated from patients admitted to healthcare facilities such as nursing homes and hospitals, or community-acquired MRSA (CA-MRSA), found in the community with no previous history of contact with healthcare environment (David and Daum, 2010; Lindsay, 2013; Otto, 2013). The infections due to *S. aureus* affect many people and cause a significant number of death annually in the United States (Kourtis et al., 2019). Similarly, MRSA has also spread to other parts of the world. It is frequently isolated from different geographical regions, including East Asia, South Asia, the Middle East, Europe, and North Africa (Lakhundi and Zhang, 2018). The therapeutic approach against MRSA generally involves the application of a non-beta-lactam class of antibiotics such as vancomycin, daptomycin, delafloxacin (Bassetti and Righi, 2015). Vancomycin, a glycopeptide antibiotic, was initially used to treat MRSA

strains. However, later new strains of *S. aureus* that were resistant to it were clinically isolated from different parts of the world; these strains were named vancomycin-intermediate *Staphylococcus aureus* (VISA) and vancomycin-resistant *Staphylococcus aureus* (VRSA) (Appelbaum, 2006). Recently, a research group has isolated MRSA strains showing resistance towards delafloxacin, a fluoroquinolone antibiotic commonly used to treat MRSA infection (Iregui et al., 2019). The *S. aureus* strains resistant to delafloxacin were found in community-acquired MRSA and MRSA isolated from healthcare-related infections, thus indicating the gravity of the problem caused by *S. aureus* (Iregui et al., 2019).

Similarly, other approved antibiotics, such as daptomycin, a lipopeptide antibiotic, also have witnessed resistance emerging against them by *S. aureus* (Stefani et al., 2015). Also, according to a report published by World Health Organization (2014), antibiotic-resistant strains pose a serious health risk to the population, a threat to food security, and a hindrance to the development of a country. Such antibiotic resistance strains have made the use of any conventional antibiotics obsolete and limited the efficacy of another therapeutic approach. In the face of such overwhelming odds, new therapeutic tools must be added to the shrinking arsenal of antibacterial agents in the fight against *S. aureus* infection.

Nanomedicine entails the application of nanotechnology in the medical field for screening, diagnosis, and therapy of the disease (Freitas, 2005; Fülöp et al., 2012). Nanomedicine has effectively emerged as a potential therapeutic alternative for leading cancer and other non-infectious diseases (Dube, 2019). However, nanotechnology for treating infectious diseases is continuously growing (Huh and Kwon, 2011; Blecher et al., 2011). Nanomaterials, specifically nanoparticles, are efficacious against various infectious diseases (Khan et al., 2016). The nanoparticles are small-sized particles generally between 1 and 100 nm (Kim et al., 2010). The nanoparticles that have been utilized in research studies against *S. aureus* are generally synthesized via three different methods: chemical, microbial-synthesized, and plant-synthesized. Chemical methods are inherently energy-

intensive, involve complex methodology, and produce byproducts injurious to the environment (Li et al., 2011). The chemical method was in vogue a few years ago. However, it has given way to the more environment-friendly methods that utilize either microbial extract or biomass or plant extract as reducing and capping agents for the synthesis of nanoparticles.

On the other hand, although plant-mediated nanoparticles synthesis is time-efficient and straightforward, it generally produces polydispersed nanoparticles due to the presence of phytochemicals, such as polyphenols, proteins, flavonoids, terpenoids, etc. (Ovais et al., 2016; Salunke et al., 2014). Further, the availability of a plant is hinged on certain factors, like the geography of the region and season of the year, that in turn affect the phytochemical profile of a plant extract to be used for the biogenic synthesis of nanoparticles (Singh et al., 2013). In comparison, the microbial route of nanoparticles synthesis is devoid of any such requirement, and the experimental conditions (temperature, pH, pressure, humidity, etc.) can be easily varied to control the size and shape of nanoparticles. The microbial methods take advantage of microorganisms like bacteria, actinomycetes, cyanobacteria, fungi, yeast, and algae to fabricate nanoparticles. The microbial-mediated synthesis of metallic nanoparticles can be either extracellular or intracellular, depending on the location where the formation of the nanoparticles takes place (Singh et al., 2013; Golinska et al., 2014). The extracellular synthesis has an advantage over the intracellular mode of synthesis because it does not require downstream processing to recover nanoparticles from within the confine of the bacterial cell wall (Iravani, 2014; Singh et al., 2016D). A distinct advantage of nanoparticles synthesis using microbial methods is that its production can be increased by scaling up microbial biomass via fermentation techniques (Moon et al., 2010).

Moreover, nature is abundant with various microbes containing diverse biomolecules that can reduce nanoparticle synthesis (Zhang et al., 2011; Li et al., 2011). The microbes-based synthesis of green nanoparticles involves bioreduction of the ionic state of metal (e.g., Au3+, Ag+) to the elemental form of the metal (e.g., Au0, Ag0) by biomolecules and enzymes found in

microorganisms (Kharissova et al., 2013; Iravani, 2014). Further, the microbial biomass can not only be used to prepare metal NPs but can also be utilized for fabricating metal oxide NPs and bi-, tri-, or multi-metallic NPs. Given such advantages, it is no surprise that several research groups have successfully synthesized metallic nanoparticles with antibacterial potential against *S. aureus* from microorganisms (Figure-1).

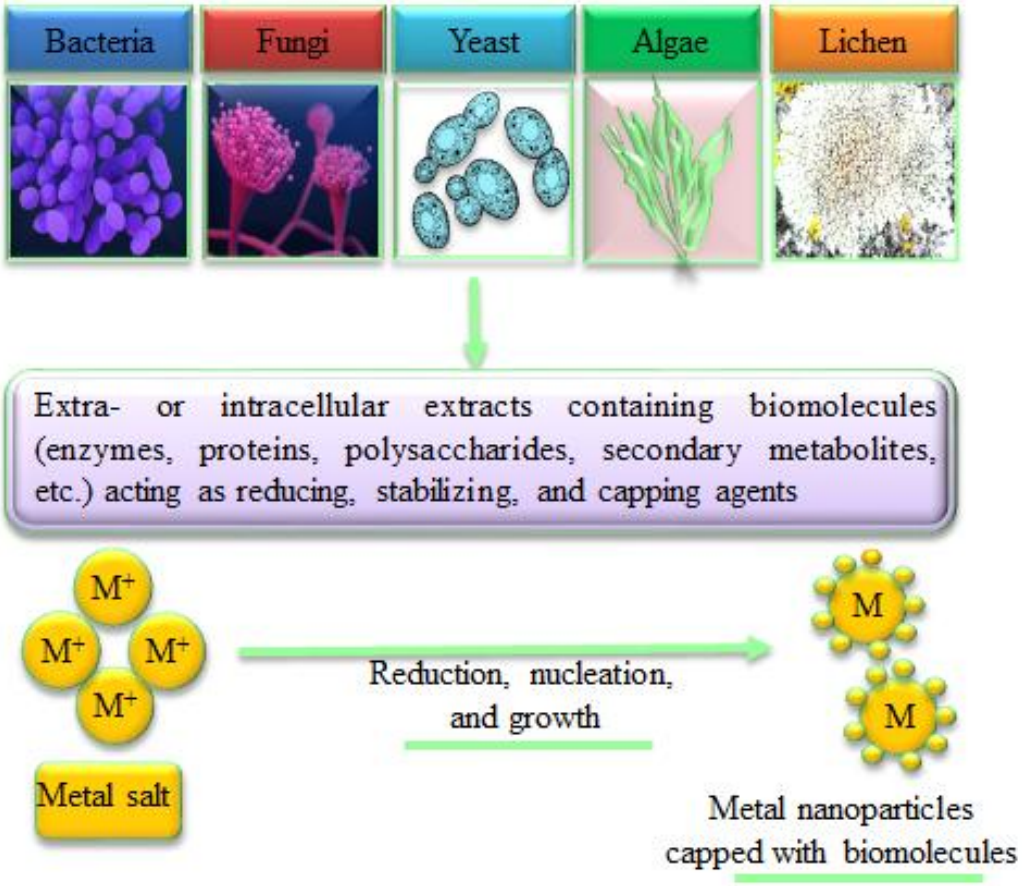

Figure 1: Synthesis of metal nanoparticles from microorganisms. The lichen image is taken from http://www.stridvall.se/lichens/gallery/Protoparmeliopsis/AAAA1582?full=1.

Bacterial-fabricated nanoparticles against *S. aureus*

Bacteria is an excellent source for nanoparticle synthesis because of their ability to acclimatize to the surrounding environment, their ready availability, and contain biomolecules that can reduce metal ions into their corresponding nanoparticles and modify the surface of NPs functionalization (Ovais et al., 2018). Many bacterial species have been utilized to synthesize metal nanoparticles

with toxic properties toward *S. aureus*. Bacteria belonging to many phyla, especially Actinobacteria, have been explored to synthesize nanoparticles showing antibacterial activities toward *S. aureus* in Table-1. Examples of bacteria belonging to the phylum Actinobacteria that have been studied for the synthesis of metal NPs to control the growth of *S. aureus* (Table-1).

Table1: *Antibacterial activities toward S. aureus* strains

S.No.	Actinobacteria sp.	References
1.	*Streptomyces aureofaciens* MTCC 356	Sundarmoorthi et al., 2011
2.	*Streptomyces* sp. VITBT7	Subashini and Kannabiran, 2013
3.	*Streptomyces* sp. JAR1	Chauhan et al., 2013
4.	*Nocardiopsis* sp. MBRC-1	Manivasagan et al., 2013
5.	*Streptomyces enissocaesilis*	Shaaban et al., 2018
6.	*Streptomyces* sp. SSHH-1E	El-Naggar et al., 2016
7.	*Kocuria rosea* BS-1	Kumar and Sujitha, 2014
8.	*Nocardiopsis valliformis*	Rathod et al., 2016
9.	*Streptomyces viridogens* strain HM10	Balagurunathan et al., 2011
10.	*Streptomyces* sp. B5	Shanmugasundaram et al., 2017
11.	*Micrococcus yunnanensis* strain J2	Jafari et al., 2018
12.	*Streptomyces rochei MHM13*	Abd-Elnaby et al., 2016
13.	Actinobacteria SH11 strain	Wypij et al., 2017
14.	*Streptomyces xinghaiensis* OF1	Wypij et al., 2018
15.	*Corynebacterium glutamicum*	Gowramma et al., 2014
16.	*Streptacidiphilus durhamensis*	Buszewski et al., 2018
17.	*Streptomyces* sp. Al-Dhabi-87	Al-Dhabi et al., 2018
18.	*Actinomycetes* VITBN4	Nabila and Kannabiran, 2018
19.	*Streptomyces zaomyceticus* Oc-5	Hassan et al., 2019
20.	*Streptomyces pseudogriseolus* Acv-11	Hassan et al., 2019

In one such study, Subashini and Kannabiran (2013) synthesized silver NPs from *Streptomyces* sp. and reported their antimicrobial activity against *S. aureus*. Similarly, in another study, biogenic silver NPs were synthesized from *Streptomyces aureofaciens*, an actinomycete, and found to be effective at a concentration as low as 50 µg/mL against *S. aureus* (Sundarmoorthi et al., 2011).

Manikprabhu and group (2016) prepared spherical silver NPs with a size range of 4-50 nm using actinobacteria *Sinomonas mesophila* MPKL 26 in a sunlight-mediated green synthesis. They reported good antibacterial activity for the nanoparticles against the multi-drug-resistant strain of *S. aureus*. Similarly, Raja and John (2017) fabricated spherical silver NPs of 80 nm size from a marine *Micromonospora* sp., actinobacteria, and clinically-isolated drug-resistant *S. aureus*.

Although most of the studies using Actinobacteria for the nanoparticles synthesis fabricate silver NPs, there are reports that synthesized gold NPs (Balagurunathan et al., 2011; Shanmugasundaram et al., 2017; Jafari et al., 2018), zinc NPs (Rajamanickam et al., 2012), selenium NPs (Shaaban et al., 2018), and metal oxide NPs (Shaaban et al., 2018; Nabila and Kannabiran, 2018; Hassan et al., 2019), with antibacterial activities against *S. aureus*. For example, Balagurunathan et al. (2011) reported intracellular biosynthesis of gold NPs by *Streptomyces viridogens* strain HM10, isolated from Himalayan mountain soil, and the biogenic gold NPs demonstrated antimicrobial action against *S. aureus*.

In addition to actinobacteria, other bacterial species have also been reported for the biogenic synthesis of metallic NPs showing antibacterial properties against *S. aureus*. These include species belonging to the genera in Table-2. Nanda and Saravanan (2009) reported the extracellular synthesis of silver NPs of the size range 160 to 180 nm in a cost-effective process by utilizing the wild strain of *S. aureus* itself. Further, the authors showed that the synthesized silver NPs interfere with the cell wall synthesis of *S. aureus* and inhibit its growth (Nanda and Saravanan, 2009). In the same way, *S. aureus* and its drug-resistant strain MRSA were utilized to synthesize selenium NPs having antibacterial properties toward *S. aureus* (Cruz et al., 2018). The authors noted that the selenium NPs synthesized from *S. aureus* and *E. coli* had their highest antibacterial activities against the microbe *S. aureus* and *E. coli*, respectively. The authors proposed an attractive theory that the metallic NPs synthesized from a particular bacteria are generally most effective towards the same bacterial species from which they were synthesized (Cruz et al., 2018).

Table 2: *Metallic NPs showing antibacterial properties against S. aureus.*

S.No.	genera	References
1.	*Alcaligenes*	Divya et al., 2019
2.	*Aeromonas*	Singh et al., 2016A
3.	*Bacillus*	Velmurugan et al., 2014; Ghiuță et al., 2018; Saravanan et al., 2018B; Sunkar and Nachiyar, 2012; Rehman et al., 2019; Shivashankarappa and Sanjay, 2015; Elbeshehy et al., 2015; Khiralla and El-Deeb, 2015; Dalvand et al., 2018; Piacenza et al., 2017; Deljou and Goudarzi, 2016; Zare et al., 2012; Shakibaie et al., 2015; Abdallah et al., 2019),
4.	*Delftia*	Shakibaie et al., 2019
5.	*Enterococcus*	Shoeibi and Mashreghi, 2017
6.	*Deinococcus*	Li Sundarmoorthi et al., 2016
7.	*Escherichia*	Cruz et al., 2018
8.	*Halococcus*	Srivastava et al., 2015
9.	*Halomonas*	Taran et al., 2018
10.	*Kinneretia*	Singh et al., 2016B
11.	*Klebsiella*	Shahverdi et al., 2007; Malarkodi et al., 2014
12.	*Lysinibacillus*	Bhatia et al., 2016
13.	*Novosphingobium*	Du et al., 2016
14.	*Ochrobactrum*	Thomas et al., 2014; Zonaro et al., 2
15.	*Pantoea*	Monowar et al., 2018
16.	*Pseudomonas*	Cruz et al., 2018; Barsainya and Singh, 2018; Ashengroph et al., 2019; Syed et al., 2016; Punjabi et al., 2018; Shakibaie et al., 2017; Gopinath et al., 2017; Banerjee et al., 2019; Pandey et al., 2018; Baker et al., 2015
17.	*Ralstonia*	Srivastava and Mukhopadhyay, 2015
18.	*Serratia*	Dhandapani et al., 2014
19.	*Shewanella*	Vaigankar et al., 2018; Ramasamy et al., 2016)
20.	*Sporosarcina*	Singh et al., 2016E; Rahimi et al., 2018
21.	*Staphylococcus*	Nanda and Saravanan, 2009; Rauf et al., 2017; Cruz et al., 2018
22.	*Stenotrophomonas*	Zonaro et al., 2015; Cremonini et al., 2018
23.	*Thermoactinomyces*	Deepa et al., 2013
24.	*Weissella*	Singh et al., 2016C

Similarly, Srivastava and Mukhopadhyay (2015) synthesized spherical-shaped selenium nanoparticles (SeNPs) with a 40–120 nm size range from non-pathogenic bacteria *Ralstonia eutropha*. They reported a very high (up to 99%) reduction in the growth of *S. aureus* in the presence of selenium NPs. Moreover, biogenic SeNPs exhibited higher efficiency, indicated by a lower MIC value of 100 µg/mL than conventional antibiotic ampicillin, with a MIC value of 250 µg/mL, against *S. aureus* (Srivastava and Mukhopadhyay, 2015). Selenium NPs synthesized by many other bacteria such as *Stenotrophomonas maltophilia* SeITE02 (Zonaro et al., 2015), *Enterococcus faecalis* (Shoeibi and Mashreghi, 2017), *Staphylococcus aureus* (Cruz et al., 2018), MRSA (Cruz et al., 2018), *Escherichia coli* (Cruz et al., 2018), and *Pseudomonas aeruginosa* (Cruz et al., 2018) also have been shown to inhibit the growth of *S. aureus*. Similarly, *Bacillus* sp. is also reported for the biosynthesis of selenium NPs that can kill *S. aureus* bacteria. For instance, Shakibaie and others (2015) synthesized selenium and selenium oxide NPs from MSh-1 strain of *Bacillus*. They showed that the nanoparticles inhibit biofilm formation by clinically-isolated *S. aureus*, including other human pathogens. Coating medical implant devices with microbial-synthesized nanoparticles can be a novel approach to remove the possibility of *S. aureus* infection. For example, Sonkusre and Cameotra (2015) coated polystyrene, glass, and catheter surfaces with SeNPs synthesized from bacteria *Bacillus licheniformis* JS2 and found that the coated surface can inhibit the biofilm formation by *S. aureus*.

Bacteria can also synthesize nanoparticles of different morphology that act against *S. aureus*. Dhandapani and group (2014) grew ZnO nanocrystals of various shapes, such as spherical nanoflower, on the cotton fabric surface by successfully utilizing activated ammonia synthesized from ureolytic bacteria Serratia ureilytica. The authors further reported that the cotton fabrics loaded with ZnO NPs showed good antibacterial activity against *S. aureus*. Singh et al. (2015) obtained anisotropic silver NPs of various shapes such as nano bar, pentagonal, spherical, icosahedral,

hexagonal, truncated triangle, and triangular shapes, with particle size ranging between 30 and 100 nm from *Bhargavaea indica* in an extracellular synthesis process. Further, the synthesized silver NPs exhibited antibacterial activity against *S. aureus*. They improved commercial antibiotics' antimicrobial activity, including lincomycin, vancomycin, novobiocin, penicillin G, cycloheximide, and rifampicin against *S. aureus* (Singh et al., 2015).

To combat *S. aureus*, bacteria-synthesized metal oxide and multi-metal nanoparticles have also been synthesized successfully from bacteria. For example, Taran et al. (2017) synthesized ZnO and TiO_2 NPs from the bacteria *Halomonas elongata* IBRC-M 1021 and reported the antibacterial activity of ZnO NPs against *S. aureus*. In another study, the bismuth oxide nanoparticles, i.e., Bi2O3, an oxide of non-toxic metal bismuth, were synthesized by Dalvand and others (2018) from the bacteria *Bacillus licheniformis* PTCC1320. The cube-shaped Bi2O3 NPs with sizes in the range of 26 to 62 nm were found to inhibit the growth of *S. aureus* in a concentration-dependent manner (Dalvand et al., 2018). Similarly, Ramasamy et al. (2016) prepared bimetallic gold-silver (Au-Ag) NPs from *Shewanella oneidensis* MR-1. They found that the bimetallic NPs are capable of inhibiting the growth and inhibiting the biofilm formation of *S. aureus*. Besides metal oxides, cadmium sulfide (CdS) and zinc sulfide (ZnS) nanoparticles have been synthesized from bacteria and possess suitable antibacterial activities against *S. aureus*. For example, Malarkodi and group (2014) synthesized spherical-shaped CdS and ZnS NPs, with sizes 10 to 25 and 65 nm, from *Klebsiella pneumoniae* (strain MAA) extracellularly. Further, the authors found excellent antibacterial activities for CdS and ZnS NPs against *S. aureus* in a concentration-dependent manner. Similarly, CDs NPs with an average size of 6.7 ± 2.4 nm obtained from the cell-free extract of bacteria *Pseudomonas chlororaphis* CHR05 also showed excellent antibacterial properties toward *S. aureus* (Ashengroph et al., 2019).

Cyanobacteria, alternatively known as blue-green algae, are particular bacteria capable of deriving energy through photosynthesis. Recently, aqueous extracts of

cyanobacteria *Trichodesmium erythraeum* were utilized to synthesize silver NPs with the cube-shaped and average size of 26.5 nm active against the tetracycline-resistant strain of *strain S. aureus* (Sathishkumar et al., 2019). The silver NPs with sizes in the range of 40 to 80 nm biosynthesized from cell biomass of cyanobacteria *Microcoleus* sp. isolated from mangrove acted as an excellent antibacterial agent toward *S. aureus* (Sudha et al., 2013). Uma Suganya et al. (2015) used protein extracted from cyanobacteria *Spirulina platensis* as a reducing and stabilizing agent to synthesize spherical-shaped gold NPs with sizes ranging from 2 to 8 nm. They reported the dose-dependent killing of *S. aureus* due to the piercing of its thick peptidoglycan layer by gold NPs. Similarly, an aqueous extract of *Spirulina platensis* was used by Sharma et al. (2015) for the extracellular synthesis of anti-*S. aureus* silver NPs. The extracts of cyanobacteria *Leptolyngbya* JSC-1 were used to fabricate silver and gold NPs with antibacterial potential toward *S. aureus* (Zada et al., 2018A; Zada et al., 2018B).

One crucial thing in the microbial fabrication of NPS is that the bacteria for the synthesis of nanoparticle that acts against *S. aureus* must be carefully chosen because nanoparticles of a metal synthesized from two different bacteria may behave differently against *S. aureus*. For example, Wang and group (2016A) synthesized gold NPs from the bacteria *Microbacterium resistance. They found* no antibacterial activity for nanoparticles against *S. aureus*. In contrast, gold NPs synthesized from *Deinococcus radiodurans* (Li et al., 2016) and *Pseudomonas fluorescens* 417 (Syed et al., 2016) could inhibit the growth of *S. aureus*.

Several studies have investigated the reduction of metal ions into nanoparticles by bacterial extract and concluded that bacterial enzymes like reductase, proteins, etc., are responsible for metal ion reduction (Iravani, S., 2014). Although bacteria have been used frequently to synthesize nanoparticles for inhibiting and killing *S. aureus*, bacterial-mediated synthesis entails a time-consuming optimization step and complex nanoparticles extraction and purification step (Narayanan and Sakthivel, 2010; Iravani, 2014).

Fungi-fabricated nanoparticles against *S. aureus*

Fungi are another microorganism that has been used to synthesize effective metal nanoparticles versus *S. aureus* (Yadav et al., 2015; Khan et al., 2018A; Guilger-Casagrande and Lima, 2019). In comparison to the bacteria, NPs synthesis from fungi has advantages like tolerating high metal concentrations. They can endure higher flow pressure and agitation in bioreactors, the easier downstream processing, faster growth rate and easier maintenance, and excellent production of extracellular enzymes that can be used as a reducing agent (Mohanpuria et al., 2008; Narayanan and Sakthivel, 2010; Saha et al., 2010; Gudikandula and Maringanti, 2016; Feroze et al., 2020). Silver nanoparticles with antibacterial properties toward *S. aureus* have been synthesized from the various fungal genus in Table-3.

Table 3: *Silver nanoparticles by means of antibacterial properties toward S. aureus, synthesized from the a number of fungal genus*

S.No.	Fungus *genus*	References
1.	*Agaricus*	Mirunalini et al., 2012; ul-Haq et al., 2015; Sriramulu and Sumathi, 2017
2.	*Alternaria*	Ibrahim and Hassan, 2016; Shaheen and Abd El Aty, 2018; Singh et al., 2017
3.	*Amylomyces*	Musarrat et al., 2010
4.	*Aspergillus*	Nayak and Anitha, 2014; Rodrigues et al., 2013; Saravanan and Nanda, 2010; Bharathidasan and Panneerselvam, 2012; Naqvi et al., 2013; Rajakumar et al., 2012; Barapatre et al.; 2016; Fatima et al., 2016; Shahzad et al., 2019; Sagar and Ashok, 2016; Kathiresan et al., 2010; Ottoni et al., 2017; Binupriya et al., 2010; Nanda et al., 2018; Balakumaran et al., 2016; Li et al., 2012; Devi and Joshi, 2012; Netala et al., 2016; Khan et al., 2018B
5.	*Beauveria*	Prabakaran et al., 2016
6.	*Bionectria*	Rodrigues et al., 2013
7.	*Calocybe*	Mirunalini et al., 2012
8.	*Chaetomium*	Singh et al., 2018
9.	*Colletotrichum*	Azmath et al., 2016
10.	Cordyceps	Wang et al., 2016B
11.	*Cryphonectria*	Dar et al., 2013
12.	*Emericella*	Barapatre et al., 2016
13.	*Fusarium*	Ingle et al., 2008; Bawskar et al., 2015; Gholami-Shabani et al., 2014; Joshi et al., 2013; Husseiny et al., 2015; Mekkawy et al., 2017
14.	*Ganoderma*	Gudikandula et al., 2017; Jogaiah et al., 2017; Mohanta et al., 2016; Sriramulu and Sumathi, 2017; Mirunalini et al., 2012
15.	*Guignardia*	Balakumaran et al., 2015
16.	*Macrophomina*	Joshi et al., 2013
17.	*Monascus*	El-Baz et al., 2016

18.	*Mucor*	Aziz et al., 2016
19.	*Nigrospora*	Shaheen and Abd El Aty, 2018; Muhsin and Hachim, 2014
20.	*Penicillium*	Singh et al., 2014; Ma et al., 2017; Sarsar et al., 2015; Hamad, 2018; Shaheen and Abd El Aty, 2018; Majeed et al., 2016; Nayak et al., 2018; Bharathidasan and Panneerselvam, 2012; Feroze et al., 2020
21.	*Pleurotus*	Kaur et al., 2018; Debnath et al., 2019; Al-Bahrani et al., 2017; Devika et al., 2012; Mirunalini et al., 2012; Nithya and Raghunathan, 2009; Vigneshwaran et al., 2007
22.	*Paecilomyces*	Devi and Joshi, 2012
23.	*Pestalotia*	Raheman et al., 2011
24.	*Phenerochaete*	Saravanan et al., 2018A
25.	*Phomosis*	Bharathidasan and Panneerselvam, 2012
26.	*Pycnoporus*	Chan and Don, 2012; Gudikandula and Maringanti, 2016
27.	*Rhizopus*	Ottoni et al., 2017
28.	*Schizophyllum*	Chan and Don, 2012; Gudikandula et al., 2015
29.	*Sclerotinia*	Saxena et al., 2016
30.	*Scopulariopsis*	Hamad, 2018
31.	*Trametes*	Gudikandula et al., 2017
32.	*Trichoderma*	Kumari et al., 2017; Fayaz et al., 2010; Saravanakumar and Wang, 2018; Ottoni et al., 2017; Ahluwalia et al., 2014

In a study, authors isolated filamentous fungi (*Aspergillus terreus* SP5, *Paecilomyces lilacinus* SF1, and *Fusarium* sp. MP5) from the soil of high altitude and cold climatic regions of eastern Himalayan. They used them to synthesize silver NPs that exhibited antimicrobial activity against *S. aureus* MTCC96 (Devi and Joshi, 2012). Furthermore, the mycosynthesized silver NPs showed a synergistic effect with antibiotics like chloramphenicol, ciprofloxacin, erythromycin, and methicillin against *S. aureus* MTCC96 (Devi and Joshi, 2012). Likewise, Gudikandula et al. (2017) isolated multiple strains of *Basidiomycetes* from a forest region. Among these two strains, *Ganoderma enigmatic* and *Trametes ljubarskyi* were utilized to synthesize silver NPs that showed antibacterial activity against *S. aureus*. Similarly, Chan and Don (2012) employed two white-rot fungi, *Schizophyllum commune* and *Pycnoporus sanguineus*, for the biosynthesis of silver NPs and examined their potential to inhibit the growth of *S. aureus*. Silver NPs synthesized from *S. commune* were shown to be most effective against *S. aureus*, as observed by its zone of inhibition of about 2.0 cm (Chan and Don, 2012). Similarly, in another study, blight-causing pathogenic

fungus *Cryphonectria* sp. was isolated from the stems of chestnut and was used for the extracellular synthesis of silver NPs (Dar et al., 2013). These silver NPs exhibited higher antibacterial activity than AgNO3 and conventional antibiotic streptomycin against *S. aureus* (Dar et al., 2013). Gudikandula and Maringant (2016) reported that fungus *Pycnoporus* sp. (HE792771) synthesized silver NPs showed more excellent antibacterial activity, with a higher zone of inhibition in the well-diffusion assay than chemically synthesized silver NPs toward *S. aureus*. Some studies used fungi synthesized metal NPs in combination with conventional antibiotics and reported synergistic antibacterial effect towards *S. aureus* at a lower concentration than when both metal NPs and antibiotics were used individually (Fayaz et al., 2010; Raheman et al., 2011; Devi and Joshi, 2012). Such a therapeutic approach enhances the efficacy of chemical antibiotics by reducing its minimum inhibitory concentration significantly against *S. aureus*.

Metal nanoparticles other than silver have also been synthesized from fungi and shown to be an excellent antibacterial agent to treat *S. aureus* infection. For example, gold NPs synthesized from marine endophytic fungus *Cladosporium cladosporioides* isolated from seaweed *Sargassum wightii* were found to inhibit the growth of *S. aureus* by disrupting its cell membrane (Hulikere M et al., 2017). Further, as per the authors, the bioreduction of gold metal salts to nanoparticles was mediated by NADPH-dependent reductase and phenolic compounds present in the aqueous extract of the fungus (Hulikere M et al., 2017). In another study, authors fabricated gold NPs with spherical shape and size ranging from 10.3 to 38.7 nm from an aqueous extract of oyster mushroom, *Pleurotus ostreatus* (Jacq. ex. Fr.) Kummer reported its growth inhibition property against *S. aureus* (Bawadekji et al., 2018). Mohamed and group (2015) employed *Alternaria alternata* fungi to synthesize cubic-shaped iron oxide NPs with antibacterial potential toward *S. aureus*.

Similarly, Sidkey et al. (2016) fabricated iron NPs intracellularly and extracellularly from *Aspergillus foetidus*. The size of the iron NPS ranges from 31.53 to 61.94 nm and 80 to 370

nm for intra- and extracellular particles, respectively, and both for both types of nanoparticles showed the ability to inhibit the growth of *S. aureus* (Sidkey et al., 2016). Munusamy and group (2014) fabricated spherical-shaped cerium oxide NPs of size 5 to 20 nm from the precursor cerium chloride heptahydrate by using culture filtrate of fungi *Curvularia lunata* and further reported the antibacterial activity of synthesized nanoparticles versus *S. aureus*. Alrabadi et al. (2017) synthesized magnesium oxide NPs extracellularly by employing fungi *Trichoderma viride*. Moreover, reported better antibacterial activity for the green NPs than the antibiotic amoxicillin against *S. aureus*.

Similarly, Ganesan and others (2020) utilized an aqueous extract of fungus belonging to *Periconium* sp. To synthesize ZnO NPs with hexagonal shape and size of 40 nm and found excellent antibacterial activity for the nanoparticles toward *S. aureus* in a concentration-dependent manner. In an exciting study, the authors used the fungus *Aspergillus welwitschia* to fabricate oval and spherical shaped tellurium NPs that exhibited antibacterial activity against MRSA; S. *aureus* was resistant toward the tellurium NPs (Abo Elsoud et al., 2018). Recently, some fungal strains such as *Aureobasidium pullulans*, *Mortierella humilis*, *Trichoderma harzianum*, and *Phoma glomerata* were utilized to biosynthesize selenium and tellurium NPs (Liang et al., 2019). Although authors did not study the antibacterial properties of fungal-synthesized selenium and tellurium NPs, these can be an excellent prospect for nanotherapeutic against *S. aureus* infection (Liang et al., 2019).

Yeast-fabricated nanoparticles against *S. aureus*

Yeast is another crucial category of organisms that have been used for the green synthesis of nanoparticles exhibiting anti-*S. aureus* activity. Like fungi, yeast also possesses more advantages than bacteria, such as fast growth rate, simple nutrient requirement, adept in producing enzymes in high amounts, etc. (Dinesh et al., 2011). Few studies have applied yeast to synthesize metal nanoparticles to counter the growth of *S. aureus*. For example, Dinesh and group (2011)

employed *Candida* sp. VITDKGB, a marine yeast, was collected from Nicobar Islands, India, to synthesize silver NPs of 87 nm size and reported the excellent antibacterial activity of NPS against *S. aureus*. Mishra et al. (2011) synthesized near-spherical silver and gold NPs in the size range of 10–20 nm and 50–70 nm, respectively, from the yeast *Candida guilliermondii*. They found both types of nanoparticles to be active against *S. aureus*. In a similar study, silver and gold NPs of the average size of 30 nm and 5 nm respectively were synthesized using cell-free extract of fungus *Candida albicans*. They inhibited the growth of *S. aureus* (Ahmad et al., 2013). *Candida albicans* was also utilized in another study to synthesize silver NPs having an average size in the range of 20-8 nm and of various shapes such as spherical, rod-like, decahedral, triangular, and platelet-like exhibited antibacterial activity against *S. aureus* in agar disc diffusion test (Rahimi et al., 2016). Bhat and group (2015) synthesized silver NPs utilizing *Candida albicans* and investigated their antibacterial effect when used alone and combined with the antibiotic ciprofloxacin on *S. aureus*. The authors found antibacterial activity for silver NPs when used alone. They observed an increase in antibacterial activity of the antibiotic when used in combination with the silver NPs against *S. aureus* (Bhat et al., 2015). Jalal and group (2018) isolated yeast *Candida glabrata* from oropharyngeal mucosa of human immunodeficiency virus patients and synthesized silver NPs. The synthesized silver NPs were spherical with size within the range of 2–15 nm and could inhibit the growth of *S. aureus* (Jalal et al., 2018). Waghmare et al. (2018) employed *Candida utilize* for the extracellular biosynthesis of silver NPs that was a spherical shape with size in the range of 20–80 nm and reported the bactericidal activity of silver NPs against *S. aureus* via agar disc diffusion assay. Eugenio and group (2016) biosynthesized silver NPs and AgCl NPs using yeast *Candida lusitaniae* isolated from the gut of termites and reported strong growth inhibitory potential of nanoparticles toward *S. aureus*. The yeast *Kluyveromyces marxianus* was employed for the bioproduction of silver NPs of spherical shape with a size range between 3 and 12 nm, and the obtained silver NPs showed antibacterial activity against the drug-resistant strain of *S.*

aureus (Ashour et al., 2014). Badhusha and Mohideen (2016) biosynthesized silver NPs of different sizes and shapes by controlling pH from *Saccharomyces cerevisiae*; the synthesized silver NPs were toxic to the *S. aureus* growth in well diffusion test.

Metal nanoparticles other than silver metals have also been synthesized from yeast and investigated for their efficacy against *S. aureus*. To give an example, Moghaddam et al. (2017) used ZnO NPs of hexagonal wurtzite structure with size in the range of 10–61 nm synthesized from the yeast *Pichia kudriavzevii* and reported the effectiveness of green ZnO NPs to inhibit the growth of *S. aureus*. Similarly, Chauhan et al. (2014) reported extracellular biosynthesis of ZnO NPs from *Pichia fermentans* JA2 isolated from spoiled fruit pulp and observed zone of inhibition against *S. aureus* in disc diffusion assay. Peiris and group (2018) biosynthesized spherical-shaped titanium dioxide NPs (TiO_2NPs) with an average size of 6.7±2.2 nm using Baker's yeast, i.e., Saccharomyces cerevisiae. Further, the authors found that the combination of green TiO_2NPs and sunlight is an excellent antibacterial agent toward *S. aureus* (Peiris et al., 2018). In another study, Venkat Kumar et al., 2019) synthesized cadmium sulfide nanoparticles (CdS NPS) of spherical shape and in size range 50-60 nm using *Candida albicans* and noted that the CdS NPs are capable of inhibiting the growth of *S. aureus* in a concentration-dependent manner.

Algae-fabricated nanoparticles against *S. aureus*

Algae are the photosynthetic eukaryotic organisms. That belong to a diverse group containing both unicellular and multicellular organisms. Algae are rich in biomolecules like carbohydrates, protein, fats, nucleic acids; pigments like carotenoids, chlorophylls, and phycobilins; and important secondary metabolites like alkaloids, terpenes, polyphenols, etc. (Michalak and Chojnacka, 2015). These natural chemicals can be an excellent reducing and stabilizing agent for the synthesis of nanoparticles. Algae, both microalgae and macroalgae have been employed in the eco-friendly and cost-effective green synthesis of metal NPS with the ability to kill *S. aureus* bacteria. To illustrate, Aziz et al. (2015) used a freshwater green algae *Chlorella pyrenoidosa. They reported* successful

biosynthesis of silver NPs with the size distribution of 8±2 nm showing antibacterial activity against *S. aureus*. According to the authors, the silver NPs capped with protein disrupted the *S. aureus* cell membrane, reached inside the cells, and caused the production of active oxygen species, thus killing the bacteria (Aziz et al., 2015). Similarly, good antibacterial activity against *S. aureus* was exhibited by silver NPs, of spherical and triangular shape and size in the range of 5 to 25 nm, synthesized from marine green algae *Caulerpa racemosa* isolated from the South-East coast of India (Kathiraven et al., 2015). Green algae *Caulerpa serrulata* was used by Aboelfetoh et al. (2017) to synthesize silver NPs with spherical shape and an average size of 10±2 nm to check the growth of *S. aureus*. The green algae such as *Chlorella Vulgaris* (Annamalai and Nallamuthu, 2016; Soleimani and Habibi-Pirkoohi, 2017), *Enteromorpha flexuosa* (wulfen) J. Agardh (Yousefzadi et al., 2014), *Spirogyra* sp (Pinjarkar et al., 2016; Salari et al., 2016), *Urospora* sp. (Suriya et al., 2012), *Pithophora oedogonia* (Mont.) Wittrock (Sinha et al., 2015), *Enteromorpha compressa* (Ramkumar et al., 2017) have also been reported for the synthesis of silver NPs with toxicity towards *S. aureus*. El-Rafie and group (2013) extracted water-soluble polysaccharides from red (*Pterocladia capillaries*, *Jania rubins*), green (*Ulva facial*), and brown (*Colpmenia sinus*) algae to reduce and stabilize silver ions for the preparation of silver NPs. The functionalized NPs were found to be stable for an extended period, and cotton fibers immobilized with the nanoparticles showed potential to be used as an antiseptic wound dressing (El-Rafie et al., 2013). Silver NPs synthesized from brown marine weed *Sargassum wightii* Greville isolated from the infected silkworm *Bombyx mori* L. A strong zone of inhibition was obtained against *S. aureus* (Govindaraju et al., 2009). Similarly, other species of genus *Sargassum*, such as *S. cinereum*, *S. ilicifolium*, *S. wightii*, have also been utilized to synthesize silver NPs having the antibacterial potential to prevent *S. aureus* growth (Mohandass et al., 2013; Kumar et al., 2012A; Shanmugam et al., 2013). Further, another brown alga like *Ecklonia cava* (Venkatesan et al., 2016) and *Turbinaria ornata* (Krishnan et al., 2015) have also emerged as efficient vehicles for the anti-*S.*

aureus silver NPs synthesis. Pugazhendhi et al. (2018), using marine red algae *Gelidium amansii* synthesized spherical-shaped silver NPs with size in the range 27-54 nm and reported its detrimental effect on *S. aureus* bacteria. Ethanolic extract of *Acanthophora specific*, marine red algae served as a capping and reducing agent in the formation of cubic-shaped silver NPs, with sizes ranging between 33 and 81 nm, that was destructive to *S. aureus* (Ibraheem et al., 2016). Similarly, Kumar et al. (2012B) also used *Acanthophora specifera* to fabricate silver NPs. However, in this case, the authors obtained spherical-shaped NPs, of 48 nm size that inhibited the biofilm formation by *S. aureus*. De Aragão and group (2019) extracted a polysaccharide from red algae *Gracilaria birdie*. They used it as a reducing and stabilizing agent for the synthesis of silver NPs to inhibit *S. aureus* growth. Aqueous extract of red algae *Amphiroa fragilissima* (Sajidha and Lakshmi, 2016) prepared silver NPs with effective antibacterial activity toward *S. aureus*. Silver chloride NPs with an average diameter of 9.8±5.7 nm prepared from *Chlorella Vulgaris* reduce the viability of *S. aureus* up to 98% in a dose-dependent manner (da Silva Ferreira et al., 2017).

Ramakritinan et al. (2013) synthesized silver, gold, and bimetallic silver-goldNPs (in three different ratios: 1:1, 1:3, and 3:1) from marine red alga *Gracilaria* sp. and found silver NPs and bimetallic NPs with Ag: Au ratio of 1:3 to be most effective against *S. aureus*. Similarly, the aqueous extract of marine algae *Gracilaria corticata* was used as a reducing agent to prepare gold NPs that showed good antibacterial activity against *S. aureus* in well diffusion test (Naveena and Prakash, 2013). Abdel-Raouf et al. (2017) prepared gold NPs with the size distribution of 3.85–77.13 nm and distinct shapes like a spherical rod, truncated, triangular, hexagonal from the ethanol extract of red algae *Galaxaura elongate* and reported the efficacy of fabricated NPs toward both MRSA and *S. aureus*. In another study, an aqueous extract of green microalga *Chlorella Vulgaris* was utilized to prepare spherical-shaped gold NPs, with sizes ranging between 2 and 10 nm, that was found to be toxic to *S. aureus* in agar well diffusion assay (Annamalai and Nallamuthu, 2015). Gold NPs of various shapes like grain, triangular, and spherical were fabricated from

diatom *Nitzschia* found to inhibit the growth of *S. aureus* (Borase et al., 2017). Diatom-fabricated gold NPs further enhanced the antibacterial effects of commercial antibiotics penicillin and streptomycin synergistically against *S. aureus* (Borase et al., 2017). Polydispersed gold NPs fabricated from marine red algae *Kappaphycus alvarezii* inhibited the growth of *S. aureus* in the disc diffusion assay (Rajasulochana et al., 2012). Abboud et al. (2014) reported the synthesis of majorly spherical-shaped copper oxide NPs (mixture of cuprous and cupric oxide NPs) of 5–45 nm dimension using brown algae *Bifurcaria bifurcata*. They showed the toxicity of nanoparticles to *S. aureus*. On the other hand, Arya et al. (2018) utilized green algae *Botryococcus braunii* to synthesize a mixture of cuprous and cupric oxide NPs. The green copper oxide NPs had cubical and spherical with an elongated shape and were an effective nanotherapeutic agent against *S. aureus (*Arya et al., 2018). Ishwarya and group (2018) prepared spherical ZnO NPs of 40-50 nm size by utilizing hot water extracts of marine seaweed *Sargassum wightii*. They recorded the anti-biofilm activity of ZnO NPs against *S. aureus*.

Lichen-fabricated nanoparticles against *S. aureus*

Lichens are the symbiosis between a fungus and an alga living mutually beneficial relationships. Lichens possess several secondary metabolites, antioxidants, etc., that can be used as reducing agents for nanoparticle synthesis. There are very few studies using lichens to synthesize nanoparticles and their use as antibacterial nanotherapeutic against *S. aureus*. For example, Alavi et al. (2019) used an aqueous extract of lichen *Protoparmeliopsis muralis* to synthesize nanoparticles of various metals such as Ag, Cu, Fe_3O_4, TiO_2, and ZnO. The synthesized metal NPs were all in a spherical shape, and the average size was 33.49±22.91, 253.97±57.2, 307±154, 133.32±35.33, and 178.06±49.97 nm for Ag, Cu, Fe_3O_4, TiO_2, and ZnO NPs, respectively. Moreover, all metallic NPs were found to possess bacteriostatic and bactericidal properties against *S. aureus,* and the antibacterial activities of nanoparticles were in the following order: Ag > ZnO > Fe_3O_4 > Cu > TiO_2 (Alavi et al., 2019). Similarly, another lichen *Usnea longissima* was used to form spherical shaped silver NPs of 9.40–

11.23 nm size, and the nanoparticles exhibited antibacterial activity toward *S. aureus* (Siddiqi et al., 2018). Din and group (2015) prepared silver NPs of 13 nm size from an aqueous extract of the lichen *Ramalina dumeticola* and reported the nanoparticles to be effective against MRSA (Figure-2).

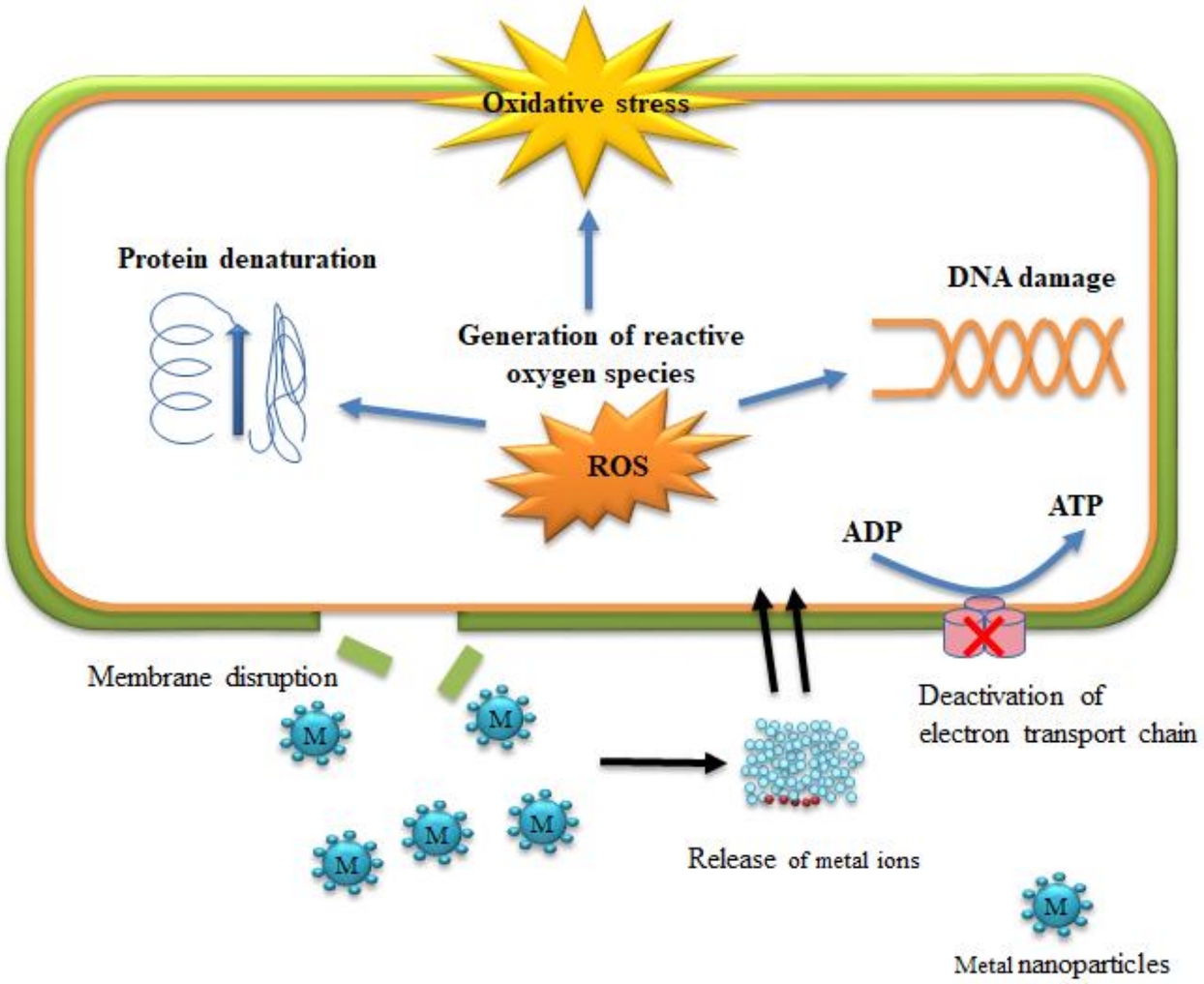

Figure 2: *Mode of antibacterial action of microbial-synthesized metal nanoparticles against S. aureus*

Conclusion

Nanomaterials have spawned a great deal of attention from the scientific community. Similarly, interest in *S. aureus* is also increasing because it is a common pathogen causing severe infections and the growing emergence of new drug-resistant strains. It is no surprise that metal nanoparticles have emerged as a great prospect to treat infectious diseases in these scenarios. Although a chemical process also produces metal nanoparticles, it is energy-intensive, cost-intensive, and environmentally harmful due to the generation of toxic materials. The synthesis of metal nanoparticles from the microorganism to treat *S. aureus* infection is an excellent alternative to the problem. The abundance and diversity of the microbial world present us with an excellent opportunity for nanoparticle synthesis that is environmentally benign and economically cost-effective. This review discussed the production of metal nanoparticles using various microbes, such as bacteria, fungi, yeast, and lichens, and their application to combat the growth of pathogenic bacteria *S. aureus*, including its resistant strains. Nanoparticles of silver metal have been most commonly synthesized from microorganisms to treat *S. aureus*. Further, nanoparticles of metals like gold, zinc, iron, titanium, copper, metal oxides, and multi-metals have also been synthesized from microbes by a substantial number of studies to combat the *S. aureus*. Though the use of microbial-fabricated metal nanoparticles as the bacteriostatic and bactericidal agent against *S. aureus* is shown to be effective by many studies, the research into their benefit and toxicity to humans must be appropriately investigated further so that they can be effectively used in practical clinical settings.

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Conflict of Intrest

The authors declare no conflicts of interest.

References:

1. Abboud, Y., Saffaj, T., Chagraoui, A., Bouari, A. E., Brouzi, K., Tanane, O., & Ihssane, B. (2014). Biosynthesis, characterization and antimicrobial activity of copper oxide nanoparticles (CONPs) produced using brown alga extract (*Bifurcaria bifurcata*). Applied Nanoscience, 4(5), 571–576. https://doi.org/10.1007/s13204-013-0233-x
2. Abd-Elnaby, H. M., Abo-Elala, G. M., Abdel-Raouf, U. M., & Hamed, M. M. (2016). Antibacterial and anticancer activity of extracellular synthesized silver nanoparticles from marine *Streptomyces rochei* MHM13. Egyptian Journal of Aquatic Research, 42(3), 301–312. https://doi.org/10.1016/j.ejar.2016.05.004
3. Abdallah, O. M., EL-Baghdady, K. Z., Khalil, M. M. H., El Borhamy, M. I., & Meligi, G. (2019). Biosynthesis, characterization and cytotoxicity of selenium nanoparticles using *Bacillus tropicus* Ism 2. Egyptian Academic Journal of Biological Sciences, G. Microbiology, 11(1), 47–57. https://doi.org/10.21608/eajbsg.2019.55269
4. Abdel-Raouf, N., Al-Enazi, N. M., & Ibraheem, I. B. M. (2017). Green biosynthesis of gold nanoparticles using *Galaxaura elongata* and characterization of their antibacterial activity. Arabian Journal of Chemistry, 10, S3029–S3039. https://doi.org/10.1016/j.arabjc.2013.11.044
5. Abo Elsoud, M. M., Al-Hagar, O. E. A., Abdelkhalek, E. S., & Sidkey, N. M. (2018). Synthesis and investigations on tellurium myconanoparticles. Biotechnology Reports, 18, e00247. https://doi.org/10.1016/j.btre.2018.e00247
6. Aboelfetoh, E. F., El-Shenody, R. A., & Ghobara, M. M. (2017). Eco-friendly synthesis of silver nanoparticles using green algae (*Caulerpa serrulata*): reaction optimization, catalytic and antibacterial activities. Environmental Monitoring and Assessment, 189(7), 349–15. https://doi.org/10.1007/s10661-017-6033-0
7. Ahluwalia, V., Kumar, J., Sisodia, R., Shakil, N. A., & Walia, S. (2014). Green synthesis of silver nanoparticles by *Trichoderma harzianum* and their bio-efficacy evaluation against *Staphylococcus aureus* and *Klebsiella pneumonia*. Industrial Crops and Products, 55, 202–206. https://doi.org/10.1016/j.indcrop.2014.01.026
8. Ahmad, T., Wani, I. A., Manzoor, N., Ahmed, J., & Asiri, A. M. (2013). Biosynthesis, structural characterization and antimicrobial activity of gold and silver nanoparticles. Colloids and Surfaces B: Biointerfaces, 107, 227–234. https://doi.org/10.1016/j.colsurfb.2013.02.004
9. Al-Bahrani, R., Raman, J., Lakshmanan, H., Hassan, A. A., & Sabaratnam, V. (2017). Green synthesis of silver nanoparticles using tree oyster mushroom *Pleurotus ostreatus* and its inhibitory activity against pathogenic bacteria. Materials Letters, 186, 21–25. https://doi.org/10.1016/j.matlet.2016.09.069
10. Al-Dhabi, N. A., Mohammed Ghilan, A.-K., & Arasu, M. V. (2018). Characterization of silver nanomaterials derived from marine *Streptomyces* sp. Al-dhabi-87 and its in vitro application against multidrug resistant and extended-spectrum beta-lactamase clinical pathogens. Nanomaterials, 8(5), 279. https://doi.org/10.3390/nano8050279
11. Alavi, M., Karimi, N., & Valadbaeigi, T. (2019). Antibacterial, antibiofilm, antiquorum sensing, antimotility, and antioxidant activities of green fabricated Ag, Cu, TiO_2, ZnO, and Fe_3O_4 NPs via *Protoparmeliopsis muralis* lichen aqueous extract against multi drug resistant bacteria. ACS Biomaterials Science & Engineering. 5(9), 4228–4243. https://doi.org/10.1021/acsbiomaterials.9b00274
12. Alrabadi, N. I., Thalij, K. M., Hussein, E. I., Al-Trad, & B. M. (2017). Antibacterial activity of Ag and MgO nanoparticles synthesized By *Trichoderma viride*. Journal of Applied Environmental and Biological Sciences, 7(8), 94-101.
13. Annamalai, J., & Nallamuthu, T. (2015). Characterization of biosynthesized gold nanoparticles from aqueous extract of *Chlorella vulgaris* and their anti-pathogenic properties. Appl. Nanosci., 5(5), 603–607. https://doi.org/10.1007/s13204-014-0353-y
14. Annamalai, J., & Nallamuthu, T. (2016). Green synthesis of silver nanoparticles: characterization and determination of antibacterial potency. Applied Nanoscience, 6(2), 259-265. https://doi.org/10.1007/s13204-015-0426-6
15. Appelbaum, P. C. (2006). The emergence of vancomycin-intermediate and vancomycin-resistant *Staphylococcus aureus*. Clinical Microbiology and Infection, 12(s1), 16–23. https://doi.org/10.1111/j.1469-0691.2006.01344.x
16. Arya, A., Gupta, K., Chundawat, T. S., & Vaya, D. (2018). Biogenic synthesis of copper and silver nanoparticles using green alga *Botryococcus braunii* and its antimicrobial activity. Bioinorganic Chemistry and Applications, 2018. https://doi.org/10.1155/2018/7879403
17. Ashengroph, M., Khaledi, A., & Bolbanabad, E. M. (2019). Extracellular biosynthesis of cadmium sulphide quantum dot using cell-free extract of *Pseudomonas chlororaphis* CHR05 and its antibacterial activity. Process Biochemistry. https://doi.org/10.1016/j.procbio.2019.10.028
18. Ashour, S.M. (2014). Silver nanoparticles as antimicrobial agent from *Kluyveromyces marxianus* and *Candida utilis*. International Journal of Current Microbiology and Applied Sciences, 3, 384-396.

19. Aziz, N., Faraz, M., Pandey, R., Shakir, M., Fatma, T., Varma, A., Barman, I., and Prasad, R. (2015). Facile algae-derived route to biogenic silver nanoparticles: synthesis, antibacterial, and photocatalytic properties. Langmuir, 31(42), 11605–11612. https://doi.org/10.1021/acs.langmuir.5b03081
20. Aziz, N., Pandey, R., Barman, I., & Prasad, R. (2016). Leveraging the attributes of *Mucor hiemalis*-derived silver nanoparticles for a synergistic broad-spectrum antimicrobial platform. Frontiers in Microbiology, 7, 1984. https://doi.org/10.3389/fmicb.2016.01984
21. Azmath, P., Baker, S., Rakshith, D., & Satish, S. (2016). Mycosynthesis of silver nanoparticles bearing antibacterial activity. Saudi Pharmaceutical Journal, 24(2), 140–146. https://doi.org/10.1016/j.jsps.2015.01.008
22. Badhusha, M. S. M., & Mohideen, M. M. A. K. (2016). Biosynthesis of silver nanoparticles using *Saccharomyces cerevisiae* with different pH and study of antimicrobial activity against bacterial pathogen. Chemical Science, 5(4), 906-911. https://doi.org/10.7598/cst2016.1275
23. Baker, S., Mohan Kumar, K., Santosh, P., Rakshith, D., & Satish, S. (2015). Extracellular synthesis of silver nanoparticles by novel *Pseudomonas veronii* AS41G inhabiting *Annona squamosa* L. and their bactericidal activity. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 136, 1434–1440. https://doi.org/10.1016/j.saa.2014.10.033
24. Balagurunathan, R., Radhakrishnan, M., Rajendran, R. B., & Velmurugan, D. (2011). Biosynthesis of gold nanoparticles by actinomycete *Streptomyces viridogens* strain HM10. Indian Journal of Biochemistry & Biophysics, 48, 331–335.
25. Balakumaran, M. D., Ramachandran, R., & Kalaichelvan, P. T. (2015). Exploitation of endophytic fungus, *Guignardia mangiferae* for extracellular synthesis of silver nanoparticles and their in vitro biological activities. Microbiological Research, 178, 9–17. https://doi.org/10.1016/j.micres.2015.05.009
26. Balakumaran, M. D., Ramachandran, R., Balashanmugam, P., Mukeshkumar, D. J., & Kalaichelvan, P. T. (2016). Mycosynthesis of silver and gold nanoparticles: Optimization, characterization and antimicrobial activity against human pathogens. Microbiological Research, 182, 8–20. https://doi.org/10.1016/j.micres.2015.09.009
27. Banerjee, A., Das, D., Rudra, S. G., Mazumder, K., Andler, R., & Bandopadhyay, R. (2019). Characterization of Exopolysaccharide Produced by *Pseudomonas* sp. PFAB4 for Synthesis of EPS-Coated AgNPs with Antimicrobial Properties. Journal of Polymers and the Environment. https://doi.org/10.1007/s10924-019-01602-z
28. Barapatre, A., Aadil, K. R., & Jha, H. (2016). Synergistic antibacterial and antibiofilm activity of silver nanoparticles biosynthesized by lignin-degrading fungus. Bioresources and Bioprocessing, 3(1), 1–13. https://doi.org/10.1186/s40643-016-0083-y
29. Barsainya, M. & Singh, D. P. (2018). Green synthesis of zinc oxide nanoparticles by *Pseudomonas aeruginosa* and their broad-spectrum antimicrobial effects. Journal of Pure and Applied Microbiology, 12(4), 2123-2134. https://doi.org/https://dx.doi.org/10.22207/JPAM.12.4.50
30. Bassetti, M., & Righi, E. (2015). Development of novel antibacterial drugs to combat multiple resistant organisms. Langenbeck's Archives of Surgery, 400(2), 153–165. https://doi.org/10.1007/s00423-015-1280-4
31. Bawadekji, A., Oueslati, M. H., Al Ali, M., & Jamith Basha, W. (2018). Biosynthesis of gold nanoparticles using *Pleurotus ostreatus* (Jacq. Ex. Fr.) Kummer extract and their antibacterial and antifungal activities. Journal of applied environmental and biological sciences, 8(3), 142-147.
32. Bawskar, M., Bansod, S., Gade, A., Deshmukh, S., & Rai, M. (2015). Comparative analysis of biosynthesised and chemosynthesised silver nanoparticles with special reference to their antibacterial activity against pathogens. IET Nanobiotechnology, 9(3), 107–113. https://doi.org/10.1049/iet-nbt.2014.0032
33. Bharathidasan, R., & Panneerselvam, A. (2012). Biosynthesis and characterization of silver nanoparticles using endophytic fungi *Aspergillus concius*, *Penicillium janthinellum* and *Phomosis* sp. International Journal of Pharmaceutical Sciences and Research, 3, 3163–3169. https://doi.org/10.13040/ijpsr.0975-8232.3(9).3163-69
34. Bhat, M. A., Nayak, B. K., & Nanda, A. (2015). Evaluation of bactericidal activity of biologically synthesised silver nanoparticles from *Candida albicans* in combination with ciprofloxacin. Materials Today: Proceedings, 2(9), 4395–4401. https://doi.org/10.1016/j.matpr.2015.10.036
35. Bhatia, D., Mittal, A., & Malik, D. K. (2016). Antimicrobial activity of PVP coated silver nanoparticles synthesized by Lysini*Bacillus* varians. 3 Biotech, 6(2). https://doi.org/10.1007/s13205-016-0514-7
36. Binupriya, A. R., Sathishkumar, M., & Yun, S.-I. (2010). Myco-crystallization of silver ions to nanosized particles by live and dead cell filtrates of *Aspergillus oryzae* var. viridis and its bactericidal activity toward *Staphylococcus aureus* KCCM 12256. Industrial & Engineering Chemistry Research, 49(2), 852–858. https://doi.org/10.1021/ie9014183
37. Blecher, K., Nasir, A., & Friedman, A. (2011). The growing role of nanotechnology in combating infectious disease. Virulence, 2(5), 395–401. https://doi.org/10.4161/viru.2.5.17035

38. Borase, H. P., Patil, C. D., Suryawanshi, R. K., Koli, S. H., Mohite, B. V., Benelli, G., & Patil, S. V. (2017). Mechanistic approach for fabrication of gold nanoparticles by *Nitzschia* diatom and their antibacterial activity. Bioprocess and Biosystems Engineering, 40(10), 1437–1446. https://doi.org/10.1007/s00449-017-1801-3
39. Buszewski, B., Railean-Plugaru, V., Pomastowski, P., Rafińska, K., Szultka-Mlynska, M., Golinska, P., Wypijc, M., Laskowski, D., & Dahm, H. (2018). Antimicrobial activity of biosilver nanoparticles produced by a novel *Streptacidiphilus durhamensis* strain. Journal of Microbiology, Immunology and Infection, 51(1), 45–54. https://doi.org/10.1016/j.jmii.2016.03.002
40. Chan, Y. S., & Don, M. M. (2012). Characterization of Ag nanoparticles produced by white-rot fungi and its in vitro antimicrobial activities. International Arabic Journal of Antimicrobial Agents, 2(3). https://doi.org/10.3823/717
41. Chauhan, R., Kumar, A., & Abraham, J. (2013). A biological approach to the synthesis of silver nanoparticles with S*treptomyces* sp JAR1 and its antimicrobial activity. Scientia pharmaceutica, 81(2), 607–621. https://doi.org/10.3797/scipharm.1302-02
42. Chauhan, R., Reddy, A., & Abraham, J. (2014). Biosynthesis of silver and zinc oxide nanoparticles using *Pichia fermentans* JA2 and their antimicrobial property. Applied Nanoscience, 5(1), 63–71. https://doi.org/10.1007/s13204-014-0292-7
43. Cremonini, E., Boaretti, M., Vandecandelaere, I., Zonaro, E., Coenye, T., Lleo, M. M., Lampis, S., & Vallini, G. (2018). Biogenic selenium nanoparticles synthesized by *Stenotrophomonas maltophilia* SeITE02 loose antibacterial and antibiofilm efficacy as a result of the progressive alteration of their organic coating layer. Microbial Biotechnology, 11(6), 1037–1047. https://doi.org/10.1111/1751-7915.13260
44. Cruz, D. M., Mi, G., & Webster, T. J. (2018). Synthesis and characterization of biogenic selenium nanoparticles with antimicrobial properties made by *Staphylococcus aureus*, methicillin-resistant *Staphylococcus aureus* (MRSA), *Escherichia coli*, and *Pseudomonas aeruginosa*. Journal of Biomedical Materials Research Part A, 106(5), 1400–1412. https://doi.org/10.1002/jbm.a.36347
45. da Silva Ferreira, V., ConzFerreira, M. E., Lima, L. M. T. R., Frasés, S., de Souza, W., & Sant'Anna, C. (2017). Green production of microalgae-based silver chloride nanoparticles with antimicrobial activity against pathogenic bacteria. Enzyme and Microbial Technology, 97, 114–121. https://doi.org/10.1016/j.enzmictec.2016.10.018
46. Dalvand, L. F., Hosseini, F., Dehaghi, S. M., & Torbati, E. S. (2018). Inhibitory Effect of Bismuth Oxide Nanoparticles Produced by *Bacillus licheniformis* on Methicillin-Resistant *Staphylococcus aureus* Strains (MRSA). Iranian Journal of Biotechnology, 16(4). 279–286. https://doi.org/10.21859/ijb.2102
47. Dar, M. A., Ingle, A., & Rai, M. (2013). Enhanced antimicrobial activity of silver nanoparticles synthesized by *Cryphonectria* sp. evaluated singly and in combination with antibiotics. Nanomedicine: Nanotechnology, Biology and Medicine, 9(1), 105–110. https://doi.org/10.1016/j.nano.2012.04.007
48. David, M. Z., & Daum, R. S. (2010). Community-associated methicillin-resistant *Staphylococcus aureus*: Epidemiology and clinical consequences of an emerging epidemic. Clinical Microbiology Reviews, 23(3), 616–687. https://doi.org/0.1128/CMR.00081-09
49. David M. Z., & Daum R. S. (2017). Treatment of *Staphylococcus aureus* Infections. In: Bagnoli F., Rappuoli R., Grandi G. (eds) *Staphylococcus aureus* (pp. 325-383). Current Topics in Microbiology and Immunology, vol 409. Springer, Cham. https://doi.org/10.1007/82_2017_42
50. de Aragão, A. P., de Oliveira, T. M., Quelemes, P. V., Perfeito, M. L. G., Araújo, M. C., de Araújo Sousa Santiago, J., Cardoso, V. S., Quaresma, P., de Almeida Leite, J. R. S., & da Silva, D. A. (2019). Green synthesis of silver nanoparticles using the seaweed *Gracilaria birdiae* and their antibacterial activity. Arabian Journal of Chemistry, 12(8), 4182–4188. https://doi.org/10.1016/j.arabjc.2016.04.014
51. Debnath, G., Das, P., & Saha, A. K. (2019). Green synthesis of silver nanoparticles using mushroom extract of *Pleurotus giganteus*: characterization, antimicrobial, and α-amylase inhibitory activity. BioNanoScience. https://doi.org/10.1007/s12668-019-00650-y
52. Deepa, S., Kanimozhi, K., & Panneerselvam, A. (2013). Antimicrobial activity of extracellularly synthesized silver nanoparticles from marine derived actinomycetes. International Journal of Current Microbiology and Applied Sciences, 2(9), 223-230.
53. Deljou, A., & Goudarzi, S. (2016). Green extracellular synthesis of the silver nanoparticles using thermophilic *Bacillus* sp. Az1 and its antimicrobial activity against several human pathogenetic bacteria. Iranian Journal of Biotechnology, 14(2), 25–32. https://doi.org/10.15171/ijb.1259
54. Devi, L. S., & Joshi, S. R. (2012). Antimicrobial and synergistic effects of silver nanoparticles synthesized using soil fungi of high altitudes of eastern himalaya. Mycobiology, 40(1), 27–34. https://doi.org/10.5941/MYCO.2012.40.1.027

55. Devika, R., Elumalai, S., Manikandan, E., & Eswaramoorthy, D. (2012). Biosynthesis of silver nanoparticles using the fungus *Pleurotus ostreatus* and their antibacterial activity. Open Access Scientific Reports, 1(12). https://doi.org/10.4172/scientificreports.557
56. Dhandapani, P., Siddarth, A. S., Kamalasekaran, S., Maruthamuthu, S., & Rajagopal, G. (2014). Bio-approach: Ureolytic bacteria mediated synthesis of ZnO nanocrystals on cotton fabric and evaluation of their antibacterial properties. Carbohydrate polymers, 103, 448–55. https://doi.org/10.1016/j.carbpol.2013.12.074
57. Din, L. B., Mie, R., Samsudin, M. W., Ahmad, A., & Ibrahim, N. (2015). Biomimetic synthesis of silver nanoparticles using the lichen *Ramalina dumeticola* and the antibacterial activity. Malaysian Journal of Analytical Sciences, 19(2), 369−376.
58. Dinesh, K.S., Karthik, L., Gaurav, K. & Bhaskara Rao, K.V., (2011). Biosynthesis of silver nanoparticles from marine yeast and their antimicrobial activity against multidrug resistant pathogens. Pharmacologyonline, 3, 1100-1111.
59. Divya, M., Kiran, G. S., & Selvin, J. (2019). Biogenic synthesis and effect of silver nanoparticles (AgNPs) to combat catheter-related urinary tract infections. Biocatalysis and Agricultural Biotechnology, 101037. https://doi.org/10.1016/j.bcab.2019.101037
60. Du, J., Singh, H., & Yi, T.-H. (2016). Biosynthesis of silver nanoparticles by *Novosphingobium* sp. THG-C3 and their antimicrobial potential. Artificial Cells, Nanomedicine, and Biotechnology, 45(2), 211–217. https://doi.org/10.1080/21691401.2016.1178135
61. Dube, A. (2019). Nanomedicines for Infectious Diseases. Pharmaceutical Research, 36(4). https://doi.org/10.1007/s11095-019-2603-x
62. El-Baz, A. F., El-Batal, A. I., Abomosalam, F. M., Tayel, A. A., Shetaia, Y. M., & Yang, S.-T. (2016). Extracellular biosynthesis of anti-*Candida* silver nanoparticles using *Monascus purpureus*. Journal of Basic Microbiology, 56(5), 531–540. https://doi.org/10.1002/jobm.201500503
63. El-Naggar, N. E.-A., Mohamedin, A., Hamza, S. S., & Sherief, A.-D. (2016). Extracellular biofabrication, characterization, and antimicrobial efficacy of silver nanoparticles loaded on cotton fabrics using newly isolated *Streptomyces* sp. SSHH-1E. Journal of Nanomaterials. https://doi.org/10.1155/2016/3257359
64. El-Rafie, H. M., El-Rafie, M. H., & Zahran, M. K. (2013). Green synthesis of silver nanoparticles using polysaccharides extracted from marine macro algae. Carbohydrate Polymers, 96(2), 403–410. https://doi.org/10.1016/j.carbpol.2013.03.071
65. Elbeshehy, E. K. F., Elazzazy, A. M., & Aggelis, G. (2015). Silver nanoparticles synthesis mediated by new isolates of *Bacillus* spp., nanoparticle characterization and their activity against Bean Yellow Mosaic Virus and human pathogens. Frontiers in Microbiology, 6. https://doi.org/10.3389/fmicb.2015.00453
66. Eugenio, M., Müller, N., Frasés, S., Almeida-Paes, R., Lima, L. M. T. R., Lemgruber, L., Farina, M., de Souza, W., & Sant'Anna, C. (2016). Yeast-derived biosynthesis of silver/silver chloride nanoparticles and their antiproliferative activity against bacteria. RSC Advances, 6(12), 9893–9904. https://doi.org/10.1039/c5ra22727e
67. Fatima, F., Verma, S. R., Pathak, N., & Bajpai, P. (2016). Extracellular mycosynthesis of silver nanoparticles and their microbicidal activity. Journal of Global Antimicrobial Resistance, 7, 88–92. https://doi.org/10.1016/j.jgar.2016.07.013
68. Fayaz, A. M., Balaji, K., Girilal, M., Yadav, R., Kalaichelvan, P. T., & Venketesan, R. (2010). Biogenic synthesis of silver nanoparticles and their synergistic effect with antibiotics: a study against gram-positive and gram-negative bacteria. Nanomedicine: Nanotechnology, Biology and Medicine, 6(1), 103–109. https://doi.org/10.1016/j.nano.2009.04.006
69. Feroze, N., Arshad, B., Younas, M., Afridi, M. I., Saqib, S., & Ayaz, A. (2020). Fungal mediated synthesis of silver nanoparticles and evaluation of antibacterial activity. Microscopy Research and Technique, 83(1), 72-80. https://doi.org/10.1002/jemt.23390
70. Freitas, R. A. (2005). What is nanomedicine? Nanomedicine: Nanotechnology, Biology and Medicine, 1(1), 2–9. https://doi.org/10.1016/j.nano.2004.11.003
71. Fülöp, Z., Kurkov, S. V., Nielsen, T. T., Larsen, K. L., & Loftsson, T. (2012). Self-assembly of cyclodextrins: formation of cyclodextrin polymer based nanoparticles. Journal of Drug Delivery Science and Technology, 22(3), 215–221. https://doi.org/10.1016/S1773-2247(12)50032-8
72. Ganesan, V., Hariram, M., Vivekanandhan, S., & Muthuramkumar, S. (2020). *Periconium* sp. (endophytic fungi) extract mediated sol-gel synthesis of ZnO nanoparticles for antimicrobial and antioxidant applications. Materials Science in Semiconductor Processing, 105, 104739. https://doi.org/10.1016/j.mssp.2019.104739
73. Ghiuță, I., Cristea, D., Croitoru, C., Kost, J., Wenkert, R., Vyrides, I., Anayiotos, A., & Munteanu, D. (2018). Characterization and antimicrobial activity of silver nanoparticles, biosynthesized using *Bacillus* species. Applied Surface Science, 438, 66–73. https://doi.org/10.1016/j.apsusc.2017.09.163

74. Gholami-Shabani, M., Akbarzadeh, A., Norouzian, D., Amini, A., Gholami-Shabani, Z., Imani, A., Chiani, M., Riazi, G., Shams-Ghahfarokhi, M., & Razzaghi-Abyaneh, M. (2014). Antimicrobial activity and physical characterization of silver nanoparticles green synthesized using nitrate reductase from *Fusarium oxysporum*. Applied biochemistry and biotechnology, 172(8), 4084–4098. https://doi.org/10.1007/s12010-014-0809-2

75. Golinska, P., Wypij, M., Ingle, A. P., Gupta, I., Dahm, H., & Rai, M. (2014). Biogenic synthesis of metal nanoparticles from actinomycetes: biomedical applications and cytotoxicity. Applied Microbiology and Biotechnology, 98(19), 8083–8097. https://doi.org/10.1007/s00253-014-5953-7

76. Gopinath, V., Priyadarshini, S., Loke, M. F., Arunkumar, J., Marsili, E., MubarakAli, D., Velusamy, P., and Vadivelu, J. (2017). Biogenic synthesis, characterization of antibacterial silver nanoparticles and its cell cytotoxicity. Arabian Journal of Chemistry, 10(8), 1107–1117. https://doi.org/10.1016/j.arabjc.2015.11.011

77. Govindaraju, K., Kiruthiga, V., Kumar, V. G., & Singaravelu, G. (2009). Extracellular synthesis of silver nanoparticles by a marine alga, *Sargassum wightii grevilli* and their antibacterial effects. Journal of Nanoscience and Nanotechnology, 9(9), 5497–5501. https://doi.org/10.1166/jnn.2009.1199

78. Gowramma, B., Keerthi, U., Rafi, M., & Rao, D. M. (2015). Biogenic silver nanoparticles production and characterization from native stain of *Corynebacterium* species and its antimicrobial activity. 3 Biotech, 5(2), 195. https://doi.org/10.1007/s13205-014-0210-4

79. Gudikandula, K., & Charya Maringanti, S. (2016). Synthesis of silver nanoparticles by chemical and biological methods and their antimicrobial properties. Journal of Experimental Nanoscience, 11(9), 714–721. https://doi.org/10.1080/17458080.2016.1139196

80. Gudikandula, K., Metuku, R. P., Burra, S., Laxmi, S. V. S. S. S., Nidadavolu, H. B., Pabba, S. K., & Alha, S. C. M. (2015). Fungus-mediated synthesis of silver nanoparticles and their activity against gram positive and gram negative bacteria in combination with antibiotics. Walailak Journal of Science and Technology (WJST), 12(7), 613-622. http://wjst.wu.ac.th/index.php/wjst/article/view/1390

81. Gudikandula, K., Vadapally, P., & Singara Charya, M. A. (2017). Biogenic synthesis of silver nanoparticles from white rot fungi: Their characterization and antibacterial studies. OpenNano, 2, 64–78. https://doi.org/10.1016/j.onano.2017.07.002

82. Guilger-Casagrande, M., & Lima, R. d. (2019). Synthesis of Silver Nanoparticles Mediated by Fungi: A Review. Frontiers in Bioengineering and Biotechnology, 7. https://doi.org/10.3389/fbioe.2019.00287

83. Hamad, M. T. (2018). Biosynthesis of silver nanoparticles by fungi and their antibacterial activity. International Journal of Environmental Science and Technology. https://doi.org/10.1007/s13762-018-1814-8

84. Hassan, S. E.-D., Fouda, A., Radwan, A. A., Salem, S. S., Barghoth, M. G., Awad, M. A., Abdo, A. M., & El-Gamal, M. S. (2019). Endophytic actinomycetes *Streptomyces* spp mediated biosynthesis of copper oxide nanoparticles as a promising tool for biotechnological applications. Journal of Biological Inorganic Chemistry, 24,, 377–393. https://doi.org/10.1007/s00775-019-01654-5

85. Huh, A. J., & Kwon, Y. J. (2011). "Nanoantibiotics": A new paradigm for treating infectious diseases using nanomaterials in the antibiotics resistant era. Journal of Controlled Release, 156(2), 128–145. https://doi.org/10.1016/j.jconrel.2011.07.002

86. Hulikere M, M., Joshi, C. G., Danagoudar, A., Poyya, J., Kudva, A. K., & BL, D. (2017). Biogenic synthesis of gold nanoparticles by marine endophytic fungus- *Cladosporium cladosporioides* isolated from seaweed and evaluation of their antioxidant and antimicrobial properties. Process Biochemistry, 63, 137–144. https://doi.org/10.1016/j.procbio.2017.09.008

87. Husseiny, S. M., Salah, T. A., & Anter, H. A. (2015). Biosynthesis of size controlled silver nanoparticles by *Fusarium oxysporum*, their antibacterial and antitumor activities. Beni-Suef University Journal of Basic and Applied Sciences, 4(3), 225–231. https://doi.org/10.1016/j.bjbas.2015.07.004

88. Ibraheem, I. B. M., Abd-Elaziz, B. E. E., Saad, W. F., & Fathy, W. A. (2016). Green biosynthesis of silver nanoparticles using marine red algae *Acanthophora specifera* and its antimicrobial activity. Journal of Nanomedicine & Nanotechnology, 7(409), 1-4. https://doi.org/10.4172/2157-7439.1000409

89. Ibrahim, H. M. M., & Hassan, M. S. (2016). Characterization and antimicrobial properties of cotton fabric loaded with green synthesized silver nanoparticles. Carbohydrate Polymers, 151, 841–850. https://doi.org/10.1016/j.carbpol.2016.05.041

90. Ingle, A., Gade, A., Pierrat, S., Sonnichsen, C., & Rai, M. (2008). Mycosynthesis of silver nanoparticles using the fungus *Fusarium acuminatum* and its activity against some human pathogenic bacteria. Current Nanoscience, 4(2), 141–144. https://doi.org/10.2174/157341308784340804

91. Iravani, S. (2014). Bacteria in Nanoparticle Synthesis: Current Status and Future Prospects. International Scholarly Research Notices, 2014. https://doi.org/10.1155/2014/359316

92. Iregui, A., Khan, Z., Malik, S., Landman, D., & Quale, J. (2019). Emergence of Delafloxacin-resistant *Staphylococcus aureus* in Brooklyn, New York. Clinical Infectious Diseases. https://doi.org/10.1093/cid/ciz787
93. Ishwarya, R., Vaseeharan, B., Subbaiah, S., Nazar, A. K., Govindarajan, M., Alharbi, N. S., Kadaikunnan, S., Khaled, J. M., & Al-anbr M. N. (2018). *Sargassum wightii*-synthesized ZnO nanoparticles – from antibacterial and insecticidal activity to immunostimulatory effects on the green tiger shrimp Penaeus semisulcatus. Journal of Photochemistry and Photobiology B: Biology, 183, 318–330. https://doi.org/10.1016/j.jphotobiol.2018.04.049
94. Jafari, M., Rokhbakhsh-Zamin, F., Shakibaie, M., Moshafi, M. H., Ameri, A., Rahimi, H. R., & Forootanfar, H. (2018). Cytotoxic and antibacterial activities of biologically synthesized gold nanoparticles assisted by *Micrococcus yunnanensis* strain J2. Biocatalysis and Agricultural Biotechnology, 15, 245–253. https://doi.org/10.1016/j.bcab.2018.06.014
95. Jalal, M., Ansari, M., Alzohairy, M., Ali, S., Khan, H., Almatroudi, A., & Raees, K. (2018). Biosynthesis of silver nanoparticles from oropharyngeal *Candida glabrata* isolates and their antimicrobial activity against clinical strains of bacteria and fungi. Nanomaterials, 8(8), 586. https://doi.org/10.3390/nano8080586
96. Jogaiah, S., Kurjogi, M., Abdelrahman, M., Hanumanthappa, N., & Tran, L.-S. P. (2017). *Ganoderma applanatum*-mediated green synthesis of silver nanoparticles: Structural characterization, and in vitro and in vivo biomedical and agrochemical properties. Arabian Journal of Chemistry. https://doi.org/10.1016/j.arabjc.2017.12.002
97. Joshi, P. A., Bonde, S. R., Gaikwad, S. C., Gade, A. K., Abd-Elsalam, K., & Rai, M. K. (2013). Comparative studies on synthesis of silver nanoparticles by *Fusarium oxysporum* and *macrophomina phaseolina* and it's efficacy against bacteria and *Malassezia furfur*. Journal of Bionanoscience, 7(4), 378–385. https://doi.org/10.1166/jbns.2013.1148
98. Kathiraven, T., Sundaramanickam, A., Shanmugam, N., & Balasubramanian, T. (2015). Green synthesis of silver nanoparticles using marine algae *Caulerpa racemosa* and their antibacterial activity against some human pathogens. Applied Nanoscience, 5(4), 499–504. https://doi.org/10.1007/s13204-014-0341-2
99. Kathiresan, K., Alikunhi, N. M., Pathmanaban, S., Nabikhan, A., & Kandasamy, S. (2010). Analysis of antimicrobial silver nanoparticles synthesized by coastal strains of *Escherichia coli* and *Aspergillus niger*. Canadian Journal of Microbiology, 56(12), 1050–1059. https://doi.org/10.1139/w10-094
100. Kaur, T., Kapoor, S., & Kalia, A. (2018). Synthesis of silver nanoparticles from *Pleurotus florida*, characterization and analysis of their antimicrobial activity. International Journal of Current Microbiology and Applied Sciences, 7(7), 4085-4095. https://doi.org/10.20546/ijcmas.2018.707.475
101. Khan, A. U., Malik, N., Khan, M., Cho, M. H., & Khan, M. M. (2018A). Fungi-assisted silver nanoparticle synthesis and their applications. Bioprocess and Biosystems Engineering, 41(1), 1–20. https://doi.org/10.1007/s00449-017-1846-3
102. Khan, S. T., Musarrat, J., & Al-Khedhairy, A. A. (2016). Countering drug resistance, infectious diseases, and sepsis using metal and metal oxides nanoparticles: Current status. Colloids and Surfaces B, 146, 70–83. https://doi.org/10.1016/j.colsurfb.2016.05.046
103. Khan, S., Ahmad, K., Ahmad, A., Raish, M., Jan, B. L., Khan, A., & Khan, M. S. (2018B). Biogenic pentagonal silver nanoparticles for safer and more effective antibacterial therapeutics. International Journal of Nanomedicine. 13, 7789–7799. https://doi.org/10.2147/IJN.S168224
104. Kharissova, O. V., Dias, H. V. R., Kharisov, B. I., Pérez, B. O., & Pérez, V. M. J. (2013). The greener synthesis of nanoparticles. Trends Biotechnol., 31(4), 240–248. https://doi.org/10.1016/j.tibtech.2013.01.003
105. Khiralla, G. M., & El-Deeb, B. A. (2015). Antimicrobial and antibiofilm effects of selenium nanoparticles on some foodborne pathogens. LWT - Food Science and Technology, 63(2), 1001–1007. https://doi.org/10.1016/j.lwt.2015.03.086
106. Kim, B. Y. S., Rutka, J. T., & Chan, W. C. W. (2010). Nanomedicine. New England Journal of Medicine, 363(25), 2434–2443. https://doi.org/10.1056/nejmra0912273
107. Kourtis, A. P., Hatfield, K., Baggs, J., Mu, Y., See, I., Epson, E., Nadle, J., Kainer, M. A., Dumyati, G., Petit, S., Ray, S. M., Emerging Infections Program MRSA author group, Ham, D., Capers, C., Ewing, H., Coffin, N., McDonald, L. C., Jernigan, J., & Cardo, D. (2019). Vital Signs: Epidemiology and Recent Trends in Methicillin-Resistant and in Methicillin-Susceptible *Staphylococcus aureus* Bloodstream Infections - United States. Morbidity and mortality weekly report, 68(9), 214–219. https://doi.org/10.15585/mmwr.mm6809e1
108. Krishnan, M., Sivanandham, V., Hans-Uwe, D., Murugaiah, S. G., Seeni, P., Gopalan, S., & Rathinam, A. J. (2015). Antifouling assessments on biogenic nanoparticles: A field study from polluted offshore platform. Marine Pollution Bulletin, 101(2), 816–825. https://doi.org/10.1016/j.marpolbul.2015.08.033
109. Kumar, P., Selvi, S. S., Prabha, A. L., Selvaraj, M., Rani, L. M., Suganthi, P., Devi, B. S., & Govindaraju, M. (2012A). Antibacterial activity of in-vitro cytotoxity assay against brine shrimp using silver nanoparticles synthesized from *Sargassum ilicifolium.* Digest Journal of Nanomaterials and Biostructures, 7, 1447–1455.

110. Kumar, P., Senthamilselvi, S., Lakshmiprabha, A., Premkumar, K., Muthukumaran, V. R., Visvanathan, P., Ganeshkumar, R. S., & Govindaraju, M. (2012B). Efficacy of bio-synthesized silver nanoparticles using *Acanthophora spicifera* to encumber biofilm formation. Digest Journal of Nanomaterials and Biostructures, 7, 511–522.
111. Kumar, C. G., & Sujitha, P. (2014). Green synthesis of Kocuran-functionalized silver glyconanoparticles for use as antibiofilm coatings on silicone urethral catheters. Nanotechnology, 25(32), 325101. https://doi.org/10.1088/0957-4484/25/32/325101
112. Kumari, M., Pandey, S., Giri, V. P., Bhattacharya, A., Shukla, R., Mishra, A., & Nautiyal, C. S. (2017). Tailoring shape and size of biogenic silver nanoparticles to enhance antimicrobial efficacy against MDR bacteria. Microbial Pathogenesis, 105, 346–355. https://doi.org/10.1016/j.micpath.2016.11.012
113. Lakhundi, S., & Zhang, K. (2018). Methicillin-Resistant *Staphylococcus aureus*: molecular characterization, evolution, and epidemiology. Clinical Microbiology Reviews, 31(4), e00020–18. https://doi.org/10.1128/CMR.00020-18
114. Li, G., He, D., Qian, Y., Guan, B., Gao, S., Cui, Y., Yokoyama, K., & Wang, L. (2012). Fungus-mediated green synthesis of silver nanoparticles using *Aspergillus terreus*. International Journal of Molecular Sciences, 13(1), 466. https://doi.org/10.3390/ijms13010466
115. Li, J., Li, Q., Ma, X., Tian, B., Li, T., Yu, J., Dai, S., Weng, Y., and Hua, Y. (2016). Biosynthesis of gold nanoparticles by the extreme bacterium *Deinococcus radiodurans* and an evaluation of their antibacterial properties. International journal of nanomedicine, 11, 5931-5944. https://doi.org/10.2147/IJN.S119618
116. Li, X., Xu, H., Chen, Z.-S., & Chen, G. (2011). Biosynthesis of nanoparticles by microorganisms and their applications. Journal of Nanomaterials, 2011. https://doi.org/10.1155/2011/270974
117. Liang, X., Perez, M. A. M.-J., Nwoko, K. C., Egbers, P., Feldmann, J., Csetenyi, L., & Gadd, G. M. (2019). Fungal formation of selenium and tellurium nanoparticles. Applied Microbiology and Biotechnology. https://doi.org/10.1007/s00253-019-09995-6
118. Lindsay, J. A. (2013). Hospital-associated MRSA and antibiotic resistance—What have we learned from genomics?. International Journal of Medical Microbiology, 303(6-7), 318-323. https://doi.org/10.1016/j.ijmm.2013.02.005
119. Lowy, F. D. (1998). *Staphylococcus aureus* infections. New England Journal of Medicine, 339, 520-32. https://doi.org/10.1056/NEJM199808203390806
120. Ma, L., Su, W., Liu, J.-X., Zeng, X.-X., Huang, Z., Li, W., Liu, Z.-C., & Tang, J.-X. (2017). Optimization for extracellular biosynthesis of silver nanoparticles by *Penicillium aculeatum* Su1 and their antimicrobial activity and cytotoxic effect compared with silver ions. Materials Science and Engineering: C, 77, 963–971. https://doi.org/10.1016/j.msec.2017.03.294
121. Majeed, S., Abdullah, M. S. b., Dash, G. K., Ansari, M. T., & Nanda, A. (2016). Biochemical synthesis of silver nanoprticles using filamentous fungi *Penicillium decumbens* (MTCC-2494) and its efficacy against A-549 lung cancer cell line. Chinese Journal of Natural Medicines, 14(8), 615–620. https://doi.org/10.1016/S1875-5364(16)30072-3
122. Malarkodi, C., Rajeshkumar, S., Paulkumar, K., Vanaja, M., Gnanajobitha, G., & Annadurai, G. (2014). Biosynthesis and antimicrobial activity of semiconductor nanoparticles against oral pathogens. Bioinorganic Chemistry and Applications, 2014: 347167. https://doi.org/10.1155/2014/347167
123. Manikprabhu, D., Cheng, J., Chen, W., Sunkara, A. K., Mane, S. B., Kumar, R., Das, M., N. Hozzein, W., Duan, Y.-Q., & Li, W.-J. (2016). Sunlight mediated synthesis of silver nanoparticles by a novel actinobacterium (*Sinomonas mesophila* MPKL 26) and its antimicrobial activity against multi drug resistant *Staphylococcus aureus*. Journal of Photochemistry and Photobiology B: Biology, 158, 202–205. https://doi.org/10.1016/j.jphotobiol.2016.01.018
124. Manivasagan, P., Venkatesan, J., Senthilkumar, K., Sivakumar, K., & Kim, S.-K. (2013). Biosynthesis, antimicrobial and cytotoxic effect of silver nanoparticles using a novel *Nocardiopsis* sp. MBRC-1. BioMed Research International, 2013. https://doi.org/10.1155/2013/287638
125. McCaig, L. F., McDonald, L. C., Mandal, S., & Jernigan, D. B. (2006). *Staphylococcus aureus*-associated skin and soft tissue infections in ambulatory care. Emerging infectious diseases, 12(11), 1715–1723. https://doi.org/10.3201/eid1211.060190
126. Mekkawy, A. I., El-Mokhtar, M. A., Nafady, N. A., Yousef, N., Hamad, M. A., El-Shanawany, S. M., Ibrahim, E. H., & Elsabahy, M. (2017). In vitro and in vivo evaluation of biologically synthesized silver nanoparticles for topical applications: effect of surface coating and loading into hydrogels. International Journal of Nanomedicine, 12, 759–777. https://doi.org/10.2147/IJN.S124294
127. Michalak, I., & Chojnacka, K. (2015). Algae as production systems of bioactive compounds. Engineering in Life Sciences., 15(2), 160–176. https://doi.org/10.1002/elsc.201400191

128. Mirunalini, S., Arulmozhi, V., Deepalakshmi, K., & Krishnaveni, M. (2012). Intracellular biosynthesis and antibacterial activity of silver nanoparticles using edible mushrooms. Notulae Scientia Biologicae, 4(4), 55–61. https://doi.org/10.15835/nsb448051

129. Mishra, A., Tripathy, S. K., & Yun, S.-I. (2011). Bio-synthesis of gold and silver nanoparticles from *Candida guilliermondii* and their antimicrobial effect against pathogenic bacteria. Journal of nanoscience and nanotechnology, 11(1), 243–248. https://doi.org/10.1166/jnn.2011.3265

130. Moghaddam, A. B., Moniri, M., Azizi, S., Rahim, R. A., Ariff, A. B., Saad, W. Z., Namvar, F., Navaderi, M., & Mohamad, R. (2017). Biosynthesis of zno nanoparticles by a new *Pichia kudriavzevii* yeast strain and evaluation of their antimicrobial and antioxidant activities. Molecules, 22(6), 872. https://doi.org/10.3390/molecules22060872

131. Mohamed, Y. M., Azzam, A. M., Amin, B. H., & Safwat, N. A. (2015). Mycosynthesis of iron nanoparticles by *Alternaria alternata* and its antibacterial activity. African Journal of Biotechnology, 14(14), 1234–1241. https://doi.org/10.5897/ajb2014.14286

132. Mohandass, C., Vijayaraj, A. S., Rajasabapathy, R., Satheeshbabu, S., Rao, S. V., Shiva, C., & De-Mello, I. (2013). Biosynthesis of silver nanoparticles from marine seaweed *Sargassum cinereum* and their antibacterial activity. Indian Journal of Pharmaceutical Sciences, 75(5), 606.

133. Mohanpuria, P., Rana, N. K., & Yadav, S. K. (2008). Biosynthesis of nanoparticles: technological concepts and future applications. Journal of nanoparticle research, 10(3), 507-517. https://doi.org/10.1007/s11051-007-9275-x

134. Mohanta, Y. K., Singdevsachan, S. K., Parida, U. K., Bae, H., Mohanta, T. K., & Panda, S. K. (2016). Green synthesis and antimicrobial activity of silver nanoparticles using wild medicinal mushroom *Ganoderma applanatum* (Pers.) Pat. from Similipal Biosphere Reserve, Odisha, India. IET Nanobiotechnology, 10(4), 184–189. https://doi.org/10.1049/iet-nbt.2015.0059

135. Monowar, T., Rahman, Md. S., Bhore, S. J., Raju, G., & Sathasivam, K. V. (2018). Silver nanoparticles synthesized by using the endophytic bacterium *Pantoea ananatis* are promising antimicrobial agents against multidrug resistant bacteria. Molecules, 23(12), 3220. https://doi.org/10.3390/molecules23123220

136. Moon, J.-W., Rawn, C. J., Rondinone, A. J., Love, L. J., Roh, Y., Everett, S. M., Lauf, R. J., and Phelps, T. J. (2010). Large-scale production of magnetic nanoparticles using bacterial fermentation. Journal of Industrial Microbiology and Biotechnology, 37(10), 1023–1031. https://doi.org/10.1007/s10295-010-0749-y

137. Muhsin, T. M., & Hachim, A. K. (2014). Mycosynthesis and characterization of silver nanoparticles and their activity against some human pathogenic bacteria. World Journal of Microbiology and Biotechnology, 30(7), 2081–2090. https://doi.org/10.1007/s11274-014-1634-z

138. Munusamy, S., Bhakyaraj, K., Vijayalakshmi, L., Stephen, A., & Narayanan, V. (2014). Synthesis and characterization of nanoceria using *Curvularia lunata* and their antibacterial properties. International Journal of Innovative Research in Science, Engineering And Technology. 2(1), 318–323.

139. Musarrat, J., Dwivedi, S., Singh, B. R., Al-Khedhairy, A. A., Azam, A., & Naqvi, A. (2010). Production of antimicrobial silver nanoparticles in water extracts of the fungus *Amylomyces rouxii* strain KSU-09. Bioresource Technology, 101(22), 8772–8776. https://doi.org/10.1016/j.biortech.2010.06.065

140. Nabila, M. I., & Kannabiran, K. (2018). Biosynthesis, characterization and antibacterial activity of copper oxide nanoparticles (CuO NPs) from actinomycetes. Biocatalysis and Agricultural Biotechnology, 15, 56–62. https://doi.org/10.1016/j.bcab.2018.05.01

141. Nanda, A., & Saravanan, M. (2009). Biosynthesis of silver nanoparticles from *Staphylococcus aureus* and its antimicrobial activity against MRSA and MRSE. Nanomedicine: Nanotechnology, Biology and Medicine, 5(4), 452–456. https://doi.org/10.1016/j.nano.2009.01.012

142. Nanda, A., Nayak, B. K., & Krishnamoorthy, M. (2018). Antimicrobial properties of biogenic silver nanoparticles synthesized from phylloplane fungus, *Aspergillus tamarii*. Biocatalysis and Agricultural Biotechnology, 16, 225–228. https://doi.org/10.1016/j.bcab.2018.08.002

143. Naqvi, S. Z., Kiran, U., Ali, Jamal, Hameed, Ahmed, & Ali. (2013). Combined efficacy of biologically synthesized silver nanoparticles and different antibiotics against multidrug-resistant bacteria. International Journal of Nanomedicine, 3187. https://doi.org/10.2147/ijn.s49284

144. Narayanan, K. B., & Sakthivel, N. (2010). Biological synthesis of metal nanoparticles by microbes. Advances in colloid and interface science, 156(1-2), 1-13. https://doi.org/10.1016/j.cis.2010.02.001

145. Naveena, B. E. & Prakash, S. (2013). Biological synthesis of gold nanoparticles using marine algae *Gracilaria corticata* and its application as a potent antimicrobial and antioxidant agent. Asian Journal of Pharmaceutical and Clinical Research, 6(2), 179-182.

146. Nayak, B. K., & Anitha, K. (2014). Amplified antibiotic potency of two different drugs combined with biosynthesized AgNPs from *Aspergillus sydowii* isolated from sand dunes. International Journal of Pharmtech Research, 6(6), 1751–1755.
147. Nayak, B. K., Nanda, A., & Prabhakar, V. (2018). Biogenic synthesis of silver nanoparticle from wasp nest soil fungus, *Penicillium italicum* and its analysis against multi drug resistance pathogens. Biocatalysis and Agricultural Biotechnology, 16, 412–418. https://doi.org/10.1016/j.bcab.2018.09.014
148. Netala, V. R., Kotakadi, V. S., Bobbu, P., Gaddam, S. A., & Tartte, V. (2016). Endophytic fungal isolate mediated biosynthesis of silver nanoparticles and their free radical scavenging activity and anti microbial studies. 3 Biotech, 6(2). https://doi.org/10.1007/s13205-016-0433-7
149. Nithya, R., & Ragunathan, R. (2009). Synthesis of silver nanoparticle using *Pleurotus sajor-caju* and its antimicrobial study. Digest Journal of Nanomaterials and Biostructures 4, 623 - 629
150. Otto, M. (2013). Community-associated MRSA: what makes them special? International Journal of Medical Microbiology, 303, 324–330. https://doi.org/10.1016/j.ijmm.2013.02.007
151. Ottoni, C. A., Simões, M. F., Fernandes, S., dos Santos, J. G., Da Silva, E. S., de Souza, R. F. B., & Maiorano, A. E. (2017). Screening of filamentous fungi for antimicrobial silver nanoparticles synthesis. AMB Express, 7(1), 1–10. https://doi.org/10.1186/s13568-017-0332-2
152. Ovais, M., Khalil, A. T., Ayaz, M., Ahmad, I., Nethi, S. K., & Mukherjee, S. (2018). Biosynthesis of metal nanoparticles via microbial enzymes: a mechanistic approach. International Journal of Molecular Sciences, 19(12), 4100. https://doi.org/10.3390/ijms19124100
153. Ovais, M., Khalil, A. T., Raza, A., Khan, M. A., Ahmad, I., Islam, N. U., Saravanan, M., Ubaid, M. F., Ali, M., & Shinwari, Z. K. (2016). Green synthesis of silver nanoparticles via plant extracts: Beginning a new era in cancer theranostics. Nanomedicine, 12(23), 3157-3177. https://doi.org/10.2217/nnm-2016-0279
154. Pandey, A., Shankar, S., Shikha, & Arora, N. K. (2018). Amylase Assisted Green Synthesis of Silver Nano-Cubes for Antibacterial Applications. Bioinspired, Biomimetic and Nanobiomaterials, 8(3), 161-170. https://doi.org/10.1680/jbibn.17.00031
155. Peiris, M. M. K., Gunasekara, T. D. C. P., Jayaweera, P. M., & Fernando, S. S. N. (2018). TiO_2 nanoparticles from Baker's yeast: A potent antimicrobial. Journal of Microbiology and Biotechnology., 28(10), 1664-1670. https://doi.org/https://doi.org/10.4014/jmb.1807.07005
156. Piacenza, E., Presentato, A., Zonaro, E., Lemire, J. A., Demeter, M., Vallini, G., Turner, R. J., & Lampis, S. (2017). Antimicrobial activity of biogenically produced spherical Se-nanomaterials embedded in organic material against *Pseudomonas aeruginosa* and *Staphylococcus aureus* strains on hydroxyapatite-coated surfaces. Microbial Biotechnology, 10(4), 804–818. https://doi.org/10.1111/1751-7915.12700
157. Pinjarkar, H., Gaikwad, S., Ingle, A.P., Gade, A., Rai, & M. (2016). Phycofabrication of silver nanoparticles and their antibacterial activity against human pathogens. Advanced Materials Letters, 7, 1010–1014. https://doi.org/10.5185/amlett.2016.6269
158. Prabakaran, K., Ragavendran, C., & Natarajan, D. (2016). Mycosynthesis of silver nanoparticles from Beauveria bassiana and its larvicidal, antibacterial, and cytotoxic effect on human cervical cancer (HeLa) cells. RSC Advances, 6(51), 44972–44986. https://doi.org/10.1039/C6RA08593H
159. Pugazhendhi, A., Prabakar, D., Jacob, J. M., Karuppusamy, I., & Saratale, R. G. (2018). Synthesis and characterization of silver nanoparticles using *Gelidium amansii* and its antimicrobial property against various pathogenic bacteria. Microbial Pathogenesis, 114, 41–45. https://doi.org/10.1016/j.micpath.2017.11.013
160. Punjabi, K., Mehta, S., Chavan, R., Chitalia, V., Deogharkar, D., & Deshpande, S. (2018). Efficiency of biosynthesized silver and zinc nanoparticles against multi-drug resistant pathogens. Frontiers in Microbiology, 9. https://doi.org/10.3389/fmicb.2018.02207
161. Raheman, F., Deshmukh, S., Ingle, A., Gade, A., & Rai, M. (2011). Silver nanoparticles: novel antimicrobial agent synthesized from an endophytic fungus *Pestalotia* sp. isolated from leaves of *Syzygium cumini* (L). Nano Biomedicine and Engineering, 3, 174–178. https://doi.org/10.5101/nbe.v3i3.p174-178
162. Rahimi, G., Alizadeh, F., & Khodavandi, A. (2016). Mycosynthesis of Silver Nanoparticles from *Candida albicans* and its Antibacterial Activity against *Escherichia coli* and *Staphylococcus aureus*. Tropical Journal of Pharmaceutical Research, 15(2), 371–375. https://doi.org/10.4314/tjpr.v15i2.21
163. Rahimi, M., Hosseini, M. R., & Bakhshi, M. (2018). Biosynthesis of Ag_3PO_4 nanoparticles in the absence of phosphate source using a phosphorus mineralising bacterium. IET Nanobiotechnology, 12(1), 18–24. https://doi.org/10.1049/iet-nbt.2017.0121

164. Raja, M. M. M., & John, S. A. (2017). Biosynthesis of silver nanoparticles by novel isolate of marine *Micromonospora* species (KU 867645) and its antibacterial activity against multidrug resistant hospital-acquired uropathogens in reference with standard antibiotics. Indian Journal of Pharmaceutical Sciences, 79(3), 369–376. https://doi.org/10.4172/pharmaceutical-sciences.1000239

165. Rajakumar, G., Rahuman, A. A., Roopan, S. M., Khanna, V. G., Elango, G., Kamaraj, C., Zahir, A. A., and Velayutham, K. (2012). Fungus-mediated biosynthesis and characterization of TiO_2 nanoparticles and their activity against pathogenic bacteria. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 91, 23–29. https://doi.org/10.1016/j.saa.2012.01.011

166. Rajamanickam, U., Mylsamy, P., Viswanathan, S., & Muthusamy, P. (2012). Biosynthesis of zinc nanoparticles using actinomycetes for antibacterial food packaging. In International Conference on Nutrition and Food Sciences IPCBEE (Vol. 39).

167. Rajasulochana, P., Krishnamoorthy, P., & Dhamotharan, R. (2012). Potential Application of *Kappaphycus alvarezii* in Agricultural and Pharmaceutical Industry. Journal of Chemical and Pharmaceutical Research, 4(1), 33-37.

168. Ramakritinan, C. M., Kaarunya, E., Shankar, S., & Kumaraguru, A. K. (2013). Antibacterial Effects of Ag, Au and Bimetallic (Ag-Au) Nanoparticles Synthesized from Red Algae. Solid State Phenomena, 201, 211–230. https://doi.org/10.4028/www.scientific.net/ssp.201.211

169. Ramasamy, M., Lee, J.-H., & Lee, J. (2016). Potent antimicrobial and antibiofilm activities of bacteriogenically synthesized gold–silver nanoparticles against pathogenic bacteria and their physiochemical characterizations. Journal of Biomaterials Applications, 31(3), 366–378. https://doi.org/10.1177/0885328216646910

170. Ramkumar, V. S., Pugazhendhi, A., Gopalakrishnan, K., Sivagurunathan, P., Saratale, G. D., Dung, T. N. B., & Kannapiran, E. (2017). Biofabrication and characterization of silver nanoparticles using aqueous extract of seaweed *Enteromorpha compressa* and its biomedical properties. Biotechnology Reports, 14, 1–7. https://doi.org/10.1016/j.btre.2017.02.001

171. Rao, N. S., Nayak, P. P., & Prasad, K. V. V. (2019). Nasal conveyance of Methicillin-resistant *Staphylococcus aureus* (MRSA) strains among dental professionals with varying levels of clinical exposure: A comparative study. Journal of Oral Biology and Craniofacial Research. In Press, Corrected Proof. https://doi.org/10.1016/j.jobcr.2019.12.002

172. Rathod, D., Golinska, P., Wypij, M., Dahm, H., & Rai, M. (2016). A new report of *Nocardiopsis valliformis* strain OT1 from alkaline Lonar crater of India and its use in synthesis of silver nanoparticles with special reference to evaluation of antibacterial activity and cytotoxicity. Medical Microbiology and Immunology, 205(5), 435. https://doi.org/10.1007/s00430-016-0462-1

173. Rauf, M. A., Owais, M., Rajpoot, R., Ahmad, F., Khan, N., & Zubair, S. (2017). Biomimetically synthesized ZnO nanoparticles attain potent antibacterial activity against less susceptible *S. aureus* skin infection in experimental animals. *RSC advances*, *7*(58), 36361-36373. https://doi.org/10.1039/C7RA05040B

174. Rehman, S., Jermy, B. R., Akhtar, S., Borgio, J. F., Abdul Azeez, S., Ravinayagam, V., Jindan, R. A., Alsalem, Z. H., Buhameid, A., and Gani, A. (2019). Isolation and characterization of a novel thermophile; *Bacillus* haynesii, applied for the green synthesis of ZnO nanoparticles. Artificial Cells, Nanomedicine, and Biotechnology, 47(1), 2072–2082. https://doi.org/10.1080/21691401.2019.1620254

175. Rodrigues, A. G., Ping, L. Y., Marcato, P. D., Alves, O. L., Silva, M. C. P., Ruiz, R. C., Melo, I. S., Tasic, L., and De Souza, A. O. (2013). Biogenic antimicrobial silver nanoparticles produced by fungi. Applied Microbiology and Biotechnology, 97(2), 775–782. https://doi.org/10.1007/s00253-012-4209-7

176. Sagar, G., & Ashok, B. (2012). Green synthesis of silver nanoparticles using *Aspergillus niger* and its efficacy against human pathogens. European Journal of Experimental Biology, 2(5), 1654-1658.

177. Saha, S., Sarkar, J., Chattopadhyay, D., Patra, S., Chakraborty, A., & Acharya, K. (2010). Production of silver nanoparticles by a phytopathogenic fungus *Bipolaris nodulosa* and its antimicrobial activity. Digest Journal of Nanomaterials and Biostructures, 5(4), 887-895.

178. Sajidha Parveen, K., & Lakshmi, D. (2016). Biosynthesis of silver nanoparticles using red algae, *Amphiroa fragilissima* and its antibacterial potential against gram positive and gram negative bacteria. International Journal of Current Science, 19(3), 93-100.

179. Sakr, A., Brégeon, F., Mège, J. L., Rolain, J. M., & Blin, O. (2018). *Staphylococcus aureus* Nasal Colonization: An Update on Mechanisms, Epidemiology, Risk Factors, and Subsequent Infections. Frontiers in microbiology, 9, 2419. https://doi.org/10.3389/fmicb.2018.02419

180. Salari, Z., Danafar, F., Dabaghi, S., & Ataei, S. A. (2016). Sustainable synthesis of silver nanoparticles using macroalgae *Spirogyra varians* and analysis of their antibacterial activity. Journal of Saudi Chemical Society, 20(4), 459–464. https://doi.org/10.1016/j.jscs.2014.10.004

181. Salunke, G. R., Ghosh, S., Kumar, R. S., Khade, S., Vashisth, P., Kale, T., Chopade, S., Pruthi, V., Kundu, G., Bellare, J. R., & Chopade, B. A. (2014). Rapid efficient synthesis and characterization of silver, gold, and bimetallic nanoparticles from the medicinal plant *Plumbago zeylanica* and their application in biofilm control. International Journal of Nanomedicine, 9, 2635-2653. https://doi.org/10.2147/IJN.S59834

182. Saravanakumar, K., & Wang, M.-H. (2018). *Trichoderma* based synthesis of anti-pathogenic silver nanoparticles and their characterization, antioxidant and cytotoxicity properties. Microbial Pathogenesis, 114, 269–273. https://doi.org/10.1016/j.micpath.2017.12.005

183. Saravanan, M., & Nanda, A. (2010). Extracellular synthesis of silver bionanoparticles from *Aspergillus clavatus* and its antimicrobial activity against MRSA and MRSE. Colloids and Surfaces B: Biointerfaces, 77(2), 214–218. https://doi.org/10.1016/j.colsurfb.2010.01.026

184. Saravanan, M., Arokiyaraj, S., Lakshmi, T., & Pugazhendhi, A. (2018A). Synthesis of silver nanoparticles from *Phenerochaete chrysosporium* (MTCC-787) and their antibacterial activity against human pathogenic bacteria. Microbial Pathogenesis, 117, 68–72. https://doi.org/10.1016/j.micpath.2018.02.008

185. Saravanan, M., Barik, S. K., MubarakAli, D., Prakash, P., & Pugazhendhi, A. (2018B). Synthesis of silver nanoparticles from *Bacillus brevis* (NCIM 2533) and their antibacterial activity against pathogenic bacteria. Microbial pathogenesis, 116, 221–226. https://doi.org/10.1016/j.micpath.2018.01.038

186. Sarsar, V., Selwal, M. K., & Selwal, K. K. (2015). Biofabrication, characterization and antibacterial efficacy of extracellular silver nanoparticles using novel fungal strain of *Penicillium atramentosum* KM. Journal of Saudi Chemical Society, 19(6), 682–688. https://doi.org/10.1016/j.jscs.2014.07.001

187. Sathishkumar, R. S., Sundaramanickam, A., Srinath, R., Ramesh, T., Saranya, K., Meena, M., & Surya, P. (2019). Green synthesis of silver nanoparticles by bloom forming marine microalgae *Trichodesmium erythraeum* and its applications in antioxidant, drug-resistant bacteria, and cytotoxicity activity. Journal of Saudi Chemical Society. https://doi.org/10.1016/j.jscs.2019.07.008

188. Saxena, J., Sharma, P. K., Sharma, M. M., & Singh, A. (2016). Process optimization for green synthesis of silver nanoparticles by *Sclerotinia sclerotiorum* MTCC 8785 and evaluation of its antibacterial properties. SpringerPlus, 5(1), 1–10. https://doi.org/10.1186/s40064-016-2558-x

189. Shaaban, M., & El-Mahdy, A. M. (2018). Biosynthesis of Ag, Se, and ZnO nanoparticles with antimicrobial activities against resistant pathogens using waste isolate *Streptomyces enissocaesilis* . IET Nanobiotechnology, 12(6), 741–747. https://doi.org/10.1049/iet-nbt.2017.0213

190. Shaheen, T. I., & Abd El Aty, A. A. (2018). In-situ green myco-synthesis of silver nanoparticles onto cotton fabrics for broad spectrum antimicrobial activity. International Journal of Biological Macromolecules. 118, 2121-2130. https://doi.org/10.1016/j.ijbiomac.2018.07.062

191. Shahverdi, A. R., Fakhimi, A., Shahverdi, H. R., & Minaian, S. (2007). Synthesis and effect of silver nanoparticles on the antibacterial activity of different antibiotics against *Staphylococcus aureus* and *Escherichia coli*. Nanomedicine: Nanotechnology, Biology and Medicine, 3(2), 168–171. https://doi.org/10.1016/j.nano.2007.02.001

192. Shahzad, A., Saeed, H., Iqtedar, M., Hussain, S. Z., Kaleem, A., Abdullah, R., Sharif, S., Naz, S., Saleem, F., Aihetasham, A., & Chaudhary, A. (2019). Size-controlled production of silver nanoparticles by *Aspergillus fumigatus* BTCB10: likely antibacterial and cytotoxic effects. Journal of Nanomaterials, 2019, 1–14. https://doi.org/10.1155/2019/5168698

193. Shakibaie, M., Adeli-Sardou, M., Mohammadi-Khorsand, T., ZeydabadiNejad, M., Amirafzali, E., Amirpour-Rostami, S., Ameri, A., & Forootanfar, H. (2017). Antimicrobial and antioxidant activity of the biologically synthesized tellurium nanorods; a preliminary in vitro study. Iranian Journal of Biotechnology, 15(4), 268–276. https://doi.org/10.15171/ijb.1580

194. Shakibaie, M., Forootanfar, H., Golkari, Y., Mohammadi-Khorsand, T., & Shakibaie, M. R. (2015). Anti-biofilm activity of biogenic selenium nanoparticles and selenium dioxide against clinical isolates of *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Proteus mirabilis*. Journal of Trace Elements in Medicine and Biology, 29, 235–241. https://doi.org/10.1016/j.jtemb.2014.07.020

195. Shakibaie, M., Hajighasemi, E., Adeli-Sardou, M., Doostmohammadi, M., & Forootanfar, H. (2019). Antimicrobial and anti-biofilm activities of Bi subnitrate and BiNPs produced by *Delftia* sp. SFG against clinical isolates of *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Proteus mirabilis*. IET Nanobiotechnology, 13(4), 377–381. https://doi.org/10.1049/iet-nbt.2018.5102

196. Shanmugam, N., Rajkamal, P., Cholan, S., Kannadasan, N., Sathishkumar, K., Viruthagiri, G., & Sundaramanickam, A. (2013). Biosynthesis of silver nanoparticles from the marine seaweed *Sargassum wightii* and their antibacterial activity against some human pathogens. Applied Nanoscience, 4(7), 881–888. https://doi.org/10.1007/s13204-013-0271-4

197. Shanmugasundaram, T., Radhakrishnan, M., Gopikrishnan, V., Kadirvelu, K., & Balagurunathan, R. (2017). In vitro antimicrobial and in vivo wound healing effect of actinobacterially synthesised nanoparticles of silver, gold and their alloy. RSC Advances, 7(81), 51729–51743. https://doi.org/10.1039/C7RA08483H

198. Sharma, G., Jasuja, N. D., Kumar, M., & Ali, M. I. (2015). Biological synthesis of silver nanoparticles by cell-free extract of *Spirulina platensis*. Journal of Nanotechnology, 2015. https://doi.org/10.1155/2015/132675

199. Shivashankarappa, A., & Sanjay, K. R. (2015). Study on biological synthesis of cadmium sulfide nanoparticles by *Bacillus licheniformis* and its antimicrobial properties against food borne pathogens. Nanoscience and Nanotechnology Research, 3(1), 6–15. https://doi.org/10.12691/nnr-3-1-2

200. Shoeibi, S., & Mashreghi, M. (2017). Biosynthesis of selenium nanoparticles using *Enterococcus faecalis* and evaluation of their antibacterial activities. Journal of Trace Elements in Medicine and Biology, 39, 135–139. https://doi.org/10.1016/j.jtemb.2016.09.003

201. Siddiqi, K. S., Rashid, M., Rahman, A., Tajuddin, Husen, A., & Rehman, S. (2018). Biogenic fabrication and characterization of silver nanoparticles using aqueous-ethanolic extract of lichen (*Usnea longissima*) and their antimicrobial activity. Biomaterials Research, 22(1), 1–9. https://doi.org/10.1186/s40824-018-0135-9

202. Sidkey, N. M., Moustafa, Y. M., Arafa, R. A., Morsi, R. E., & Elhateir, M. M. (2016). Corrosion resistance and antimicrobial activity of extra- and intracellular Fe (II) nanoparticles biosynthesized via *Aspergillus foetidus* ATCC 14916. American Chemical Science Journal 17(1): 1-10. https://doi.org/10.9734/ACSJ/2016/28674

203. Singh, D. K., Kumar, J., Sharma, V. K., Verma, S. K., Singh, A., Kumari, P., & Kharwar, R. N. (2018). Mycosynthesis of bactericidal silver and polymorphic gold nanoparticles: physicochemical variation effects and mechanism. Nanomedicine, 13(2), 191–207. https://doi.org/10.2217/nnm-2017-0235

204. Singh, D., Rathod, V., Ninganagouda, S., Hiremath, J., Singh, A. K., & Mathew, J. (2014). Optimization and characterization of silver nanoparticle by endophytic fungi *Penicillium* sp. isolated from *Curcuma longa* (Turmeric) and application studies against MDR *E. coli* and *S. aureus*. Bioinorganic Chemistry and Applications, 2014. https://doi.org/10.1155/2014/408021

205. Singh, H., Du, J., & Yi, T.-H. (2016A). Biosynthesis of silver nanoparticles using *Aeromonas* sp. THG-FG1.2 and its antibacterial activity against pathogenic microbes. Artificial Cells, Nanomedicine, and Biotechnology, 45(3), 584–590. https://doi.org/10.3109/21691401.2016.1163715

206. Singh, H., Du, J., & Yi, T.-H. (2016B). *Kinneretia* THG-SQI4 mediated biosynthesis of silver nanoparticles and its antimicrobial efficacy. Artificial Cells, Nanomedicine, and Biotechnology, 45(3), 602–608. https://doi.org/10.3109/21691401.2016.1163718

207. Singh, P., Kim, Y. J., Singh, H., Mathiyalagan, R., Wang, C., & Yang, D. C. (2015). Biosynthesis of anisotropic silver nanoparticles by *Bhargavaea indica* and their synergistic effect with antibiotics against pathogenic microorganisms. Journal of Nanomaterials, 2015. https://doi.org/10.1155/2015/234741

208. Singh, P., Kim, Y. J., Wang, C., Mathiyalagan, R., & Yang, D. C. (2016C). *Weissella oryzae* DC6-facilitated green synthesis of silver nanoparticles and their antimicrobial potential. Artificial Cells, Nanomedicine, and Biotechnology, 44(6), 1569–1575. https://doi.org/10.3109/21691401.2015.1064937

209. Singh, P., Kim, Y.-J., Zhang, D., & Yang, D.-C. (2016D). Biological synthesis of nanoparticles from plants and microorganisms. Trends in Biotechnology, 34(7), 588–599. https://doi.org/10.1016/j.tibtech.2016.02.006

210. Singh, P., Singh, H., Kim, Y. J., Mathiyalagan, R., Wang, C., & Yang, D. C. (2016E). Extracellular synthesis of silver and gold nanoparticles by *Sporosarcina koreensis* DC4 and their biological applications. Enzyme and Microbial Technology, 86, 75–83. https://doi.org/10.1016/j.enzmictec.2016.02.005

211. Singh, R., Wagh, P., Wadhwani, S., Gaidhani, S., Kumbhar, A., Bellare, J., & Chopade, B. A. (2013). Synthesis, optimization, and characterization of silver nanoparticles from *Acinetobacter calcoaceticus* and their enhanced antibacterial activity when combined with antibiotics. International Journal of Nanomedicine, 8, 4277. https://doi.org/10.2147/IJN.S48913

212. Singh, T., Jyoti, K., Patnaik, A., Singh, A., Chauhan, R., & Chandel, S. S. (2017). Biosynthesis, characterization and antibacterial activity of silver nanoparticles using an endophytic fungal supernatant of *Raphanus sativus*. Journal of Genetic Engineering and Biotechnology, 15(1), 31–39. https://doi.org/10.1016/j.jgeb.2017.04.005

213. Sinha, S. N., Paul, D., Halder, N., Sengupta, D., & Patra, S. K. (2015). Green synthesis of silver nanoparticles using fresh water green alga *Pithophora oedogonia* (Mont.) Wittrock and evaluation of their antibacterial activity. Applied Nanoscience, 5(6), 703–709. https://doi.org/10.1007/s13204-014-0366-6

214. Soleimani, M., & Habibi-Pirkoohi, M. (2017). Biosynthesis of Silver Nanoparticles using *Chlorella vulgaris* and Evaluation of the Antibacterial Efficacy Against *Staphylococcus aureus*. Avicenna Journal of Medical Biotechnology, 9(3), 120–125.

215. Sonkusre, P., & Cameotra, S. S. (2015). Biogenic selenium nanoparticles inhibit *Staphylococcus aureus* adherence on different surfaces. Colloids and Surfaces B: Biointerfaces, 136, 1051–1057. https://doi.org/10.1016/j.colsurfb.2015.10.052

216. Sriramulu, M., & Sumathi, S. (2017). Photocatalytic, antioxidant, antibacterial and anti-inflammatory activity of silver nanoparticles synthesised using forest and edible mushroom. Advances in Natural Sciences: Nanoscience and Nanotechnology, 8(4), 045012. https://doi.org/10.1088/2043-6254/aa92b5

217. Srivastava, N., & Mukhopadhyay, M. (2015). Green synthesis and structural characterization of selenium nanoparticles and assessment of their antimicrobial property. Bioprocess and Biosystems Engineering, 38(9), 1723–1730. https://doi.org/10.1007/s00449-015-1413-8

218. Stefani, S., Campanile, F., Santagati, M., Mezzatesta, M. L., Cafiso, V., & Pacini, G. (2015). Insights and clinical perspectives of daptomycin resistance in *Staphylococcus aureus*: A review of the available evidence. International journal of antimicrobial agents, 46(3), 278–289. https://doi.org/10.1016/j.ijantimicag.2015.05.008

219. Subashini, J., & Kannabiran, K. (2013). Antimicrobial activity of *Streptomyces* sp. VITBT7 and its synthesized silver nanoparticles against medically important fungal and bacterial pathogens. Der Pharmacia Lettre, 5, 192-200.

220. Sudha, S. S., Rajamanickam, K., & Rengaramanujam, J. (2013). Microalgae mediated synthesis of silver nanoparticles and their antibacterial activity against pathogenic bacteria. Indian Journal of Exprimental Biology, 52, 393-399.

221. Sundarmoorthi, E., Devarasu, S., & Vengadesh Prabhu, K. (2011). Antimicrobial and wound healing activity of silver nanoparticlessynthesized from *Streptomyces aureofaciens*. International Journal of Pharmaceutical Research and Development, 12, 69–75.

222. Sunkar, S., & Nachiyar, C. V. (2012). Biogenesis of antibacterial silver nanoparticles using the endophytic bacterium *Bacillus* cereus isolated from *Garcinia xanthochymus*. Asian Pacific Journal of Tropical Biomedicine, 2(12), 953. https://doi.org/10.1016/S2221-1691(13)60006-4

223. Suriya, J., Bharathi Raja, S., Sekar, V., & Rajasekaran, R. (2012). Biosynthesis of silver nanoparticles and its antibacterial activity using seaweed *Urospora* sp. African Journal of Biotechnology, 11, 12192–12198. https://doi.org/10.5897/AJB12.452

224. Syed, B., Prasad, N. M. N., & Satish, S. (2016). Endogenic mediated synthesis of gold nanoparticles bearing bactericidal activity. Journal of Microscopy and Ultrastructure, 4(3), 162–166. https://doi.org/10.1016/j.jmau.2016.01.004

225. Taran, M., Rad, M., & Alavi, M. (2018). Biosynthesis of TiO_2 and ZnO nanoparticles by *Halomonas elongata* IBRC-M 10214 in different conditions of medium. BioImpacts, 8(2), 81–89. https://doi.org/10.15171/bi.2018.10

226. Thomas, R., Janardhanan, A., Varghese, R. T., Soniya, E. V., Mathew, J., & Radhakrishnan, E. K. (2014). Antibacterial properties of silver nanoparticles synthesized by marine *Ochrobactrum* sp. Brazilian Journal of Microbiology, 45(4), 1221–1227. https://doi.org/10.1590/s1517-83822014000400012

227. Tong, S. Y. C., Davis, J. S., Eichenberger, E., Holland, T. L., & Fowler, V. G. (2015). *Staphylococcus aureus* infections: epidemiology, pathophysiology, clinical manifestations, and management. Clinical Microbiology Reviews, 28, 603–661. https://doi.org/10.1128/CMR.00134-14

228. ul-Haq, M., Rathod, V., Singh, D., Singh, A. K., Ninganagouda, S., & Hiremath, J. (2015). Dried mushroom *Agaricus bisporus* mediated synthesis of silver nanoparticles from Bandipora district (Jammu and Kashmir) and their efficacy against methicillin resistant *Staphylococcus aureus* (MRSA) strains. Nanoscience and Nanotechnology: An International Journal, 5(1), 1-8.

229. Uma Suganya, K. S., Govindaraju, K., Ganesh Kumar, V., Stalin Dhas, T., Karthick, V., Singaravelu, G., & Elanchezhiyan, M. (2015). Blue green alga mediated synthesis of gold nanoparticles and its antibacterial efficacy against Gram positive organisms. Materials Science and Engineering: C, 47, 351–356. https://doi.org/10.1016/j.msec.2014.11.043

230. Vaigankar, D. C., Dubey, S. K., Mujawar, S. Y., D'Costa, A., & S.K., S. (2018). Tellurite biotransformation and detoxification by *Shewanella baltica* with simultaneous synthesis of tellurium nanorods exhibiting photo-catalytic and anti-biofilm activity. Ecotoxicology and Environmental Safety, 165, 516–526. https://doi.org/10.1016/j.ecoenv.2018.08.111

231. VanEperen, A. S., & Segreti, J. (2016). Empirical therapy in methicillin-resistant *Staphylococcus aureus* infections: an up-to-date approach. Journal of Infection and Chemotherapy, 22(6), 351-359. https://doi.org/10.1016/j.jiac.2016.02.012

232. Velmurugan, P., Iydroose, M., Mohideen, M. H. A. K., Mohan, T. S., Cho, M., & Oh, B.-T. (2014). Biosynthesis of silver nanoparticles using *Bacillus subtilis* EWP-46 cell-free extract and evaluation of its antibacterial activity. Bioprocess and Biosystems Engineering, 37(8), 1527–1534. https://doi.org/10.1007/s00449-014-1124-6

233. Venkat Kumar, S., Sowmya, B., Geetha, R., Karpagambigai, S., Rajeshkumar, S., & Lakshmi, T. (2019). Preparation of yeast mediated semiconductor nanoparticles by *Candida albicans* and its bactericidal potential against *Salmonella typhi* and *Staphylococcus aureus*. International Journal of Research in Pharmaceutical Sciences, 10(2), 861-864. https://doi.org/10.26452/ijrps.v10i2.262

234. Venkatesan, J., Kim, S.-K., & Shim, M. (2016). Antimicrobial, antioxidant, and anticancer activities of biosynthesized silver nanoparticles using marine algae *Ecklonia cava*. Nanomaterials, 6(12), 235. https://doi.org/10.3390/nano6120235

235. Vigneshwaran, N., Kathe, A. A., Varadarajan, P. V., Nachane, R. P., & Balasubramanya, R. H. (2007). Silver−protein (core−shell) nanoparticle production using spent mushroom substrate. Langmuir, 23(13), 7113–7117. https://doi.org/10.1021/la063627p

236. Waghmare, S. R., Mulla, M. N., Marathe, S. R., & Sonawane, K. D. (2015). Ecofriendly production of silver nanoparticles using *Candida utilis* and its mechanistic action against pathogenic microorganisms. 3 Biotech, 5(1), 33. https://doi.org/10.1007/s13205-014-0196-y

237. Wang, C., Singh, P., Kim, Y. J., Mathiyalagan, R., Myagmarjav, D., Wang, D., Jin, C.-G., & Yang, D. C. (2016A). Characterization and antimicrobial application of biosynthesized gold and silver nanoparticles by using *Microbacterium resistens*. Artificial Cells, Nanomedicine, and Biotechnology, 44(7), 1714–1721. https://doi.org/10.3109/21691401.2015.1089253

238. Wang, L., Liu, C.-C., Wang, Y.-Y., Xu, H., Su, H., & Cheng, X. (2016B). Antibacterial activities of the novel silver nanoparticles biosynthesized using *Cordyceps militaris* extract. Current Applied Physics, 16(9), 969–973. https://doi.org/10.1016/j.cap.2016.05.025

239. World Health Organization. (2014). Antimicrobial resistance: global report on surveillance 2014. https://apps.who.int/iris/bitstream/handle/10665/112642/9789241564748_eng.pdf (Accessed 22 January 2020)

240. Wypij, M., Czarnecka, J., Świecimska, M., Dahm, H., Rai, M., & Golinska, P. (2018). Synthesis, Characterization and Evaluation of Antimicrobial and Cytotoxic Activities of Biogenic Silver Nanoparticles Synthesized From Streptomyces Xinghaiensis OF1 Strain. World Journal of Microbiology and Biotechnology, 34(2), 23. https://doi.org/10.1007/s11274-017-2406-3

241. Wypij, M., Golinska, P., Dahm, H., & Rai, M. (2017). Actinobacterial-mediated synthesis of silver nanoparticles and their activity against pathogenic bacteria. IET Nanobiotechnol., 11(3), 336–342. https://doi.org/10.1049/iet-nbt.2016.0112

242. Yadav, A., Kon, K., Kratosova, G., Duran, N., Ingle, A. P., & Rai, M. (2015). Fungi as an efficient mycosystem for the synthesis of metal nanoparticles: progress and key aspects of research. Biotechnology Letters, 37(11), 2099–2120. https://doi.org/10.1007/s10529-015-1901-6

243. Yousefzadi, M., Rahimi, Z., & Ghafori, V. (2014). The green synthesis, characterization and antimicrobial activities of silver nanoparticles synthesized from green alga *Enteromorpha flexuosa* (wulfen) J. Agardh. Materials Letters, 137, 1–4. https://doi.org/10.1016/j.matlet.2014.08.110

244. Zada, S., Ahmad, A., Khan, S., Iqbal, A., Ahmad, S., Ali, H., & Fu, P. (2018A). Biofabrication of gold nanoparticles by *Lyptolyngbya* JSC-1 extract as super reducing and stabilizing agents: Synthesis, characterization and antibacterial activity. Microbial Pathogenesis, 114, 116–123. https://doi.org/10.1016/j.micpath.2017.11.038

245. Zada, S., Ahmad, A., Khan, S., Yu, X., Chang, K., Iqbal, A., Ahmad, A., Ullah, S., Raza, M., Khan, A. & Ahmad, S. (2018B). Biogenic synthesis of silver nanoparticles using extracts of *Leptolyngbya* JSC-1 that induce apoptosis in HeLa cell line and exterminate pathogenic bacteria. Artificial cells, nanomedicine, and biotechnology, 46(sup3), S471-S480. https://doi.org/10.1080/21691401.2018.1499663

246. Zare, B., Faramarzi, M. A., Sepehrizadeh, Z., Shakibaie, M., Rezaie, S., & Shahverdi, A. R. (2012). Biosynthesis and recovery of rod-shaped tellurium nanoparticles and their bactericidal activities. Materials Research Bulletin, 47(11), 3719–3725. https://doi.org/10.1016/j.materresbull.2012.06.034

247. Zhang, X., Yan, S., Tyagi, R. D., & Surampalli, R. Y. (2011). Synthesis of nanoparticles by microorganisms and their application in enhancing microbiological reaction rates. Chemosphere, 82(4), 489–494. https://doi.org/10.1016/j.chemosphere.2010.10.023

248. Zonaro, E., Lampis, S., Turner, R. J., Qazi, S. J. S., & Vallini, G. (2015). Biogenic selenium and tellurium nanoparticles synthesized by environmental microbial isolates efficaciously inhibit bacterial planktonic cultures and biofilms. Frontiers in Microbiology, 6, 564. https://doi.org/10.3389/fmicb.2015.00584