

GREEN SYNTHESIS OF SILVER NANOPARTICLE USING OYSTER SPENT MUSHROOM WASTE: A POTENTIAL ANTIMICROBIAL AGENT

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Abstract: Silver nanoparticles were successfully synthesised from AgNO₃ through a reliable, eco-friendly, and simple green route using oyster spent mushroom waste. This review discusses the use of oyster mushroom spent as a green reducing and capping agent of the AgNP synthesis for their potential antimicrobial agents. The AgNPs synthesised by oyster spent exhibit 11-40 nm particle sizes that have excellent antimicrobial activity against Gram-positive and Gram-negative bacteria, including multidrug-resistant bacteria.

Keywords: Green Synthesis, Silver Nanoparticle, Oyster Mushroom, Antimicrobial Agent, Spent Mushroom substrate

1. Introduction: Silver nanoparticles have unique physicochemical, optical, electrical, catalytic, sensing and broad-spectrum antimicrobial properties. Due to these properties, silver nanoparticles have gained attention over the past decades [12,13]. The global market of AgNP will reach \$2.2 billion by 2027, with uses in healthcare, food packaging, water purification, and textile industries [13, 16]. The traditional methods of synthesising AgNP were using a chemical reducing agent (hydrazine, sodium borohydride) and physical techniques (UV irradiation, laser ablation) that involve toxic reagents, high energy consumption, and generate hazardous byproducts. The chemical and physical methods have high environmental risk and are hazardous to humans. Due to the generation of residual toxicity, their application in biomedical applications is limited [12, 13]. Researchers have found an alternative to emerging from this problem using green synthesis technology. The green synthesis technology is the utilisation of biological materials, plant extract, microorganisms, or any agricultural waste as reducing and capping agents. The green technology has advantages, including cost-effectiveness, eco-friendliness, single step synthesis over the traditional methods. It also enhances the biocompatibility [12, 13].

The agricultural waste materials are an underutilised resource for the green synthesis of nanoparticles. Moreover, the spent mushroom substrate (SMS) is the residual material after mushroom cultivation. The SMS is generated by oyster mushrooms in huge quantities globally. The SMS from oyster mushrooms has high lignocellulosic content, proteins, polysaccharides, enzymes, and secondary metabolites that have reducing capabilities [2, 8]. The synthesis of AgNP from oyster mushroom SMS offers dual benefits: one is utilization of mushroom spent waste into high-value nanomaterials, and the second is the production of antimicrobial agents with reduced environmental impacts [2, 7]. Recently, it has been reported that SMS mediated AgNP exhibits excellent antimicrobial activity against several pathogenic microorganism. The review gives concise information about the conversion of waste into a fruitful output [2, 5, 20, 21].

2. Spent Mushroom Substrate: Composition and Bioactive Components

2.1. Composition of Oyster SMS: The chemical composition of spent mushroom waste mainly depends on the species of mushroom which was cultivated. The main components are Cellulose (25-35%), hemicellulose (15-25%), lignin (10-20%), proteins/peptides (8-15%), phenolic compounds (2-8%), polysaccharides (15-25%), enzymes (laccase, manganese peroxidase), minerals (5-10%) [2, 8].

2.2. Reduction and Stabilisation by Bioactive Compounds: The SMS make a strong complex interaction between silver ions and bioactive compounds. The most important reducing and stabilizing agents includes.

Proteins and peptides: The proteins which are found in SMS is a type of secreted protein play a crucial role in AgNP synthesis. This protein contains a core shell structure around silver nanoparticles and providing stability. The amino and thiol group which are present in protein strongly bind to silver surfaces, preventing aggregation [8].

Phenolic compounds: Phenolics which are present in SMS contains hydroxyl groups acts as powerful reducing agents [13].

Enzymatic activity: Oyster mushroom contains several enzymes including laccase, manganese peroxidase, and lignin peroxidase. These enzymes catalyse the metal ions reduction and the enzymatic pathway provides controlled reduction kinetics, resulting in shaping uniform particle sizes [2, 21]. (Table 1)

Polysaccharides: in the oyster SMS Beta-glucans and other polysaccharides serve as capping agents, and adsorbing onto nanoparticle surfaces and proving steric stabilization [5, 21].

Table 1. Bioactive Components of Oyster Mushroom SMS Involved in AgNP Synthesis

Bioactive Component	Function in AgNP Synthesis	References
Proteins/Peptides	Reduction and stabilization	[8]
Phenolic compounds	Electron donation and reduction	[12,13]
Polysaccharides	Capping and stabilization	[5,21]
Laccase	Enzymatic reduction	[2,21]
Manganese peroxidase	Metal ion reduction	[2]
Lignin peroxidase	Catalytic reduction	[2,21]

3. Antimicrobial Activity:

3.1. Spectrum of Antimicrobial Activity: The AgNP produced by SMS have broad spectrum antimicrobial activity against clinically relevant gram positive (*Staphylococcus aureus*, *Bacillus subtilis*, *Bacillus cereus*, *Klebsiella pneumoniae*) and gram negative (*Escherichia coli*, *Pseudomonas aeruginosa*, *Ralstonia solanacerum*) pathogens. Recently, it is fount to work against some fungi namely *Candida albicans* [1, 2, 4, 20]. (Table 2)

Table 2. Antimicrobial Activity of SMS-Derived Silver Nanoparticles

Microorganism	Type	Reported Activity	References
<i>Staphylococcus aureus</i>	Gram-positive	Growth inhibition	[1,4,21]
<i>Bacillus subtilis</i>	Gram-positive	Antibacterial activity	[1,2]
<i>Bacillus cereus</i>	Gram-positive	Growth suppression	[2]
<i>Klebsiella pneumoniae</i>	Gram-negative	Antibacterial activity	[4,21]
<i>Escherichia coli</i>	Gram-negative	Strong inhibition	[1,3,4]
<i>Pseudomonas aeruginosa</i>	Gram-negative	Growth inhibition	[2,5]

Microorganism	Type	Reported Activity	References
<i>Ralstonia solanacearum</i>	Gram-negative	Significant antibacterial effect	[20]
<i>Candida albicans</i>	Fungus	Antifungal activity	[5,21]

3.3. Mechanism of antimicrobial action: The AgNP which is produced by oyster SMS contributes multiple antimicrobial mechanisms efficacy. There are five mechanisms are reported by AgNP by SMS of oyster mushroom. Firstly, it works by cell wall and membrane disruption. Secondly, it produces reactive oxygen species (ROS) which damage DNA, protein, and lipids. Third, Silver ion release which disrupt metabolism fourth, intracellular damage and last synergistic effect [5, 13, 15, 21].

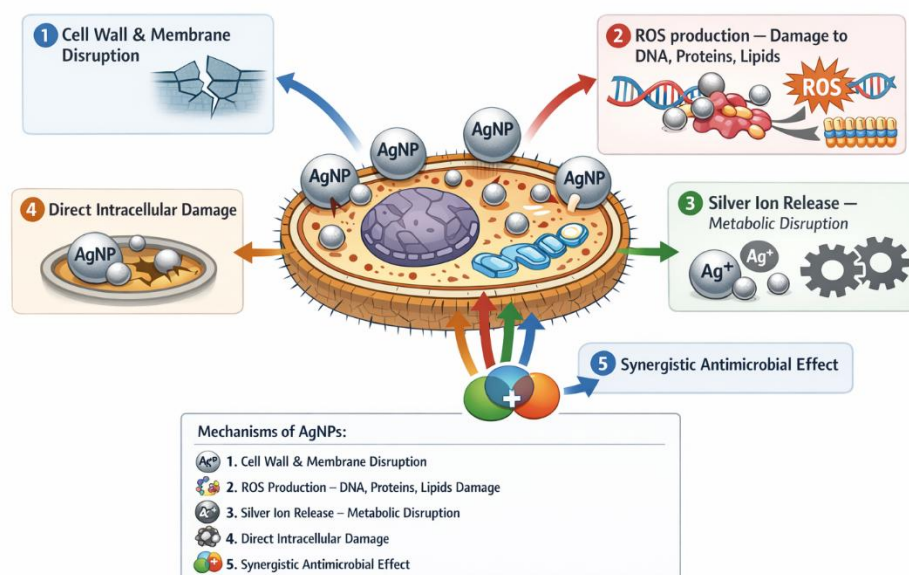


Figure 1. Showing antimicrobial mechanism of oyster mushroom SMS-derived silver nanoparticles (AgNPs)

4. Conclusions: The green synthesis of silver nanoparticles using oyster spent mushroom waste found a paradigm shift nanomaterial production, combining sustainability with functionality. The AgNP used against many health issues like wound healing, medical device coatings, drug delivery. It is very much economic and ecofriendly process and reduced residual of oyster mushroom.

5. References:

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