NANOGUARD: ENHANCING FOOD SAFETY AND SHELF LIFE WITH SILVER NANOPARTICLES AND PROBABLE BIO-APPLICATION

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Abstract - Silver is known for its antimicrobial activity from experiments on preventing bacterial and spoilage fungal growth. From studies on inhibiting bacterial and spoilage fungus growth, silver is known for its antimicrobial action. Due to their potential to extend the shelf life of food products packed with silver nanoparticles (AgNPs), AgNPs are currently the subject of extensive research. The potential effects of utilizing silver in food packaging are discussed in this review paper. Silver nanoparticle-infused polymers were found to be substantially more effective and efficient than traditional food packaging techniques at preventing decomposition and extending shelf life. Concerns exist regarding the potential for silver to leak or migrate into food that is packaged using a polymer that contains AgNPs, as well as the consequences for our health and possible solutions.

IndexTerms - AgNPs, Fungal growth, nanoparticles.

I.INTRODUCTION:

Due to their environmentally friendly, non-toxic, biodegradable or compostable, and biocompatible qualities, natural biopolymer-based packaging materials are gaining popularity.

Proteins, lipids, and polysaccharides are the biopolymers that are frequently employed to create packaging materials. These organic polymers have a strong ability to form films or coatings and have a cohesive structure, so they can cover the surface of food with a thin layer of protection. In general, biopolymer-derived films and coating could preserve the quality and lengthen the stability and shelf-life of food products by (a) regulating the exchange of moisture, gases, and lipids between food and the external environment, (b) safeguarding against microbial contamination, and (c) preventing losses of desirable compounds like flavor volatiles. Additionally, biopolymers materials can be used as transporters for antibacterial agents, antioxidants, flavoring and coloring agents, vitamins, or other minerals, enhancing the packed product's sensory qualities and nutritional value. Recent studies have concentrated on the potential for employing edible packaging to transport probiotic bacteria. Incorporating living microorganisms into edible films and coatings not only improves consumer health but also preserves the quality and safety of food by preventing the growth of pathogenic or rotting microbes since they create antimicrobial metabolites.

I. APPLICATIONS OF ANTIMICROBIAL SILVER NANOPARTICLES IN THE FOOD INDUSTRY

Microbial food spoilage is a major global concern that can reduce the shelf life of food while increasing the risk of food borne diseases. In this framework, the use of well-known potent
An antimicrobial agent such as silver nanoparticles constitutes an interesting approach.

Ag-NPs Size	Ag-NPs Concentration	Gram (-) Pathogens	Gram (+) Pathogens	Yeast/Fungus	Main Results
-	0.034 µg Ag/mL	*Escherichia coli* K12	-	-	2 log reduction of *E. coli* after membrane filtration.
≈ 7 nm and 27.5 nm	0.26–26.5 mg Ag/dry g paper	*Escherichia coli*	*Enterococcus faecalis*	-	After filtration, the paper with a higher content of Ag-NPs almost completely deactivated bacterial growth. Reductions of 7 and 3 log were produced for *E. coli* and *E. faecalis*, respectively.
75 nm (spherical) and 5–20 nm (triangular)	-	*Escherichia coli, Pseudomonas aeruginosa, Salmonella typhi, Acinetobacter baumannii, Enterobacter cloacae, Haemophilus influenzae, Klebsiella pneumoniae, Neisseria mucosa, Proteus mirabilis, Serratia odorifera, Vibrio parahaemolyticus* and *Paenibacillus koreensis*	*Staphylococcus aureus, Bacillus subtilis* and *Paenibacillus koreensis*	-	The highest antimicrobial activity of the Ag-NPs was against *E. coli* and *P. aeruginosa*. For *S. typhi* and *B. subtilis* this activity was moderate and low for *S. aureus*.
14.6 nm	0.2, 0.5, 1, 1.5, 2 mg/mL	*Escherichia coli, Pseudomonas aeruginosa* and *Klebsiella pneumoniae*	*Lactobacillus rhamnosus* GG, *Bacillus cereus* and *Listeria monocytogenes*	*Aspergillus* and *Penicillium*	Inhibition of bacterial growth was dose dependent. *P. aeruginosa* was the bacteria most sensitive to Ag-NPs, followed by *E. coli*. On the contrary *L. monocytogenes* was the most resistant.
10, 20, 40, 60 and 80 nm	6 µg Ag/mL (10 nm), 11 µg Ag/mL (20 nm), 5 µg Ag/mL (40, 60 and 80 nm)	*Escherichia coli* and *Pseudomonas fluorescens*	-	*Saccharomyces cerevisiae*	Nanoparticles of a size equal to or less than 10 nm were more bioavailable when interacting with the cells. It was also shown that the toxicity of Ag-NPs decreased with increasing size.

Fig 1- Recompilation of studies about the antimicrobial effects of Ag-NPs against food borne pathogens.

In addition to shortening food's shelf life and raising the danger of food borne illnesses, microbial food deterioration is a major global concern. Using well-known, effective antibacterial agents like silver nanoparticles in this architecture is an intriguing strategy. The antibacterial efficacy of Ag-NPs against multi-drug resistant (MDR) Campylobacter strains obtained from the poultry food chain and clinical patients was demonstrated by Silvan et al. among other pertinent findings. A different study found that the most prevalent food borne pathogens, including Listeria monocytogenes, Vibrio parahaemolyticus, Escherichia coli O157:H7, and Salmonella typhimurium, were resistant to the antimicrobial effects of nanoparticles produced from water extract from Forsythia suspensa fruit. When Ag-NPs produced from jack fruit seeds were tested against S. typhimurium and E. coli, similar outcomes were found.

II. REGULATION ABOUT SILVER NANOPARTICLES USE IN FOODS AND FOOD INDUSTRY PACKAGING (SAFETY):

The European Food Safety Agency (EFSA) panel on food additives and sources of nutrients added to food concluded that there is insufficient information on Ag to assess its risk; as a result, Ag-NPs are not allowed in food supplements or food packaging in the European Union (EU) unless specifically authorized. 0.05 mg/L in water and 0.05 mg/kg in food are the maximum levels of Ag migration allowed by the EFSA. Therefore, testing for migration, genotoxicity, absorption, distribution, metabolism, and in vitro excretion must be done by manufacturers. With the help of all this information, EFSA will conduct a risk analysis of the particular situation to decide whether or not that package can be marketed. No goods that have received approval as of yet are known.

II. TOXICITY OF AgNPs AGAINST IMMUNE CELLS:

Since AgNPs in humans serve no significant biological purpose, when administered intravenously, they can reach and harm the liver. They have been observed to interact with human primary PBMC and raise neutrophil oxidative stress. Human blood mononuclear cells were found to be toxic to AgNPs as tiny as 10 nm, and the toxicity was dose- and time-dependent. The AgNPs were able to induce an inflammasome when exposed to human monocytes, despite the fact that they were not specifically examined as an immunogenic. They can control cytokines involved in wound healing, which is a plus.

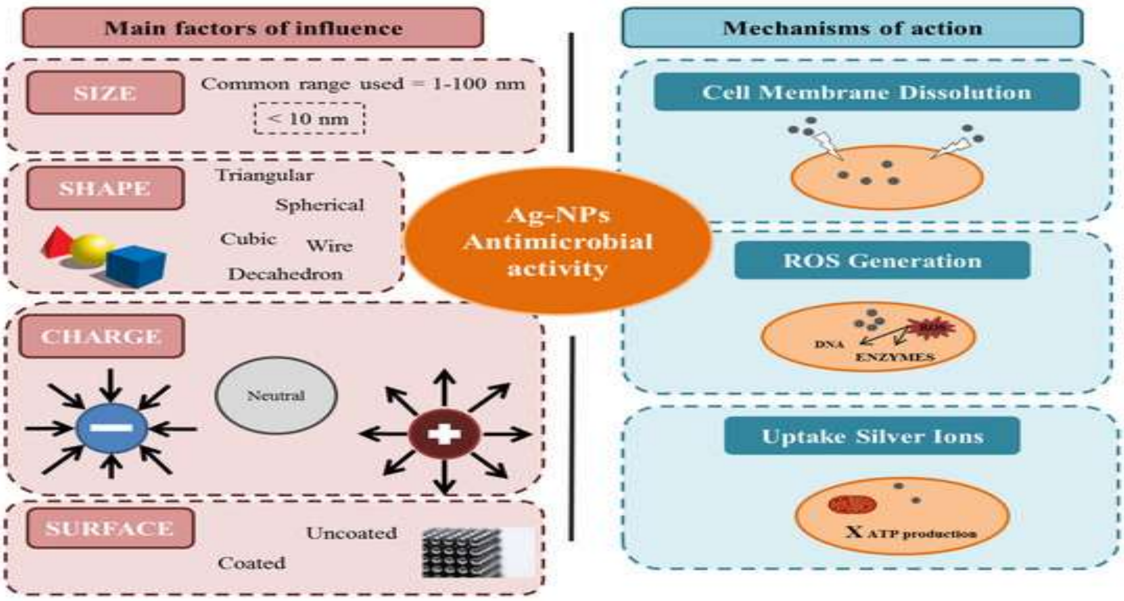


Fig 2- Main factors of influence and hypothetical mechanisms for the antimicrobial activity of silver nanoparticles.

III. MECHANISM OF SILVER NANOPARTICLES (AgNPs) BIOSYNTHESIS:

Ag-NPs' antibacterial actions have not yet been fully understood, but two primary theories have been put forth: (i) a direct contact between the nanoparticle and the cell membrane; and (ii) the release of ionic silver. According to the first theory, the Ag-NPs would stick to the cell membrane either through interactions with the sulfur and phosphorylated proteins found in the cell wall or through electrostatic interactions between the positive charges of the nanoparticles and the negative charges of the cells. In any case, its partial breakdown would result from the Ag-NPs' interaction with the cell membrane (Figure 1). According to the second theory, the Ag-NPs would enter the Silver ions are released from the cell, which causes an increase in reactive oxygen species (ROS), which in turn damages the enzymes involved in cellular oxidation-reduction respiration and ultimately results in cell death.

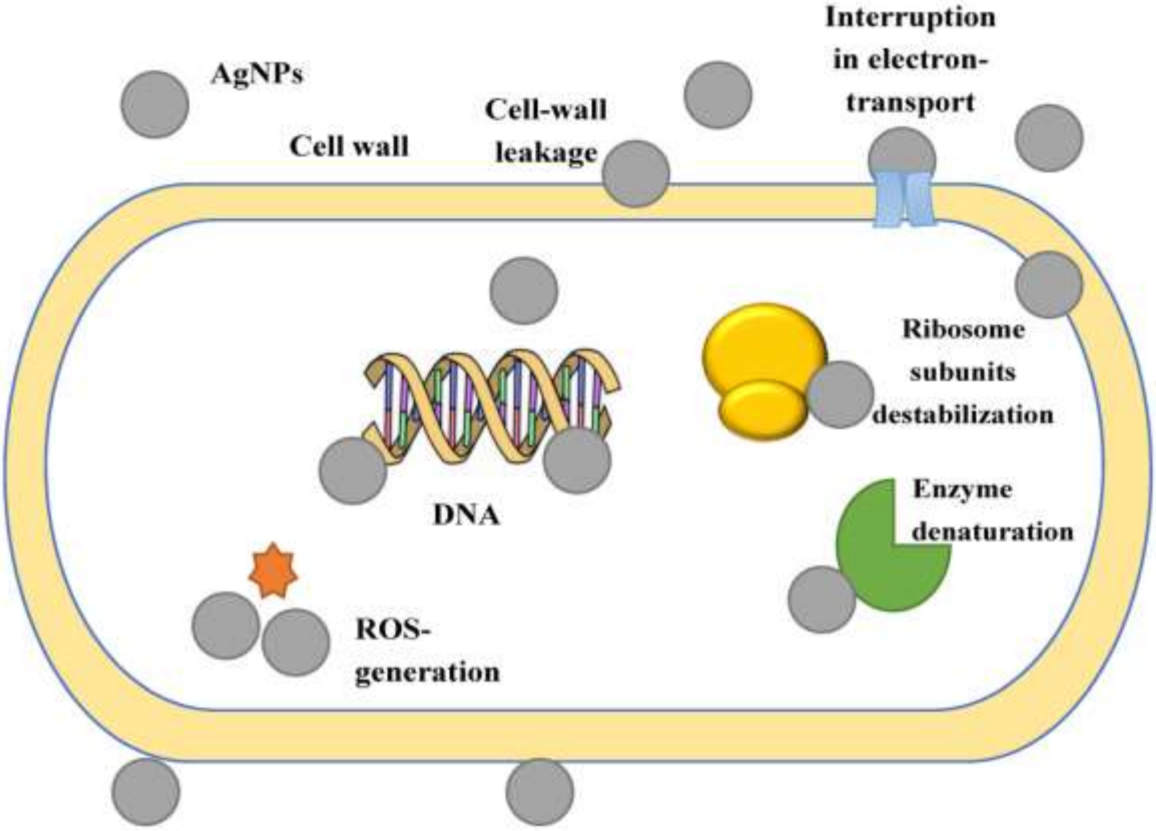
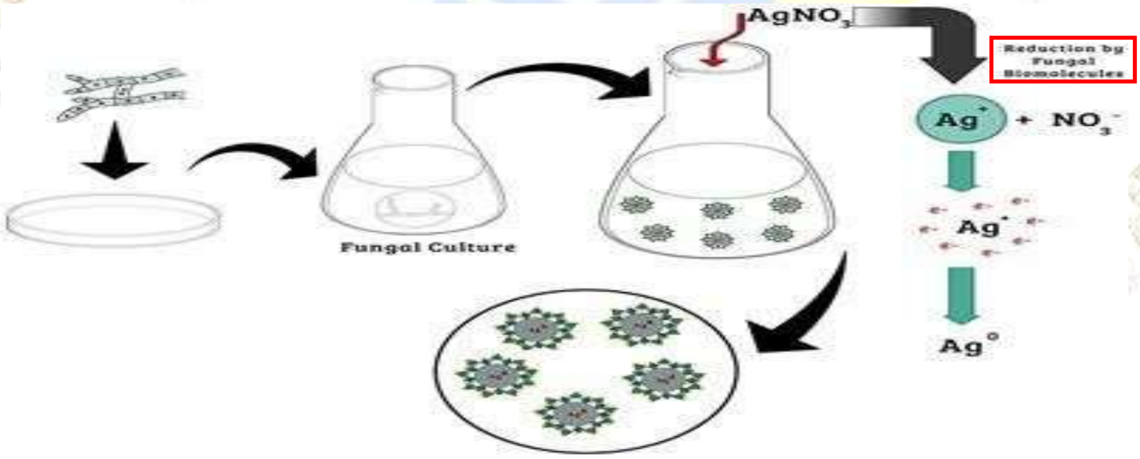


Fig 3- The supposed mechanism of silver nanoparticle (AgNP) biosynthesis**.**

IV. SYNTHESIS OF SILVER NANOPARTICLES:

Since it is regarded as a reliable and environmentally sound process, research into the biological synthesis of AgNPs, which involves bacteria, fungi, and biomolecules, has been conducted extensively. Additionally, biological synthesis doesn't produce any harmful byproducts, and the manufacture of metallic nanoparticles can also use plant extracts. Metallic nanoparticles (NPs) produced by microorganisms can either be produced intracellular or extracellular, and they can vary in size, shape, and antibacterial potency. A promising type of active food packaging, AgNPs-based antimicrobial packaging helps to improve the shelf life of foods while lowering the risk of pathogens.



V. BIOSYNTHESIS OF SILVER NANOPARTICLES:

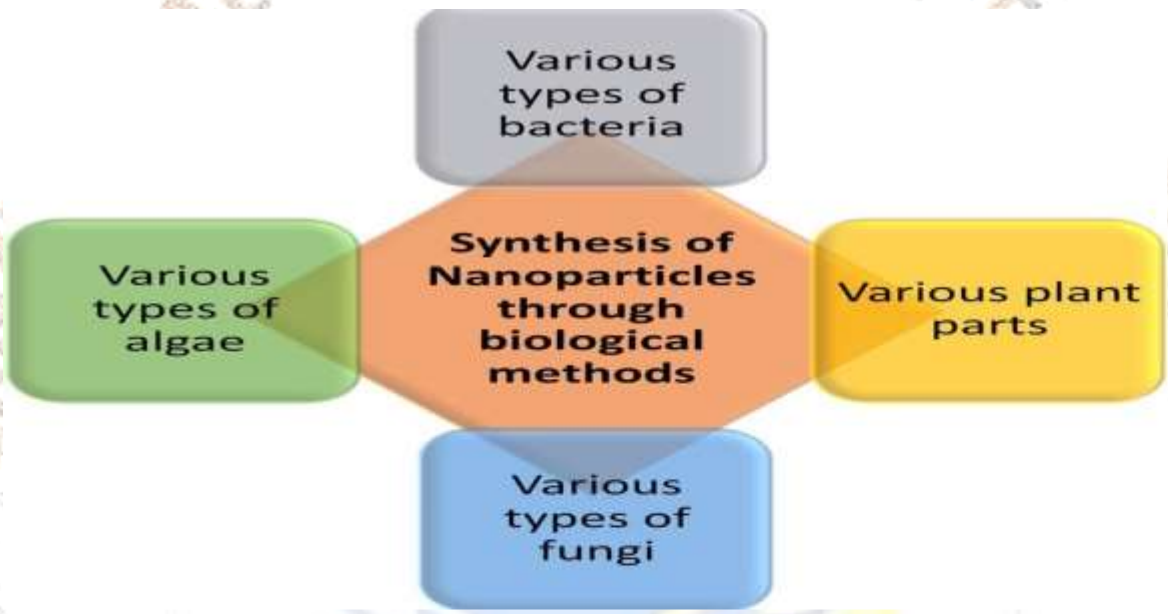
Bacillus spp., Streptomyces spp., and Pseudomonas spp. are the principal genera of bacteria that produce AgNPs efficiently. Heavy metal-contaminated soil samples were used to isolate strains of Bacillus spp., which are very effective in producing AgNPs both inside and outside of cells. AgNPs produced by actinomycete strains (Streptomyces parvulusSSNP11) isolated from samples of maritime sediment. Gram-positive and -negative bacteria such P. putida, K. pneumoniae, B. subtilis, and S. typhi were all successfully combated by the AgNPs' antibacterial activity.

VI. PREPARATION OF AgNPs USING FENUGREEK:

Distilled water is used to wash the Trigonella foenum-graecum, or TF, plant first. After the plant has dried out in the sun for roughly an hour, the leaves are weighed and divided into pieces in order to extract the plant's nutrients. The parts are cooked in distilled water for an hour. The plant extract is added in drops to an $AgNO_3$ solution to lower the AgO content. The drops are added gradually while stirring continuously at a speed of 60 rpm while the mixture is at room temperature. From being colorless to yellow to reddish brown, the solution changes. The need for protection against food borne illnesses and the growing demand for longer fresh food shelf lives drove the development of antimicrobial food packaging. The combination of organic-inorganic packaging, specifically polymer embedded metal nanoparticles, emerged as one of the most effective techniques.

- Research has demonstrated that the size and form of Ag NPs affect their toxicity. For instance, a study with alveolar macrophages found that AgNPs with a mean size of 15 nm caused the highest reduction in mitochondrial function.

Because the action of AgNPs in mitochondria is species-specific and hence cannot be generalized, these investigations are unsatisfactory.



VII. IMPACT OF DIETARY EXPOSURE TO SILVER NANOPARTICLES IN HEALTH: GUT NANOTOXICOLOGY EFFECTS:

The potential of nanotechnology in food science and industry grows along with the amount of research being done on its use in the food business, which in turn increases human exposure to these compounds. The primary human exposure source for antimicrobial silver nanoparticles used in the food sector, the subject of this review, is through the oral and gastrointestinal system. The average daily intake of Ag-NPs is thought to be between 70 and 90 g. Following ingestion, Ag-NPs come into touch with the esophageal and oral cavity lumen. Feces may contain some of the initial nanoparticle intake. The structure of the digestive tract reveals numerous settings, each of which is distinguished by a certain micro biota makeup. More than 100,000 billion microorganisms, including bacteria, fungus, viruses, protozoa, and archaea, are found in the gut micro biota, with bacteria making up the majority of these species. The Firmicutes (containing the genera of Clostridium, Enterococcus, Lactobacillus, and Ruminococcus) and Bacteroidetes make up the majority of the gut bacterial phyla.

VIII. CONCLUSION AND FUTURE PERSPECTIVES:

The method of silver nanoparticle migration from bio-based packaging material to the product, as well as their effects on the human body and the environment, still need to be studied in order to allay customer worries regarding the safety of their use. Due to its shown "antimicrobial" properties, silver nanoparticles have enormous promise as a surface protector in laboratories. Since people consume food in large quantities and the effects are discussed in this review article, it is important to note that there is technology out there that makes it possible to use AgNPs as surface protectants without endangering humans. However, there is no promising technology available for achieving the same goal in the food industry. Therefore, more investigation is required to establish the ideal concentrations of silver nanoparticles that can be used in nonmaterial without endangering human health. In conclusion, research into silver nanoparticles is of significant interest to the food business due to their potential and diverse capabilities against food borne pathogens, but it is not without challenges that must be overcome in order to guarantee the safety of their usage.

IX. REFERENCES:

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