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Review Paper

An exploration of nanoparticle synthesis techniques and therapeutic applications, with a focus on silver and metallic nanoparticles in food packaging

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Abstract

Nanoparticles are minuscule particles that measure between 10-1000 nanometers in diameter, rendering them invisible to the naked eye. Various materials are utilized in producing nanoparticles, including proteins, polysaccharides, and human-made polymers. The selection of matrix materials relies on several factors such as the desired nanoparticle size, drug properties, surface traits, and antigenicity of the finished product, all of which play crucial roles in the synthesis of nanoparticles. Ongoing technological innovations are enabling the use of modernized techniques to create nanoparticles. The review provides an extensive exploration of these techniques, their biological and chemical properties, and therapeutic impact. The research examines the role of silver nanoparticles, which are commonly used in food packaging and preservation due to their antibacterial and anti-browning properties, and the potential applications of other metallic particles for similar purposes. Furthermore, silver nanoparticles' digestion and physiological benefits, such as their action on mucosa-associated lymphatic tissuesare addressed in detail. These nanoparticles are recommended for medicinal use due to their potential health benefits. Researchers have focused on metallic nanoparticles, particularly magnetic nanoparticles, for their ability to prevent microbial growth. Biopolymers are often utilized as carriers for various particles, and blending organic compounds with metallic Nano-compounds is a straightforward process.

Keywords: Nanomaterials, Silver Nanoparticles, Metallic Nanoparticles, Digestion Tract, Polymers.

Introduction

Nanoparticles are solid particles ranging from 10-1000nm in size[1-4]. Few molecules that are used for the preparation of nanoparticles are proteins, polysaccharides and synthetic polymers. A few factors that affect the selection of the matrix material for nanoparticles include the required nanoparticle size, the intrinsic drug properties, the material's surface properties, such as permeability, biodegradability, and toxicity, the desired drug release profile, and the antigenicity of the finished product[5-6]. Using premade polymer dispersions, monomer-based polymerization, and ionic gelation or coacervation of hydrophilic polymers are just a few examples of the unique properties of nanoparticles. Supercritical fluid technology[7] and particle reproduction in non-wetting templates (PRINT)[8] have drawn the most attention in research as two ways to make nanoparticles. Latter has great importance because it has control over size, shape and composition during production of nanoparticles[6].

Synthesized Nanoparticles

Various chemicals and biological methods are used in nanoparticles manufacturing. Kinds of nanoparticles include copper, zinc, titanium, magnesium, alginate gold, silver, alloy, magnetic and show some properties that are essential for industrial uses[9,10]. Silver nitrate (3mM) and avocado seed aqueous extract are combined to start the synthesis of AgNP. The reaction was conducted at 32°C in the dark to avoid photoactivation of silver ions. A colour change from light to dark reddish-brown was seen after 24 hours of incubation, demonstrating the reduction of silver ions from Ag+ to Ag0 and verifying the formation of nanoparticles. It was determined that AgNPs were produced by analysing the UV-Visible region between 300 and 800nm, as shown in Figure-1.

Results from a study on the UV-Visible absorption of silver nanoparticles, avocado seed extract, and silver nitrate solution are shown in Figure-1. The silver nanoparticles stand out from the extract and the silver nitrate solution due to a peak in their absorption spectra at 428nm that is specific to them. This peak confirms the successful synthesis of these nanoparticles. In contrast, neither the avocado seed extract nor the silver nitrate solution exhibits a peak at this wavelength.

Formation of AgNP's is indicated by the peak at 480nm in the spectrum. Creation of nanoparticles is encouraged by the phytochemicals in the extract that can decrease silver ions.

The yield and stability of AgNPs were examined in relation to various seed extract concentrations (ranging from 10% to 50%) and a concentration of 3mM $AgNO_3$. The yield of the produced AgNPs was analyzed for different extract concentrations, and the results are presented in Table-1. For each extract concentration, the table displays the amount of silver nanoparticles produced in milligrams.

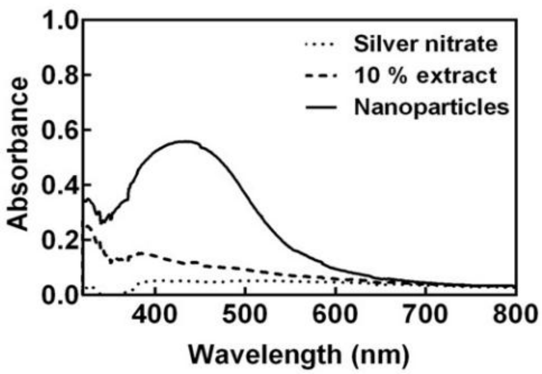

Figure-1: UV-Visible absorption of silver nanoparticles, avocado seed extract, and silver nitrate solution.

Table-1: Different extract concentrations of AgNPs.

AgNPs yield (mg ± SD)	ASAE concentration
0.783 ± 0.028a	10% ASAE
1.750 ± 0.050b	20% ASAE
2.450 ± 0.050c	30% ASAE
3.050 ± 0.050d	40% ASAE
3.540 ± 0.052e	50% ASAE

Yield of AgNP's was increased after 24 hours of incubation due to extract concentration. 30% of the extract increased linearly but no significant change was observed at 40% and 50% of the extract concentration. Investigation was made on the effect of changing time on nanoparticle production by measuring the absorption of wavelength of 428nm. There are few reducing agents that are involved in the synthesis of nanoparticles are time dependent. After 4hours linear increase was observed at 10% of extract.

After 30 minutes of reaction time, AgNPs began to produce at their highest levels, and after 4 hours as the concentration of avocado seed extract increased (20, 30, 40, and 50%), saturation was reached.

Morphological properties of nanoparticles are not changed by changing the extract concentration and this demonstration is given by FESEM tests. There have been reports that nanoparticle morphology may change or aggregate at increasing concentrations of plant extract or during the manufacturing of nanoparticles[11,12].

Table-2: The milligrams silver nanoparticle production throughout different time periods.

AgNPs yield (mg ± SD)	Incubation time (hours)
0.266 ± 0.057a	1
0.366 ± 0.057b	2
0.366 ± 0.057b	4
0.500 ± 0.100c	20
0.566 ± 0.057d	24
0.633 ± 0.057e	46
0.633 ± 0.115e	50

Digestion of Nanoparticles

Food particles can interact with the body through means other than digestion and assimilation. Food comes in contact with body by mucosal layer of the digestive passages that play its role in the breakdown of food at the end of digestion process. Particles of small size can be taken by mucosa associated lymphatic tissues (MALT). Apart from this, food possess some characteristics of a specific Polydisperse system. It consists of various tiny particles of varying size and characters. Some data from research have proved that there is direct contact of small particles with MALT and antioxidant small particles interact with lymphatic vessels. Such interactions are proved to by physiologically beneficial[13]. Digestive system and human skin are totally opposite to each other depending upon the particles and substances they interact. Digestive tract has different function than human skin because these two interact with different substances. Digestive tract defends body from external harms and act as a barrier[14].

The mucosa of the digestive tract serves as a defense mechanism against toxic substances, including small natural and artificial particles. These particles follow a specific pathway, traveling first through the epithelial layer of the digestive tract and then passing through the lymphatic vessels and lymph nodes before reaching other parts of the body. The pathway of these particles was first demonstrated by the decomposition of raw starch in the gut mucosa of rats[13,15]. Particles of a particular size are capable of passing through the lymphatic tissue in the digestive tract mucosa[13]. Only physically and chemically stable foods are able to produce meaningful reactions in the body[16]. These raw materials contain various chemicals, heat-insensitive proteins, and free molecules[17].

Medical Applications of Metallic Nanoparticles

Metal nanoparticles made of materials such as gold, zinc, and silver possess unique properties such as photoluminescence, optoelectronics, and catalytic activity that make them promising candidates for use in medicine[18]. Nanotechnology, through atomic scale material tailoring, is expected to revolutionize disease prevention and treatment, as well as improve human health by enabling modification of crucial substances and properties of systems at the nanoscale. Nanomaterials are similar in size to biological molecules and structures, making them useful in various in-vivo and in-vitro studies. Nanoparticles have been employed in the development of diagnostic tools, analytical devices, physical therapy applications, and drug delivery systems. Silver nanoparticles in particular have shown strong antibacterial properties and have been used in medicine to treat infections and burns[19-23]. Economically, various silver salts and derivatives are used as antibacterial agents[24]. Electron microscopy has been used to determine the size of bacteria-carrying silver nanoparticles, and research is ongoing to determine their stability in order to control bacterial activity[19, 25].

Cardiovascular Disease: Major cause of death around the globe is cardiovascular disease (CVD). Understanding the situation there is a need for effective treatment of this disease. Nanoparticles are proved to be effective in treatment of CVD due to its specific properties. Currently, the identification and localization of atherosclerotic plaques using iron oxide nanoparticles (NPs) has received significant attention in the medical field. In addition to this NP's accelerate the targeted stem cell delivery that are capable to recover regenerative capacity of the injured. In addition to their anti-oxidative and anti-inflammatory properties gold nanoparticles perform specific function of tracking down of plaques and identification of inflammatory markers. Silver NP's increases the negative effect of cardiovascular system. Shortly, NP's have negative impact including inflammation and cholesterol uptake, intensified atherosclerosis. In addition, silver NPs have been shown to have the ability to contribute to bradycardia, cardiovascular diseases, and even cardiac death[26].

Cancer Disease: The unique characteristics of gold nanoparticles, such as their size, shape, morphology, and chemical properties, make them highly versatile and valuable in various fields. Their surface Plasmon resonance, magnetic properties, and fluorescence resonance properties, for example, make them suitable for use in DNA hybridization, protein and nucleic acid biosensors, CT-MRI, and immunological assays. Beyond these applications, gold nanoparticles have been shown to have potential therapeutic applications for the treatment of a variety of diseases. Gold nanoparticles have variety of optical characteristics. They are vastly used in biomedical field due to their high surface area and high scattering properties. Gold nanoparticles are also utilized in biological analysis and have variety of absorption. The width of AuNP's that is advantageous for all kinds of cells, tissues and cancerous elements is 50nm[28]. It is really obvious that cancerous cells divide faster than normal cells and gold particles can incorporate in them and can remove them from the body by the help of secretions. Gold nanoparticles that are coupled with trastuzumab antibodies have demonstrated promise in focusing on HER-2 receptors in SKBR-3 breast cancer cells despite a number of obstacles. The cytotoxicity of trastuzumab may increase by up to twice when the gold HER particle attaches to the receptor and is internalized by the cell[29]. Additionally, radiotherapy has proven to be an effective treatment option for this type of cancer[30].

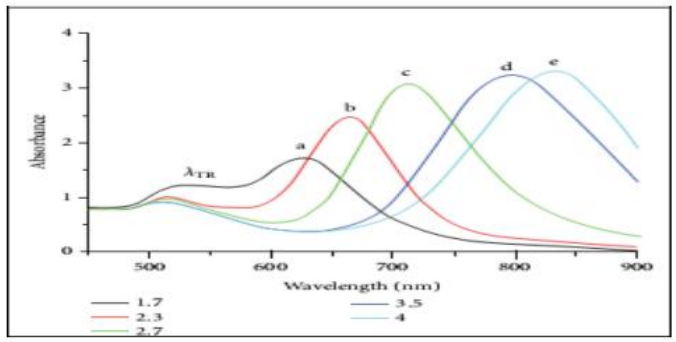

Figure-2: Absorption spectra of gold nanoparticles[27].

Central Nervous System (Cns) Disease: Various studies have proved that inhalation of NP's brings threats to CNS[31,32]. Due to their tiny size, NP's are exposed to humans by inhalation as they stick to the mucus of nose[33] and also have ability to penetrate in lungs, broccoli and alveoli[34,35]. In addition to the glomeruli of the olfactory bulb, the olfactory nerve or trigeminal, or the blood-cerebrospinal fluid to the choroid plexus, the olfactory epithelium is in charge of transporting nanoparticles (NPs) from the nasal cavity to these and other places. Via the olfactory nerve, NPs can penetrate the blood-brain barrier and reach the brain directly (BBB)[34,36,37]. This has been seen with a variety of metal nanoparticles, including titanium dioxide NPs, ultrafine manganese dioxide NPs, CdSe/ZnS quantum dots, copper oxide nanoparticles, and ultrafine silver nanoparticles (Ag NPs) (TiO_2 NPs)[38-43]. Ingested metal nanoparticles (NPs) can enter the bloodstream through alveolar epithelial cells and go to the lymphatic system, where they can build up in numerous organs such the heart, bone marrow, lymph nodes, spleen, and brain[44-46] Aluminum oxide NPs (Al_2O_3NPs)[45,47] or lead NPs (Pb NPs)[48] are also their along with other NP's. Microphages inside the alveoli play their role in picking of small metal NP's and dissolve in phagosomes. Oxidized NP's generally release insoluble ions. Released ions can pass through the BBB[49].

Emerging Role in Food Packaging

The use of silver nanoparticles in food packaging has emerged as a potential solution for food preservation due to their anti-bacterial and anti-browning properties[50]. Unlike other nanoparticles, silver nanoparticles derived from phytochemicals have garnered attention for their antibacterial, antiviral, antifungal, and anti-inflammatory properties[51]. These nanoparticles are important for protection, preservation and extension of food shelf life. Changes in lifestyles, use of pesticides and various chemicals effect quality of food to the great deal. Various metallic nanoparticles are used to improve the quality and shelf life of food due to its anti-bacterial properties. Researchers have showed their interest in utilizing nanoparticles due to their food saving properties. MNP's can be easily mixed with biopolymers and serve as carrier for the other nanoparticles. Identification of hazards and risks in essential before using nanoparticles[52]. Extensive use of pesticides and biological and chemical compounds in food effects the nutrition of food as these are used in the overall handling and protection of food[53]. MNP's have sought a lot of attention because of their anti-microbial activity that prevents bacterial development and extends its shelf life[54]. Anti-microbial activities of MNP's have made them crucial in the application of food preservation[55].

Conclusion

The field of nanoparticle synthesis techniques and their therapeutic applications is a rapidly growing area of research with immense potential. In this article, we have explored various synthesis methods, including physical, chemical, and biological techniques, highlighting the advantages and disadvantages of each method. We have also discussed the potential of silver and metallic nanoparticles in food packaging as a means of increasing food shelf life and reducing waste.It is clear that the use of nanoparticles in medicine and food packaging has enormous potential to positively impact human health and the environment. However, it is important to consider the potential risks and limitations associated with their use. Further research and development are necessary to fully understand the long-term effects and safety concerns of these particles. Overall, this article has shed light on the exciting possibilities of nanoparticle synthesis techniques and their potential applications, while also emphasizing the importance of responsible use and continued research in this rapidly evolving field.

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