Eco-friendly Synthesis of Silver Nanoparticles from Banana Peel Extract for Sustainable Food Preservation

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Abstract

Nanotechnology-based nourishment conservation strategies have obtained increasing consideration caused to their antimicrobial properties and potential to extend the rack life of food and protect it. From these strategies, silver nanoparticles (AgNPs) are known for their capacity to restrain bacterial and oxidation activities, and upgrade the shelf life of perishable food. This considers points to synthesize AgNPs utilizing banana peel extract (G.B.E) as a green synthesis strategy and considers their role in controlling the oxidation and the antibacterial activities on apple slices To obtain the B.P.E., the peels are boiled in distilled water at 60°C for 1 hour, taken after by filtration to get a clear extract. color altered from colorless to dark brown, appearing the decrease of silver particles into nanoparticles. The nanoparticles are then synthesized using two methods: the classical chemical method and the microwave-assisted method, which will be compared later. The characterization of AgNPs will be done using the UV-Vis Spectrophotometry and the Fourier Transform Infrared Spectroscopy (FTIR). And to evaluate the antibacterial and Antioxidation effects, apple slices will be immersed in different concentrations of AgNPs solutions (0.5% and 10%) and stored at room temperature for 5 days. The Visual observation will be performed to analyze the effectiveness of AgNPs on the antibacterial and oxidation activities of both the AgNP-treated apple slices and the untreated control slices. This study highlights the possibility of offering a normal alternative to traditional additives used to preserve nutrients and prevent their waste by using AgNPs synthesized from banana peel extract.

Keywords: Silver nanoparticles, banana peel extract, antioxidation, antibacterial activities

Introduction

Food spoilage, resulting from microbial contamination and oxidative reactions, is a serious global problem. It causes significant post-harvest food losses of approximately 15% to 20%, with substantial economic and environmental impacts[1]. Toxin formation in food is the result of microbial agents, including Pseudomonas aeruginosa, bacilli, molds, and yeasts, which produce these toxins. Biochemical spoilage, particularly lipid oxidation and enzymatic browning (produced by enzymes such as PPO and POD), leads to a deterioration in sensory properties, a reduction in nutritional value, and potentially serious health problems[2]. Nanotechnology, particularly the use of metallic nanoparticles, has emerged as a prominent and successful method for maintaining food safety and extending its shelf life. AgNPs have demonstrated potent antimicrobial and antioxidant activities. Their nanoscale size (typically 1–100 nm) allows them to interact strongly and optimally with microbial membranes, resulting in structural damage, enzyme inhibition, and ultimately cell death. In the field of food safety, AgNPs have demonstrated their effectiveness against spoilage microorganisms and have been successfully incorporated into edible coatings and packaging materials to prevent and halt oxidation and microbial growth [3].

The use of plant-based approaches may utilize natural reduction and stabilizing agents as phenols, flavonoids, and terpenoids, among which they have a reduced environmental impact, and they have garnered a lot of interest [4]. Contrary to other methods and techniques for the generation of the AgNPs, chemical reduction or physical techniques, there is a need for high energy and elaborate procedures, as well as it is usually toxic to the environment [5]. Synthesis of green AgNPs with diverse biogenic extracts (from plants, fungi, and bacteria) offers a safer and sustainable option, therefore [6]. An abundant as well as unexplored source of raw biomass used is the banana peel, which is a lignocellulosic waste that is a good source of phenolic compounds, flavonoids, cellulose, and lignin [7], as well as antioxidants such as dopamine and gallatechin. Several studies have shown that banana peels can be used for the synthesis of silver nanoparticles to obtain spherical nanoparticles (about 20–55 nm) that show significant antibacterial activity against Gram-positive and Gram-negative bacteria and

antioxidant properties of free radical scavenging [8]. One study demonstrated the successful production of silver nanoparticles (approximately 23.7 nm in size) using B.P.E. These particles exhibited strong antibacterial effects and synergistic effects with conventional antibiotics [9]. Another study demonstrated the formation of silver nanoparticles with an average size of 45 nm using Green Banana Peel Extract G.B.P.E. which also demonstrated significant antimicrobial activity against E. coli and S. epidermidis [10].

Materials and Methods

1. Preparation of the B.P.E

Banana peels were washed with distilled water, cut into small pieces 5 cm long, and weighed at 20 grams using a laboratory balance. To get the banana peel extract, the peels were boiled in 100 ml of water for 1 hour at 70°C. The filtration phase was then completed, using Whatman filter paper to remove the solid residues. Followed by centrifugation at 5,000 rpm twice for 10 minutes to get a clear extract for synthesizing the silver nanoparticles [11].

2. The Synthesis of AgNPs

2.1 Using the classical chemical method

25 mL of B.P.E. was mixed with 17 mg of silver nitrate (AgNO3) and stirred for 3 hours to synthesize the silver nanoparticles [11].

2.2 Using the Microwave-Assisted Method

10 ml of B.P.E was mixed with 10.5 mg of AgNO3 and mixed for 30 min. To compare the results, the experiment was repeated using different microwave powers (100, 180, and 300 W) and also different time intervals (1, 5, and 10 minutes) [12].

3. Detecting the Antibacterial and Antioxidant Activities of AgNPs on Fresh Apple Slices for Food Preservation:

Four treatments were applied: a control group (without treatment), apple slices with banana peel extract alone, apple slices with 5% and 10% concentration of AgNPs, and banana peel extract. Each treatment was applied to one apple slice. The samples were stored at room temperature and observed for 5 days to study their antibacterial and antioxidant effects.

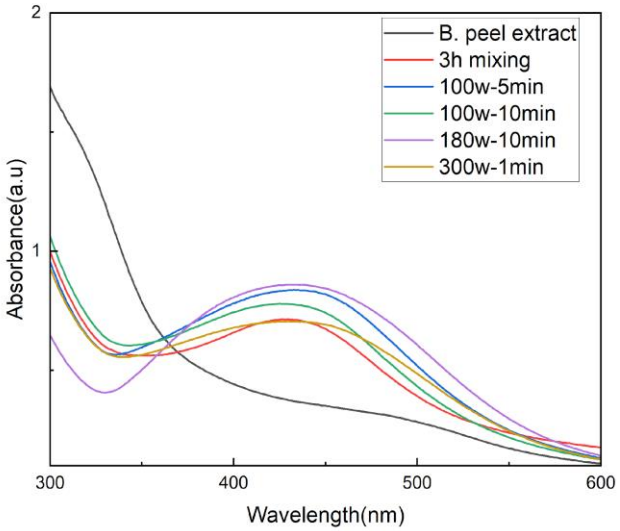
4. Characterization

The synthesized AgNPs were characterized using UV-Vis and FTIR.

Result and Discussion

1. Characterization of AgNPs using UV-vis

To confirm the results, we repeated the experiment twice. Figure 1 shows the UV-Vis spectra of (AgNPs synthesized from banana peel extract using classical chemistry and microwave-assisted methods. Both figures confirm an absorption peak between ~420 and ~445 nm, which confirms the nanoparticle formation in all samples. Using the conventional heating method (3 hours of mixing), a peak around 435 nm,, indicating the formation of nanoparticles, but with a larger size distribution. On the other hand, Microwave-assisted heating at 180 W for 10 minutes produced a strong and sharp peak (around 430–435 nm), presenting and showing the formation of smaller, more homogeneous, and more stable silver nanoparticles.



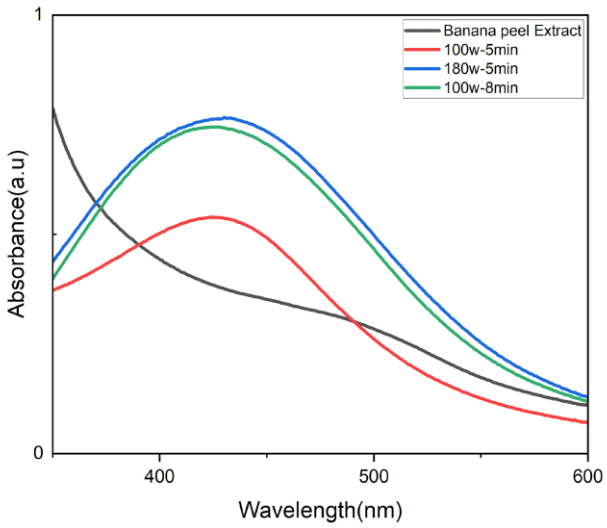


Figure 1(a,b). Characterization of AgNPs using UV-vis

2. Characterization of AgNPs [FTIR]

The FTIR spectrum of AgNPs is reported in Fig.2 the absorption bands due to the involvement of the banana peel extract were observed. (Figure 9: FTIR spectrum of AgNPs .) Furthermore, the peak at 3300 cm-¹ is due to the presence of hydroxyl (O–H) groups that can belong to polyphenols or alcohols, which can be used as reducing and capping agents.

The 2920 cm-¹ peak is due to C–H stretching and corresponds to alkane groups. The band at 1630-1650 cm¹ can be attributed to the stretching vibrations of C=O or C=C groups due to flavonoids and polyphenols. The 1400 cm¹ peak is attributed to O–H bending or symmetric COO^- stretching for carboxylic acids or phenolic compounds, which stabilize the nanoparticles. The 1000–1100 cm-¹ band is from the C–O–C or C–O stretching, indicating the presence of alcohols or ethers in the stabilization of the nanoparticle.

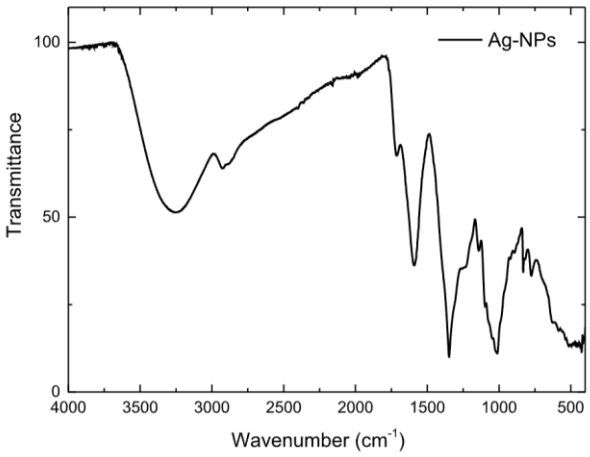
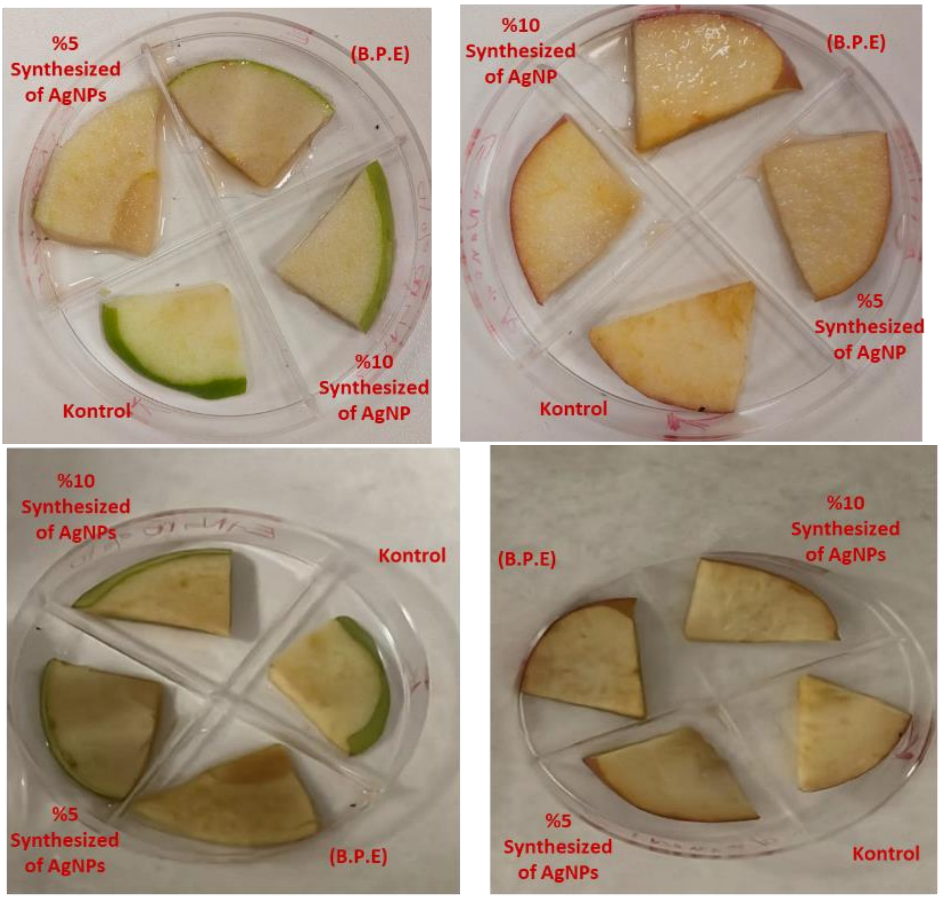


Figure 2. FTIR characterization of AgNPs

3. The Antibacterial and Antioxidant Activities of AgNPs on Fresh Apple Slices:

As shown in the Figures 3, a three day as a three-day control developed browning and microbial growth. Banana peel extract inhibited browning to some extent, but with some microbial activity from the 5th day. The 5% AgNP had a more significant effect on the browning and microbial growth compared to the extract alone. At the end of 5 days, treatment with 10% AgNPs resulted in the best effects, with limited browning and no apparent visible microbial growth.



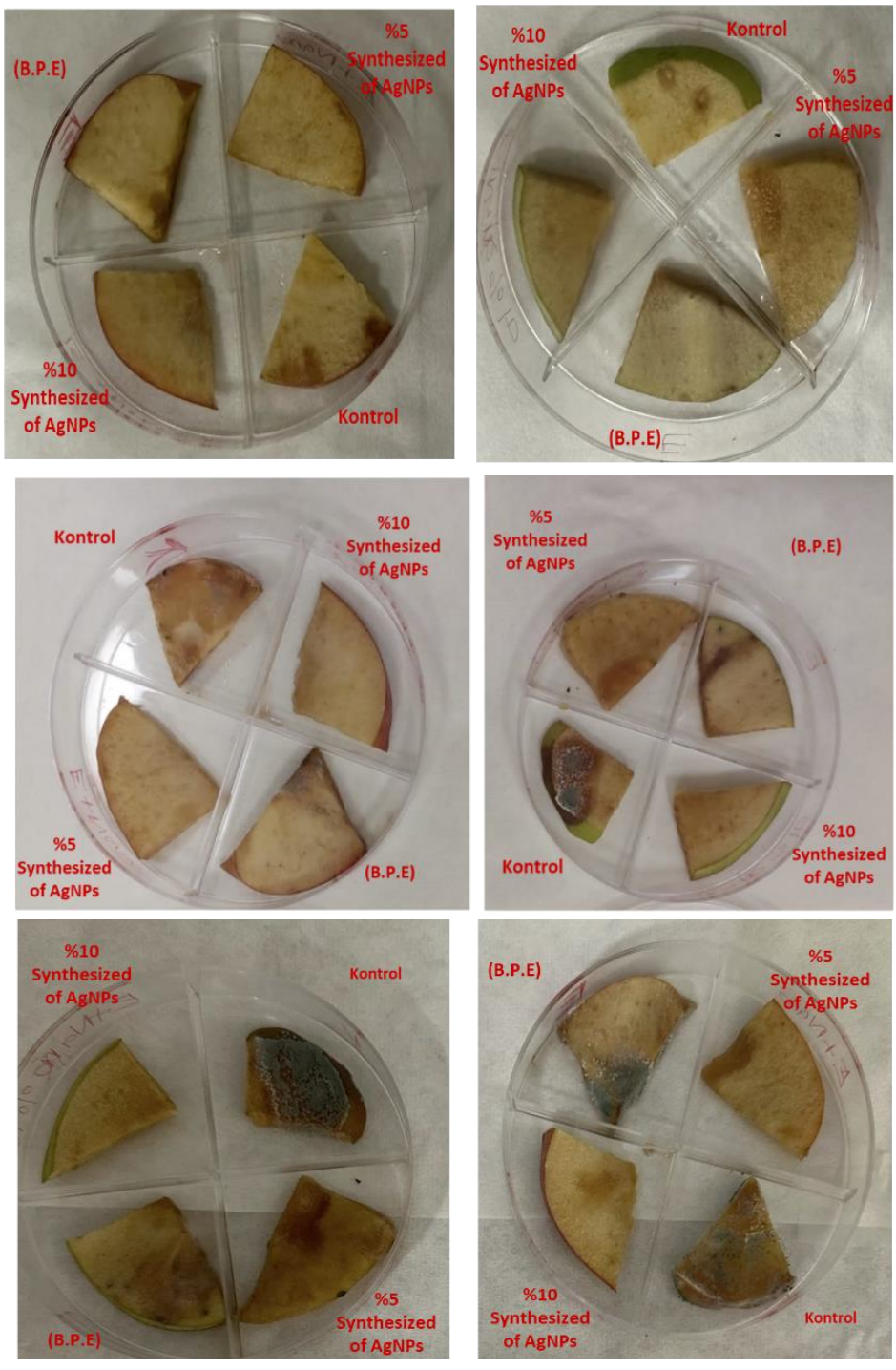


Figure 3.(a,b,c,d,e,f,g,h,i,j) The 5 days of the observation

Conclusions

This study demonstrates the intriguing potential of AgNPs synthesized using banana peel extract (BPE) as an eco-friendly approach for food preservation. The assembly of AgNPs by microwave strategy (specifically at 180 W for 10 min) was validated using UV-Vis spectroscopy, yielding smaller, more uniformly sized, and stable NPs than those made by the classical chemical strategy. Beneficial BPE phytochemicals, polyphenols, and flavonoids groups that can reduce and tune the nanoparticles were also distinguished by FTIR examination.

AgNPs, particularly at the 10% level, inhibited enzymatic browning and bacterial growth well when bound to apple slices for 5 days. B.P.E also played a significant role in inhibiting contaminant growth and oxidation, confirming that B.P.E acts as both a reducing operator and a beneficial additive at the same time. Future studies should examine quantitative factors such as pH changes, surface survey, or microbial counts to better obtain preservation tools. And also other safety perspectives like nanoparticle

movement and cytotoxicity counting, and extension of the application to other nutrients and capacity conditions, need to be addressed in the near future for this green food preservation strategy to be used in practice.

References

[1] Parlapani, F. F., Panagou, E. Z., & Nychas, G. J. E. (2021). Microbial spoilage and safety of fresh produce: Insights from metagenomic analysis. Food Microbiology, 95, 103669.

[2] Martins, S., et al. (2017). Enzymatic browning in fruits: mechanism and prevention strategies. Innovative Food Science &Emerging Technologies, 39, 94-101.

[3] Thakur, S., et al. (2021). Silver nanoparticles: synthesis, characterization, properties, applications, and therapeutic approaches. Journal of Food Science and Technology, 58(5), 1591-1603.

[4] Aday, M. S., & Yener, U. (2015). Use of plant extracts for food preservation: Antioxidant and antimicrobial activity. Food Chemistry, 187, 200-205.

[5] Iravani, S., Korbekandi, H., Mirmohammadi, S. V., & Zolfaghari, B. (2020). Synthesis of silver nanoparticles: chemical, physical and biological methods. Research in Pharmaceutical Sciences, 9(6), 385-406

[6] Iravani, S. (2011). Green synthesis of metal nanoparticles using plants. Green Chemistry, 13(10), 2638-2650.

[7] Ashraf, S., et al. (2021). Banana peel extract-mediated synthesis of silver nanoparticles: characterization and antimicrobial activity. Materials Today: Proceedings, 46, 2483-2488.

[8] Salem, M. Z. M., et al. (2022). Green synthesis of silver nanoparticles from banana peel extract and evaluation of their antibacterial activity. Applied Nanoscience, 12, 203-212.

[9] Gupta, S., et al. (2021). Synergistic antibacterial effects of banana peel extract mediated silver nanoparticles with antibiotics. Microbial Pathogenesis, 157, 104962.

[10] Raybaudi-Massilia, R. M., Mosqueda-Melgar, J., & Martín-Belloso, O. (2009). Antimicrobial activity of essential oils on Salmonella enteritidis, Escherichia coli and Listeria innocua in fruit juices. Food Microbiology, 26(2), 142-150.

[11] Ohiduzzaman, M., Khan, M. N. I., Khan, K. A., & Paul, B. (2024). Biosynthesis and characterizations of silver nanoparticles by using green banana peel extract: Evaluation of their antibacterial and electrical performances. Heliyon, 10(10), e31140.

[12] 12.Phoemthaisong, T., Ksapabutr, B., Chaiyut, N., & Panapoy, M. (2023). *Biosynthesis of silver nanoparticles using extract of banana peel waste assisted by microwave irradiation*. IOP Conference Series: Materials Science and Engineering, 1280(1), 012013.