NOVEL SYNTHESIS AND CHARACTERIZATION OF ANTIBACTERIAL ACTIVITY OF SILVER AND GOLD NANOPARTICLES SYNTHESIZED FROM *ARCTIUM LAPPA LIN* ROOT'S EXTRACTS

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ABSTRACT

In this study, Silver nanoparticles (AgNPs) and Gold nanoparticles (AuNPs) were synthesized by a simple and eco-friendly process: using extracts from roots of *Arctium lappa Linn* (Burdock) as a reducing agent for both two substances $AgNO_3$ and $HAuCl_4$. Modern analytical techniques including UV-Vis, TEM, FT-IR, XRD and EDX were used to analyze the properties of AgNPs and AuNPs. The synthesized AgNPs from the extracts showed the antimicrobial activity with the diameter of inhibition zone for *Bacillus subtilis, Agrobacterium tumefaciens*, *Staphylococcus aureus, Escherichia coli* and *Trichoderma harzianum* is 6.5mm; 6.5mm; 7.0mm; 7.0mm and 10.0mm, respectively. More interestingly, our results showed the minimum inhibitory concentration (MIC) to bacteria as well as fungi is significantly low compared to antibiotics ampicillin. In detail, it is 0.11; 0.22; 0.32; 1.08 and 2.16µg/µL for *Bacillus subtilis, Agrobacterium tumefaciens*, *Staphylococcus aureus, Escherichia coli* and *Trichoderma harzianum,* respectively. AuNPs did not show the antimicrobial activity on both five species used in this study. Our study revealed that *Arctium lappa Lin* root's extracts could be further considered as a highly potential substance in the process to synthesize AgNPs or other nanoparticles with the strongly antimicrobial properties without causing the toxicity to the body.

Key words: ***Silver nanoparticles, Gold nanoparticles, Novel synthesis, Arctium lappa Linn, Antibacterial activity***.

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INTRODUCTION

The concept of "nanometers" was first proposed by Richard Adolf Zsigmondy, the 1925 Nobel Prize in Chemistry. He provided the definition of nanometers to describe particle size, and he also was the first man to measure particles such as colloidal gold with a microscope [1].

Modern nanotechnology is the brainchild of Richard Feynman (1918-1988), who won the Nobel Prize in Physics in 1965 [1]. At the meeting of the American Physical Society in Caltech in 1959, he presented a lecture entitled "There's plenty of room at the bottom," in which he introduced the notion of interference in materials at atomic level. From this new idea with the new ways of thought, his theories have been correctly proven in later. For these reasons, he was considered as the father of modern nanotechnology [1]. Moreover, in 1974, a Japanese scientist, Norio Taniguchi, was the first to use the term "nanotechnology" to define that as the handling, separation, consolidation, and deformation of materials by one atom or one molecule [1].

The golden age of nanotechnology began in the 1980s when Kroto, Smalley and Curl discovered fullerenes (a form of carbon, a large molecule that was made up by many C20 carbon atoms, C60 ...). In 1986, Eric Drexler published "Engines of Creation: The Coming Era of Nanotechnology." The prospect of Drexler nanotechnology is often called "molecular nanotechnology.". The science of nanotechnology has gone further when Iijima, a Japanese scientist, developed carbon nanotubes [1].

The beginning of the 21st century, we witnessed the development of new areas of nanoscience and nanotechnology. President Bill Clinton endorsed the financing of this new technology research in his speech at Caltech in January 21, 2000. Three years later, President George W. Bush signed a law about the research and development of nanotechnology in the 21st century. This law has contributed to the study of nanotechnology as a national priority [2].

Over the course of about half 20 century, nanotechnology has become the cornerstone of outstanding industrial applications and exponential growth. For example, in pharmaceuticals, nanotechnology has had a profound impact on medical devices such as sensors of biological diagnostics, drug delivery systems and image probes. In the food and cosmetic industry, the use of nanomaterials has increased considerably to improved production, packaging, lifespan and bioavailability [3].

Today, nanotechnology affects the lives of people. The potential benefits are numerous and varied. However, due to the wide exposure of humans to the nanoparticles, there is a significant

concern about health and environmental hazards. These concerns led to the emergence of additional sciences including nanotoxicology and nanomedicine [4]. Some of the benefits of medical nanomaterials include improved drug delivery, antimicrobial resistance of medical devices, reduced inflammation, and the detection of cancer cells. However, due to the lack of reliable toxic data, the ability to effect human health has remains a major concern [5].

Nanomaterials have the ranges from a few nanometers to a few hundred nanometers [6] and depending on the properties of the material they will be classified into [7]: Metallic nanomaterials, Semiconductor nanomaterials, Magnetic nanomaterials and Bio-nanomaterials.

Nanomaterials have been shown that they provide diverse benefits with several applications from anti-microrganisms, cosmetics, food industry to medical applications [8-14].

More importantly, the combination of the government's scientific management policy in some advanced countries and invested enormous number of enterprises have promoted the progress of science and the rapid commercialization of research achievements to create products. In 2004, the United States was the world leader in investing in nanotechnology for $1.7 billion a year [15]. Japan was $1 billion a year, South Korea was No. 6, Australia was No.9, China was No.10 and Taiwan was No.11, reaching $120 million a year [15,16]. Based on these tremendous investments, nanotechnology will certainly have a huge impact on our society and our lives over the next few decades. Nano objects will give humanity enormous economic potential in the 21st century.

In this study, we used the biological method to synthesize the nanoparticles including Ag and Au nanoparticles, and our methods showed that it is simple, eco-friendly strongly effective on anti-microorganism activity [17] and can create nanoparticles with large numbers [15].

MATERIALS & METHODS

Materials

Burdock's root (BR) was used as reductant to synthesize the nanoparticles purchased at Khai Minh Company (Ho Chi Minh City, Vietnam).

Methods

The Burdock's root extract was extracted and used to synthesize the nanoparticles using the protocol from Dhuper *et al.* [18] with slight modification and that briefly described in **Figure 1-3** as below:

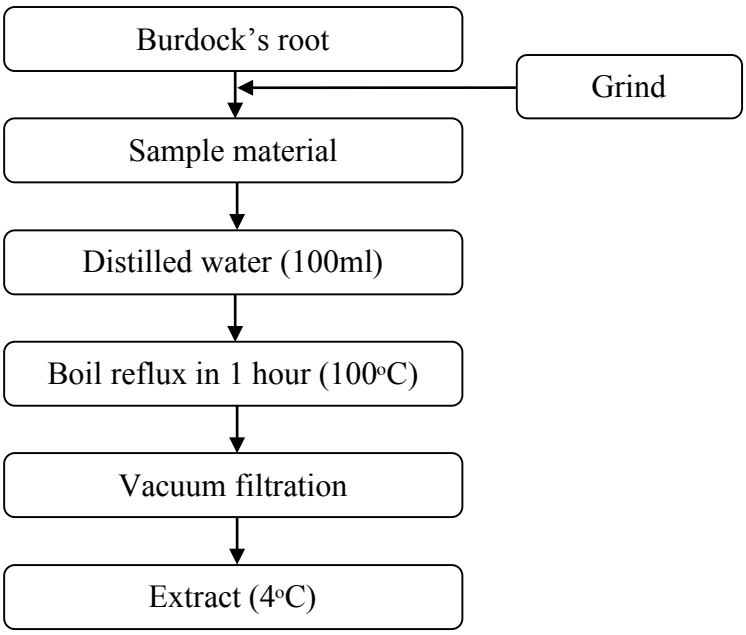

Figure 1. The preparation process of BR extracts

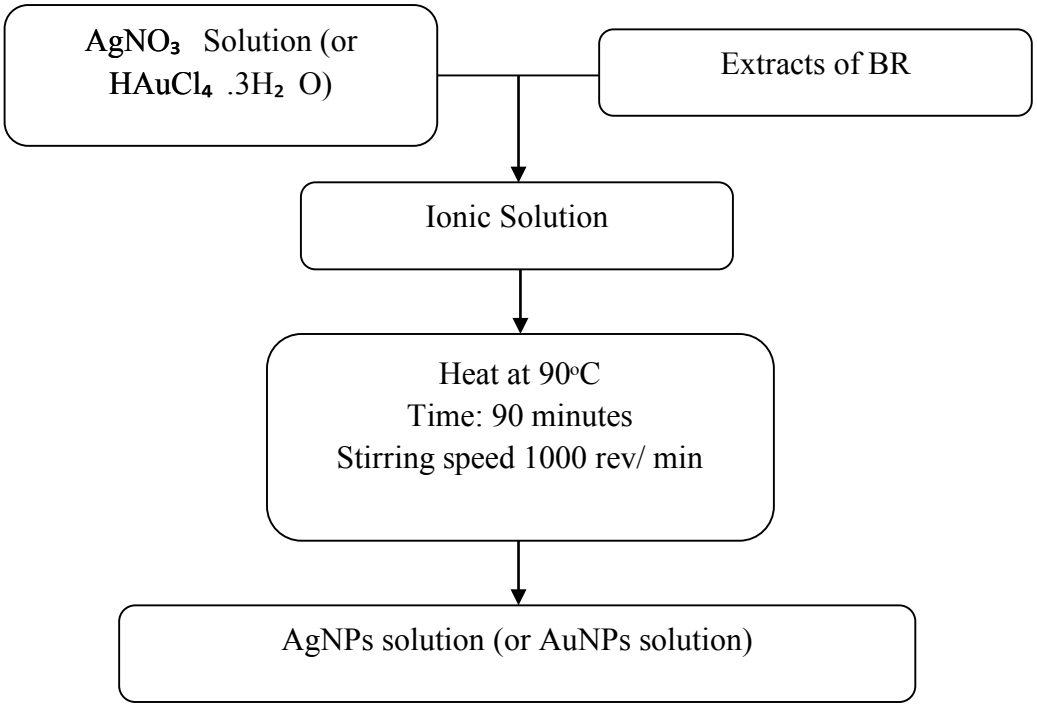

Figure 2. The AgNPs and AuNPs Synthesis Process

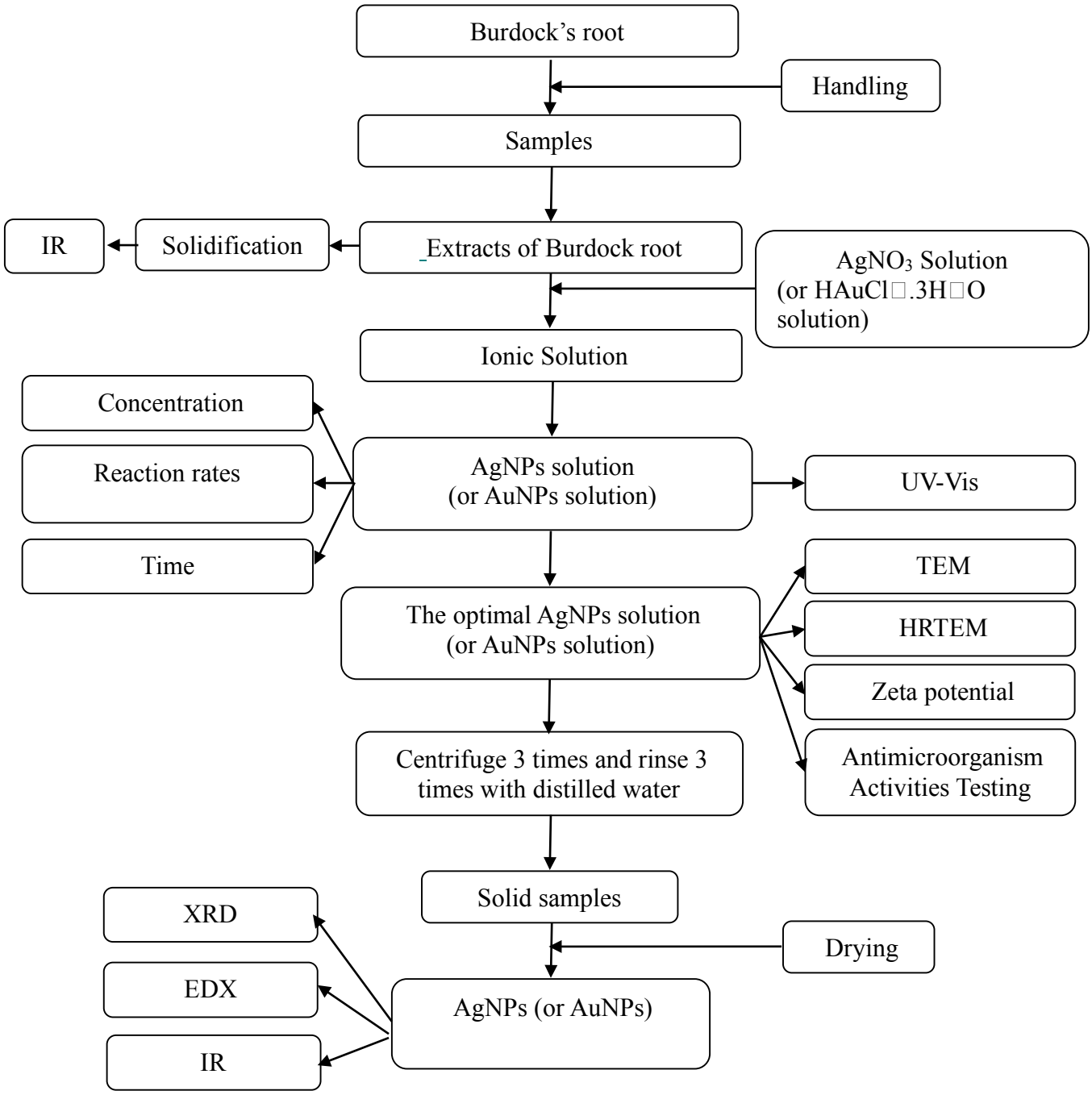

Figure 3. A complete process for AgNPs and AuNPs synthesis

RESULTS

To detect the anti-microorganism activity of AgNPs and AuNPs biologically synthesized from our experiments, we used four strains of bacteria (*Bacillus subtilis, Agrobacterium tumefaciens, Staphylococcus aureus and Escherichia coli,* and one fungus (*Trichoderma harzianum*) to confirm that. While AgNPs showed the strong antimicrobial activity on all species used in our study with the MIC (Minimum Inhibitory Concentration) values described in **Table 1** and **Figure 4 - 8**, no antimicrobial ring was found from the treatment with AuNPs.

Table 1. Results of antimicrobial activity of AgNPs on Types of studied model

Types of investment model	Minimum Inhibitory Concentration (MIC) (µg)	Zone of inhibition (mm)
Bacillus subtilis	0.11	6.5
Agrobacterium tumefaciens	0.22	6.5
Staphylococcus aureus	0.32	7.0
Escherichia coli	1.08	7.0
Trichoderma harzianum	2.16	10.0

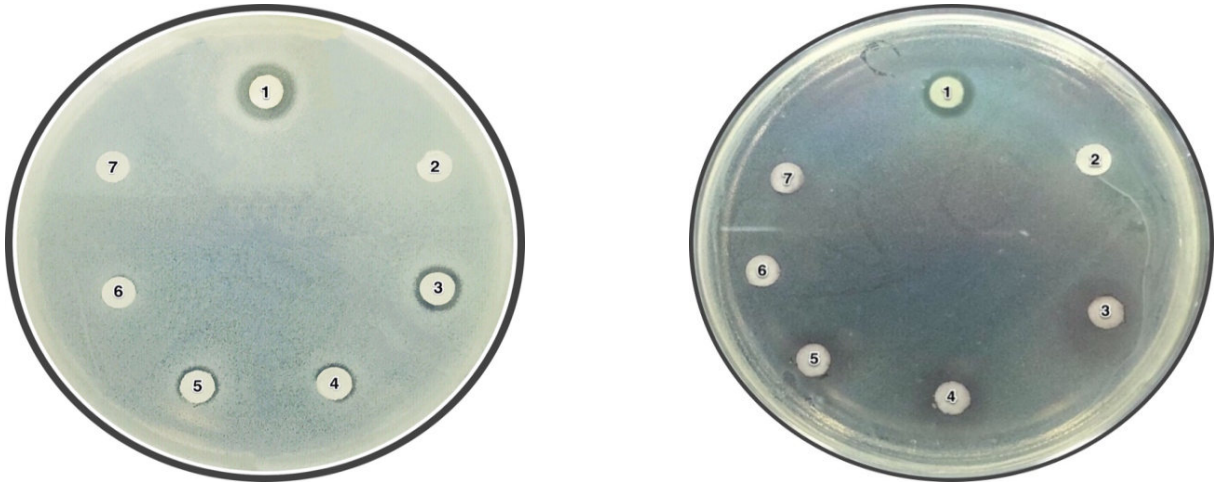

Figure 4. Results of antimicrobial activity of AgNPs and AuNPs against *Agrobacterium tumefacien*. **A (AgNPs)**: 1. Ampicillin (0.03µg), 2. LB medium, 3. BR AgNPs solution (0.54µg), 4. BR AgNPs solution (0.43µg), 5. BR AgNPs solution (0.32µg), 6. BR AgNPs solution (0.22µg), 7. BR AgNPs solution (0.11µg). **B (AuNPs)**: 1. Ampicillin (0.03µg), 2. LB medium, 3. BR AuNPs solution (11.82µg), 4. BR AuNPs solution (7.88µg), 5. BR AuNPs solution (5.91µg), 6. BR AuNPs solution (3.94µg) and 7. BR AuNPs solution (1.97µg).

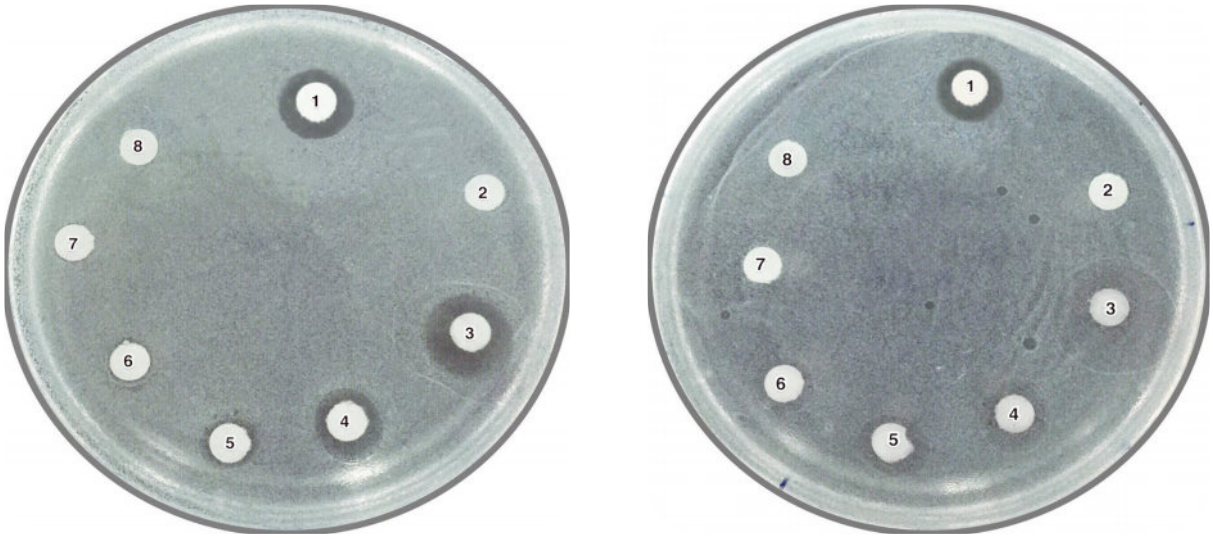

Figure 5. Results of antimicrobial activity of AgNPs and AuNPs against *Escherichia coli.* **A(AgNPs)**: 1. Ampicillin (2.00µg), 2. LB medium, 3. BR AgNPs solution (4.32µg), 4. BR AgNPs solution (2.16µg), 5. BR AgNPs solution (1.62µg), 6. BR AgNPs solution (1.08µg), 7. BR AgNPs solution (0.54µg), 8. BR AgNPs solution (0.32µg). **B (AuNPs)**: 1. Ampicillin (2.00µg), 2. LB medium, 3. BR AuNPs solution (7.88µg), 4. BR AuNPs solution (3.94µg), 5. BR AuNPs solution (2.95µg), 6. BR AuNPs solution (1.97µg), 7. BR AuNPs solution (0.98µg) and 8. BR AuNPs solution (0.59µg).

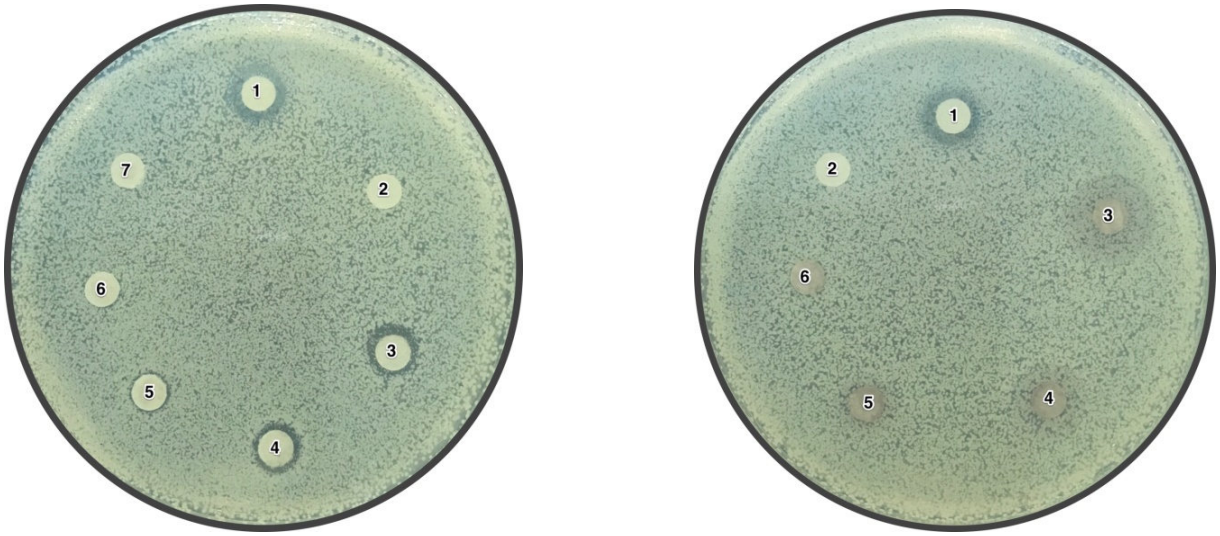

Figure 6. Results of antimicrobial activity of AgNPs and AuNPs against *Staphylococcus aureus*. **A (AgNPs)**: 1. Ampicillin (0.03µg), 2. LB medium, 3. BR AgNPs solution (1.08µg), 4. BR AgNPs solution (0.54µg), 5. BR AgNPs solution (0.32µg), 6. BR AgNPs solution (0.22µg) and 7. BR AgNPs solution (0.11µg). **B (AuNPs)**: 1. Ampicillin (0.03µg), 2. LB medium, 3. BR AuNPs solution (7.88µg), 4. BR AuNPs solution (5.91µg), 5. BR AuNPs solution (3.94µg), 6. BR AuNPs solution (1.97µg).

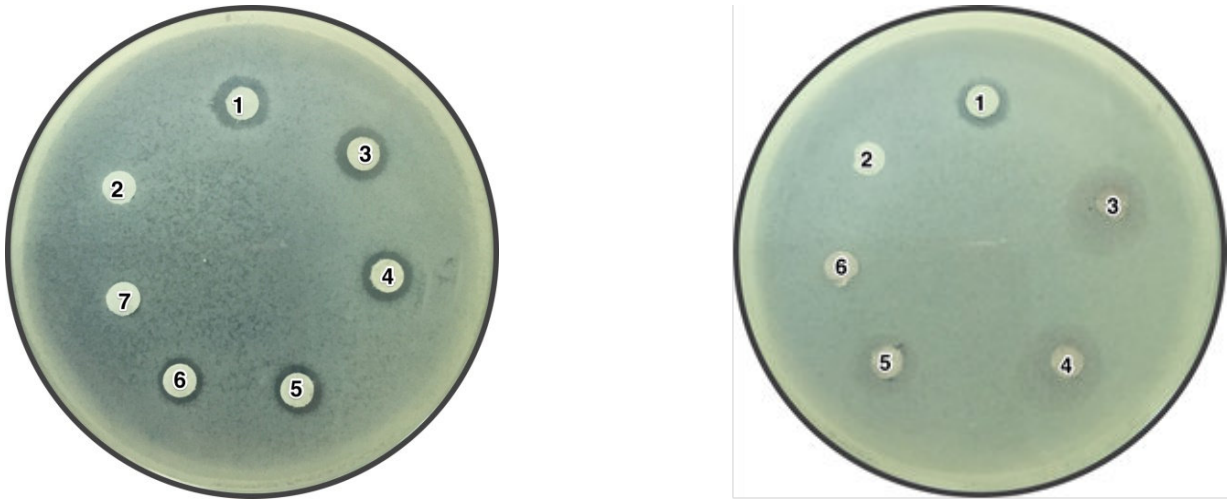

Figure 7. Results of antimicrobial activity of AgNPs and AuNPs against *Bacillus subtilis*. **A(AgNPs)**: 1. Ampicillin (3.00µg), 2. LB medium, 3. BR AgNPs solution (1.08µg), 4. BR AgNPs solution (0.54µg), 5. BR AgNPs solution (0.32µg), 6. BR AgNPs solution (0.21µg) and 7. BR AgNPs solution (0.11µg). **(B) AuNPs**: 1. Ampicillin (3.00µg), 2. LB medium, 3. BR AgNPs solution (1.08µg), 4. BR AgNPs solution (0.54µg), 5. BR AgNPs solution (0.32µg), 6. BR AgNPs solution (0.22µg) and 7. BR AgNPs solution (0.11µg).

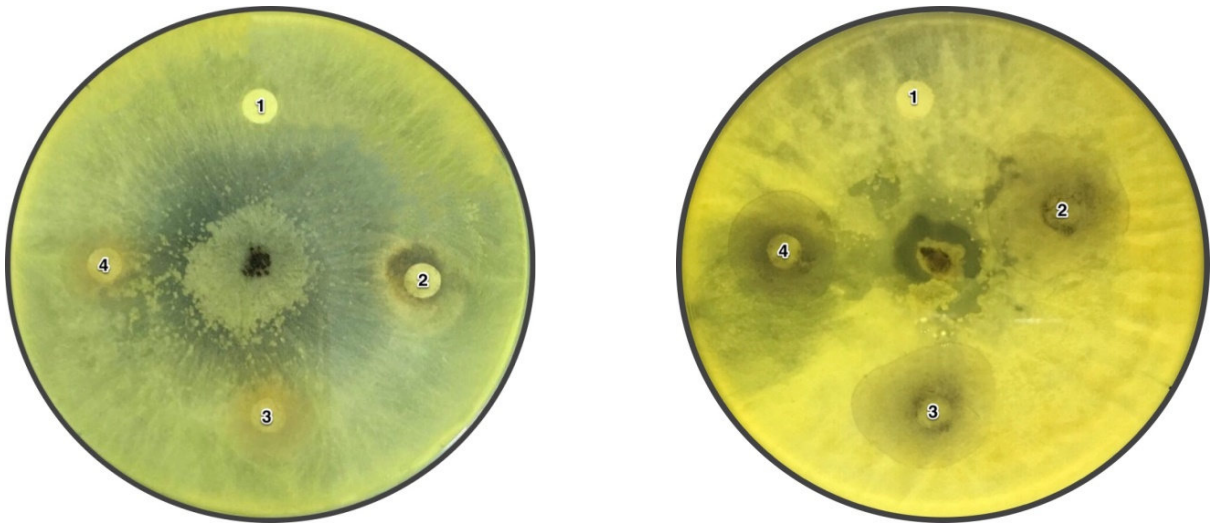

Figure 8. Results of antimicrobial activity of AgNPs and AuNPs against *Trichoderma harzianum*. **A (AgNPs)**: 1. Ampicillin: (100.00µg), 2. AgNPs solution (4.32µg), 3. AgNPs solution (3.24µg) and 4. AgNPs solution (2.16µg). **B (AuNPs)**: 1. Ampicillin (100.00µg), 2. AuNPs solution (29.55µg), 3. AuNPs solution (23.64µg) and 4. AuNPs solution (19.70µg)

CONCLUSION

We successfully synthesized AgNPs and AuNPs using BR extract, and our method is simple, effective, cost effective and eco-friendly. The BR extracts have shown highly potential reduction properties with the ability of protecting and stabilizing the nanoparticles in colloidal solution.

Although, AgNPs showed the strong anti-microorganism activity with *Agrobacterium tumefaciens, Escherichia coli, Staphylococcus aureus, Bacillus subtilis* and *Trichoderma harzianum* at MIC are 0.22 µg, 1.08µg, 0.32µg, 0.11µg, 2.16µg; respectively, AuNPs revealed no that activity for all those species.

Our study revealed that *Arctium lappa Lin* root's extracts could be further considered as a highly potential substance in the process to synthesize AgNPs or other nanoparticles with the strongly antimicrobial properties without causing the toxicity to the body.

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