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# Green Synthesis and Antibacterial Activity of Silver Nanoparticles: A Review

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## Abstract

*The purpose of this study was to determine the effect of silver nanoparticles (AgNPs) from different green synthesis medium and their various particle sizes on antibacterial activity. The article review method compares the results of 11 studies obtained from the PubMed database, Web of Science, and ScienceDirect indexed by Scopus in the last five years. The search was conducted based on the phrases nanoparticles, antibacterial, Green synthesis, and AgNPs. Green synthesis of AgNPs with various plant extracts produces different sizes of nanoparticles. The smallest size AgNPs were obtained in the range of 5-15 nm and an average of 13 nm extracted using the leaves of the Pacific Yew tree (Taxus brevifolia). Meanwhile, AgNPs with the best antibacterial effectiveness were obtained from the Blume flower extract (Wedelia urticifolia) measuring less than 30 nm providing a zone of inhibition for S. aureus, K. pneumoniae, E. coli, and P. aeruginosa bacteria.*

***Keywords**: Green synthesis; Silver nanoparticle; particle size; Antibacterial.*

## Introduction

At present, there have been many applications of nanoparticles in the world of science. In addition to their abundance, nanoparticles were chosen because they have various benefits (Al-Ansari et al., 2019). One of them is using silver nanoparticles (AgNPs) for antibacterial activity, which is made eco-friendly or known as green synthesis. AgNPs have great potential for the development of the world of science, especially in the biomedical field, because of their antibacterial activity (Hameed et al., 2019). Various methods have been designed to synthesize AgNPs, one of which is the Green synthesis which has the advantage of producing environmentally friendly products and does not leave organic waste (Aryan et al., 2021).

Recently, a new green method of synthesizing nanoparticles has been proposed by Phyto-nanotechnology. The method is environmentally friendly, stable, simple, fast, and cost-effective. Behind its slow kinetic process, green synthesis offers several advantages, namely growth control, stabilization and better work. This makes the method not require high temperatures and pressures like toxic chemicals(Sarli et al., 2020). Green synthesis is considered an effective way to reduce production costs, energy efficiency and reduce toxic chemicals (Aryan et al., 2021). Green synthesis can be done in various ways, one example is replacing harmful reagents with natural sources to obtain environmentally friendly nanomaterials. Extracts of soybeans, alfalfa sprouts, lemongrass, and green tea have been used in various nanoparticle synthesis (Boonupara & Kajitvichyanukul, 2020). In producing nanoparticles using plant extracts, the extract is mixed with a metal-salt solution at room temperature and the reaction lasts for several minutes (Behravan et al., 2019).

Nanostructures are particles, granules, functional structures, and devices whose dimensions are at least one dimension in the size of 1-100 nm. Distinctive properties of nanoparticles when compared to large-sized materials are their smaller size, wider surface area, and higher volume ratio. Based on these characteristics, the synthesis of nanoparticles is an essential process in nanotechnology research (Kato et al., 2020). Nanostructured metals have high attractiveness due to their wide application today. The primary purpose of utilizing nanoparticle dye degradation is to reduce toxicity to the environment. Metal-doped nanoparticles such as NiO, $TiO_2$, ZnO, ZnS, and titania are used to degrade dyes such as orange-II, reactive black, methyl orange and methylene blue (Joseph Kirubaharan et al., 2020).

Silver nanoparticles (AgNPs) have attracted attention due to their distinctive size, shape, and formation properties. These nanoparticles are widely used in pharmacology, biomedical equipment, textiles, water purification and cosmetics (Al-Ansari et al., 2019). The most crucial use of AgNPs in the medical industry is as a topical ointment to prevent infection in open wounds. In addition, the antibacterial effect of AgNPs depends on their size, the smaller the size, the greater the antibacterial effect (Sarli et al., 2020). Many methods are available for the synthesis of AgNPs, including physical, chemical, and biological synthesis. Biological synthesis has received good attention compared to the other two methods because of its low cost, simplicity, environmental friendliness, and efficient substitute for mass production of nanoparticles. AgNPs are synthesized using fungi, microbes, and plants (Al-Ansari et al., 2019).

Based on the research of Al-Ansari et al., (2019), the antibacterial activity of the synthesized AgNPs was analyzed by well diffusion method. Meanwhile, in analysis of Hameed et al., (2019), agar disk diffusion method was used to study the antibacterial activity of nanoparticles and heterostructures. In the mechanism of antibacterial activity, AgNPs can attach to the surface of the cell membrane of bacteria through interaction with sulfur-containing proteins. From these interactions, cell death can occur due to disruption of permeability and respiratory function in cells (Mane Gavade et al., 2015).

The purpose of this study was to determine the effect of silver nanoparticles (AgNPs) from several green syntheses and their various particle sizes on antibacterial activity using the review article method.

## Methodology

The method used in this study is through literature reviews (LRs). The literature review is done by comparing the results of several research articles. The research articles were obtained from the PubMed, Web of Science, and ScienceDirect databases, which Scopus indexed in the last six years. The search was conducted based on the phrase nanoparticles, antibacterial, green synthesis, and AgNPs. This research was conducted online for one month.

## Result and Discussion

Synthesis of nanoparticles (AgNPs) mediated from plant extracts is generally characterized by producing a color change from colorless to yellowish-brown, as shown in **Fig 1**. Analysis and identification of the morphology, structure, crystal form of the synthesized AgNPs can be carried out using an XRD, SEM, FESEM, HRTEM, TEM, AFM, EDS, DEX, UV-Vis and FTIR spectrophotometer. The antibacterial activity of nanoparticles (AgNPs) can be analyzed through various methods, including disc diffusion, well diffusion, utilization of liquid medium, and MIC (Minimum Inhibitory Concentration). An example of the comparison of the antibacterial activity of AgNPs of plant extracts can be seen in **Fig 2**.

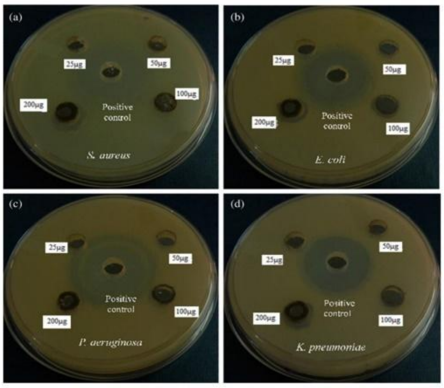


**Figure 1.** Changes in Color of Blue Flower Extract in Various Concentrations (Adapted from Rather et al., 2020).


**Figure 2.** Comparison of The Results of The Zone of Inhibition of AgNPs from Blume Flower Extract on *S. Aureus*, *E. Coli*, *P. Aeruginosa*, and *K. Pneumoniae* (Adapted from Rather et al., 2020).

The following are some studies that have been conducted on the synthesis of Ag nanoparticles (AgNPs): Research conducted by Al-Ansari et al., (2019), Ag nanoparticles (AgNPs) were synthesized using water extract from the leaves of *Lilium lancifolium* or what is known as the tiger lily plant. Fresh tiger lily leaves are sliced to 0.5-1 cm in size. A total of 10 g of simplicial was inoculated in 100 mL of boiling water for 10 minutes. The mixture was filtered, and the leaf extract (filtrate) was collected into an Erlenmeyer flask at room temperature. A total of 5 mL of *L. lancifolium* leaf extract was poured into 100 mL of 1 mM $AgNO_3$ solution and stirred for 3 hours at room temperature. The formation of AgNPs was characterized by a change in the color of the solution from colorless to brown. The results of the AgNPs synthesis were characterized based on morphological properties, particle structure, and optical properties, which were analyzed using UV-Vis and FTIR, XRD, AFM and TEM spectrophotometer, respectively.

Antibacterial activity of AgNPs was tested using the well diffusion method against gram-positive and gram-negative bacterial strains, including *B. subtilis*, *S. pneumoniae Pseudomonas aeruginosa*, and *E. coli*. Based on the results of research by Al-Ansari et al., (2019), the UV-Vis spectrum was obtained, which showed good absorbance at 411 nm. While the FTIR spectrum showed poor transmittance due to the color change of the synthesized AgNPs solution. XRD results show that AgNPs have a face-centered cubic (fcc) structure with high crystalline properties. The optical properties of AgNPs based on AFM and TEM images showed a particular shape and anisotropic shape with an average size of 45 nm. Antibacterial activity of AgNPs worked well against *B. subtilis*, *S. pneumoniae*, and *P. aeruginosa* bacteria at a concentration of 25 μL AgNPs. At this concentration, the antibacterial activity against *Escherichia coli* showed less than optimal results. Overall, the green synthesis AgNPs method is relatively easy, convenient, time-saving and environmentally friendly. In addition, the synthesized AgNPs can be applied to various fields such as surgical equipment, pharmaceutical products, polymer nanocomposites, adhesive technology, water purification and food packaging.

The synthesis of Ag nanoparticles (AgNPs) from the aqueous extract of the leaves and roots of *Berberis vulgaris* under the trade name barberry was carried out by Behravan et al., (2019). The steps include preparing leaves and roots into simplicia, making water extracts of leaves and roots, green synthesis of AgNPs, characterization, and testing of antibacterial activity. The leaves and roots of the barberry plant were washed using 2L distilled water followed by drying for two days at room temperature. The sample is sliced and put into a grinding machine to produce simplicial in powder form. A total of 10 g of leaf powder and root powder were put into a shaker containing

100 mL of distilled water separately. Shaking was carried out for two days at room temperature. The extract was filtered, and the filtrate was accommodated in a container and then stored at 4°C. Green synthesis (AgNPs) was carried out in various concentrations of $AgNO_3$, (0.5; 1; 3; 10 mM), extract water volume (3; 5; 10; 15; 30 mL), and synthesis time (1; 2; 6; 12; 24; hours). The synthesized AgNPs were characterized using XRD and TEM. The antibacterial activity test was carried out using the Disk Diffusion method and the MIC test against *E. coli* and *Staphylococcus aureus*. Based on the research, XRD results and TEM analysis showed that AgNPs had a spherical shape with a size of 30-7 nm. Bacterial activity test showed that AgNPs had antibacterial activity against *E. coli* and *Staphylococcus aureus*. Overall, the Green AgNPs synthesis method is clean, cost-effective, safe, and environmentally friendly.

Boonupara & Kajitvichyanukul, (2020) synthesized Ag/AgCl nanoparticles using garlic extract. Antibacterial activity of Ag/AgCl nanoparticles was tested using *E. coli* bacteria. The morphological properties, crystal shape and structure of the nanoparticles resulted from the synthesis were characterized by XRD, FTIR, TEM and SEM analysis. The results of several FTIR spectra of garlic extracts show its complex nature. In addition, the functional groups in the aqueous extract of garlic were also found in Ag/AgCl-G nanoparticles. Ag/AgCl nanoparticles were obtained in a spherical shape with an average diameter of about 250 nm and crystal size of about 17 nm. Ag/AgCl-G showed strong antibacterial activity against *E. coli* with a concentration of $25 \mu g.mL^{-1}$ nanoparticles Ag/AgCl-G showing 50% bacterial efficiency, 50 $\mu g.mL^{-1}$ nano particles Ag/AgCl-G showing 81.2 % efficiency of bacteria, and $100 \mu g.mL^{-1}$ nanoparticles Ag/AgCl-G showed 100% efficiency of bacteria. The antibacterial activity produced is thought to come from allicin and diallyl sulfide compounds. In its mechanism, the antibacterial activity can occur because Ag/AgCl nanoparticles can produce reactive oxygen species (ROS) such as hydroxyl radicals (OH*) and hydrogen peroxide ($H_2O_2$), which can damage lipid membranes and trigger damage to mitochondrial and DNA functions. The synthesis of nanoparticles provides an economical and efficient approach to microbial decontamination due to the simple manufacture of the synthesis.

The synthesis of Ag nanoparticles (AgNPs) was initiated by preparing the *Daucus carota* leaf extract, washed and cut into small pieces (Joseph Kirubaharan et al., 2020). Then 20gr of *D. carota* leaves in 100mL of deionized water were boiled at 80°C for 10 minutes, filtered, and the filtrate was *D. carota* extract. The next step is *D. carota* leaf extract is added to the $AgNO_3$ solution (1 mM) and stirred using a magnetic stirrer for 30 minutes to produce a color change from yellow to brown which indicates the formation of D-Ag nanoparticles. Morphological properties, crystal shape and structure of nanoparticles resulting from the synthesis were characterized by UV-vis spectrophotometer, TEM, XRD and FTIR analysis. Antibacterial activity of Ag nanoparticles (AgNPs) was analyzed with three different bacterial cultures, namely *Klebsiella pneumonia*, *Vibrio cholerae* and *E. coli* using the zone of inhibition method compared with ampicillin as a positive control. The structure of nanoparticles (AgNPs) was obtained in the form of a spherical shape and a triangle shape with an average diameter of 18-25nm and for a triangle shape it was 40-50nm. From the results, the antibacterial activity of D-AgNPs nanoparticles against *Klebsiella pneumonia* has an inhibition zone of 36 mm, *Vibrio cholera* has an inhibition zone of 44 mm and *E. coli* has an inhibition zone 18 mm. Nanoparticles synthesized with *D. carota* extract have good antibacterial activity, so they can be used for water disinfection. *D. carota* extract can be an environmentally friendly reducing agent for the synthesis of functional nanoparticles. In addition, nanoparticles based on plant extracts show the advantages of being cheap and environmentally friendly.


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Blume flower extract contains various biomolecules such as enzymes and secondary metabolites (alkaloids, tannins, flavonoids, steroids, terpenoids, and polyphenols). These compounds can act as reducing agents for metal ions, including Ag. Based on the XRD results, a sharp and strong spectrum is produced, indicating that AgNPs are in the form of a crystal lattice with a face centered cubic and spherical particles based on the TEM results with a particle size of less than 30 nm. The brown-colored solution proved the synthesis and presence of AgNPs. Antibacterial activity was tested using two types of gram-positive bacteria (*S. aureus* and *K. pneumoniae*) and two gram-negative bacteria (*E. coli* and *P. aeruginosa*). The results showed that at a concentration of 100 g, the inhibition zones for *S. aureus*, *K. pneumoniae*, *E. coli*, and *P. aeruginosa* bacteria were obtained, respectively, 10 nm, 11 nm, 9 nm, and 9 nm. While at a concentration of 200 g were obtained respectively 13 nm, 14 nm, 10 nm, and 12 nm (Rather et al., 2020). This potential antibacterial activity is thought to stem from the tendency of AgNPs to release silver ions. Because the silver ion has a reactive nature, it can damage proteins and nucleic acids from cell membranes, thus triggering DNA damage. From this study, it can be concluded that AgNPs from Blume flower extract showed bacterial activity but were not significant.

Mane Gavade et al., (2015) conducted a green synthesis of AgNPs using water extract of star fruit (*Averrhoa carambola*) and $AgNO_3$ solution as a source of Ag ions. Star fruit is used because it contains many biomolecules such as proteins, enzymes, polysaccharides, amino acids, and vitamins with antioxidant and antimicrobial activities. The presence of polysaccharides and ascorbic acid ($C_6H_8O_6$) in star fruit acts as a reducing agent in the synthesis of AgNPs. Based on XRD results, the crystalline structure of AgNPs was obtained as a face centered cubic with an average crystal size of 18 nm. Meanwhile, TEM analysis showed that most of the AgNPs particles have a spherical shape with a particle size range of 10 – 40 nm. Antibacterial activity testing was carried out on *E. coli* and *P. aeruginosa* using the agar well diffusion method with inhibition zone diameters of 14 nm and 6 nm for AgNPs concentration of 50 ppm, respectively. AgNPs stick to the surface of bacterial cell membranes and interact with sulfur-containing proteins, disrupting the function of permeability and cellular respiration, leading to cell death.

Sarli et al., (2020) reported that the leaves, stems, and bark of *Taxus brevifolia* tree are being prepared to determine the levels of Taxol in various parts of the tree. Silver nitrate ($AgNO_3$) as the main source of silver ions was studied. Traditional medicine Taxol was used as a standard solution for HPLC assay. Antibacterial activity of AgNPs was conducted by preparing *Staphylococcus aureus*, *E. coli*, and *P. aeruginosa* bacteria. Based on HPLC experiments, the leaf extract of *T. brevifolia* was only used to synthesize nanoparticles. The size and shape of the nanoparticles depend on different factors such as concentration of leaf extract, saline solution, pH, temperature and time. The obtained AgNPs were characterized by ultraviolet-visible spectroscopy (UV-vis), scanning electron microscopy (SEM), X-ray diffraction spectroscopy (XRD) and Fourier-transform infrared spectroscopy (FTIR). The results obtained that the average particle size of AgNPs is 13 nm and the particle range is 5-25 nm. Series solutions were prepared and then added to 96-well plates in seven different wells. Brain Heart Infusion (BHI) active bacterial suspension was added to each well. The positive control consisted of certain bacterial suspension and BHI solution. Meanwhile, the negative control consisted of BHI and the studied solution, namely extract, silver nitrate, and silver nanoparticles. After that, it was incubated at 37°C for 24 hours. The OD value is determined to test the turbidity of the well. The antibacterial activity test of *S. aureus* showed inhibition zones of 20 mm at 50mM, 18 mm at 25 mM, 16 mm at 12.5mM, 14 mm at 6.25 mM, 13 mm at 3.1 mM, and 12 mm at 1.5 mM. Meanwhile, *E. coli* and *P. aeruginosa* did not show any bacterial inhibitory activity.

The materials used in the synthesis of nanoparticles in the research of Umoren et al., (2017) is an aqueous solution of $AgNO_3$ and strawberry extract. Strawberry water extract with various concentrations was mixed with $AgNO_3$ in an Erlenmeyer flask. The mixture was then allowed to stand for 24 hours at room temperature. The characterization of the formed AgNPs was tested using UV-vis spectroscopy, SEM, EDS, XRD, TEM, and FTIR. AgNPs showed an SPR band at 450 nm based on the results of UV-vis spectroscopy. In addition, there was a color change from yellow to dark brown within 96 hours. Then, it was shown that AgNPs have a spherical shape with sizes in the 7-65 nm range through TEM results. The optical absorption peak of metallic silver nanoparticles can be seen at 3 keV through the EDS image. This proves the existence of AgNPs. Antibacterial activity testing was carried out in two methods, namely "cup and plating" or disc diffusion and the method using a liquid medium. The bacteria tested were *P. aeruginosa* and *Bacillus licheniformis*. AgNPs with a concentration of $4 \times 10^{-4}$ M gave the diameter of bacterial inhibition in *P. aeruginosa* and *B. licheniformis* of 3.0 mm and 4.5 mm, respectively. Meanwhile, at a lower concentration, namely $4 \times 10^{-5}$ M, the diameters of bacterial inhibition produced were 2.5 mm and 3.5 mm, respectively. Although AgNPs showed antibacterial activity, their activity level was lower than antibiotics, such as amoxicillin and ciprofloxacin. The resulting nanoparticles depend on the concentration of $AgNO_3$ and strawberry extract.

Based on the research of Aryan et al., (2021), silver nanoparticles were synthesized by stirring 5 ml of plant extract solution with 45 ml (1mM) of silver salt at 60 for 20 minutes. Antibacterial activity testing was carried out by disc diffusion method by going through the incubation process. Antibacterial activity of AgNPs was determined by measuring the diameter of the zone of inhibition. Through XRD results it can be seen that AgNPs have a crystalline structure. Then, based on the results of FESEM and HRTEM showed that AgNPs have a spherical shape. In addition, the presence of silver that dominates is also confirmed through EDX analysis. The distribution of AgNPs was determined through Zeta potential, where the average distribution of AgNPs in colloidal solution was 40.8 nm with -26.7 mV as the zeta potential value.

The *Kalanchoe pinnata* plant contains compounds such as flavonoids, polyphenols, alkaloids, and terpenoids and is well known as a source of antibacterial activity. Through the research, spherical *K. pinnata* AgNPs, which have a smaller size showed an increase in antibacterial activity. Among AgNPs, $AgNO_3$, and plant extracts, the largest zone of inhibition was obtained from AgNPs against gram-negative bacteria *E. coli*. Aryan et al., (2021) stated that size is one of the factors that strongly influences this. The smaller AgNPs' size, the wider bacterial inhibition zone. In addition, the penetration of the cell membrane also occurs due to electrostatic attraction between Ag+ and negative charge of the cell membrane. Penetration also causes changes in respiration and cell permeability. It can be concluded that *K. pinnata* provides better antibacterial activity than ordinary extracts.

In a study conducted Rajivgandhi et al., (2020) silver nanoparticles (AgNPs) were synthesized using *Morinda citrifolia* (*M. citrifolia*) extract, which is rich in flavonoids. The extract was prepared using HPLC and continued with the detection of the active fraction using GC-MS. Ag nanoparticles 420 nm were used in UV spectrometer, and surface morphology with available chemical composition, shape and size of AgNPs were confirmed by XRD, SEM with EDX and TEM. In addition, the phytochemical and antioxidant activity of AgNPs were confirmed by the total antioxidant and free radical DPPH assay. AgNPs synthesized against *Staphylococcus aureus* (*S. aureus*) biofilm formation were confirmed using MIC. In addition, bacterial viability, exopolysaccharide degradation, intracellular membrane damage, inhibition of mature biofilms, architectural damage and morphological changes were settled by CLSM and SEM. Finally, the synthesized AgNPs were reacted with methylene blue (MB) dye and underwent 100% degradation at an irradiation time of 140 min. Green synthesized AgNPs have excellent antioxidant, antibacterial results through intracellular membrane damage, cell cycle arrest and removal of methylene blue dye. *S. saprophyticus* is a dangerous MDR bacteria because it produces enterotoxigenic bacteria. *Saprophyticus* that contaminates food causes many problems. Our study proves that *S. saprophyticus* is more sensitive to AgNPs and it causes damage to intracellular membrane and cell wall damage. Therefore, the biosynthesized AgNPs are promising for photocatalysis and antibacterial agents through dye removal and cell cycle arrest of *S. saprophyticus*.

The research conducted by Hameed et al., (2019) aims to investigate the physical and biological properties of *Silybum marianum* using ZnONPs and Ag-ZnO hetero structures. His experiments characterized nanoparticles using ultraviolet-visible and infrared spectroscopy, x-ray diffraction, high-resolution electron microscopy, potential analysis and thermo-gravimetry. As a result, the annealing of ZnO–NPs at 500◦ C resulted in highly crystalline nanoparticles. Through Debye-Scherrer calculations, the average size of ZnO-NPs found 31.2 nm.

**Table 1**. Differences in Particle Size and Antibacterial Activity Results from Various Literatures

| No. | Journal Author | Media | Size | Activity |
|---|---|---|---|---|
| 1 | Al-Ansary et al., 2019 | Lilium lancifolium water extraxt | 10-70 nm; average of 45 nm | 25 μL antibacterial activity<br>50 μL biofilm inhibition |
| 2 | Behravan et al., 2019 | Water extract from the roots and leaves of Berberis vulgaris | 30-70 nm | |
| 3 | Boonupara & Kajitvichyanukul, 2020 | Garlic water extract | 250 nm (crystallin size 17 nm) | 25 μL efficiency 50,4<br>50 μL efficiency 81,2<br>More than 100 μL efficiency 100 |
| 4 | Kirubaharan et al., 2020 | Water extract from Daucus carota leaves | 18-25 nm (D-AgNPs)<br>Triangle shaped 40-50 nm | 1200 μg/mL efficiency 88,9% |
| 5 | Rather et al., 2020 | Water extract from Wedelia urticifolia flower | Less than 30 nm | 25 μg and 50 μg |
| 6 | Gavade et al., 2015 | Water extract from carambola fruit | 10-40 nm | |
| 7 | Sarli et al., 2020 | Water extract from the leaves, stems, bark of the taxus brevifolia tree | 5-25 nm; average of 13 nm | 1,5 mM |
| 8 | Umoren et al., 2017 | Water extract from strawberry fruit | 7-65 nm | $410^{-5}$ M (3-4,5mm) inhibition<br>$410^{-7}$ M (2,5-2,5mm) inhibition |


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| 9 | Aryan et al.,2021 | Water extract from the leaves of Kalanchoe pinnata (Bryophyllum pinnatum) | 10-50 nm | 7,88mm Inhibition zone leaf extract<br>11,90mm AgNPs inhibition zone |
| 10 | Rajivgandhi et al., 2020 | Methanol extract from M. citrifolia leaves | 10-100 nm (diameter average size of 35 nm) | 50 µg/mL gave the highest MIC (antibacterial) with a percentage of inhibition of 94% |
| 11 | Hameed et al., 2019 | Water extract from the plant Silybum marianum | Average of 35.3 nm | 150 µg/mL |

Both nanomaterials (ZnO and Ag-ZnO) showed a dose-dependent antimicrobial response. Ag–ZnO–NPs showed slightly higher antimicrobial potential than ZnO–NPs. Both samples were effective in eliminating Leishmania effectively at higher doses. In terms of antibacterial activity, ZnO-NPs were more effective against *B. subtilis* than *P. aeruginosa*. However, different results were obtained from the Ag-ZnO heterostructure where it had greater effectiveness against *P. aeruginosa* than *B. subtilis*. Good antileishmanial properties were obtained (IC50 = 246 g/ml for Ag–ZnO; 341 g/ml for ZnO) and there was an antioxidant potential of enzyme inhibition which was effective against pathogenic fungi and bacterial strains. So, the nanoparticles produced by green synthesis show interesting biological properties and are good for further application.

The differences in particle size and antibacterial activity results from various literatures are shown in **Table 1**. Based on the results of all journals, research from *T. brevifolia* extract showed the smallest size AgNPs, namely at an average size of 13 nm. Particle size is one of the factors that can affect antibacterial activity. The smaller the particle size, the larger the bacterial cells reached by AgNPs and the wider the inhibition zone. Meanwhile, in the study AgNPs from flower *W. urticifolia* extract showed the best antibacterial activity. This is evidenced by testing using two types of bacteria, namely gram-positive bacteria (*S. aureus* and *K. pneumoniae*) and gram-negative bacteria (*E. coli* and *P. aeruginosa*). Where these AgNPs have a zone of inhibition against more bacteria than other types of AgNPs.

## Conclusions

Overall, several green syntheses were carried out by several researchers on the effect of silver nanoparticles (AgNPs) on particle size and antibacterial activity. The best results were obtained with the smallest particle size in the range of 5-25 nm and an average of 13 nm from the leaf extract of the Pacific Yew tree (*T. brevifolia*). Meanwhile, the best antibacterial effectiveness was obtained from the Blume flower extract (*W. urticifolia*) with a particle size of less than 30 nm. The results showed that there were zones of inhibition against *S. aureus*, *K. pneumoniae*, *E. coli*, and *P. aeruginosa* bacteria from AgNPs from the Blume flower extract.

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