Green synthesis of silver nanoparticles using leaf and stem bark extract of *Pometia pinnata* J.R. Forst & G. Forst

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Abstract. *Pometia pinnata* (Matoa) is widely known for its use in traditional medicines and as fruit sources in Indonesia. Stem bark and leaves of Matoa are the most used parts. Each part contains secondary metabolites, including flavonoids, tannins, triterpenoids, glycosides, and saponins. These compounds could act as reducing agents in the biosynthesis of silver nanoparticles. Our research attempts to compare the efficacy of aqueous extracts of Matoa leaf and stem bark in the biosynthesis of silver nanoparticles. We characterized products of silver nanoparticles using UV-Vis spectrophotometer, transmission electron microscope, and particle size analyzer to compare the biosynthesis between the two parts based on ratios of various concentrations of plant extract to silver nitrate (AgNO₃). We found that the solution (extract and AgNO₃) became darker as the concentration and reaction time increased. Increasing reaction time also caused an increase in absorption peak intensity due to the reduction process of silver ions. The use of leaf and stem bark for biosynthesis resulted in different shapes and sizes of silver nanoparticles; the use of leaves and stem bark resulted in sphere-shaped silver nanoparticles, whereas the use of aqueous leaf extracts triangle-shaped silver nanoparticles formed.

Keywords: Biosynthesis, leaves, *Pometia pinnata*, stem bark, silver nanoparticles

1. Introduction

As the applications of nanoparticles proliferate in many aspects, the process for the synthesis of nanoparticles begins to gain the spotlight due to the associated environmental impacts. Synthesizing nanoparticles with plant extracts (biosynthesis) is preferable despite to using chemical synthesis because the chemicals produce by-products that are highly reactive and harmful to the environment. Therefore, new methods for biosynthesizing nanoparticles from plants show promise in being more environmentally friendly and cost-effective [1, 2].

*Pometia pinnata* (Matoa) could potentially be used as a reducing agent in the biosynthesis of silver nanoparticles. Matoa is endemic to Southeast Asia, including Indonesia [3] and has a history of use in medical applications [4] because the leaves and bark contain flavonoids, tannins, triterpenoids, glycosides, and saponins. This plant is adapted to warm, hot, and humid environments, which is very
common in tropical regions. The plant can also survive in slightly acidic environments and in partial or full shade. In our study, we compared the use of *P. pinnata* leaves and stem bark as reducing agents in the biosynthesis of silver nanoparticles.

2. Materials and method

2.1. Extract from leaves and stem barks of *P. pinnata*

We washed and dried *P. pinnata* in an oven at 40 °C to eliminate its water content until it reached a constant weight. We then ground each plant tissue (leaves and bark) separately into a powder. We used the powder to make an aqueous extract: one for leaves and one for bark.

The extract solution was prepared by mixing the *P. pinnata* powder with double-distilled water to a 2% concentration. The solution was boiled for 15 minutes along with stirring using a magnetic stirrer. The solution was stirred as it cooled until it reached 40 °C. The aqueous solution was then filtered through a Whatman No.1 filter paper to remove dirt and debris. Filtered extracts were then stored in a refrigerator for 2 weeks.

2.2. Biosynthesis of silver nanoparticles

A precursor solution was prepared from 1 mM AgNO₃ (Merck). The AgNO₃ solution was mixed with plant extract at concentration of 1:20; 1:10; 1:5 and 1:2 (extract to AgNO₃, v/v) for the biosynthesis process. The samples were then incubated for 24 h, during which the darkening of the solution and UV–Vis absorption spectra were recorded every hour. The temperature and pH of the solutions were not modified. The size and shape were examined with a transmission electron microscope (TEM) (FEI Tecnai G2 SuperTwin) and a particles size analyzer (Malvern Zetasizer Nano series), obtained from Nanotechnology Laboratory, Balit Pasca Panen, Cimanggu, Bogor, to complement the UV–visible absorption spectral analysis.

3. Results and discussion

3.1. Characterization of UV–visible absorption spectra

UV–visible spectral observations performed at each concentration and reaction period at 1 h intervals revealed that the all absorptions peaked between 350–500 nm, which exhibits the characteristics of silver nanoparticles [5]. The absorption peak of the leaf extract solution was higher at higher concentrations of plant extract (figure 1). The optimum absorption peak for the 1:2 (extract: AgNO₃) solution ratio occurred at 24 h, but then declined slightly thereafter. A similar trend occurred with the bark extract, except that the absorbance continued increasing after an incubation of 24 h. In addition, the reaction time for the formation of silver nanoparticles using the bark extract solution tended to be slower; most changes only occurred after about 24 h. Reaction time is one factor affecting reactions in the biosynthesis of nanoparticles [6].

Properties of the new silver nanoparticles were observed after 1 hour, depicted by the peak in the absorption curves using stem bark extract (figure 2a) and leaf extract (figure 2b). At time 24 h, it appears that the 1:2 solution had the highest absorbance values, observed as a darkening of color (figure 2) using both. Meanwhile, spectrum absorption from AgNPs reaction with 1:5, 1:10, and 1:20 ratios were progressively lower. These results suggest that reaction between the leaf extract and silver ion precursor happened faster and provides more nanoparticles (figure 2b). Undetectable redshifts existed at the absorption peak, which means that there was no magnification in the size of the silver nanoparticles. Small peaks were detected in the reaction for the leaf extract at approximately 670 nm wavelength (figure 2b). This is possibly a response to other elements in the sample. Other researches have also discovered that concentration ratios influence nanoparticle biosynthesis [6].
Figure 1. Spectrum absorbance of *Pometia pinnata* extract at a 1:2 ratio [extract to silver nitrate (AgNO₃) solution, v/v] over a 15-min to 48-h reaction period: (a) for leaf extract and (b) for stem bark extract.

Figure 2. Spectrum absorbance of silver nanoparticles and solution darkening that occurred during the synthesis of nanoparticles in solution after a 24-hour reaction time: (a) stem bark extract and (b) leaf extract.

Spectrum absorption at wavelength around 672 is known to be the characteristic of triangular nanoparticles, while the wavelength of 400–480 nm is known to be the character of nanoparticles with spherical shapes. The absorbance value at wavelength 672 is lower than the absorbance value between 400–500 nm. This indicates that silver nanoparticles with a spherical shape tend to be dominant than triangular silver nanoparticles. Triangular silver nanoparticles are formed over time [7].
Figure 3. Transmission electron microscope images of nanoparticle biosynthesis using Pometia pinnata extracts: (a) from leaf and (b) from stem bark. Biosynthesis using leaf extract results in triangular-shaped nanoparticles.

Table 1. Polydispersity index (PDI) and zeta potential from AgNPs synthesized using leaf extract and stem bark extract of Pometia pinnata.

| Plant part   | Ratio | PDI   | Zeta potential (mV) |
|--------------|-------|-------|---------------------|
| Leaves       | 1:2   | 0.740 | −10.9               |
|              | 1:10  | 0.890 | −19.7               |
| Stem bark    | 1:2   | 0.109 | −17.5               |
|              | 1:10  | 0.230 | −16.2               |

3.2. Size distribution and TEM imaging
The diameter of silver nanoparticles in P. pinnata leaf extract was around 50 nm (figure 3). However, based on the distribution of volume data, the resulting nanoparticles varied in size from 10 to 200 nm. Moreover, around 20 nm diameter nanoparticles were produced (20 %) than particles of other diameters (approximately 6 %) based on PSA result. As the volume of nanoparticles declined, their diameters increased. Interestingly, our results showed that there are triangular nanoparticles were produced during the process. This suggests that perhaps P. pinnata leaf extract had potential to behave as a particle-shape controller in the biosynthesis process.

The silver nanoparticles biosynthesized from leave and stem bark extract had a zeta potential value between (10–19) mV (table 1), suggesting that the particles are relatively stable [8]. This result means that the nanoparticles will retain their size during biosynthesis. Lower potential values would indicate that the particles are less stable, which is common for in resulting large particles [9], where the particles tend to aggregate. This also suggests that difficulties may arise in biosynthesizing particles using stem bark extract if the resulting particles are small and slower in reduction time, which is need more modification to maintain the size using certain stabilizing agent.

4. Conclusion
Silver nanoparticles can be biosynthesized using aqueous extracts of leaf and stem bark of P. pinnata. These two plant part vary in how they affect the shape, size, distribution, and stability of the produced nanoparticles. Biosynthesis using stem bark extract tends to produce larger nanoparticles. Nanoparticles size can potentially be regulated using P. pinnata leaf extract. Although the resulting nanoparticles using leaf extract are relatively stable, smaller silver nanoparticles are produced.
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