**Bio-Friendly Synthesis Of Silver Nanoparticles Using Mangrove *Rhizophora Stylosa* Leaf Aqueous Extract And Its Antibacterial And Antioxidant Activity**

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**Abstract**

Plant mediated biosynthesis of nanoparticles is going important dueto simple process and non-toxic materials utilization. Rhizophora stylosa  (RS) mangrove leaf extract was successfully used as a bioreductor in the production of AgNPs. The absorption spectrum in the range between 439-453nm confirmed that AgNPs have been succesfully synthesized. FT-IR absorption band shows the possible biomolecules of *Rhizophora stylosa* responsible for the synthesis of silver nanoparticles were amine, alcohol, phenol, alkyl halide, and aromatic combinations groups. The XRD pattern regulates that the synthesized AgNPswas in a face centered cubic (FCC) crystal structure with an average size of 25 nm. TEM images revealed that the synthesized AgNPs have spherical shape with a size range between 9 to 57 nm. The average size of nanoparticles was 30 nm. The solution of stable silver nanoparticle colloid from 1 until 3-month incubation. AgNPs have good antibacterial and antioxidant activity compared to pure plant extract AgNPs mediated with extract.

**Keywords:** Silver nanoparticles, *Rhizophora stylosa*, antibacterial, green synthesis

**Introduction**

Nanotechnology is one of the most important parts in the synthesis of nanoparticles (NP) with dimensions of 1-100 nm. The atoms of nanoparticles are more concentrated on surface than those of microparticles, which increases their functional ability (P. Singh et al., 2015). They have excellent properties such as large surface area, structural properties, and long shelf life, nano material properties have the potential for disease diagnosis.Plant mediated synthesis called biosynthesis provides more effective technique than physical and chemical methods. The main advantages of biosynthesis are not using toxic chemicals, temperature, energy, and high pressure during nanoparticles synthesis(Chandhru et al., 2019). Biological methods as a safe, clean, and environmentally friendly synthesis can be established for large-scale production(Gnanadesigan et al., 2012). Silver nanoparticles exhibit very high potential in biological applications, especially as antibacterial and antioxidant agent(Mcgillicuddy et al., 2017; Rauwel et al., 2015).

The current use of antibiotics results in antibiotic resistance for human pathogenic bacteria. Nanoparticles currently used as antibiotics have potential to overcome the problem of bacterial resistance. AgNPS has attracted many researcher’s concern in the field of biomedical applications, especially antimicrobial against gram-positive and gram-negative bacteria(Franci et al., 2015).In this study, *Escherichia coli and Staphylococcus aureus*were used to test the antibacterial activity of plant mediated synthesized AgNPs.

Mangrove plants as traditional medicinal plants(Bandaranayake, 1998) have been widely used by coastal communities. Rhizophora genus has been used traditionally as a source of dyes and medicines, especially bark (Takara et al., 2008).It also has been investigated as antibacterial and antioxidant activity due to the content of two flavon-3-ol glycosides, glabraoside A, glabraoside B, and seven flavanol derivatives, mainly catechin, and epicatechin. This mangrove Rhizophora stylosa(RS) can be found along the coast of Riau Archipelago, Indonesia. Leaf extracts of mangrove plants act as capping and reducing agents as well, which are responsible for crystal growth, hence determine the nature of silver nanoparticles (Bhuvaneswari et al., 2016).There are very few mangrove species investigated for antimicrobial and antioxidant compounds and need to be explored further (Nilesh Lakshman Dahibhate, Ankush Ashok Saddhe, 2018).

It is recommended to use a renewable source of mangrove plants from natural products combined with AgNPs as an antibacterial and antioxidant agent. In this study, the secondary metabolic components in mangrove extract such as flavonoids are expected to reduce Ag+ to Ag0 and act as a capping agent at once to stabilize it. Hence, any additional reducing agent was not necessary.This study aims to determine the ability of mangrove  RSleaf extractin synthesizing and determining the characteristics of silver nanoparticles such as particle size, crystal structure, and stability. The parameters in this study such as the concentration of the precursor and the amount of extract were variated. Besides, the inhibitory effect of bioactive compounds derived from mangroves required further investigation as an antimicrobial agent against bacterial infections andtheir antioxidant activity. This is a first and novel report on biosynthesis silver nanoparticles synthesis using aqueous leaf extract of RS as reducing agent.

**Materials and Methods**

**Collection of plant material**

Leaves of RS mangrove were collected from mangrove forest Tanjungpinang, Indonesia. Firstly, the leaves were washed thoroughly with running tap water to remove adhering salt, epiphytes, animal castings, attached debris, and sand particles. The clean leaves were then shade dried for 15 days and turned intofine powder. RS leaf were identified in Laboratory of the marine science department, Faculty of marine science of fisheries Maritim Raja Ali Haji University Tanjungpinang with a specified number of 0101/2018.

**Preparation of the Mangrove Aqueous Extract and Biosynthesis of silver nanoparticles**

The dried fine powder of RS was extracted using deionized water. 10 grams of dried powder was soaked in 100 ml of deionized water, heated for 1 hour at 65oC and then filtered using Whatmann paper No. 1. The extract was placed in a sealed bottle at temperature of 4oC for further use. Preparation of AgNP nanoparticles using RS leaf extract was conducted based onapproved procedures by Priyabtra et al 2016 (Priyabrata Thatoi, Rout George Kerry, shusanto gouda and Patra, 2016; R. bhuvaneswari, R.John Xavier, 2016). The concentrationof silver nitrate was variated by 1, 5 and 10 mM, in order to. The objective of using 3 concentration of AgNO3 was to optimize the metal concentration which would be most productive optimum for the smallestsize of AgNPs. In this study, several different amount of leaf extract (1, 2, and 3%) were used to investigate the effect of plant extract amount on the properties of AgNPs. In addition, the relation between reaction time and stability of silver nanoparticles was also studied. Silver solution was added to different amount of mangrove leaf extracts. The reaction mixture was incubated at room temperature up to 3 months and the absorbance of the sample were monitored rhytmically using UV-Vis spectrofotometer. During the mixing process, the colour change of the sample were observed.

**Phytochemical activity**

Qualitative phytochemical analysis of RS leaf extract was carried out using the methodology described by Parekh and Chanda (Vaghasia et al., 2011) by testing the alkaloid, flavonoid, phenolic, triterpene, saponin, and tannin components. The results of this test are stated qualitatively as positive (+) or negative (-) which are described in tabular form.

**The Characterization of Silver Nanoparticles**

Colloidal AgNPs (1 ml sample diluted in 10 ml deionized water) was monitored using UV-VIS Spectrophotometer (Shimadzu 1800) in wavelength range between 200-800 nm after reaction time of 0, 30, 60,120,180,240, 300,and 360 minutes. The absorbance of the samples was then continueously measured up to incubation time of 3 month. To obtain powder for further analysis, colloidal silver nanoparticles was prepared by increasing the concentration of all reagents up to 10 times. The precipitated AgNPs was separated by the supernatant, then was washed with distilled water and dried in oven in temperature of 110oC to obtain dry powder. The concentration of colloidal silver nanoparticles was increased 10 times. The dry powder of the nanoparticles were suspended in deionized water and dried in oven at 80oC over night. X ray difraction (philips X-pert powder PAN Analytical) analysis was conducted to investigate the crystallinity of the prepared AgNPs. The crystalline size was calculated using the Scherrers formula (D = K λ/ βcos θ). The morphology, size ditribution, and shape of AgNPs were determined using TEM (JEOL JEM 1400). Fourier Transform Infra Red Spectroscopy (FT-IR, Perkin-Elmer) was used to examine the functional group contained in the bioactive compounds of RS leaf extract which could be responsible in the formation of nanoparticles. PSA and Zeta potensial (Horiba SZ-100) were used to determine the size distribution and colloidal stability of as-synthesized AgNPs.

**Antibacterial Activity**

The agar well diffusion method against gram-positive and gram-negative test bacteria was carried out for the evaluation of the RS-AgNPs antibacterial activity (Venkatesan et al., 2016) Antibacterial activity tests was carried out againts *Staphylococcus aureus* (S. aureus) and *Escherichia coli* (E. coli) bacteria with positive control of amoxicillin. This methodology refer to (Labanni et al., 2019). Some of 2 grams of nutrient agar (merck) boiling in 100 mL aquadest, homogeneous media is sterilized at 121oC in 15 minutes. Both bacteria were grown in NA and allowed for 24 h. Sterile cotton with RS-AgNPs sample (various concentration) were placed on well. All the media were incubated for 18-24 hours at 37°C to measure the inhibition zone (mm). The test was conducted in duplicate.

**Antioxidant Activity**

Antioxidant activity of the sample was characterized determinedusing 1,1-diphenyl-2-picrylhy-drazyl hydrate (DPPH, Merck). Silver nanoparticles were screened for DPPH free radical scavenging activity method as described by Patil et al., with minor modification. Briefly, 3.8 ml of 30 µg/mL DPPH was mixed with 0.2 mL different concentrations of 30-70 µg/ml of silver nanoparticles then was incubated in dark for 30 minutes. The absorbance of the samples was determined by Spectrofotometer UV-Vix at 517 nm. DPPH in methanol without sample was used as control and Vitamin C was used as standard. The antioxidant activity theleaf extract was also tested as control. All measurements were repeated in triplicates. Antioxidant activity was estimated by calculating the percentage of free radical scavenging by the following formula:

DPPH radical scavenging effect (%) = x 100

The IC50 value was defined as the minimum antioxidant required to scavenge 50% of the DPPH free radicals.

**Result and Discussion**

**Phytochemical analysis of Rhizophora stylosa leaf extracts**

The leaf extract of RS was simply extracted using double-distilled water which showed a positive test result for the content of some bioactive compounds. The result of phytochemicals analysis (Table 1) suggests the presence of steroid, triterpenoid, flavonoid, and polyphenol in the RS leaf extract. These secondary metabolite groups are expected to reduce Ag+ to Ag0. Similar active compound were also found in the species of *Rhizophora Lamarckii* (Kumar et al., 2017), *Avicenna marina*, and RS (Azizi et al., 2013). Furthermore, Gnanadesigan et al.reported *Rhizophora mucranata* leaf extract containing terpenoids which proved to have good potential activity in formingand stabilizing the nanoparticles (M Gnanadesigan et al., 2011).

**Table 1**: Phytochemical analysis of RS Leaf extracts

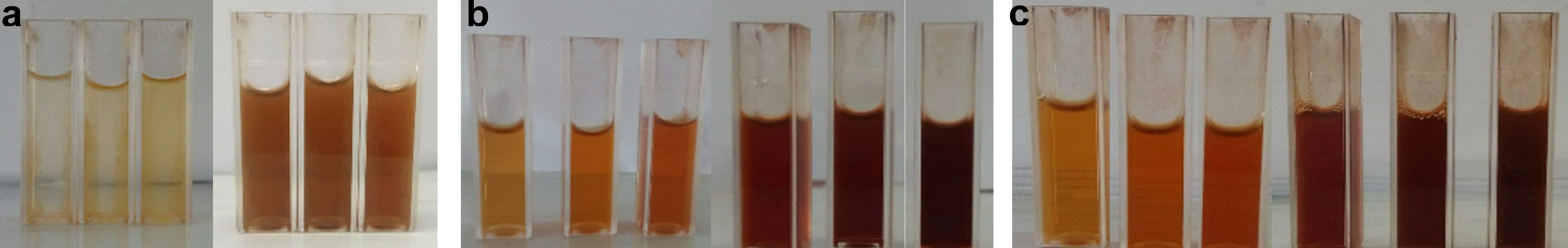
|  |  |
| --- | --- |
| Types of secondary metabolites | Aquabidestilat water |
| Alkaloid | - |
| Steroid | + |
| Triterpenoid | + |
| Flavonoid | + |
| Saponin | - |
| Polyphenol/ tannin | + |

+ : Present - : not present

Based on previous research, Li et al. have reported that 7 flavanol derivatives including epicateching and catechin, cinchonain 1b, 3.7-O-diacetyl(-) epicatechin, and 3-O-acetyl(-)-epicatechin were isolated from steam and twigs of the mangrove plant RS (Li et al., 2007).

**Biosynthesis of AgNPs**

A detailed characterization study on AgNPs extracellular biosynthesis using variations in the quantity of mangrove leaf extract was carried out. When mangrove leaf extract (with a concentration of 1,2, 3%) was allowed to react with a solution of silver nitrate (1, 5 and 10) mM with a total volume of 50 ml synthesis solution. Briefly the samples were coded as AgNPs-A-1-1, AgNPs-A-5-1, and AgNPs-A-10-1 which means silver nanoparticles with a precursor concentration of (1, 5 and 10) mM and extract concentration of 1%. After mixturing, the colorturned to pale yellow and dark brown which shows a gradual reduction of AgNO3 by leaf extract (Figure 1). The reaction mixture turns to yellowish brown color after 20 minutes. The color remained change up to 4 hours, which suggested that the reduction process had been completed. The reaction of AgNO3 mixture with 1 mM shows a yellowish color, while the 10 mM AgNO3 produces a dark brown color at the end of the reaction. This color change pattern is due to surface plasmon resonance excitation (SPR) in AgNPs (Kumar et al., 2017).

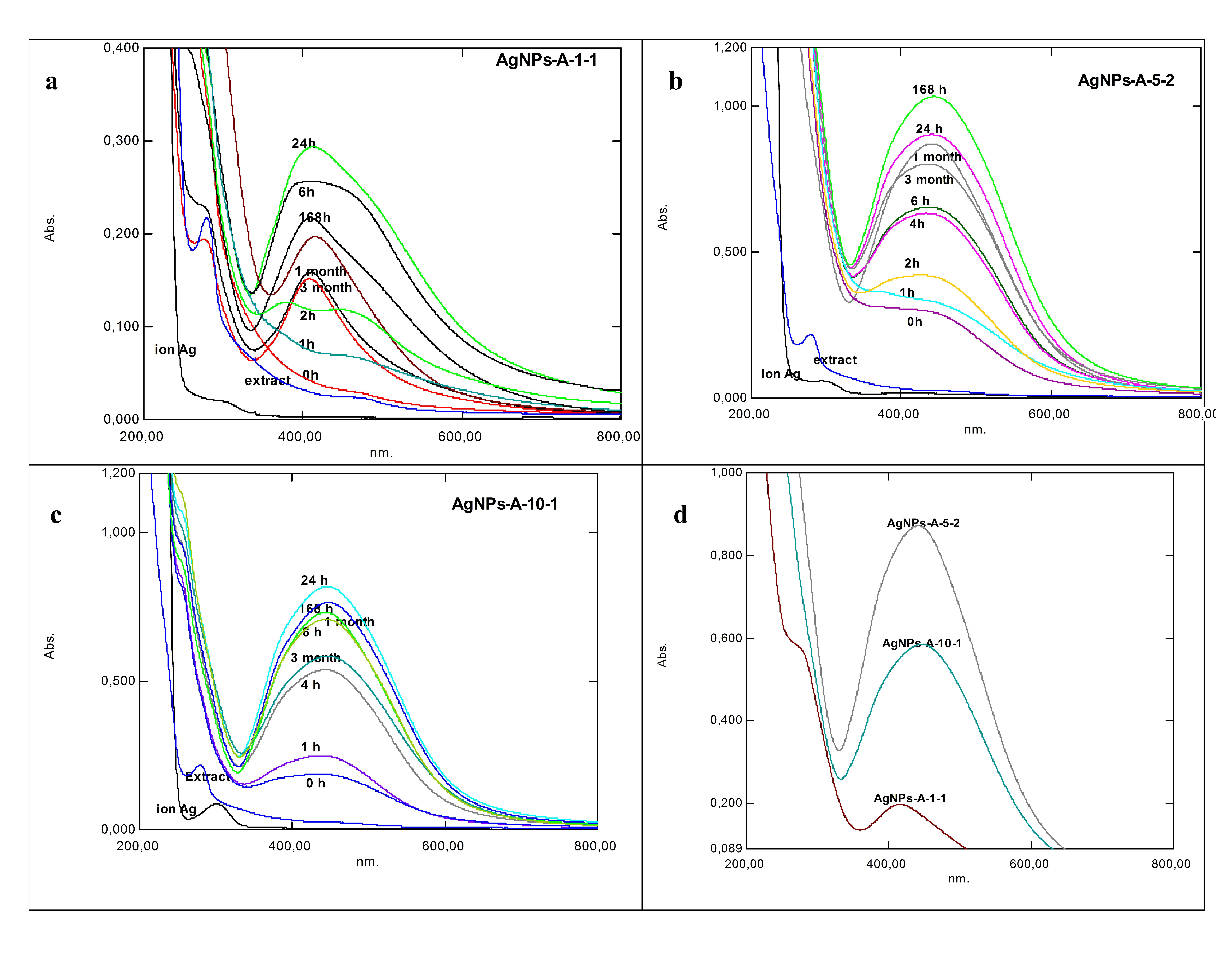
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**Fig. 1:** Photograph of the mixture of leaf extract (1,2,3)% and silver nitrat solution (1,5,10)mM over 6 hours periode,a: 1mM; b: 5mM; c: 10 mM (0-6) hours.

**UV-Vis Spectrum in the Formation of Silver Nanoparticles in various time**

Figure 2 shows the UV-Vis colloidal silver spectra, obtained at different leaf extract concentrations (1, 2, and 3%) v/v. UV Vis spectrophotometer analysis spectrum shows that the using of high concentration leaf extract resulted in sharper absorbance peak, which might be due to the higher number of biomolecules involved in the reduction reaction. The position of the peak of the plasmon depends on the size and shape of the particles (Schwegmann et al., 2010; P. Singh et al., 2015).

The maximum absorption peak for nanoparticles synthesized using precursor concentration of 1, 5, and 10 mM were in wavelength of 439, 448 and 453 nm, respectively. Figure 2 shows that as time increases, the absorption of the solution increases. Previous research also revealed that the absorbance in wavelength range of 420-450 nm were associated with AgNP with a size range varied between 2-100 nm (Rajeshkumar and Bharath, 2017). The reduction process was completed after 4 hours of incubation. Reduction of Ag+ ions to Ag0 was ariseddue to the role of mangrove extract as a reducing agent. Increased metal ion concentration induces an SPR band shift from 439 to 453 nm and simultaneous band expansion in the reaction medium. The spectrum showed a shift towards the redshift or blue shift depending on particle size, shape, state of aggregation and surrounding dielectric media (Schwegmann et al., 2010). The stability of silver nanoparticle colloids was observed up to 3 months. Nanoparticles with a concentration of 1 mM are more stable than the concentration of 10 mM. While the 5 mM concentration was stable at the addition of extracts of 2%. This happens because the higher the concentration, the faster the agglomeration occurs causing reduced nanoparticle uptake. Thus, UV-visible spectroscopy is a suitable method for the initial prediction of nanoparticle production.



**Fig. 2:** (a,b,c) UV–visible absorbance spectra of as-prepared AgNPs at (1, 5, and 10) mM with extract added and (d). stability of nanoparticles for 3 month.

**Fourier Transforms Infrared Spectroscopy (FTIR)**

This uptake of RS dry powder extract showed a typical uptake role of the hydroxyl (OH-) group with a broad and strong band at 3302.81 cm-1 referred to alcoholic, phenolic and flavonoid groups which act as capping agents on the surface of the nanoparticles. The FTIR spectra of RS dry powder showed a typical peak of hydroxyl (-OH) group with a broad and strong band at 3302.81 cm-1. This -OH groups might be referred to alcoholic, phenolic and flavonoid groups. The absorption of alcoholic CO groups is observed at 1051.21 cm-1. While the absorption bands of 808.08 cm-1 and 657.04 cm-1 showed that various phytochemicals were presented in leaf extract which acted as capping agents. The peak at 1051 cm-1 (CO stretch of the alcoholic group) in extract was shifted to a lower wavenumber of 1270.57 cm-1 (CN stretching band of the aromatic amine group) (Figure 3). It might be due to the reduction of silver ion to silver nanoparticles by carboxyl groups and amine groups as stabilizer on the surface of nanoparticles (M. Gnanadesigan et al., 2011)​. The shifting of wavenumber in leaf extract and AgNps suggested that there is an interaction between functional groups contained in biomolecules of leaf extract and silver kation due to the oxidation and reduction process of silver nanoparticles (Kumar et al., 2017). These biomolecules including enzymes, proteins, amino acids and polysaccharides, including the enzyme nitrate reductase which plays the most vital role in this process (Bakshi et al., 2015). This evidence suggests that biological molecules can be utilized in the formation and stabilization of colloidal silver nanoparticles in aqueous media.



**Fig. 3:** FTIR spectra extract of RS and RS-AgNPs

**XRD ( X-Ray Diffraction)**

The structural determination of RS-AgNPs was characterized using XRD analysis. The diffraction pattern is shown in Figure 4. The peaks observed at 2θ values of 38.27◦, 44.45◦, 64.56◦ and 77.53◦ are correspond to (1 1 1), (2 0 0), (2 2 0), and (3 1 1) planes face-centered cubic (FCC) structure of silver (Joint Committee on Powder Diffraction Standard (JCPDS) file: 04-0783). In addition, peak in 2θ of about 46.05 degree is observed which attributed to RS extract and confirmed the presence of stabilizing agent in AgNPs sample as reported by (Mallikarjuna et al., 2014). Similar observations are also reported by Ramayana et al that the extract plays a role in reducing, capping, and maintaining particle size (Ramanarayanan et al., 2019). The crystal size of the silver nanoparticles formed in the reaction was found to be 26-32 nm, based on Scherrer equation.



**Fig. 4:** XRD pattern of the RS-AgNPs synthesized, RS extract and Ag Standar.

**Transmission Electron Microscopy (TEM)**

|  |  |  |
| --- | --- | --- |
| D:\DESERTASI S3 NANCY OK\LAPORAN PENELITIAN  dan PROGRES REPORT\TEM\7. Nancy W Andalas\AgNPs 2\AgNPs_20190313_1341_33.bmp  **a.** | D:\DESERTASI S3 NANCY OK\LAPORAN PENELITIAN  dan PROGRES REPORT\TEM\7. Nancy W Andalas\AgNPs 2\AgNPs_20190313_1339_56.bmp  **b.** | **c.** |

**Fig. 5:** TEM image of silver nanoparticle 1 mM in two magnifications (a) 50nm (b) 20 nm (c) Histogram distribution particle size.

TEM images Figure 5 (a and b) reveal that the synthesized AgNPs have spherical shapewith a size range between 9 to 57 nm. The distribution size histogram shows that the particles most often are in the range of 29 nm and the average size of nanoparticles is 30 nm was calculated by “image J” software. The previous biosynthesis of AgNPs using mangrove plant have reported the average particles size 71-110 nm using Avicenna marina  (Gnanadesigan et al., 2012),  Exoecaria agallocha in range 23-42 nm (R. bhuvaneswari, R.John Xavier, 2016), and Rhizophora mucranata 4 to 26 nm (Umashankari et al., 2012). It has been found that protein, chlorophyll, and metabolites are present in plant material extracts which act as capping agents in AgNPs synthesis (Rajeshkumar and Bharath, 2017). Under careful observation, as seen in the Figure 5b. Anedge of the nanoparticle is brighter than the center of the nanoparticle.Silver nanoparticles are surrounded by a thin layer that shows that these particles are encapsulated by biomolecules such as proteins and other secondary metabolites in RS extract.

**Antibacterial Activity**

The use of medicinal plants such as gambir (Arief et al., 2015) and mangrove leaf (C. R. Singh et al., 2015)is an alternativebioreducing agent in synthesizing metal nanoparticles. The antibacterial activity of mangroves such as *Rhizophora Mucranata* (Umashankari et al., 2012), *Rhizophora Apiculata* (J.J Antony et al., 2011), *Rhizophora Lamarcki* (Kumar et al., 2017)have been reported. The colloid solution tested is colloidal which is stable for up to 1 month. The antibacterial activity was carried out using disc diffusion method against *S. aureus* and *E. coli* with amoxicillin as positive control and distilled water as negative control.

1 % 2% 1% 2% 1 % 2 %

AgNPs 1mM

AgNPs 5mM

AgNPs 10mM

Leaf Extract

Amoxillin

**Fig. 6:** Inhibition zone of RS-AgNPs

Figure 6 shows the result of antibacterial activity test of AgNps synthesized with precursor concentration of 1, 5, and 10 mM based on inhibition zone. All samples showed higher activity against *E. coli* than those against *S. aureus*. This might be due to the different thickness of the cell was of the bacteria, where gram negative bacteria has thinner cell wall than those of gram positive bacteria (Suganya et al., 2015; Zhou et al., 2012). The AgNps using of 5 and 10 mM concentration of precursor showed higher activity than AgNps prepared using 1 mM precursor concentration. Althought there was no significant difference between sample with 5 and 10 mM precursor concentration, these result showed that the concentration of precursor affects the antibacterial activity of AgNps. Under certain conditions, agglomeration with the amount of extract and certain silver concentrations affect antibacterial activity. However, the result showed that as-synthesized AgNps showed higher antibacterial activity than AgNps previously report by Mouafi et al. (2014), who synthesized AgNps using *Rhizoporastylosa* extracted using ethyl acetate. The antibacterial activity of AgNps might occurred due to the binding between nanoparticles microorganism membranes through electrostatic interactions, disruption of cell walls and influencing intracellular processes such as DNA, RNA, and synthesis of proteins. Based on these result, it can be concluded that AgNps have potential to be developed as antibacterial agent.

**Antioxidant Activity**

Table 1 shows the result of antioxidant activity test of AgNPs synthesized using precusor concentrarion of 1,5,10 mM with 1 mL extract, based on based on IC50 values. The percentage of inhibition was determined by comparing the absorbance of pure DPPH to the absorbance of tested AgNPs at a wavelength of 517 nm.The lower the value of IC50, the more toxic the nanoparticles.

**Table 2:** IC50 values of DPPH radical scavenging activity of RS-AgNPs synthesized

|  |  |
| --- | --- |
| Samples | IC50 DPPH (μg/ml) |
| AgNPs-A-1-2 | 50.62 0.46 |
| AgNPs-A-5-2 | 48.34 0.20 |
| AgNPs-A-10-2 | 44.09 0.39 |
| Leaf Extract | 53.77 0.60 |
| Ascorbic Acid | 23.67 0.39 |

Notes: Values are expressed as mean ± SD (n=3).

It is assumed that the DPPH radical cleaning activity of silver nanoparticle mediated by RS marine plants is related to the contain of hydroxyl group. Compounds that have adjacent hydroxyl groups on the B-ring have a higher activity as reported by (Li et al., 2007).than the antioxidant activity of new acetylated flavanol, 3,7-O-diacetyl (-) - epicatechin (3), and seven known flavanol derivatives 1, 2, 4–8 isolated from the stems and twigs of the *Rhizophora stylosa* mangrove plant and had been reported their. From the above data, it can be concluded that the main component responsible for the antioxidant activity of the RS extract is a flavanol derivative due to the content of phenolics, flavonoid and polysaccharides.

**Conclusion**

Green synthesis of AgNPs using an aqueousextract of Rhizophora stylosa has been successfully conducted where the extract acted as fast, reliable, and nontoxic stabilizer, reducing agent, and capping agent. The resulting AgNPs are stable for 3 months for 1mM and 5mM concentration. These nanoparticles have the potential to be used in biomedical applications.

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**Reference**

Antony, Jacob, J., Periyasamy, S., Durairaj, S., Soundararajan, K., Kumarasamy, A., Raman, S., Muthukalingan, K., and Shanmugam, A. 2011. Comparative Evaluation of Antibacterial Activity of Silver Nanoparticles Synthesized Using Rhizophora Apiculata and Glucose. *Colloids. Surfaces B: Biointerfaces,* 88:134–140.

Arief, S., Vivi, G., Diana, V., and Takayuki, B. 2015. Hydrothermal Synthesized Ag Nanoparticles Using Bioreductor of Gambier Leaf Extract ( Uncaria Gambier Roxb ). *J. Chem. Pharm. R.,* 7:189–192.

Azizi, Susan, Farideh, N., Mahnaz, M., Mansor, B. A., and Rosfarizan, M. 2013. “Biosynthesis of Silver Nanoparticles Using Brown Marine Macroalga, Sargassum Muticum Aqueous Extract. *Materials,* 6: 5942–50.

Bakshi, Madhurima, Somdeep Ghosh, and Punarbasu Chaudhuri. 2015. Green Synthesis, Characterization and Antimicrobial Potential of Sliver Nanoparticles Using Three Mangrove Plants from Indian Sundarban. *BioNanoScience*, 5: 162-170.

Bandaranayake, W. M. 1998. Traditional and Medicinal Uses of Mangroves. *Mangroves and Salt Marshes,* 2:133–148.

Bhuvaneswari, R., John, X., Arumuga, M. 2016. Facile Synthesis of Multifunctional Silver Nanoparticles Using Mangrove Plant Excoecaria Agallocha L . for Its Antibacterial , Antioxidant and Cytotoxic Effects. J. King Saud Univ. - Sci., 28: 318–323.

Chandhru, M., R. Logesh, S.Kutti Rani, Neesar Ahmed, and N. Vasimalai. 2019. One-Pot Green Route Synthesis of Silver Nanoparticles from Jack Fruit Seeds and Their Antibacterial Activities with Escherichia Coli and Salmonella Bacteria. *Biocatal. Agric. Biotechnol.,* 20:101241.

Chinnappan, Ravinder Singh, Kathiresan Kandasamy, and Anandhan Sekar. 2015. A Review on Marine Based Nanoparticles and Their Potential Applications. *African J. Biotechnol.,* 14:1525–1532.

Dahibhate, Nilesh Lakshman, Ankush Ashok Saddhe, and Kundan Kumar. 2018. Mangrove Plants as a Source of Bioactive Compounds: A Review. *The Natural Products J.* 9:86–97.

Franci, Gianluigi, Annarita, F., Stefania, G., Luciana, P., Mahendra, R., Giancarlo, M., and Massimiliano, G. 2015. Silver Nanoparticles as Potential Antibacterial Agents. *Molecules,* 20:8856–8874.

Gnanadesigan, M., M. Anand, S. Ravikumar, M. Maruthupandy, M. Syed Ali, V. Vijayakumar, and A. K. Kumaraguru. 2012. Antibacterial Potential of Biosynthesised Silver Nanoparticles Using Avicennia Marina Mangrove Plant. *Applied Nanosci.,* 2:143–47.

Gnanadesigan, M., M. Anand, S. Ravikumar, M. Maruthupandy, V. Vijayakumar, S. Selvam, M. Dhineshkumar, and A. K. Kumaraguru. 2011. Biosynthesis of Silver Nanoparticles by Using Mangrove Plant Extract and Their Potential Mosquito Larvicidal Property. *Asian Pac. J. Trop. Med.,* 4:799–803.

Kumar, Sekar, D., Ganesan, S., Singaravelu, A., Kadarkarai, M., Marcello, Nicoletti, and Giovanni Benelli. 2017. Mangrove-Mediated Green Synthesis of Silver Nanoparticles with High HIV-1 Reverse Transcriptase Inhibitory Potential. *J. Clust. Sci.,* 28:359–67.

Labanni, A., Zulhadjri, Z., Dian, H., Yutaka, O., and Syukri, A. 2019. The Effect of Monoethanolamine as Stabilizing Agent in Uncaria Gambir Roxb. Mediated Synthesis of Silver Nanoparticles and Its Antibacterial Activity. *J. Dispersion Sci. Technol.,* 0:1–8.

Li, Dong Li, Xiao Ming Li, Ze Yu Peng, and Bin Gui Wang. 2007. Flavanol Derivatives from Rhizophora Stylosa and Their DPPH Radical Scavenging Activity. *Molecules,* 12:1163–1169.

Mallikarjuna, K., N. John Sushma, G. Narasimha, L. Manoj, and B. Deva Prasad Raju. 2014. Phytochemical Fabrication and Characterization of Silver Nanoparticles by Using Pepper Leaf Broth. *Arabian J. Chem.*, 7:1099–1103.

McGillicuddy, E., I. Murray, S. Kavanagh, L. Morrison, A. Fogarty, M. Cormican, P. Dockery, M. Prendergast, N. Rowan, and D. Morris. 2017. Silver Nanoparticles in the Environment: Sources, Detection and Ecotoxicology. *Sci. Total Environ.,* 57: 231–246.

Priyabrata, T., Rout, G., Shusanto, G., Hrudayanath, and Jayanta, K. P. 2016. Photo-Mediated Green Synthesis of Silver and Zinc Oxide Nanoparticles Using Aqueous Extracts of Two Mangrove Plant Species, Heritiera Fomes and Sonneratia Apetala and Investigation of Their Biomedical Applications.  *J. Photochem. Photobio. B: Biology.*, 163**:** 311-318.

Rajeshkumar, S. and L. V. Bharath. 2017. Mechanism of Plant-Mediated Synthesis of Silver Nanoparticles – A Review on Biomolecules Involved, Characterisation and Antibacterial Activity. *Chemico-Biol. Interactions,* 27: 219–27.

Ramanarayanan, R., Niveditha, C., Nijisha, P., Bhabhina, N. M., and Sindhu, S. 2019. The Deterministic Role of Resonance Energy Transfer in the Performance of Bio-Inspired Colloidal Silver Nanoparticles Incorporated Dye Sensitized Solar Cells. *Materials R. Bulletin,* 11:28–36.

Rauwel, Protima, Siim, K., Stanislav, F., and Erwan, R. 2015. A Review on the Green Synthesis of Silver Nanoparticles and Their Morphologies Studied via TEM. *Advances in Materials Sci. Eng.,* 2:1–9.

Schwegmann, Heiko, Andrew J. Feitz, and Fritz H. Frimmel. 2010. Influence of the Zeta Potential on the Sorption and Toxicity of Iron Oxide Nanoparticles on S. Cerevisiae and E. Coli. *J. Colloid and Interface Sci.,* 347:43–48.

Singh, Priyanka, Yeon J. K., Hina, S., Ramya, M., Chao, W., and Deok, C. Y.. 2015. Biosynthesis of Anisotropic Silver Nanoparticles by Bhargavaea Indica and Their Synergistic Effect with Antibiotics against Pathogenic Microorganisms. *J. Nanomaterials,* 2:1–10.

Suganya, K. S.Uma, K. Govindaraju, V.Ganesh Kumar, T.Stalin Dhas, V. Karthick, G. Singaravelu, and M. Elanchezhiyan. 2015. Blue Green Alga Mediated Synthesis of Gold Nanoparticles and Its Antibacterial Ef Fi Cacy against Gram Positive Organisms. *Materials Sci. Eng. C.,* 47:351–356.

Umashankari, Jaganathan, Dhinakarasamy, I., Thipramalai T,. Ajithkumar, and Thangavel, B. 2012. Mangrove Plant, Rhizophora Mucronata (Lamk, 1804) Mediated One Pot Green Synthesis of Silver Nanoparticles and Its Antibacterial Activity against Aquatic Pathogens. *Aquatic Biosystems,* 8:1–7.

Venkatesan, Jayachandran, Se-Kwon, K., and Min, S. 2016. Antimicrobial, Antioxidant, and Anticancer Activities of Biosynthesized Silver Nanoparticles Using Marine Algae Ecklonia Cava. *Nanomaterials,* 6:235-346.

Zhou, Yan, Ying, K., Subrata, K., Jeffrey, D., Cirillo, and Hong, L. 2012. Antibacterial Activities of Gold and Silver Nanoparticles against Escherichia Coli and Bacillus Calmette-Guérin. *J. Nanobiotechnology,* 10:1–9.