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Biosynthesized silver nanoparticles as antimicrobial agents and photocatalytic degradation of methylene blue

K. Roja[a,#], Priya Mehta[a,#], M. Premalatha[a], K. Jeyadheepan[b], C. Gopalakrishnan[c], N. Meenakshisundaram[d], Kamatchi Sankaranarayanan[a,*]

[a]*Department of Energy and Environment, NIT, Tiruchirapalli 620015, India, email: rojakrishna4@gmail.com (K. Roja), mehta33priya@gmail.com (P. Mehta), latha@nitt.edu (M. Premalatha), Tel. +91-9790801563, email: kamatchi.sankaran@gmail.com, kamatchi@nitt.edu (K. Sankaranarayanan)*
[b]*Multifunctional Materials & Devices Lab, Anusandhan Kendra-II, SASTRA Deemed to be University, Tirumalaisamudram, Thanjavur 613 401, India, email: jeyadheepan@eee.sastra.edu (K. Jeyadheepan)*
[c]*Nanotechnology Research Centre, SRM Institute of Science and Technology, Kattangulatur, Kancheepuram-603203, India, email: cg_krishnan@yahoo.com (C. Gopalakrishnan)*
[d]*Department of Physics, Vivekananda College, Tiruvedakam West, Madurai 625234, India, email: nrmsundar@gmail.com (N. Meenakshisundaram)*

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ABSTRACT

In recent days there is a growing need for biosynthesized nanoparticles (NPs) as they are one of the most promising and novel therapeutic agents. Silver nanoparticles (BSNPs) were synthesized through bio-reduction of silver ions using *Pongamia pinnata*, Green tea extract and *Spirulina platensis*. The phytochemicals of marine algae that include hydroxyl, carboxyl, and amino functional groups can serve as effective metal reducing agents and as capping agents to provide a robust coating on the metal NPs. BSNPs were characterized using UV-visible spectroscopy, X-ray diffraction (XRD), scanning electron microscopy (SEM) and Fourier transform infra-red (FTIR). These nanoparticles indicated an absorption peak at 430 nm in the UV-visible spectrum. The antimicrobial activity of BSNPs has been tested by measuring the inhibition zone (minimum inhibitory concentration). Photocatalytic degradation of organic dyes using these nanoparticles has been also carried out and they prove to be highly suitable for environmental applications. The biosynthesis of BSNPs using green resources is a simple, environmentally friendly, pollutant-free and low-cost approach.

Keywords: *Pongamia pinnata*; Green tea; *Spirulina platensis*; Silver nanoparticles; Photocatalytic degradation

1. Introduction

The need for environmentally non-toxic synthetic protocols for the synthesis of nanoparticles leads to an increasing awareness in biological methods, which are free from the use of toxic chemicals and the formation of toxic byproducts. In this regard, there is an increasing demand for 'green nanotechnology'. Green synthesis provides advancement over chemical and physical methods as it is cost effective, environment friendly, easily scaled up for large scale synthesis, and no need to use high pressure, energy, temperature and toxic chemicals [1–3].

Silver nanoparticles have unique optical, electrical, and thermal properties and are being incorporated into products that range from photovoltaics to biological and chemical sensors [4]. The natural products involving in the synthesis of Ag-NPs received tremendous attention in the field of

*Corresponding author.

[#]Contributed equally to the work

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bio-nanomaterial. Among the biological materials, microorganisms, plants, and green algae have been reported for the synthesis Ag-NPs [5].

Pongamia pinnata (family: Leguminosae) is a medium sized glabrous tree popularly known as Indian beech in English. The *P. pinnata* plant is used for anti-inflammatory, anti-plasmodial, anti-nociceptive, anti-hyperglycemic, anti-lipid peroxidative, anti-diarrhoeal, anti-ulcer, anti-hyperammonic and antioxidant activity [6,7]. Green tea is one of types of tea (*Camellia sinensis* L.) which inhibit lipid oxidation in edible oils namely lard oil, canola oil, rapeseed oil and marine oils. *Spirulina platensis* is a filamentous photoautotrophic cyanobacterium that inhabits various environments, such as soils, lakes, brackish, and marine water, forming a green scum on the water surface. It has a tremendous role in bioremediation of toxic and precious metals and their bioconversion to different nontoxic forms.

Biosynthesis of metal nanoparticles was proficient using fungi, microorganisms and plant extracts are being attempted due to the ease of synthesis and greater stability of the NPs [8–10]. In 2011, Sun et al. [11] and his coworkers conducted studies on the stability of silver nanoparticles synthesized by bio reduction method. Zhang et al. biosynthesized Ag-NPs from aloe leaf extract and studied the antibacterial properties. From this study, it has been observed that biosynthesized Ag-NPs can be used for antimicrobial applications, biosensor materials, catalytic applications, and many other applications [12]. Plant extracts are often environmentally and economically friendly materials, and have been explored in the synthesis of silver nanoparticles. Arumai et al. synthesized Ag-NPs from green tea, turmeric and garlic extracts and phytochemical, antioxidant studies were conducted [13]. Green tea contains different phytochemicals and it can be used as a stabilizing and reducing agent for the synthesis of various metal nanoparticles. Green tea extract can be used as reducing and stabilizing agent for the biosynthesis of Ag-NPs in an aqueous solution in ambient conditions. Ag-NPs are easily aggregated to form larger colloids and usually require capping agents to keep the nanoparticles at nanoscale. Polyhydroxy groups of catechins reduce silver ions to form metallic silver, which ultimately leads to the formation of Ag-NPs [14]. Plant extracts are reported to be able to reduce silver ions, faster than fungi or bacteria. Besides, plant-based Ag-NPs are more stable when compared to those produced by aforesaid organisms and polyphenols as well as phenolic acids present in the extract provide extra protection on Ag-NPs due to surface interaction between nanoparticle and phenolics [15–18]. Among the lower organisms, microalgae have a tremendous role in bioremediation of toxic and precious metals and their bioconversion to different nontoxic forms [19].

In textile and paper industry, recently silver nanoparticles are used to degrade the organic dyes as they exhibit enhanced photocatalytic property for degrading organic dyes under solar radiation [20]. The photocatalytic degradation of methyl orange by biosynthesized Ag nanoparticles was carried out by Rashed and El-Amin in 2007 [21]. Wang et al. stated that, Ag nanoparticles are good, highly efficient and stable photocatalysts under ambient temperature with visible light illumination for degrading organic compounds and dyes [22]. Moreover, scientists have also shown considerable interest in using nanoparticles for the photocatalytic degradation of dyes. K. Rajamanickam et al. [23] had determined silver nanoparticles have significant perspectives as antimicrobial agents against pathogenic bacteria and fungi. It is well known that *Escherichia coli* is one of the most common causes of bloodstream infection.

In the present study, aqueous extracts of *Pongamia pinnata*, green tea and *Spirulina platensis* were used for the synthesis of silver nanoparticles via bio-reduction method. Till date, silver nanoparticles synthesized using aqueous extract of *Pongamia pinnata*, green tea and *Spirulina platensis* have been and not been used for photocatalytic degradation of methylene blue. Using different techniques like XRD, FTIR and SEM, the structure and morphology of the prepared Ag-NPs were studied. To identify the phytochemicals present in *Pongamia pinnata*, green tea and *Spirulina platensis* extracts, preliminary phytochemical analysis was carried out. Anti-microbial analysis was conducted with the bio-synthesized Ag-NPs. The photocatalytic degradation of methylene blue was carried under solar irradiation.

2. Experimental methods

2.1. Materials

The reagent used for the synthesis of Ag-NPs were silver nitrate, DPPH (2,2-diphenyl-1-picrylhydrazyl), ABTS (2,2′-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid), butylatedhydroxytoluene, potassium ferricyanide, trichloro acetic acid, ferric chloride, methylene blue (MB) and potassium persulfate were all purchased from Sigma-Aldrich. The other reagents and chemicals used in this experiment were of analytical grade. The reaction contents were prepared freshly with deionized water.

2.2. Preparation of extracts

Leaves of *Pongamia pinnata* were collected from the NIT campus. The aqueous leaf extract was used as a reducing agent for the synthesis of Ag-NPs. *Pongamia pinnata* leaves weighing about 25 g mixed with 250 mL of ultra-pure water in 500 mL Erlenmeyer flask and boiled for 10–15 min. The filtrate was extracted using Whatmann filter paper (No. 40) and the obtained aqueous extract was used for Ag-NPs synthesis.

The aqueous green tea extract was used as a reducing agent for the synthesis of Ag-NPs. The green tea weighing about 25 g were combined with 250 mL of ultra-pure water in 500 mL Erlenmeyer flask and boiled for 10–15 min. The filtrate was extracted using Whatmann filter paper (No. 40) and the obtained aqueous extract was used for Ag-NPs synthesis.

Spirulina platensis was bought from nearby research lab. The aqueous algae extract was used as a reducing agent for the synthesis of Ag-NPs. *Spirulina platensis* weighing about 25 g mixed with 250 mL of ultra-pure water in 500 mL Erlenmeyer flask and boiled for 10–15 min. The filtrate was extracted using Whatmann filter paper (No. 40) and the obtained aqueous extract was used for Ag-NPs synthesis.

2.3. Synthesis of Ag-NPs

1 mM of aqueous silver nitrate solution was standardized and prepared for the synthesis of silver nanoparticles.

The formation of Ag-NPs was performed by adding 10 ml of the aqueous extracts (*Pongamia pinnata*, green tea and *Spirulina platensis*) with 90 ml of the prepared silver nitrate solution and incubated at 60–70°C for 15–20 min. The extract was dried in hot air over for overnight and Ag-NPs. Then, the obtained Ag-NPs were crushed into powder.

2.4. Characterization

The synthesized silver nanoparticles were analyzed using UV-1800-Shimadzu spectrophotometer using quartz cells of 1 cm path length. FTIR spectra of Ag-NPs were recorded at room temperature on Perkin–Elmer spectrophotometer in the range 4000–400 cm^{-1}. The crystallographic nature and phases of the synthesized silver nanoparticles were analyzed using X-Ray diffraction with Cu Kα1 (1.5406 Å). The surface morphology and distribution of synthesized Ag-NPs were studied using scanning electron microscope, using a VEGA3 model SEM.

2.5. Determination of phytochemicals

For determining the presence of polyphenols in the plant extract, several drops of a 5% ferric chloride aqueous solution were added to 2 mL of the plant extract. The appearance of a dark green color indicates the presence of poly phenolic compounds.

For flavonoids detection, 5 mL of diluted ammonium solution were mixed with 2 mL of plant extract and then several drops of concentrated sulfuric acid were added. The appearance of a yellowish color indicated the presence of flavonoids.

2.6. Anti-microbial activity

The antimicrobial activity of the synthesized Ag-NPs were tested against four bacteria such as *Pseudomonas aeruginosa* (MTCC 424), *Staphylococcus aureus* (MTCC 3160), and the other two pathogenic bacteria like *E. coli* and *Salmonella typhi* were obtained from King Institute of Preventive Medicine, Guindy, Tamil Nadu, India. The organisms were periodically sub-cultured and maintained at 4°C. The antibacterial activity was determined by the modified tube dilution method. The minimum inhibitory concentration (MIC) of the synthesized Ag-NPs was investigated according to the batch cultures containing different concentration of silver nanoparticles in suspension (6.5 µg/ml, 12.2 µg/ml, 25 µg/ml, 50 µg/ml and 100 µg/ml). Muller Hinton broth was prepared, the tested bacterial inoculum of 1×10^6 cfu/mL was cultured and the different concentrations of the synthesized nanoparticles were added to the respective tubes. The tubes were then incubated for 24 h by providing high rotary shaking speed to determine MIC. All the experiments were performed out in triplicate. The bacterial growth was assessed at 650 nm using a spectrophotometer. The experiment was carried out along with positive control (tubes containing nanoparticles and Muller Hinton broth without the presence of inoculum) and a negative control (tubes containing inoculum and Muller-Hinton broth without the presence of nanoparticles). The growth in all the tubes at different concentration of Ag-NPs with positive and negative control was compared to determine the inhibition after the incubation period.

2.7. Photocatalytic degradation

Photo-catalytic setup was developed indigenously to analyze the photo-catalytic properties of Ag-NPs. In this setup (Fig. 1), visible light was used for the direct photo-catalytic phenomena, and the light energy is absorbed by the dye molecule and the electrons from the dye molecule is injected into the conduction band of the photo-catalytic materials used. The developed photo-catalytic reactor is a water cooled chamber housing a 1000 W tungsten-halogen light source at the center and the test tubes of sample and dye located at the distance of 5 cm from the center of the chamber (i.e., from the light source). Water cooling is necessary to avoid the thermal degradation of the dye molecule and to quantify only the photo-catalytic performance. The reactor is designed in such a way that five samples can be tested at a single exposure of light. In the sixth test tube, a light intensity sensor BH1750 is placed to measure the light intensity. The sensor is interfaced with Arduino based microcontroller to maintain a light intensity as constant by contolling the lamp power. The lamp power and then

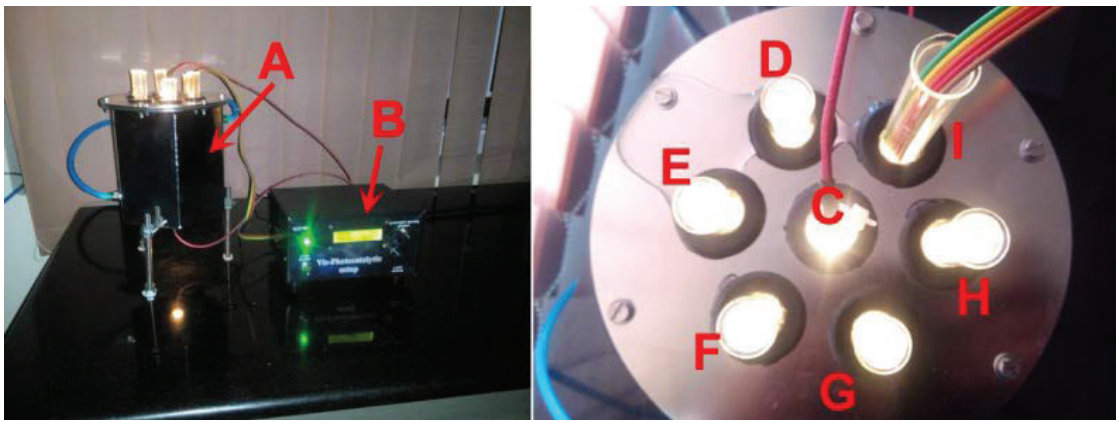

Fig. 1. Photographic images of developed visible photo-catalytic setup, (A) Water cooled chamber, (B) PID Intensity controller, (C) 1000 W tungsten-halogen lamp, (D–H) test tube having sample and dye, (I) test tube having BH1750 intensity sensor.

the intensity is controlled by a PID driven SCR power controller. Intensity of Light used is 200 W/m^2. In the present work, 50 ppm concentration of MB was prepared and it was taken in test tube and Ag-NPs were added at a concentration of 1 mg/mL to the test tubes separately and a blank as well. The degradation studies were determined by measuring the absorbance using UV-spectrophotometer for every 30 min. The studies were conducted for 2 h. The percentage degradation of MB was calculated from the absorbance and the graph between % degradation and time was plotted.

3. Results and discussion

In the present work, aqueous extracts of *Pongamia pinnata*, green tea and *Spirulina platensis* have been used for the synthesis of Ag-NPs. The biomolecules present in these extracts are responsible for the reduction of Ag^+ ions to Ag^0 in a single step.

$$AgNO_3 \rightarrow Ag^+ + NO^{3-} \quad (1)$$

$$Ag^+ + \text{Extracts} \rightarrow Ag^0 \quad (2)$$

The extract-mediated phyto-reduction of Ag(I) into Ag-NPs can be monitored by the change in color during the progress of the reaction (Supplementary section – Fig. S1). The color change is attributed to excitation of surface plasmon vibration caused by Ag-NPs. Generally, the metal nanoparticles exhibit surface plasmon resonance absorption due to the vibration of free electrons of metal in resonance with the light wave, and the concentration of metal nanoparticles determines the intensity of peak.

The Ag Nps were dispersed in water and the UV-visible spectrum (Fig. 2) exhibits typical absorbance peak at wavelength 430 nm for *Pongamia pinnata* Ag-NPs, 400 nm for green tea Ag-NPs and 430 nm for *Spirulina platensis* Ag-NPs. The absorbance peak usually arises as a result of the excitation of localized surface plasmon oscillations of the conduction electrons in case of noble metal nanoparticles such as silver.

The Ag Nps were characterized using XRD and are shown in Fig. 3. Crystallinity and different phases of biogenic nanoparticles were identified by analyzing X-ray diffraction pattern. The XRD pattern exhibits prominent peaks at 38.4^0, 42^0, 63.5^0, 78.2^0 and 118.2^0 indexed as (111), (200), (220), (311), (222) and (420) reflection planes of Ag for *Pongamia pinnata* Ag-NPs, for green tea Ag-NPs at 38.24^0, 44.38^0, 64.43^0 and 78.2^0 indexed as (111), (200), (220) and (311) reflection planes and for *Spirulina platensis* at 37.8^0 and 41.3^0 (002) and (101) reflection planes of Ag. The peak corresponding to the (111) plane is more intense than other planes for *Pongamia pinnata* Ag-NPs and green tea Ag-NPs. This result shows that these nanoparticles are crystalline and face-centered cubic in nature in accordance with JCPDS.

Fig. 4 shows the FTIR spectroscopy used to identify the functional groups responsible for the bio-reduction of Ag^+ to Ag^0, and capping of the bio-reduced Ag-NPs synthesized using different extracts. *Pongamia pinnata*, Green tea and *Spirulina platensis* extracts exhibit broad band in the region 3300–3400 cm^{-1}, which is characteristic of the -OH stretching of flavonoids and phenolic compounds, whereas Ag-NPs

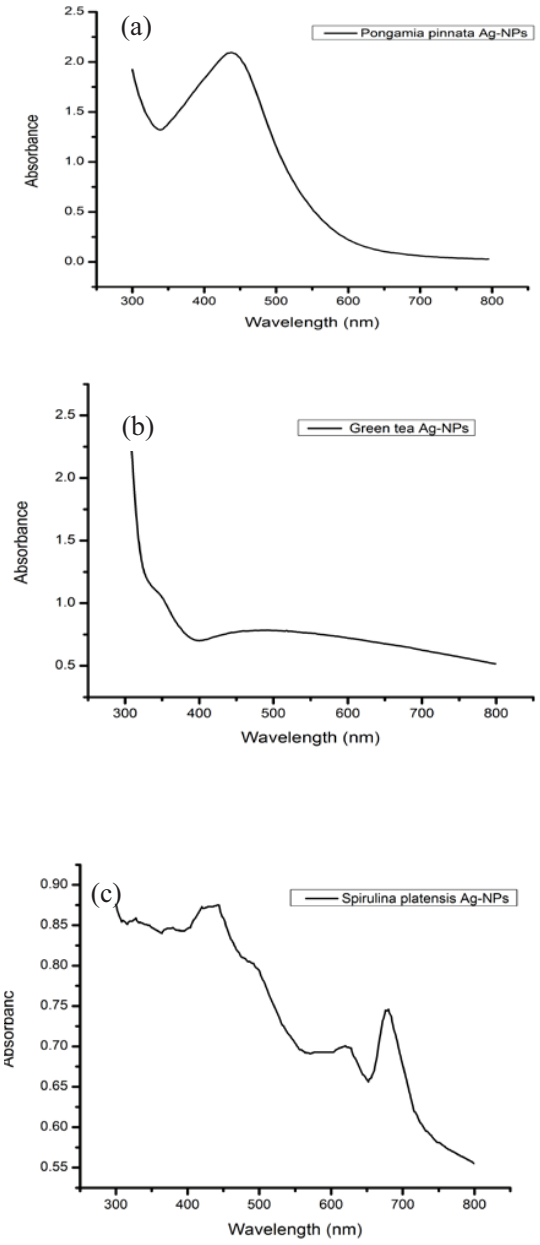

Fig. 2. UV VIS Spectroscopy for (a) *Pongamia pinnata* Ag-NPs (b) Green tea Ag-NPs (c) *Spirulina platensis* Ag-NPs.

synthesized using these extracts exhibits the same band at lower frequency. The sharp absorption peak observed in the region 1609–1615 cm^{-1} may be assigned to the amide I bond due to carbonyl stretching in the amide linkages, suggesting that the proteins are interacting with green synthesized Ag-NPs and that their secondary structure was not affected during the reaction with Ag^+ ions or after binding with Ag-NPs. These observations confirmed that a carbonyl group of amino acid residues has a strong binding ability with the metal that act as capping agent to prevent agglomeration and providing stability to the medium. The biologically synthesized Ag-NPs from *Pongamia pinnata* and

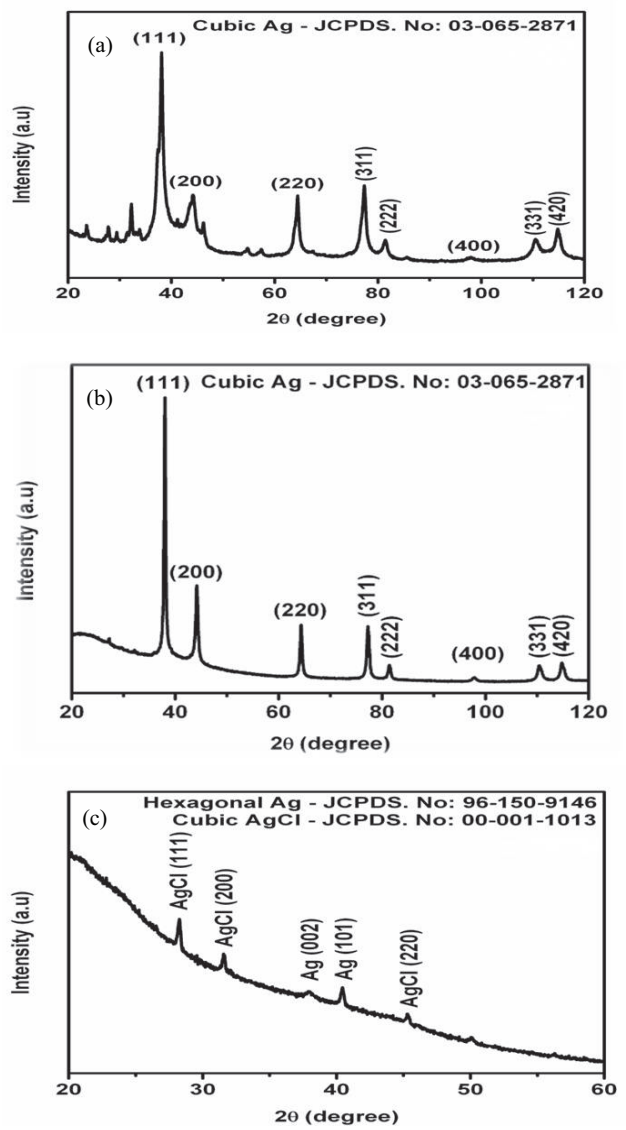

Fig. 3. XRD analysis for (a) *Pongamia pinnata* Ag-NPs (b) Green tea Ag-NPs (c) *Spirulina platensis* Ag-NPs.

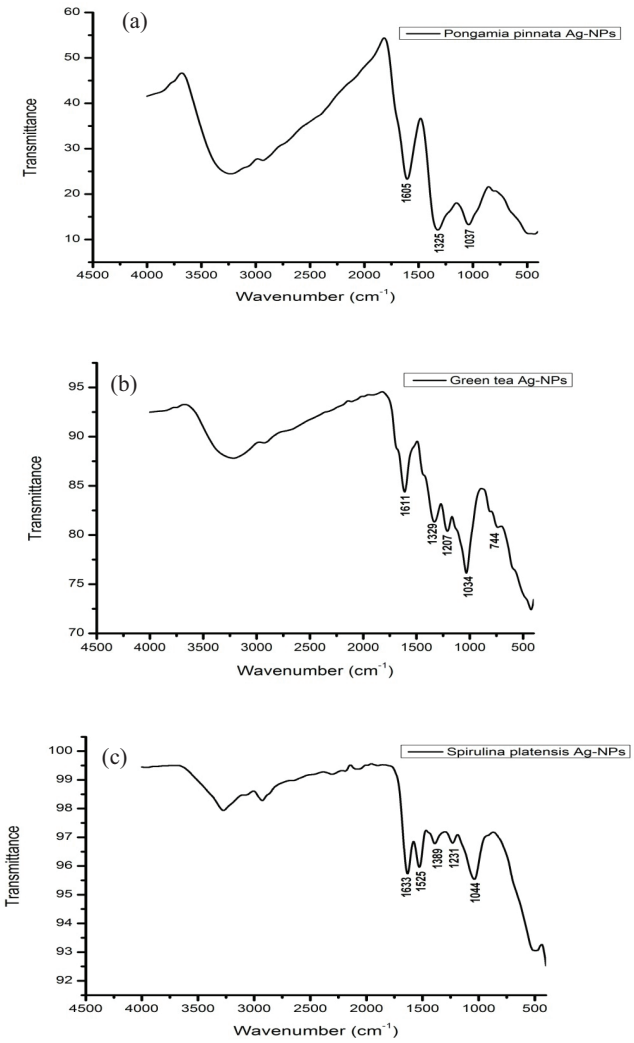

Fig. 4. FTIR analysis for (a) *Pongamia pinnata* Ag-NPs (b) Green tea Ag-NPs (c) *Spirulina platensis* Ag-NPs.

green tea exhibit a medium intense band in the region 1325 cm^{-1} and 1329 cm^{-1} respectively, representing the presence of hydroxyl and phenolic hydroxyl groups. A band in the region 1200–1270 cm^{-1} corresponds to the stretching vibration of C-N groups. The band obtained between 1034 cm^{-1} for green tea, 1037 cm^{-1} for *Pongamia pinnata* and 1044 cm^{-1} for *Spirulina platensis* represents C-N stretching vibration possibly due to the presence of aliphatic amines that are commonly found in proteins. The intense band observed in the region 744 cm^{-1} shows the indication of heterocyclic compounds due to the presence of flavonoids. The overall observation proves the involvement of antioxidants such as flavonoids/phenolic compounds as reducing agent, and proteins may act as the coating/stabilizing agent.

SEM techniques were employed to visualize the size of the synthesized Ag-NPs (Fig. 5) and corresponding EDX pattern is also plotted. The size and shape of the Ag-NPs depends on the green extracts used for the synthesis. It was shown that relatively spherical and uniform Ag-NPs were formed with diameter of 30–40 nm from *Pongamia pinnata* and for *Spirulina platensis* Ag-NPs it can be observed that it is getting agglomerated. Ag-NPs synthesized from green tea extract found spherical in shape with the particle size ranged between 9 and 12 nm. The SEM image of silver nanoparticles was due to interactions of hydrogen bond and electrostatic interactions between the bioorganic capping molecules bound to the Ag-NPs. EDX spectra clearly shows the presence of Ag. Particle size analysis of the Ag-NPs carried out using Malvern Zetasizer, showed a lowest of 10 nm for green tea Ag-NPs while the *Pongamia pinnata* and for *Spirulina Platensis* Ag-NPs, due to agglomeration showed higher particle size (Supplementary section - Fig S2).

The preliminary phytochemical screening was done to determine the presence of flavonoids and polyphenols in the extracts and given in Table 1. It has been obtained that flavonoids and polyphenols are present in all extracts.

It has been reported that silver nanoparticles (SNPs) are non-toxic to humans and most effective against bacte-

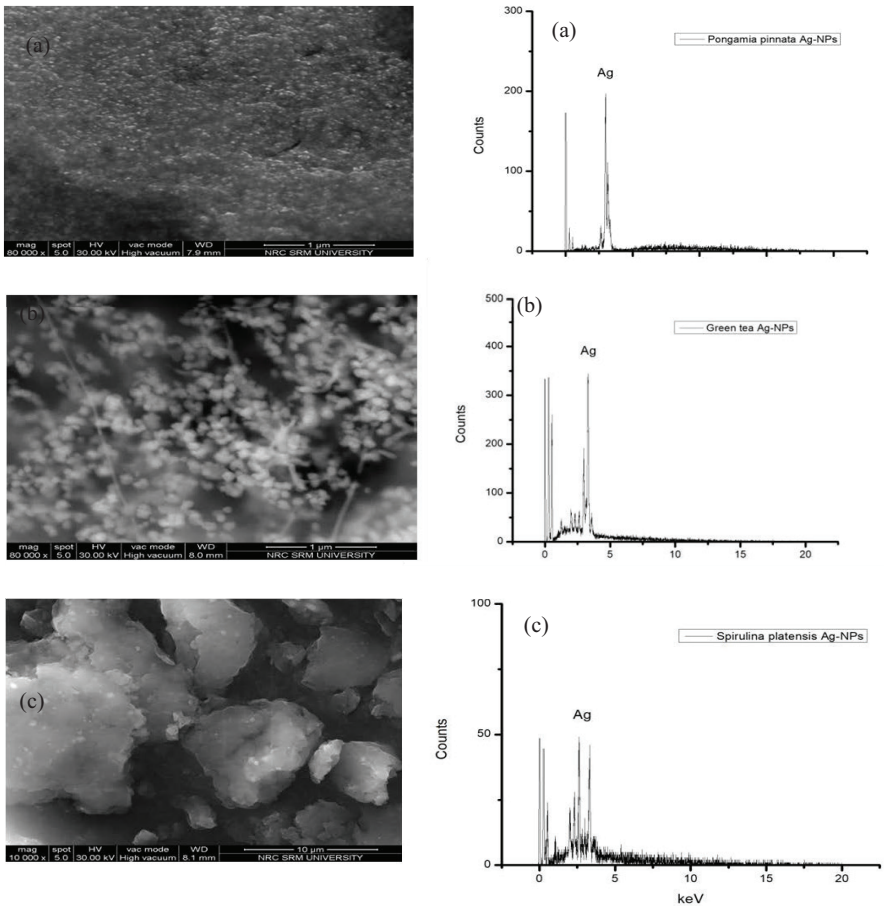

Fig. 5. SEM and EDX analysis for (a) *Pongamia pinnata* Ag-NPs (b) Green tea Ag-NPs (c) *Spirulina platensis* Ag-NPs.

Table 1
Phytochemical screening of plant extract

Plant extracts	Flavonoids	Polyphenols
Pongamia pinnata	Present	Present
Green tea	Present	Present
Spirulina platensis	Present	Present

ria, virus and other eukaryotic micro-organism at low concentrations and without any side effects [24]. Antimicrobial activity of the synthesized AgNPs was evaluated against gram positive (*S. aureus*) and gram negative (*P. aeruginosa, E. coli, S. typhi*) bacterial strains at different concentrations and the corresponding responses are expressed as zone of inhibition, as presented in Table 2 along with the Minimum Inhibitory Concentration in µg/ml. From our experimental investigations, it is found that the AgNPs shows potential antibacterial activity for all the three AgNPs. Green tea Ag-NPs shows the best result with the minimum concentration required is nearly 6.5 µg/ml against *P. aeruginosa*, *S. typhi* and *S. aureus* bacterial strains. MIC for *Pongamia pinnata* is 50 µg/ml against *P. aeruginosa*, *S. typhi* and *S. aureus*. lethal concentration 50 for *Pongamia pinnata* requires is 11.9 µg/ml against *E. coli* bacteria which is actually very less amount to kill half of the population of bacteria.

3.1. Photocatalytic degradation

Photocatalytic degradation of MB dye was investigated using biosynthesized Ag-NPs at different time intervals. The characteristic absorption peak of MB solution was found to be 663 nm. Degradation of MB was visualized by decrease in peak intensity within 2 h of incubation time. Fig. 6a shows the UV visible spectra of the MB dye with and without Ag-NPs after 120 min. There is no considerable shift in peak position for MB solution without exposure to Ag-NPs. The dye degradation (%) was calculated using the following equation and its variance with the time of exposure is shown in Fig. 6b. The images of the MB solution before and after exposure of light is shown in supplementary section (Fig. S3).

$$\%\ \text{Degradation} = \frac{C_0 - C_t}{C_0} \tag{3}$$

where C_0 is the initial concentration of the methylene blue solution and C_t is the concentration of the dye solution after t minutes of exposure in the irradiation. During exposure in the light, when the photons hit the nanoparticles present in the colloidal mixture, the electrons at the particle surface are excited. The dissolved oxygen molecules in the reacting medium accept the excited electrons from particle surface and are converted into oxygen anion radicals. These radi-

Table 2
Antimicrobial activity of silver nanoparticles

Samples	Minimum inhibitory concentration µg/ml			
	Pseudomonas aeruginosa	*E. coli*	*Salmonella typhi*	*Staphylococcus aureus*
Pongamia pinnata silver nanoparticle	25[b] (52.2[a])	50[b] (11.9[a])	25[b] (25.3[a])	25[b] (55.2[a])
Green tea silver nanoparticle	6.5[b] (51.72[a])	50[b] (52.8[a])	6.5[b] (64.36[a])	6.5[b] (70.1[a])
Spirulina platensis silver nanoparticle	50[b] (28.5[a])	100[b] (22.6[a])	50[b] (15.47[a])	12.2[b] (14.2[a])

[a]LC50 values are expressed as the concentration that causes 50% decrease in optical density of microorganism suspension.
[b]Nanoparticle concentration (µg/ml) which inhibit the microbial growth.

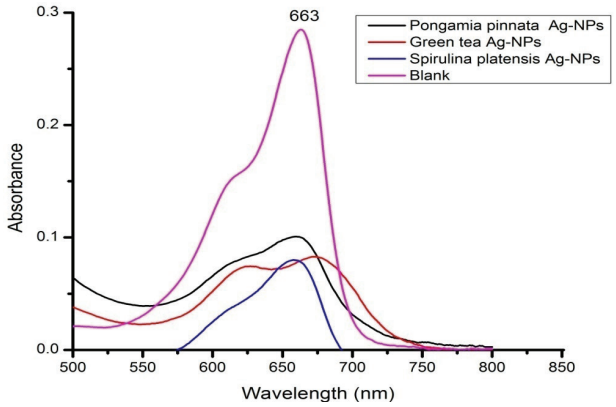

Fig. 6. a. UV VIS Spectra for MB and MB with Ag-NPs after 120 min.

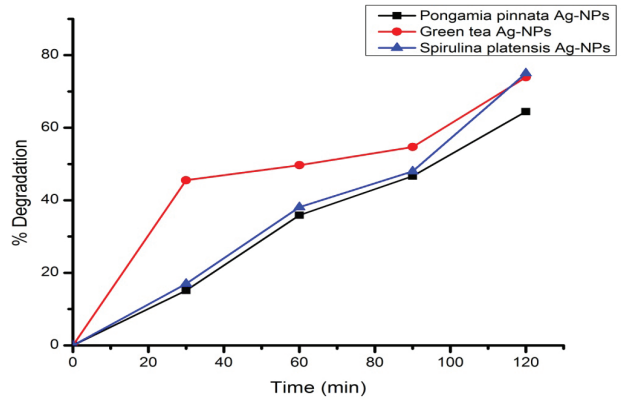

Fig. 6. b. % Degradation of MB using Ag-NPs after 120 min.

cals break the organic dye into simpler organic molecules leading to the rapid degradation of the dye [25, 26]. Therefore, the biosynthesized Ag nanoparticles may act as a stable and efficient photocatalyst for degradation of methylene blue under visible light irradiation [27].

The percentage degradation of MB dye after 2 h of exposure is 64.4% with *Pongamia pinnata* Ag-NPs, 73.9% with green tea Ag-NPs and 75% with *Spirulina platensis* Ag-NPs. From the results, Ag-NPs synthesized from green tea and *Spirulina platensis* shows better degradation of MB. This must be due to the presence of flavonoids and polyphenols as revealed by phytochemical screening and FTIR studies.

The Langmuir- Hinshelwood model is used to describe the kinetics of degradation of MB. It basically relates the degradation rate (r) and reactant concentration (C) at time t, which is expressed by the following equation.

$$r = \frac{dC}{dt} = \frac{K_r K_{ad} C}{1 + K_{ad} C} \tag{4}$$

where K_r is the rate constant and K_{ad} is the adsorption equilibrium constant. When the adsorption in the reaction is relatively weak or if the reactant concentration is low, the above equation can be simplified to the pseudo-first order kinetics with an apparent first order rate constant K_{app}.

$$\ln\left(\frac{C_0}{C}\right) = K_r K_{ad} t \; = K_{app} t \tag{5}$$

where C_0 is the initial concentration of MB. Fig. 6c shows the linear relation of $\ln(C_0/C)$ with time. Rate constant and correlation coefficient (R^2) were calculated for reaction and is shown in Table 3. The high value of R^2 indicate suitability of applying Langmuir- Hinshelwood model and the degradation rate constant was determined from the slope of the line and highest for green tea Ag-NPs followed by *Pongamia pinnata* Ag-NPs.

4. Conclusion

Biological synthesis of silver nanoparticles has emerged as a simpler and better option than physical and chemical procedures as it is fast, clean and eco-friendly alternative that does not involve any costly instruments as well. Ag-NPs were successfully synthesized using the aqueous extracts of *Pongamia pinnata*, green tea and *Spirulina platensis* by bio-reduction. UV spectra exhibit the peak at 400 nm for green tea Ag-NPs and at 430 nm for *Pongamia pinnata* and *Spirulina platensis* Ag-NPs which indicates the characteristics of Ag-NPs. Crystalline nature of the particles was verified by XRD. FT-IR spectroscopy revealed the involvement of functional groups in the bio-reduction of Ag^+ to

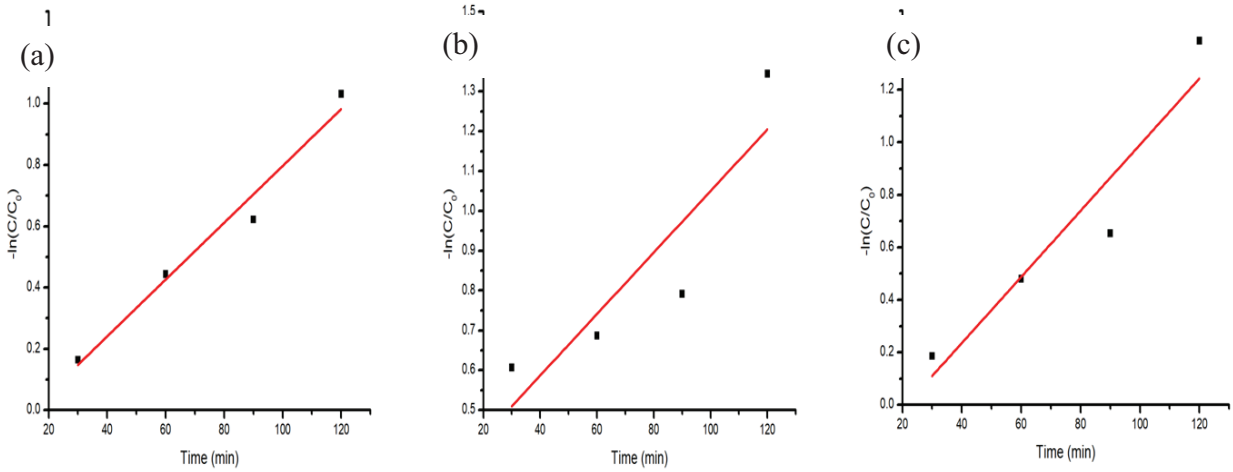

Fig. 6. c. First-order kinetics plots for MB using (a) *Pongamia pinnata* Ag-NPs (b) Green tea Ag-NPs (c) *Spirulina platensis* Ag-NPs after 120 min.

Table 3
Rate constant for first- order kinetics plots for MB using Ag-NPs after 120 min

Photocatalytic degradation of MB using	Slope constant (min^{-1})
Pongamia pinnata Ag-NPs	0.012
Green tea Ag-NPs	0.009
Spirulina platensis Ag-NPs	0.007

Ag. SEM images confirmed the crystalline nature of synthesized Ag-NPs. For Ag-NPs synthesized from *Pongamia pinnata* and green tea was in nanometer range but for Ag-NPs from *Spirulina platensis* got agglomerated. The preliminary phytochemical studies showed the presence of polyphenolic compounds in green tea extracts which was responsible for the formation of Ag-NPs. The synthesized Ag-NPs have bactericidal activity and showed potential application of antibacterial agent against pathogens. The result of the photocatalytic study concludes that these biogenic silver nanoparticles have efficiency to degrade methylene blue under solar irradiation. Therefore, they can find applications in textile industry and water treatment plants.

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Supplementary Information

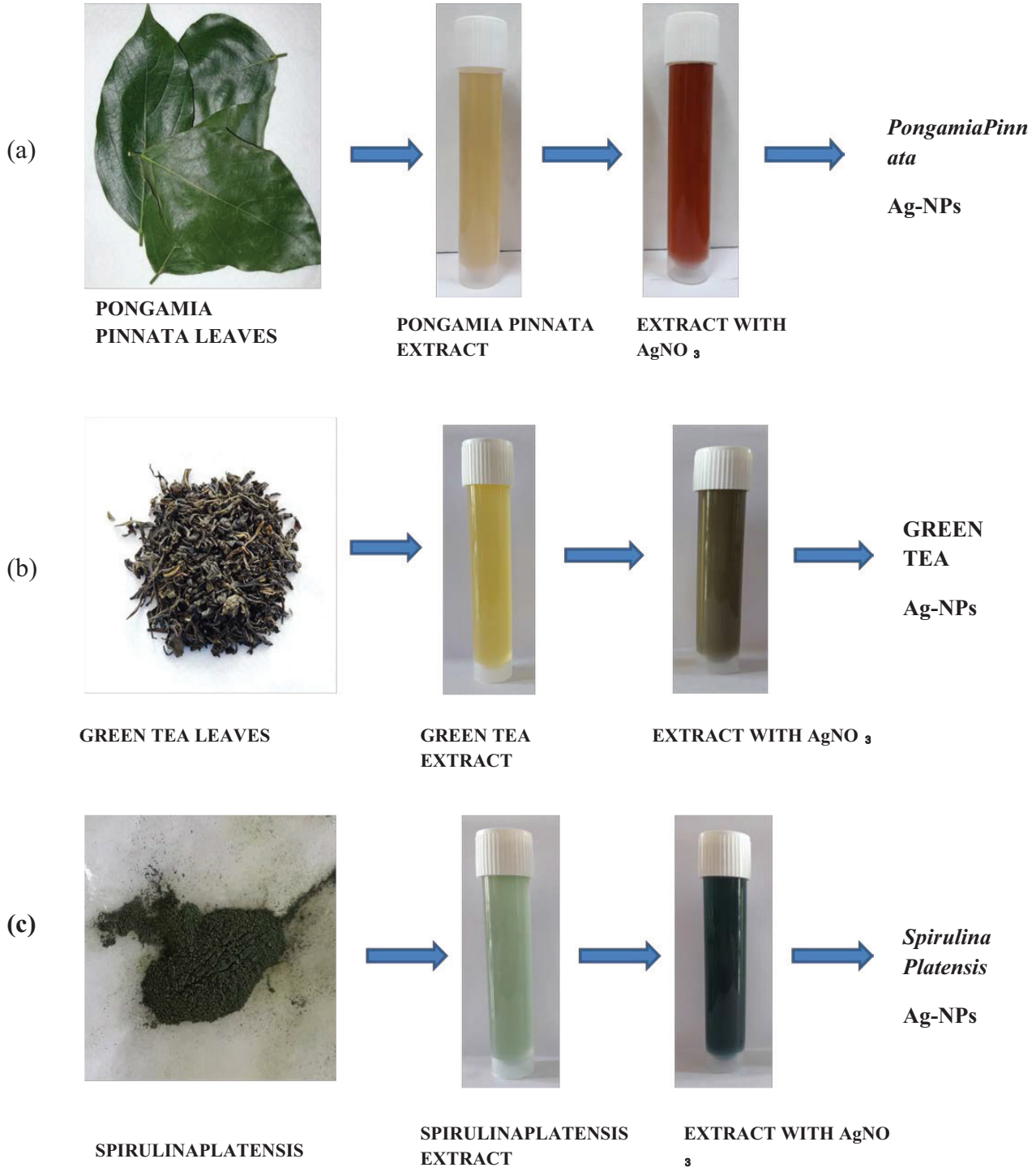

Fig. S1. Preparation of Ag-NPs from (a) *PongamiaPinnata* leaves (b) green tea leaves (c) spirulina platensis.

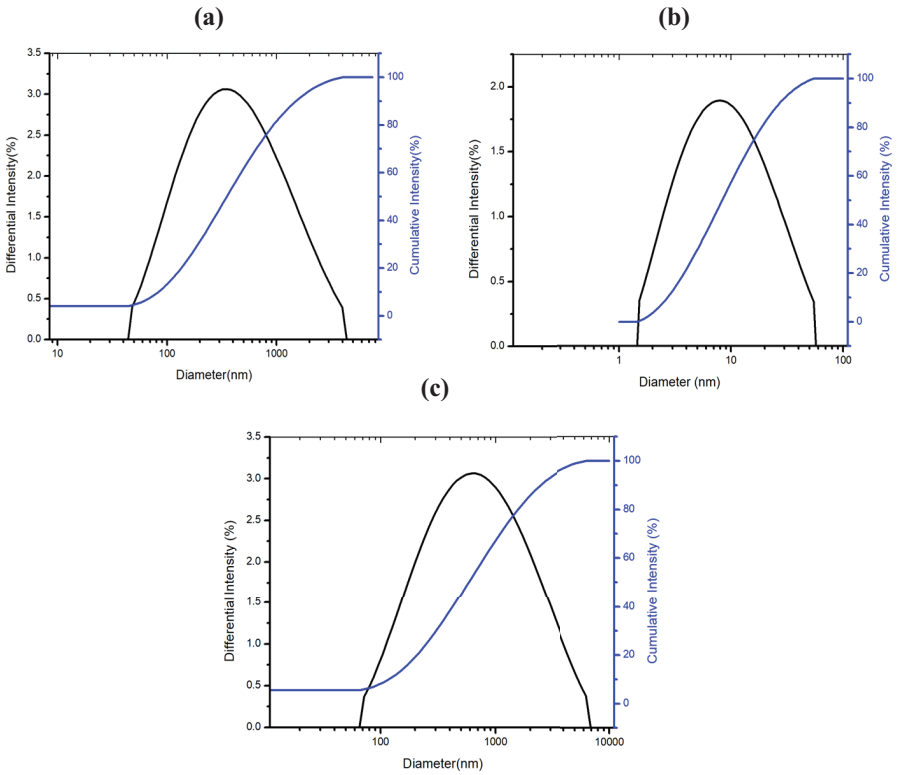

Fig. S2. Particle size analysis for (a) *Pongamia Pinnata* Ag-NPs (b) Green tea Ag-NPs (c) *Spirulina Platensis* Ag-NPs.

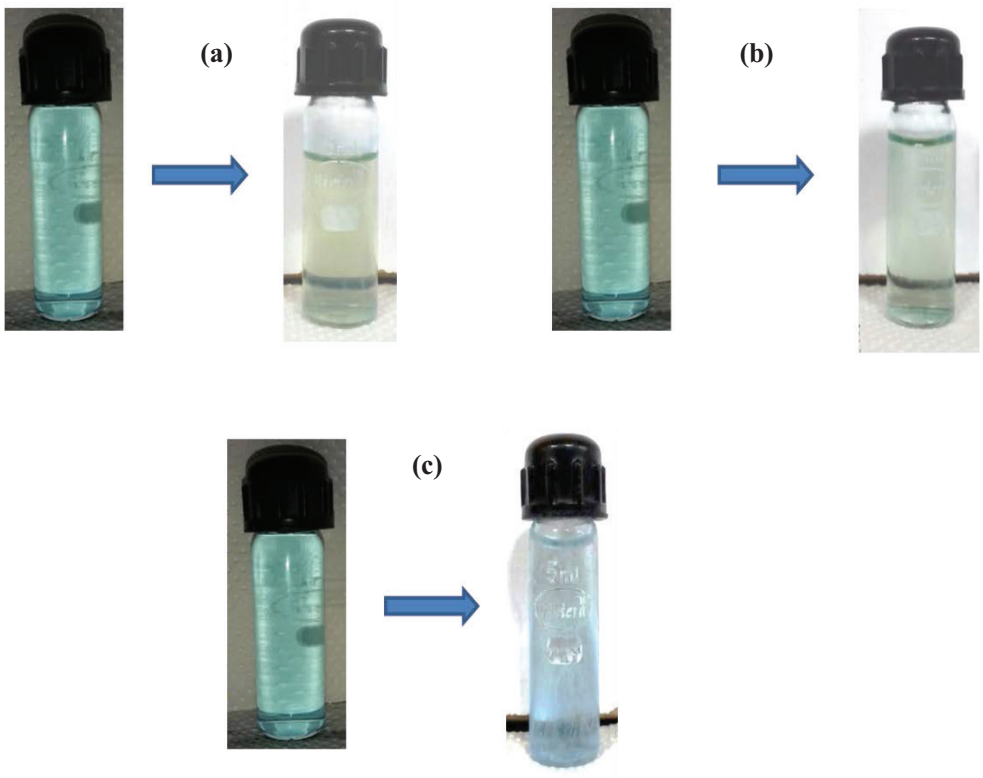

Fig. S3. Colour change for Methylene Blue before and after 2 h of irradiation for (a) *Pongamia Pinnata* Ag-NPs (b) Green tea Ag-NPs (c) *Spirulina Platensis* Ag-NPs.