Original Research Article

Optimization of Reaction Conditions for Green Synthesis of Silver Nanoparticles Using CoffeA Arabica Leave Extract

ABSTRACT

Present study describes a rapid and eco-friendly synthesis of silver nanoparticles (AgNPs) using CoffeA Arabica leaf extract in single process via green Chemistry. We have successfully synthesized AgNPs using CoffeA Arabica leaf as a reductant and a capping or stabilizing agent through green chemistry. In the typical synthesis of AgNPs, CoffeA Arabica leaf extract was added into aqueous solution of $AgNO_3$ in a conical flask at 80 ^{0}C temperature. Different reaction concentrations of CoffeA Arabica extract and $AgNO_3$ solution were subjected. AgNPs were synthesized by using aqueous silver nitrate solution as a precursor with aqueous solution of CoffeA Arabica leaf extract as the reductant and stabilizing agents. The AgNPs were characterized using Fourier transform infrared spectroscopy (FTIR), X-Ray Diffraction (XRD), Atomic Absorption Spectroscopy (AAS) and UV-Vis spectroscopy. The optimum conditions for this process were a temperature of *80 °C*, pH 9, and reactant ratio 1:4. XRD results reveal that, the green synthesis yields stable, face centered cubic structure AgNPs with a sizes range of 39.664-24.708 nm. Preparation of AgNPs using plant extracts are eco-friendly, biocompatible and cost effective. The synthesis method applied in this study involved the application of the green chemistry principles which emphasizes on the use of nontoxic solvents and reagents to protect the environment. AgNPs have a vital role in different nanotechnology-based processes because of their unique characteristics and can be exploited on a large scale for medical application.

Keywords: CoffeA Arabica; Green synthesis; Aqueous Extract; Nanoparticles

1. INTRODUCTION

Nanotechnology is a powerful and attractive branch of science that can be considered as the most important technological advancement in recent years due to its new and profitable applications [1]. Nanoparticles have exceptional properties due to their size, morphology and distribution. Thus, the nanoparticles are very chief components in the field of nanotechnology. Silver (Ag) has been famous for more than 2000 years as a metal that displays good medical properties, silver-based compounds being used in numerous antimicrobial applications. Ag ions are so toxic for microorganisms and then, they have various roles in the field of medicine [2].

Silver nanoparticles (AgNPs) have been very essential part of nanoscience because they do not induce modification on living cells and so, are unable to cause microbial resistance. Silver nanoparticles have been extensively used in the fields of biology and medicine due to their attractive and unique physiochemical properties [3]. Numerous researches conducted in the late 1970s and used Ag particles for the treatment of orthopedic diseases caused by various infections with microorganisms and a faster bone recovery was noticed. A lot of applications can be ascribed to AgNPs, for instance: the catalysts showing in chemical reactions, the bio-labeling, and the spectral selective coatings to absorb solar energy, textile industries, food additives etc. [4].

AgNPs can be prepared using conventional/unconventional techniques, as well as using: “top-down” and “bottom-up” approaches. The unconventional techniques use either biological microorganisms (example: fungi, bacteria, yeasts, marine algae) or various alcoholic/aqueous plant extracts. Green synthesis has various advantages over classical route: it is eco-friendly, cost effective, do not use toxic chemical reagents and not require high energy, pressure and temperature [5]. Plant-mediated synthesis of silver nanoparticles is more advantageous compared to the methods that are used microorganisms because they can be easily improved, are less bio-hazardous and do not involve the elaborate stage of growing cell cultures [6].

Conventional methods of preparation of metal nanoparticles use high amount of energy, toxic solvents and hazardous chemicals [7]. Therefore, we need to develop other method of synthesis that are energy efficient and which make use of non-toxic solvents, environment-friendly and renewable resources such as phytochemicals extracted from plants. The main advantage of the use of plant extracts for biogenesis of AgNPs is that they are safe, easily available, and nontoxic, have a lot of metabolites which can share to reduce Ag ions into Ag metals and are faster than microbes for the synthesis. Green nanotechnology is also considered as photo-biological approach that utilizes plants or their extracts as reducing and capping agents in the synthesis of AgNPs [8]. Developing green protocols to prepare AgNPs have considered as a novel field of science and referred to as green nanotechnology.

The aim of this study was to synthesize AgNPs using sliver nitrate aqueous solution with aqueous extract of CoffeA Arabica leaves as the capping agent and reductant. The result of this study possess its own involvement into the scientific knowledge in plant mediated synthesis of silver nanoparticles. The synthesis method applied in this study involved the application of the green chemistry principles which emphasizes on the use of nontoxic solvents and reagents to protect the environment. Moreover, as far as our knowledge is concerned, there is no any report regarding the green synthesis of Ag nanoparticles using CoffeA Arabica leaf extract.

2. MATERIALS AND METHODS

2.1. Preparation of the Leaf Extracts

For the preparation of the aqueous extract, fresh green leaves of CoffeA Arabica was used. Some amount of CoffeA Arabica leaves was weighed, washed with tape water followed by distilled water to remove all the dirt. Then the clean leaf was shade dried, grounded using mortar and pestle, and was boiled in 250 ml of distilled water at 80^{0}C for 3 minutes. Finally, the solution was cooled and filtered with What-man No.1 filter paper and thus, the aqueous extract was kept at 4^{0}C for AgNPs preparation [9].

2.2. Preparation of $AgNO_3$ solutions

$AgNO_3$ was carefully weighed using analytical balance and then transferred into 1000 ml volumetric flask that contained 400 ml of distilled water. The solid material was completely dissolved and distilled water was added to fill up to the mark. A 0.004 M solution of $AgNO_3$ was prepared in an amber bottle and stored in a cool and dry place [10].

2.3. Green Synthesis of AgNPs

In the typical synthesis of AgNPs, aqueous CoffeA Arabica leaf extract (20 g/250 ml) was added into the aqueous solution of 4 mM $AgNO_3$ in a conical flask at 80 ^{0}C. Different reaction concentrations of CoffeA Arabica extract and $AgNO_3$ solution were subjected. Ag ion was reduced into Ag metal. The prepared AgNPs was characterized using XRD, FTIR, AAS and UV-Vis spectroscopy [11].

2.4. Spectrophotometric Analysis of the Samples

UV-Vis spectroscopy refers to absorption/emission in the range of UV-Vis spectral region. Usually, 350–700 nm light is used for characterizing 2 to 100 nm sized metal nanoparticles [12]. UV–vis spectroscopy is a tool that can be used to evaluate the formation and stability of AgNPs in aqueous solution [13]. Spectrophotometric absorption measurements in the wavelength ranging from 380 up to 500 nm that is used to characterize silver nanoparticles [14]. The spectroscopic analysis was done using Cary 60 version 2, double beam UV-Vis instrument, with scan rate of 4800 nm/min at a wavelength range of 350-700 nm.

2.5. FTIR and XRD Analysis of Ag-NPs

FTIR studies were carried out using a shimadzu spectrophotometer (model 100, Japan). The samples were synthesized using KBr pellet method and CoffeA Arabica leaf extract as well as the synthesized Ag nanoparticles were analyzed for the presence of bio-functional moieties of under optimized conditions. FTIR spectra of AgNPs were recorded at a resolution of 2 cm^{-1} in transmission mode between 3500 and 650 cm^{-1}. XRD pattern of synthesized nanoparticles was done by using DX-2700 X-Ray Diffractometer. X-ray source was obtained in Cu-K_{α} radiation with 0.154 nm wavelength. The XRD system was run at 30 mA current and 40 KV voltage and the nanomaterials were scanned in the range of 3 - 80^0.

2.6. AAS Analysis of AgNPs

The conversion of Ag ions to Ag metal can be inferred with this measurement. During the reaction at regular intervals, the aliquots of sample was withdrawn and shake, so that the supernatant solution was contained the unreacted $AgNO_3$ solutions for the reason that Ag^+ ions are so much smaller than Ag metal and the pellets were contained AgNPs. The supernatant solution was examined using AAS for identifying the concentration of Ag ions. The reduction rate of the concentration of Ag ion was exhibited the conversion of Ag ion into Ag metal.

3. RESULTS AND DISCUSSION

3.1. UV-Visible Spectroscopy Characterization

3.1.1. Effect of Temperature on CoffeA Arabica leaf extract AgNPs Synthesis

Temperature is another physical factor that plays a great role in controlling the nucleation reaction of nanoparticles fabrication. The absorbance property of silver nanoparticle was recorded at a temperature 25^0C, 50^0C, 60^0C, 70^0C and 80^0C. On the basis of UV-Vis studies better synthesis was demonstrated at 80°C, as shown in Fig.1.

As indicated in the figure below, a wide peak has been observed at 450 nm at 25^0C for the reaction mixture. Broadening band attributed to agglomeration or increase in size of the particles [15]. Increasing absorbance, increase the temperature from 25 to 80^0C and the bands become narrow. Besides, nanoparticles synthesized at higher temperature, increase in temperature increased the rate of formation of AgNPs from silver ions, retarding the secondary reduction process and others reported similar result and attributed the trend to the increased solubility of the water soluble phenolic at higher temperatures [16]. Increasing the absorbance of the reaction mixture increases the incubation temperature markedly showing higher productivity of AgNPs, at elevated temperature. The sharpness of absorbance peak depends on size of the nanoparticles. As the nanoparticle size become smaller when the temperature is higher resulting in sharpness of the Plasmon resonance band of silver nanoparticles [17].

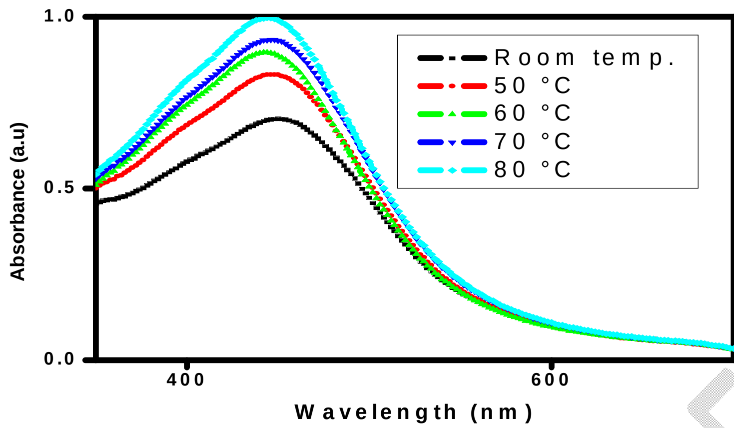

Fig. 1. UV-Vis absorption spectra of silver nanoparticles synthesized by CoffeA Arabica leaf extract at various temperatures

3.1.2. Effect of pH on CoffeA Arabica leaf extract of AgNPs synthesis

The preparation of Ag nanoparticles using leaf extract of CoffeA Arabica was conducted over a pH range of 3–11. Fig.2 shows the UV-Vis spectra of CoffeA Arabica leaf extract silver nanoparticles showing the effect of variation in pH on CoffeA Arabica leaf extract of AgNPs preparation.

The UV-Vis absorption peak is very wide at pH five as indicated in Fig.2. This wide result may be because of increase in AgNPs size. The presence of larger nanoparticles and platelets at low pH can be attributed to the uncontrolled nucleation as well as aggregation at lower pH because of the improved interaction of negatively charged ions. At lower pH, increasing the size of AgNPs yield large nanoparticles is favored over the nucleation [18]. An efficient AgNPs were prepared, when the pH is 9 and the size remained smaller but enhancing pH agglomeration was noticed at pH 11, therefore, nine is the optimal pH value for efficient AgNPs synthesis. As the pH value becomes diminished while the absorption decreases. Then, preparation of AgNPs is suitable at pH 9. This agrees with what has been reported elsewhere [19].

At higher pH, the large number of phenolic functional groups available for silver binding facilitated a lot of silver ions to bind and consequently, produce a lot of nanoparticles with smaller diameters. There isn't formation of silver nanoparticles at pH < 5, this may be due to the instability of the nanoparticles at acidic pH [20]. Acidic conditions avoid the formation of AgNPs whereas, basic conditions enhance the formation of AgNPs. This shows that the pH helps a very essential role in keeping the size and shape of Ag nanoparticles synthesis.

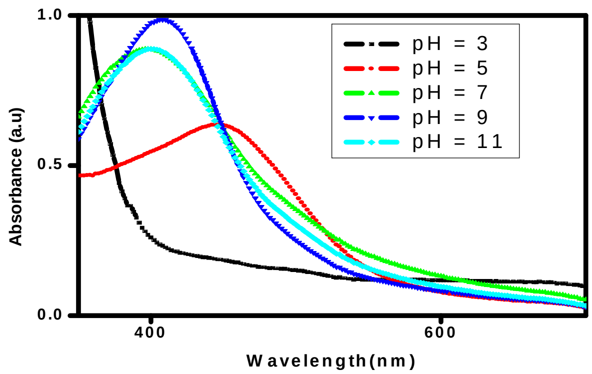

Fig. 2. UV-Vis absorption spectra of AgNPs synthesized by CoffeA Arabica leaf extract at various pH values

3.1.3. <u>Effect of reaction time on CoffeA Arabica leaf extract AgNPs Synthesis</u>

The reaction between reducing agent and Ag ion in the extract was undergone for 6, 12, 24 and 48h at room temperature. The color change of the solution from yellow to brownish-yellow to deep brown was the indication of synthesis of AgNPs when 4mM $AgNO_3$ was added to CoffeA Arabica leaf extract at different time interval. The UV-Vis absorption of the colloidal solution was noted as depicted in Fig. 3. It should be noted that the intensity of the color of the reaction mixture was directly proportional to the incubation time due to excitement in the surface Plasmon resonance phenomenon. The maximum absorbance occurs for 12 h time interaction of the reactants. When the absorbance was increased, the interaction time of Ag ions with CoffeA Arabica leaf extract was also increased up to 12 h. Then start to decrease from 24-48 h, the UV-Vis spectra in Fig.4 shown that the best synthesis was observed at 12 h of incubation. The obtained results demonstrated that absorbance increases and more AgNPs are formed as the reaction time increases up to 12 h and similar results were also reported [21]. An optimum period is required due to the unsteadiness of the AgNPs synthesis, as agglomeration after optimum time interval resulting in larger sizes of particles. As absorption increases, the incubation time increases from 6 up to 12 h. Due to the instability of Ag nanoparticles, a maximum time is needed as AgNPs agglomeration occurs after the optimum duration resulting in larger particle sizes [22].

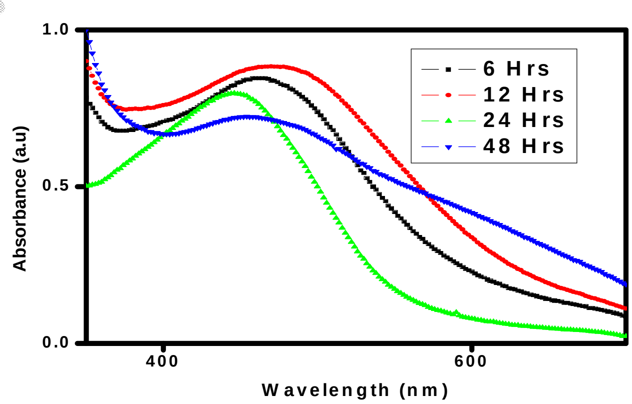

Fig. 3. UV-Vis absorption spectra of silver nanoparticles synthesized by CoffeA Arabica extract at different reaction time

3.1.4. Effect of CoffeA Arabica leaf extract Concentration on AgNPs Synthesis

The absorbance peak of CoffeA Arabica leaf extract Ag-NPs, when the CoffeA Arabica leaf extract concentration was 5 g/250 ml is broad and less intense as shown in Fig.3. and the peak was appeared at 454 nm. However, as the CoffeA Arabica leaf extract concentration increases gradually from 5 g/250 ml to 20 g/250 ml, the absorbance peak becomes narrower and more intense. There is a gradual increase absorbance peak as the CoffeA Arabica leaf extract concentration increases from 5 g/250 ml to 20 g/250 ml. Based on the UV-Vis studies, the synthesis of AgNPs was better demonstrated at 20 g/250 ml.

Sharp and intense peaks were related by diminishing the size of AgNPs. At lower extract concentrations, a lesser number of nucleation sites were present so more reduction were taken place at one nuclei leading to the formation of a larger particle. It is also possible that at higher concentrations the polyphenols in the CoffeA Arabica leaf extract had effectively reduced Ag^+ ions to Ag^0 and provided enough capping agent for the stabilization of the synthesized nanoparticles through steric hindrance thus preventing their aggregation, which probably leads to the formation of smaller particles at a higher extract concentration [23]. These results were in agreed with what was reported before [24].

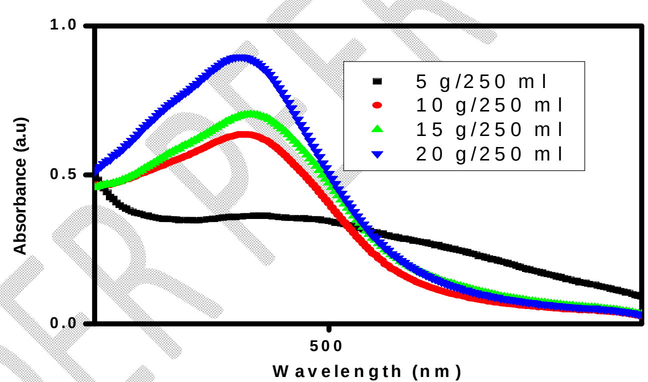

Fig. 4. UV-Vis spectra showing absorbance of silver nanoparticles synthesized by different CoffeA Arabica Leaf extract

3.1.5. Effect of silver ion concentration on CoffeA Arabica leaf extract of AgNPs Synthesis

Various concentration like 0.5, 1, 2, 3 and 4 mM $AgNO_3$ were maximized for the optimum preparation of nanoparticles. Interestingly, 4 mM concentration was supported rapid formation compared to other concentrations Fig.5 on the basis of UV-Vis studies. When $AgNO_3$ concentration was increased the number of Ag-NPs was risen. Rising the amount of Ag ions are available for the reduction Ag ions by the reductant to silver metals as the $AgNO_3$ concentration increases. When $AgNO_3$ concentration was risen from 0.5 up to 4mM, the yield of Ag nanoparticles were also increased. Hence 4mM concentration of $AgNO_3$ was chosen for further experimentation. The concentration of metal ion has an essential role in the nanoparticles production. Similar effect of varying concentration of silver salt on yield, size and disperse of AgNPs was reported by others [25].

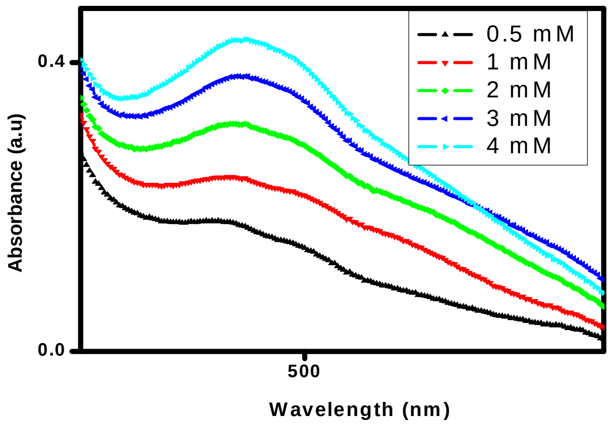

Fig. 5. UV-Vis absorption spectra of silver nanoparticles synthesized by CoffeA Arabica leaf extract at various silver ion concentration

3.1.6. Effect of Ratio of Reactants on CoffeA Arabica leaf extract of AgNPs Synthesis

Effect of various volume of reactants on Ag nanoparticles preparation was examined. Different volume of 10, 20, 30, 40 and 50 % plant extracts was added to 4 mM $AgNO_3$ aqueous solution at room temperature. The results were characterized using UV-Vis after 12 h. Fig.6 shows the UV-Vis spectra of AgNPs at different volume of CoffeA Arabica leaf extract (10-50 mL). The maximum absorbance occurs at 20 mL CoffeA Arabica leaf extract with narrow peak. The absorbance increases with increasing CoffeA Arabica leaf extract volume until the maximum was reached at 20 % then start to decrease from 30 – 50 mL UV-Vis spectra Fig.4 indicated that 20 % CoffeA Arabica leaf extract yielded best result. The optimal concentration of the reactant ratio was 1:4. The obtained results were assigned to Ag-NPs formation in 20 % CoffeA Arabica leaf extract similar findings were also reported by [26]. The stability of the colloidal solution was influenced by the absorbing species present and concentration of reducing agents [27].

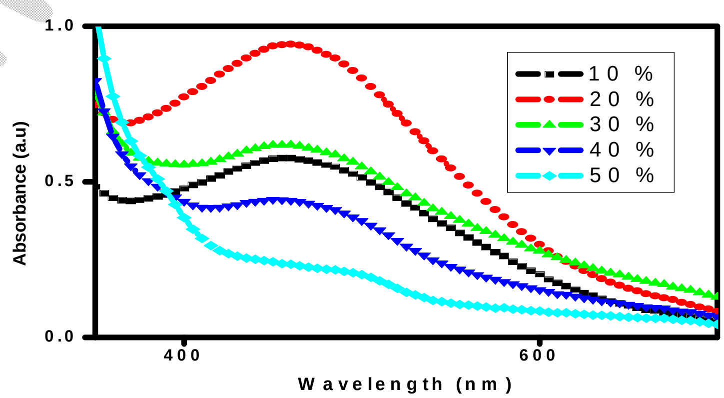

Fig. 6. UV-Vis absorption spectra of silver nanoparticles synthesized by CoffeA Arabica leaf extract at different ratio of reactants (v/v %)

3.1.7. Effect of Light on CoffeA Arabica leaf extract-AgNPs Synthesis

Effect of light on the rate of AgNPs synthesis clearly demonstrated better synthesis in daylight compared with other light sources such as moonlight and dark room. Sunlight was an essential source for the synthesis of the nanoparticles and the fast production of was under the help of daylight as photosensitization of the molecules present in the plant extract. Fig.4. shows the UV-Vis absorption spectra of synthesized AgNPs at different light sources. The reaction mixture did not show any color when kept overnight in dark and the synthesis was delayed, similar findings were reported by others [28]. Light is significantly executing for AgNPs green synthesis and the effect may vary species to species.

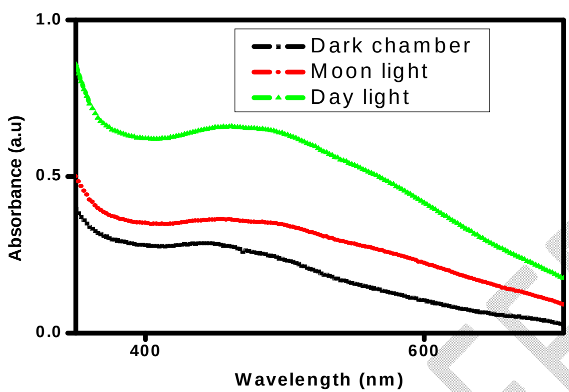

Fig. 7. UV-Vis absorption spectra of synthesized AgNPs at different light sources

3.2. FTIR Analysis

The FTIR spectra of CoffeA Arabica leaf extract and synthesized AgNPs is shown in Fig. 8. FTIR measurement of CoffeA Arabica leaf extract and synthesized AgNPs was carried out to identify the functional groups present on AgNPs and proteins surrounding AgNPs as stabilization agent. The sample contains alcoholic, phenolic and carboxylic groups indicating that intense broad band around 3440 cm^{-1}, corresponding to O–H stretching of hydroxyl group; moreover, primary and secondary amines as well as amides can be signified by N–H stretching vibrations. This band can be attributed to the non-dissociative adsorbed water molecules as well as the presence of N-H stretching can be clearly proven the presence of band at 1600 cm^{-1} due to the deformation vibration of water molecules. The peak around 1154 cm^{-1} is ascribed to C–N stretching vibration of aromatic primary and secondary amines and the bands at 900–700 cm^{-1} correspond to primary and secondary amines and amides (–NH_2 wagging). The presence of ketones, aldehydes, quinines and esters can be shown by the peaks around 1600 cm^{-1} assigned to the C=O vibration of carbonyl groups. The band at 2949 cm^{-1} is attributed to C–H stretching of alkanes. The band at 2310, 2154, 1377 and 1018 cm^{-1} assigned to strong stretching vibrations of C–N aromatic and aliphatic amines. The peak at 1600 cm^{-1} is assigned to C=C vibration of aromatic structure whereas, the peak at 1274 cm^{-1} is assigned to C–O stretching of phenolic groups. Another broad band centered around 1030 cm^{-1} is attributed to aromatic ethers and polysaccharides (C–O–C stretch) [29]. Carbonyl groups proposed the presence of OH functional groups and proteins show the presence of phenolic compounds in the CoffeA Arabica leaf extracts. After AgNPs formation, there are some shifts of valuable peaks such as the O–H vibration from 3449.96 cm^{-1} to 3448.75 cm^{-1}, N–H vibration from 2958.85 cm^{-1} to 2949.21 cm^{-1}, 2725.46 cm^{-1} to 2726..43 cm^{-1}, C–N vibration from 1456.28 cm^{-1} to 1458.21 cm^{-1} and 1154.42 cm^{-1} to 1153.45 cm^{-1}, disappearance of peaks 2154.52 cm^{-1} indicating that reduction occurred.

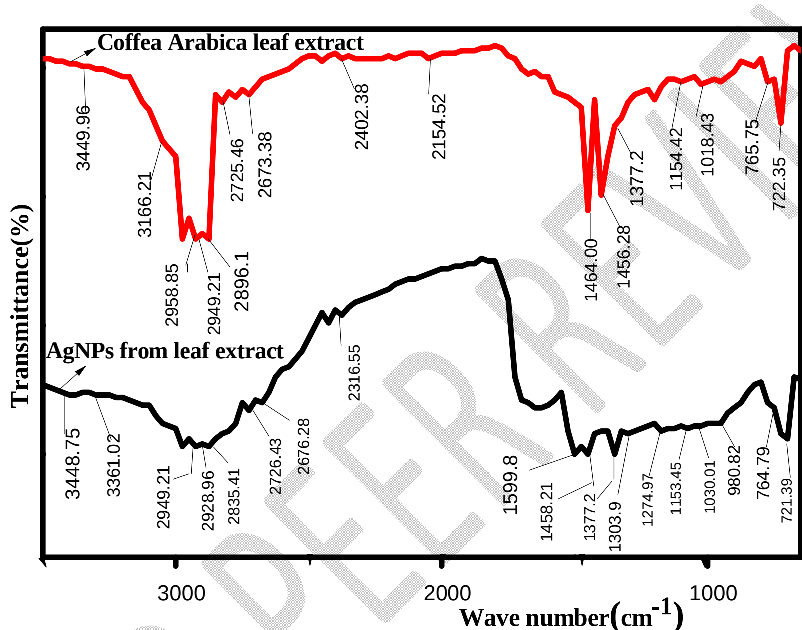

Fig. 8. FTIR spectra of CoffeA Arabica leaf extract and synthesized AgNPs capped with leaf extract

3.3. XRD Analysis

The XRD pattern of dried AgNPs synthesized using CoffeA Arabica leaf extract is shown in Fig. 9. The XRD pattern shows that, the structure of AgNPs is face-centered cubic [30]. The XRD analysis of synthesized silver nanoparticles has four peaks at 38.115°, 44.229°, 64.443°, 77.4° which corresponds to (1 1 1), (2 0 0), (2 2 0), (3 1 1) diffraction peaks. Sharp peak of (1 1 1) with high intensity was observed depicting thin film formation on the substrate. This agrees with what has been reported [31]. The sharp bands of Bragg's peak show that the particles are in Nano form and are stabilized by the reducing agents in the CoffeA Arabica leaf extract. Additionally, the Bragg's peak representation of silver nanocrystals, the XRD pattern also shows additional peaks due to the organic compounds present in the CoffeA Arabica leaf extract and responsible for silver reduction and stabilization of the resulting nanoparticles [32]. Hence from the XRD pattern, it is clear that silver nanoparticles formed by the reduction of Ag^{+} ions using the

CoffeA Arabica leaves extract were essentially crystalline. The crystallite size was calculated by using the Debye Scherer's formula [33].

$$d = \frac{K\lambda}{\beta\ Cos(\theta)} \qquad (3.1)$$

Where D is the average crystallite domain size perpendicular to the reflecting planes, k is Debye Scherer's constant taken as 0.9, λ is the X-ray wavelength 0.15406 nm used Cu-Kα, β is the full width at half maximum (FWHM), and θ is the diffraction angle. The average crystallite size according to Scherer's equation calculated was found to be 29.3 nm.

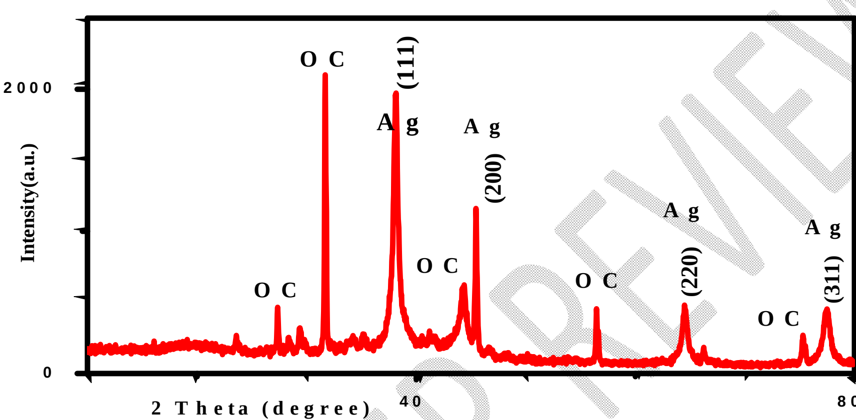

Fig. 9. X-ray diffraction pattern of as-synthesized AgNPs using CoffeA Arabica leaf Extract

3.4. Scanning Electron Microscopy (SEM) Analysis

The morphology of green synthesized siver nanoparticles was analyzed using FESEM as shown in Fig.4.. The FESEM image showed that silver nanoparticles formed were well dispersed with a spherical shape and some of these are oval and due to this shape, it is very difficult to measure its particle size. the biosynthesized silver nanoparticles were disperesed thoroughly in the solution according Saba et al, 2019 [34].

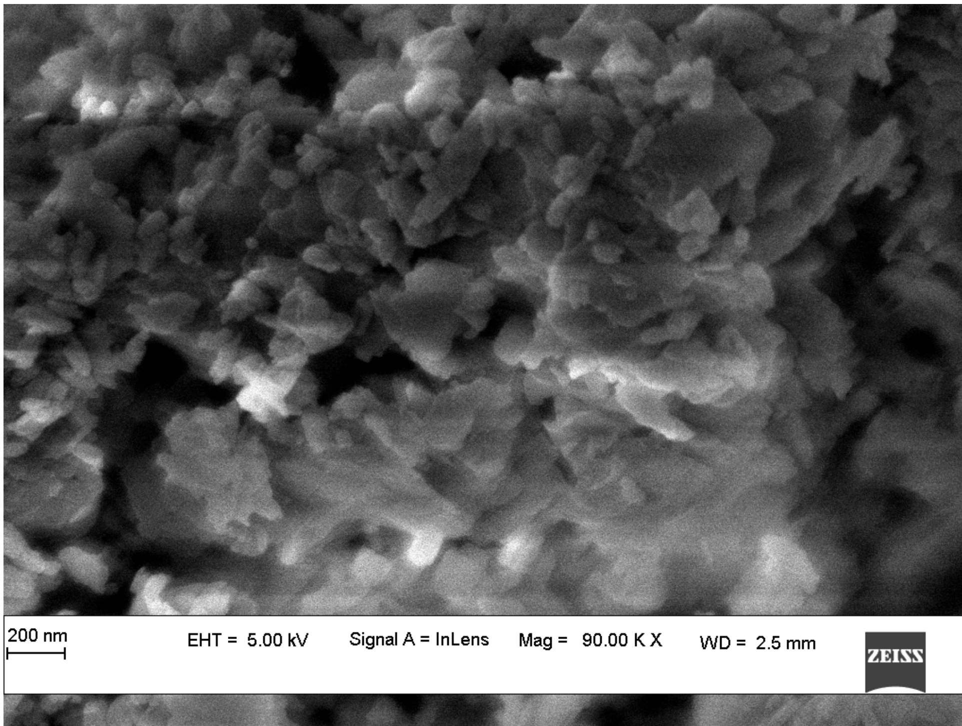

Fig. 10. SEM diagram of a-synthesized AgNPs using plant leaves extract

3.5. Atomic Absorption Spectroscopy

Fig. 11 shows graph of Ag^+ concentration in reaction mixture using AAS. AAS analysis was done for the reacting solution at regular time intervals and shown the conversion of Ag^+ ions into silver metal. Initially, standard solution of 5.0 ppm of $AgNO_3$ was prepared and analyzed using AAS at 0 min. Then, Ag^+ ion concentration in the reaction solution, after adding CoffeA Arabica leaf extract was monitored at regular time intervals (Document No. F5.08-3 and Job number; EAL-18N0577). The result shows that decreasing in concentration of Ag^+ ions 5.0, 4.05, 4.03, 4.01 and 2.93 ppm at 0, 5, 10, 15 and 20 min. respectively displaying the conversion of Ag^+ ion to Ag metal.

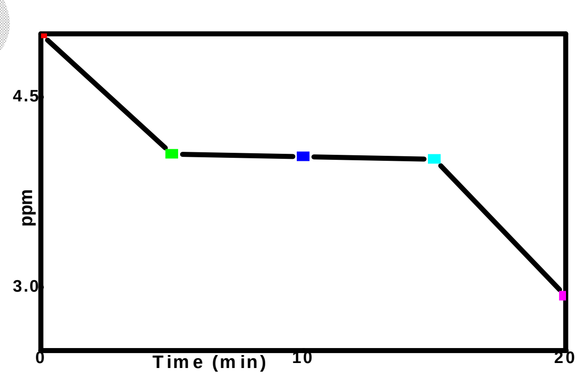

Fig. 11. Graph of Ag^+ concentration in reaction mixture using AAS

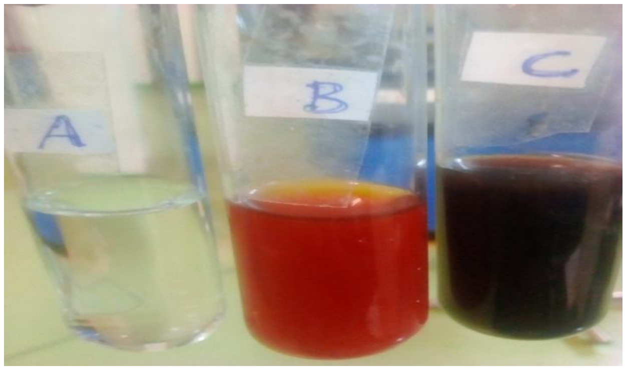

Fig. 12. Visual indication of synthesized AgNPs: A) 4mM $AgNO_3$ solution (colorless) B) aqueous extract of CoffeA Arabica leaves (yellowish brown) C) synthesized $AgNO_3$ (deep brown)

4. CONCLUSIONS

In conclusion, present study describes a rapid and eco-friendly synthesis of AgNPs using CoffeA Arabica leaf extract in single process via green Chemistry. We have successfully synthesized AgNPs using CoffeA Arabica leaf as a reductant and a capping or stabilizing agent through green chemistry. The optimum conditions for this process were a temperature of *80 °C*, pH 9, and reactant ratio 1:4. XRD results reveal that, the green synthesis yields stable, face centered cubic structure AgNPs with a sizes range of 39.664-24.708 nm. Preparation of AgNPs using plant extracts are eco-friendly, biocompatible and cost effective. Generally AgNPs have a vital role in different nanotechnology-based processes because of their unique characteristics and can be exploited on a large scale for medical application.

REFERENCES

[1] Benjamin G, Bharathwaj S. Biological synthesis of silver nanoparticles from Alliumcepa (onion) and estimating its antibacterial activity. International Conference on Bioscience, Biochemistry and Bioinformatics. 2011; 5:35-38.

[2] Galdiero S, Falanga A, Vitiello M, Marra V, Galdiero M. Silver nanoparticles as potential antiviral agents. Molecules. 2011; 16:8894-8918.

[3] Kairemo K, Ebra P, Bergstron K, Pauwels J. Nanoparticles in Cancer, Current radiopharmaceuticals. 2008; 1: 30-36.

[4] Hall W, Salome N, Richard P, Duyne V. LPSR biosensor signal enhancement using nanoparticles, Antibody Conjugate. Physical Chemistry. 2011; 115:11410-11414.

[5] Kharissova OV. The greener synthesis of nanoparticles. Trends in Biotechnology. 2013; 31:240-248.

[6] Roy S, Das TK. Plant mediated green synthesis of silver nanoparticles. A review International Journal of Plant Biology & Research. 2015; 3:1044-1055.

[7] Parashar K, Srivastava A. Parthenium leaf extract mediatedsynthesis of silver nanoparticles. Digest Journal of Nanomaterials and Biostructures. 2009; 4: 45-50.

[8] Johnson T, Hemen T, Efiong E, Eteng E. Evaluation of anti-nutrient contents of water melon (Citrullus lanatus). Annals of Biological Research. 2012; 3: 5145-5150.
[9] Ndikau M, Noah N, Masika E, Andala D. Green Synthesis and Characterization of Silver Nanoparticles Using Citrullus lanatus Fruit Rind Extract. International Journal of Analytical Chemistry. 2017; 1-9.
[10] Andrea R, David K. Biological activity of green-synthesized silver nanoparticles depends on the applied natural extracts: a comprehensive study, International Journal of Nanomedicine. 2017; 12: 871-883.
[11] Sharm G, Sharm AR, Kurian M. Green synthesis of silver nanoparticle using myristica fragrans (nutmeg) seed extract and its biological activity. Digest Journal of Nanomaterials and Biostructures. 2014; 9: 325-332.
[12] Mittal AK, Chisti Y, Banerjee UC. Synthesis of metallic nanoparticles using plant extracts. Biotechnology Advances. 2013; 31: 346-356.
[13] Bar H, Bhui DK, Sahoo GP, Sarkar P, Misra A. Green synthesis of silver nanoparticles: Physicochemical and Engineering Aspects. 2009; 348: 212-216.
[14] Mittal AK, Bhaumik J, Kumar S, Banerjee UC. Biosynthesis of silver nanoparticles: therapeutic potential. Journal of Colloid and Interface Science 2014; 415: 39-47.
[15] Anamika M, Sanjukta C, Prashant R, Geeta W. Evidence based green synthesis of nanoparticles. Advanced Materials Letters. 2012; 3: 519-525.
[16] Muhammad A, Farooq A, Muhammad R, Saeed A, Umer R. Green Synthesis of Silver Nanoparticles through Reduction with Solanum xanthocarpum L. Berry Extract: Characterization, Antimicrobial and Urease nhibitory Activities against Helicobacter pylori. International Journal of Molecular Sciences. 2012; 13: 9923-9941.
[17] Daizy P. Green synthesis of gold and silver nanoparticles using Hibiscus rosa sinensis. Physica E: Low-dimensional Systems and Nanostructures. 2010; 42: 1417-1424.
[18] Sathishkumar M, Sneha K, Won W, Cho W, Kim S, Yun YS. Cinnamon zeylanicum bark extract and powder mediated green synthesis of nanocrystalline silver particles and its bactericidal activity. Colloids and Surfaces. 2009; 73: 332-338.
[19] Thamer NA, Almashhedy LA. Green synthesis optimization and characterize of silver nanoparticles using aqueous extract of Crocus sativus. L. IJPBS, 2014; 5: 759-770.
[20] Sadowski IH, Maliszewska B, Grochowalska I, Polowczyk T, Kozlecki. Synthesis of silver nanoparticles using microorganisms. Materials Science. 2008; 26: 419-424.
[21] Mittal AK, Bhaumik J, Kumar S, Banerjee UC. Biosynthesis of silver nanoparticles: Elucidation of prospective mechanism and therapeutic potential. J. Colloid Interface Sci. 2014; 415: 39-47.
[22] Dubey SP, Lahtinen M, Sarkka H, Sillanpaa M. Bioprospective of Sorbus aucuparia leaf extract in development of silver and gold nanocolloids. Colloids Surf. B Biointerfaces. 2010; 80: 26-33.

[23] Rastogi L, Arunachalam J. Green synthesis route for the size controlled synthesis of biocompatible gold nanoparticles using aqueous extract of garlic (Allium sativum). Advances in Material Letters. 2013; 7:548-555.

[24] Subramanian R, Subbramaniyan P, Raj V. Antioxidant activity of the stem bark of Shorearox burghii and its silver reducing power. SpringerPlus. 2013; 2: 28.

[25] Dwivedi AD, Gopal K. Biosynthesis of silver and gold nanoparticles using Chenopodium album leaf extract. Colloids Surf. A. 2010; 369:27-33.

[26] Christensen L, Vivekanandhan S, Misra M, Mohanty AK. Biosynthesis of silver nanoparticles using Murraya koenigii (curry leaf): an investigation on the effect of broth concentration in reduction mechanism and particle size. Adv. Mat. Lett. 2011; 2: 429-434.

[27] Prathna TC, Chandrasekaran N, Raichur AM, Mukherjee A. Biomimetic synthesis of silver nanoparticles by Citrus limon (lemon) aqueous extract and theoretical prediction of particle size. Colloids Surf. B Biointerfaces. 2011; 82: 152-159.

[28] Rajoriya P, Misra P, Shukla PK, Ramteke PW. Light regulatory effect on the phytosynthesis of silver nanoparticles using aqueous extract of garlic (Allium sativum) and onion (Allium cepa) bulb. Curr. Sci. 2016; 111: 1364-1368.

[29] Szymczycha-Madeja A, Welna M, Zyrnicki W. Multi-element analysis, Bioavailability and fractionation of herbal tea products. J Brazil Chem Soc. 2013; 24:777-787.

[30] Shameli K, Ahmad MB, Yunus WMZW, Ibrahim NA. Synthesis and Characterization of silver/talc nanocomposites using the wet chemical reduction method. Int. J. Nanomed. 2010; 5, 743-751.

[31] Prasad T, Elumalai E. Bio fabrication of Ag nanoparticles using Moringa oleifera leaf extract and their antimicrobial activity. Asian Pacific Journal Tropical Biomedical, 2011; 1, 439-442.

[32] Alaraidh IA, Ibrahim MM, Arabia S, El-Gaaly GA. Evaluation of green synthesis of Ag nanoparticles using Eruca sativa and Spinacia oleracea leaf extracts and their antimicrobial activity. Iran. J. Biotech. 2014; 12: 50-55.

[33] Hoseyni F, Dowlatababdi GA, Maryam MS. Investigation of the antimicrobial effect of silver doped Zinc Oxide nanoparticles. Nanomed. J. 2017; 4: 50-54.

[34] Saba P, Maryam G, Saeid B, Green synthesis of silver nanoparticles using the plant extract of Salvia spinosa grown in vitro and their antibacterial activity assessment. Journal of Nanostructure in Chemistry. 2019; 9:1-9.