Annual Research & Review in Biology

35(7): 10-22, 2020; Article no.ARRB.58252
ISSN: 2347-565X, NLM ID: 101632869

Synthesis of Silver Nano Particles from *Adansonia digitata* Leaf Extract and Its Antimicrobial Properties

A. O. Akintola[1*], A. M. Azeez[2], B. D. Kehinde[3] and I. C. Oladipo[1]

[1]Department of Science Laboratory Technology, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.
[2]Department of Pure and Applied Biology, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.
[3]Department of Biochemistry, Faculty of Basic Medical Sciences, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors Author BDK designed the study. Author AOA wrote the protocol and wrote the first draft of the manuscript. Author AMA synthesized the nano particles. Author ICO managed the antimicriobial analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2020/v35i730243
Editor(s):
(1) Paola Angelini, University of Perugia, Italy.
Reviewers:
(1) Ivo Diego de Lima Silva, Federal University of Pernambuco, Brazil.
(2) Fadi Ibrahim, Saad bin-alrabee Alansari School, Kuwait.
(3) Hasta Handayani Idrus, Universitas Muslim Indonesia, Indonesia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/58252

Original Research Article

Received 08 May 2020
Accepted 13 July 2020
Published 27 July 2020

ABSTRACT

Silver nano particles (AgNPs) were green synthesized using *Adansonia digitata* leaf extract. The synthesized silver nano particles were characterized in terms of synthesis, size, shape, morphology and capping functionalities by UV-Visible Spectroscopy, Scanning Electron Microscopy (SEM) and Fourier Transform Infrared Spectroscopy (FTIR). Antimicrobial activity of the synthesized silver nano particles was investigated by well diffusion method. The antibacterial activity of the nano particle was studied against *Staphylococcus aureus*, *Escherichia coli*, *Bacillus subtilis, Pseudomonas aeurigunosa, Salmonella typhi* and *Klebsiella pneumonae* while the antifungal activity was studied against *Candida albicans*, *Aspergillus niger*, *Penicillum notatum* and *Rhizopus stolomifer*. The synthesized AgNPs was active against all the studied microorganisms. *Staphylococcus aureus* was the most susceptible bacterium (inhibition zones ranging from 12.00 to

**Corresponding author: E-mail: aoakintola@lautech.edu.ng;*

28.00 mm, MIC: 30 µl, MBC: 50 µl) while *Aspergillus niger* was the most susceptible fungi (inhibition zones ranging from 10.00 to 18.00 mm, MIC: 90 µl, MFC: 120 µl. In conclusion the synthesized silver nanoparticles was found to have antimicrobial activity against the pathogenic bacteria and fungi tested and hence has a great potential in biomedical application for the treatment of microbial infections.

Keywords: Silver nanoparticles; Adansonia digitata; antimicrobial activity; nano particles; methanolic extract.

1. INTRODUCTION

In recent years, transmission of infectious pathogens to the community has caused outbreak of diseases such as influenza, diarrhea, cholera etc. throughout the world [1]. These infectious diseases have not only occurred in developing countries with low levels of hygiene and sanitation but have also been recognized in developed countries. Food and water borne pathogens are the main factors for the outbreak of these diseases and the outbreak of re-emerging and emerging infectious diseases are a significant burden on global and public health [2]. Their emergence is thought to be driven largely by socio-economic, environmental and ecological factors. The comprehensive treatments of environments containing infectious pathogens using advanced disinfectant nanomaterials have been proposed for prevention of the outbreak [3,4]. Among these nanomaterials silver nanoparticles (AgNPs) with unique properties of high antimicrobial activity have attracted much interest from scientists and technologies to develop nanosilver based disinfectant products [5,6]. AgNPs have been synthesized by physio-chemical techniques such as chemical reduction [7], gamma ray radiation [8], micro emulsion [9], electrochemical method [10], laser ablation [11], autoclave [12], microwave [13] and photochemical reduction [14]. These methods have effective yield but they are associated with some limitations like use of toxic chemicals and high operational cost and energy needs [15,16]. Considering the drawbacks of physiochemical methods, cost effective and energy efficient new alternative for AgNPs synthesis using microorganisms [17], plant extracts [6] and natural polymers [18] as reducing and capping agents are emerging very fast. Several authors have used plant extracts, bacteria, fungi and algae for the synthesis of metal nanoparticles [19,20]. *Adansonia digitata* L is commonly known as Baobab tree native to Africa. Baobab is a multipurpose tree which offers protection and provides food clothing as well as raw materials for many useful items. The fruit pulp, seeds leaves, flowers, roots and bark of baobab are edible and they have been studied by scientists for their useful properties [21]. The fruit pulp have very high vitamin C, calcium, phosphorus, carbohydrates, fibers, potassium, proteins and lipid content which can be used in seasoning as an appetizer and also make juices [22,23,24]. Seeds contain appreciable quantities of phosphorus, magnesium, zinc, sodium,iron and high levels of lysine and thiamine [24]. Baobab has numerous biological properties including antioxidant, antimicrobial, antimalarial, diarrhea, anaemia, asthma and anti-inflammatory activities amongst others [25,26,27,28]. Currently there are no reports on the use of *Adansonia digitata* for the biosynthesis of silver nanoparticles. In this study, green synthesis of silver nanoparticles using the leaf extract of *Adansonia digitata* and evaluation of its antimicrobial activity against various human pathogenic bacteria and fungi was reported.

2. MATERIALS AND METHODS

2.1 Reagents

All reagents were of analytical grade and obtained from Sigma-Aldrich Chemical, Germany.

2.2 Plant Materials

Fresh leaves of *Adansonia digitata* were collected from Ladoke Akintola University of Technology, Ogbomoso school farm. The plant was authenticated at the botanical unit of the Department of Pure and Applied Biology, Ladoke Akintola University of Technology, Ogbomoso by Prof. Ogun Kunle with voucher number LHO 544. Healthy leaves with no sign of damage were air dried under shade at temperature of 35°C and relative humidity of 44.6% for four weeks before being pulverized into powdery form.

Fig. 1. *Adansonia digitata* plant

2.3 Microorganisms

The microorganisms used in this study were clinical isolates obtained from the Department of Pharmaceutical Microbiology, University of Ibadan. The organisms were maintained on agar slant at 4°C and subcultured on a fresh appropriate agar slant, 24 hours prior to the antimicrobial test. Two Gram-positive bacteria: *Staphylococcus aureus*, *Bacillus subtilis;* four Gram-negative bacteria: *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Klebsiella pneumonae* and four fungi: *Candida albicans, Aspergillus niger*, *Penicillum notatum* and *Rhizopus stolomifer* were used for the bioassay.

2.4 Preparation of Plant Extract

Two kilogrammes of the pulverized material was soaked in 6.0 litres of methanol for two weeks. After soaking period, the liquid portion was separated from the shaft with the aid of Whatman (No1) filter paper and the filtrate was concentrated using a rotary evaporator (Hitech Model 7811000) at the rotation speed of 50-160 rpm and pressure 400-600 mmHg. This technique helps to remove the methanol from the extract completely thereby eliminating solvent associated toxicity. Before it was finally dried on a water bath at 45°C to obtain a dry residue which is the crude methanolic extract (yield weight 110 g) which was stored in a dessicator until used.

2.5 Phytochemical Screening

The methanolic extract was screened for the presence or absence of alkaloids, saponins, tannins, flavonoids, steroids and phenols using standard methods [29,30].

2.6 Synthesis of Silver Nanoparticle

0.2 g of the powdered extract was suspended in 20 ml of distilled water and centrifuge at 4000 rpm for 20 min. The supernatant obtained was used to synthesize silver nanoparticles as described by [31]. About ImL of the supernatant was added to the reaction vessel containing 40 ml of 1 mM silver nitrate (AgNO3) solution for the reduction of silver ion. The reaction was carried out in static condition at room temperature (30 ± 2°C) for 2 hrs. The formation of silver nanoparticles was monitored through visual observation of the change of colour and measurement of the absorbance spectrum of the reaction mixture using UV-Visible spectrophotometer while deionized water was used as blank.

2.7 Characterization of Silver Nanoparticle

2.7.1 UV-visible spectroscopy analysis

The formation of silver nanoparticles by the reduction of the aqueous silver ion during exposure of *Adansonia digitata* methanolic leaf extract was monitored by UV-VIS spectroscopy. The reduction of silver ions was monitored from 200 – 900 nm using UV-VIS spectrophotometer (UV – 2450 Shimadzu). The spectrum data recorded was then plotted.

2.7.2 FTIR analysis

Fourier transform infrared spectroscopy (FTIR) was employed to detect organic compound present in the leaf extract that was responsible for the reduction of silver ions to form silver nanoparticles and for stabilization of the

nanoparticle. The emission spectrum was recorded using an LF-45 fluorescence spectrophotometer Shimadzu IR Prestige FTIR instrument in the wavelength range 4000 – 500 cm^{-1} and scanned four times.

2.7.3 SEM analysis

Scanning electron microscopy micrograph was obtained using a Hitachi scanning electron microscope (model S-2600N, Tokyo, Japan) operating in the high vacuum anode with an acceleration voltage of 20KV byafilter paper soaked in the silver nano particle solution.

2.7.4 Antimicrobial assay

The assessment of antimicrobial activity of the synthesized silver nanoparticles was carried out using the well diffusion method [32]. Two gram-positive bacteria, four gram-negative bacteria and six fungi were used for the bioassay. The bacteria cultures were inoculated in nutrient broth and incubated for 24 hours at 37°C while the fungal cultures were inoculated on potato dextrose agar and incubated for 48 hours at 28°C. From freshly cultured bacteria and fungal colonies, 100 µl of the inoculum were taken and spread on Mueller Hinton agar plates. A sterile cork borer was then used to create wells (6 mm diameter) for different concentration of the synthesized silver nanoparticle. Using a micropipette, 30 µl, 60 µl, 90 µl, 120 µl, 150 µl and 180 µl of the nanoparticle solution samples were poured into the wells on all plates. Wells containing standard antimicrobials: Gentamycins (10 µg/ml) and Tiaconazole (70%w/v) were included to serve as positive control. A 0.5 ml portion of sterile methanol was introduced into another well to serve as negative control. The bacteria plates were incubated at 37°C for 24 hours while the fungal plates were incubated at 28°C for 48 hours. After incubation, the plates were examined for the presence of zone of inhibition, indicated by clear zone around the wells and the diameters of zones were measured.

2.7.5 Determination of minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC) and minimum fungicidal concentration (MFC)

MIC, MBC and MFC were determined using the agar dilution method [33]. For the bacterial and fungal isolates, 30 µl, 60 µl, 90 µl, 120 µl, 150 µl and 180 µl of the silver nanoparticles were separately added to 18 mL of agar in test tubes. Then 1 mL of 18 hours old of each bacterial and fungal cultures earlier adjusted at 10^{-7} CFU/mL was added to each test tube. For bacteria cultures, the tubes were incubated at 37°C for 24 hours while for fungal cultures, the tubes were incubated at 28°C for 48 hours and observed for growth in form of turbidity. The lowest concentration of nanoparticles that produced no visible bacterial and fungal growth (no turbidity) by visual inspection was considered the MIC. The MBC and MFC were determined by removing 100 µl of bacterial and fungal suspension from MIC tube that did not show any growth and subcultured onto Mueller Hinton agar plates and incubated at 37°C for 24 hours for bacterial cultures and 28°C for 48 hours for fungal cultures. After incubation, the concentration at which no visible growth was seen was recorded as the MBC or MFC.

3. RESULTS

3.1 Phytochemical Screening

Qualitative phytochemical screening revealed the presence of alkaloids, flavonoids, phenols, saponins, tannins and steroids.

3.2 Visual Inspection

Preliminary identification of nanoparticles formation was carried out by observing the colour change of the reaction solution. The formation of silver nanoparticles by leaf methanolic extract of *Adansonia digitata* was facilitated within a period of 10 minutes, with the colour stabilizing within 20 minutes. The colour of the solution changed from light yellow to dark brown after 20 minutes of addition of the extract to silver solution (Fig. 2) suggesting the formation of silver nanoparticles. Synthesised silver nanoparticles exhibit dark-yellowish-brown colour due to thesurface plasmon resonance phenomenon.

3.3 UV-Visible Spectroscopy

The reduction of Ag^{+} into Ag particles was further confirmed using UV-VIS spectroscopy. (Fig. 3) depicts the UV-VIS spectrum of the synthesized silver nanoparticles from *Adansonia digitata* extract. Absorption spectrum of the silver nanoparticle formed in the reaction medium has absorbance peak at 418 nm which is a characteristics band for silver. No other peak was observed in the spectrum which confirms that the synthesized products were silver nanoparticles.

(a) (b)

Fig. 2. Colour change in the reaction mixture (silver nitrate + *Andansonia digitata* extract)
(a) Colour of the mixture after mixing the extract with silver nitrate solution (b) Colour change of the mixture after 20 minutes

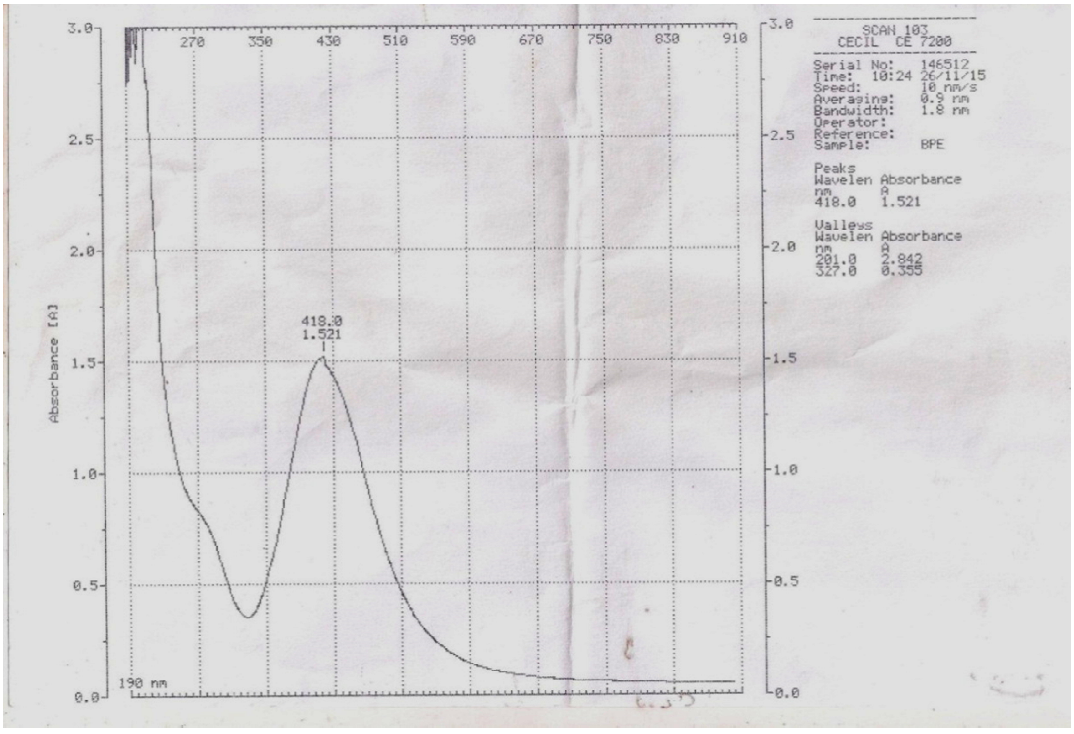


Fig. 3. UV-VIS spectrum of silver nanoparticles synthesised from methanolic leaf extract of *Adansonia digitata*

3.4 Fourier Transform Infrared Spectroscopy (FTIR)

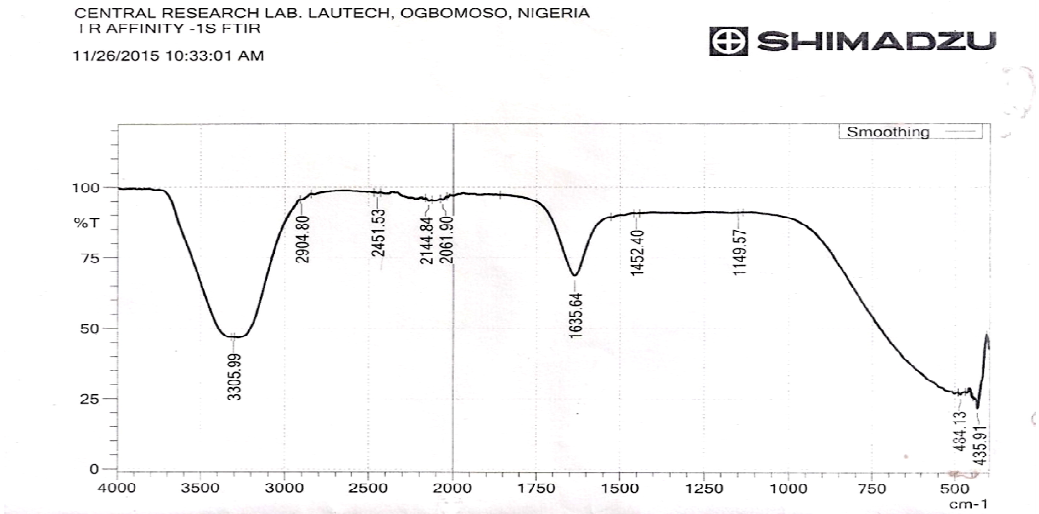
FTIR measurement was carried out in order to identify the presence of various functional groups in the biomolecules responsible for the bioreduction of Ag^+ and capping/stabilization of silver nanoparticles (Fig. 4). The observed intense bands were compared with standard values to identify the functional groups. FTIR spectrum showed absorption bands at 3305.39, 2904.80, 2451.53, 2144.84, 2061.90, 1635.64, 1452.40, 1149.57, 484.13 and 435.91 cm^{-1} indicating the presence of capping agent with the nanoparticle. The bands at 3305.39 cm^{-1} correspond to O-H stretching from the secondary amine. Bands at 2904.80, 2451.53, 2144.84 and 2061.90 cm^{-1} arising from C – H stretching of aromatic compounds. The band at 1635.64 cm^{-1} in the spectrum corresponds to N-H [34]. The band at 1452.40 cm^{-1} was assigned for N – H stretch vibration present in the amide linkage of protein. The band at 1149.54 cm^{-1} exemplifies C – O – C stretching typical of propionates and higher esters. Band at 484.13 and 435.91 cm^{-1} might be attributed to C – H stretching of the aromatic compounds. The number of scan was 4 for the functional groups. From the FTIR study, it may be concluded that protein could play the role of reducing and capping agents resulting in the formation of silver nanoparticles in the medium.

3.5 Scanning Electron Microscopy (SEM)

SEM revealed information about the size, shape and morphology of the synthesized silver nanoparticles. The SEM image showed relatively spherical shaped nanoparticles with diameter range of 40 – 50 nm (Fig. 5). Better resolution studies with SEM analysis provides further insight into the size, shape and percentage presence of AgNP in the reaction medium. SEM analysis at 300 nm shows the AgNP are spherical in shape having size range from 12-14 nm [34].

3.6 Antimicrobial Study

Table 1 depicts the result of the antimicrobial screening of the silver nanoparticle synthesized from *Adansonia digitata.* In this study, the synthesized silver nanoparticle was evaluated against ten microorganisms: Six bacteria and four fungi. It was observed that the synthesized silver nanoparticle was active against all the studied microorganisms with bacteria being more



	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area	Comment
1	435.91	21.55	10.71	447.49	408.91	2666.945	224.151	
2	484.13	26.49	0.91	491.85	470.63	1547.259	7.182	
3	1149.57	90.95	0.01	1151.50	1136.07	139.166	0.193	
4	1452.40	90.70	0.05	1460.11	1442.75	161.049	0.472	
5	1635.64	68.58	23.39	1859.38	1527.62	4223.896	2025.286	
6	2061.90	95.47	0.71	2075.41	2036.83	153.366	10.760	
7	2144.84	95.18	0.66	2164.13	2127.48	163.354	11.686	
8	2451.53	97.91	0.22	2468.88	2432.24	72.596	3.091	
9	2904.80	95.64	0.21	2910.58	2846.93	223.812	11.163	
10	3305.99	46.79	0.07	3317.56	3300.20	923.114	0.656	

Fig. 4. FTIR spectrum of silver nanoparticles synthesized from methanolic leaf extract of *Adansonia digitata*

Table 1. Antimicrobial activity of silver nanoparticles synthesized from methanolic leaf extract of *Adansonia digitata* diameter of zone of inhibition (mm)

Conc. (µl)	*S. aureus*	*E. coli*	*B. subtilis*	*P. aeuriginosa*	*S. typhi*	*K. pneumonae*	*C. albicans*	*A. niger*	*R. stolomifer*	*P. notatum*
180	28	20	24	26	24	20	18	18	16	18
150	26	18	20	22	20	18	16	16	14	16
120	24	16	18	18	16	16	14	14	12	12
90	16	14	14	14	14	14	12	12	10	10
60	14	12	12	12	12	12	10	10	-	-
30	12	10	10	10	10	10	-	-	-	-
Gentamycin							-	-	-	-
(10µg/ml)	38	38	40	40	40	40	-	-	-	-
Tiaconazole										
(70% w/v)	-	-	-	-	-	-	28	28	26	28
Methanol	-	-	-	-	-	-	-	-	-	-

means no zone of inhibition

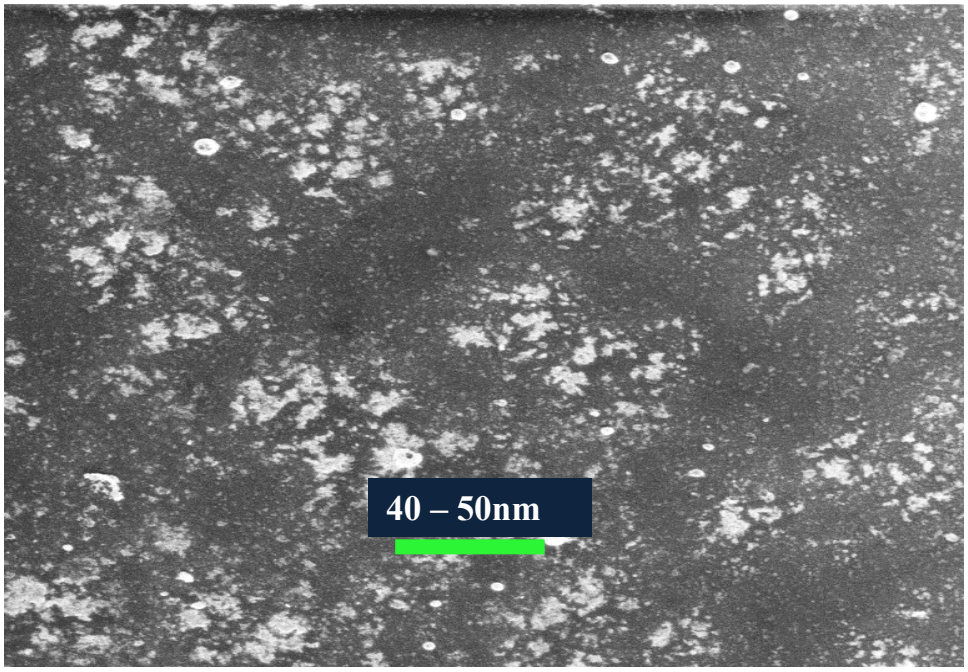


Fig. 5. SEM image of silver nanoparticles synthesized from methanolic leaf extract of *Adansonia digitatata*

susceptible than the fungi. *Staphylococcus aureus* was the most susceptible bacteria of all the tested bacteria with inhibition zones ranging from 12.00 to 28.00 mm while *Candida albicans* and *Aspergillus niger* were the most susceptible fungi with inhibition zones ranging from 10.00 to 18.00 mm. Result of the minimum inhibitory concentration (MIC), Minimum bactericidal concentration (MBC) and minimum fungicidal concentration (MFC) of the synthesized silver nanoparticles from *Adansonia digitata* leaf extract are presented in Table 2. The synthesized silver nanoparticles demonstrated good antimicrobial activity with the MIC value against the bacteria ranging from 30 µl to 120 µl, MIC for the fungal was 100 µl. The synthesized silver nanoparticle showed the lowest MIC against *Staphylococcus aureus* (30 µl). The broadest activity of the silver nanoparticle against most of the tested bacteria was 90 µl as MIC while broadest activity of 150 µl was recorded against most fungi tested. The silver nanoparticle synthesized from methanolic extract of *Adansonia digitata* also showed bactericidal and fungicidal activities on the bacteria and fungi isolates with *Staphylococcus aureus* being the susceptible microorganism. At a small concentration of 90µl, the synthesized silver nanoparticle was able to kill the organism. These findings are in agreement with previous studies that examine the antimicrobial activity of silver nanoparticles against many human pathogens [35,36]. Introduction of silver into bacteria cells induces a high degree of structural and morphological changes which can lead to cell death. As the silver nanoparticles come in contact with the bacteria, they adhere to the cell wall and cell membrane [37]. Once bound, some of the silver passes through to the inside and interacts with phosphate containing compounds like DNA and RNA while another portion adheres to the sulphur-containing proteins on the membrane. The silver-sulphur interactions at the membrane cause the cell wall to undergo structural changes like the formation of pits and pores [38]. Through these pores, cellular compounds are released into the extracellular fluid simply due to the osmotic difference. Within the cell, the integration of silver creates a low molecular weight region where DNA then condenses [38]. Having DNA in a condensed state inhibits the cells replication proteins contact with the DNA. Thus the introduction of silver nanoparticles inhibits replication and is sufficient to cause death of the cell [39]. This has been correlated to the suppression of enzymes and inhibited expression of proteins that relate to the cell's ability to produce ATP. Although, it varies from every type of the cell proposed, as their membrane composition varies greatly. It has

been seen that in general, silver nanoparticles with an average size of 10 µm or less show electronic effect that greatly increase their bactericidal activity [40]. This could be partly due to the surface area to the volume ratio. The formation of free radicals by the silver nanoparticles may be considered to be another mechanism by which the cell dies (Fig. 6). Some studies suggested that there is formation of free radicals by the silver nanoparticles when in contact with the bacteria and these free radicals have the ability to damage the cell membrane and make it porous which can ultimately lead to cell death [41,42]. It has also been proposed that there can be release of silver ions by the nanoparticles [43] and these ions can interact with the thiol groups of many vital enzymes and inactivate them [44]. The bacteria cells in contact with silver take in silver ions which inhibit several functions in the cell and damage the cells. Then there is generation of reactive oxygen species which are produced possibly through the inhibition of respiratory enzyme by the silver ions and attack the cell. Silver is a soft acid and there is a natural tendency of an acid to react with a soft base [45]. The cells are majorly made up of sulfur and phosphorus which are soft bases. The action of these nanoparticles on the cell can cause the reaction to take place and subsequently lead to a death. Another fact is that the DNA has sulphur and phosphorus as its major components, the nanoparticles can act on the soft bases and destroy the DNA which would definitely lead to cell death. The interaction of the silver nanoparticles with the sulfur and phosphorus of the DNA can lead to problems in the DNA replication of the bacteria and thus terminate the microbes. It has also been found that the nanoparticles can modulate the signal transduction in bacteria. It is a well established fact that phosphorylation of protein substrate in bacteria influences bacteria signal transduction. Dephosphrelyation is noted only in tyrosine residue of Gram-negative bacteria. The phosphotyrosine profile of bacteria peptides is altered by the nanoparticle. It was found that the nanoparticles dephosphorylated the peptide substrate on tyrosine residues which lead to signal transduction inhibition and thus the stoppage of growth. It has been noted that silver nanoparticles establish synergistic activity with common antibiotics already in use today such as

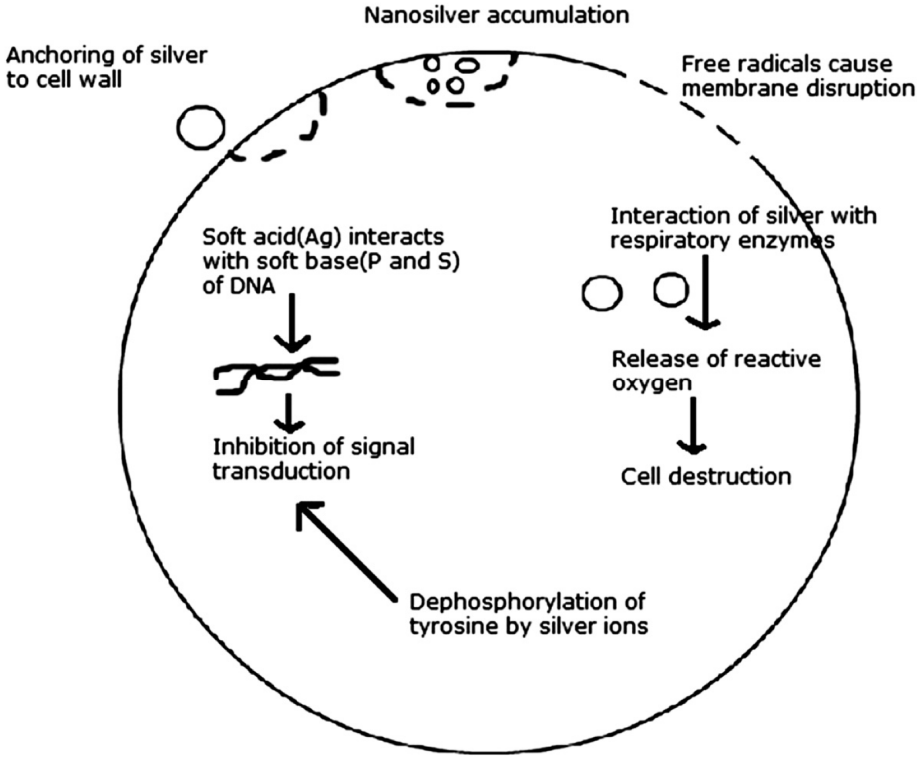


Fig. 6. How silver nanoparticles kill bacteria

Table 2. Minimum inhibitory concentration (MIC), mimimum bactericidal concentration (MBC) and Minimum fungicidal concentration of the silver nanoparticles synthesised from methanolic leaf extract of *Adansonia digitata*

Test organisms	MIC (µl)	MBC/MFC (µl)
Staphylococcus aureus	30	90
Escherichia coli	90	120
Bacillus subtilis	90	120
Pseudomonas aeruginosa	90	120
Salmonella typhi	90	120
Klbesiellapneumonae	90	150
Candida albicans	120	150
Aspergillusniger	90	120
Penicilliumnotatum	120	150
Rhizopusstolomifer	120	150

penicillin G, ampicillin, erythromycin, chindamycin and vanomycin against *E. coli* and *Staphylococcus aureus* [46]. Silver nanoparticles can prevent bacteria from growing on or adhering to the surface. This can be useful in surgical setting where all surfaces in contact with the patient must be sterile. Interestingly, silver nanoparticles can be incorporated in materials used for coating many type of surfaces including metals, plastics and glass [47]. In medical equipments, it has been shown that silver nanoparticles lower the bacterial count on devices used compared to the old techniques. Silver nanoparticles are more commonly used in skin graft for burn victims as the silver nanoparticle embedded with the graft provide better antimicrobial activity and result in significantly less scarring of the victim. Now silver nanoparticles are used in bandages and patches to help heal certain burns and wounds.

4. CONCLUSION

This study reported that silver nanoparticles were green synthesized by simple efficient and ecofriendly method using the leaf extract of *Adansonia digitata*. The leaf extract contains reducing agents (mainly protein) that reduces silver ions and formed silver nanoparticles and this was confirmed by UV-VIS and FTIR studies. The biologically synthesized silver nanoparticles inhibited the growth of all the tested microorganism and hence could be of immense use in medical field as a potential antimicrobial agent.

ACKNOWLEDGEMENT

The authors wish to appreciate the support of Prof. A. Lateef of the Department Of Pure And Applied Biology, LAUTECH, Ogbomoso, who is currently the Head of Nanotechnology Research Group, LAUTECH, Ogbomoso for assistance rendered during the synthesis of the nanoparticle and also Davejosh Global Resource Laboratory, Oyo State, Nigeria for the support during the analysis of the research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Rasko DA, Webster DR, Sahi JIN, Bashir A, Boisen N, Scheutz F, Paxinos EE, Sobra R, Chin CS, Illopolos D, Klammer A, Peluso P, Lee L, Kislyuk AO, Bullar J, Kasarshis A, Wang S, Eld J, Rank D, Rodman JC, Steyert SR, Frimodt-Moller J, Struve C, Peterson AM, Knogfelt KA, Nataro JP, Schadt EE, Waldor M. Origin of *E. coli* strain causing an outbreak of hemolytic-uremic syndrome in Germany. N. Engl J. Med. 2011;365(8):709–717.
2. Jones KE, Patel NG, Levy MA, Storeygard A, Balik D, Gultterron JL, Daszak P. Global trends in emerging infections diseases. Nature. 2008;45(718):990–993.
3. Erick Taylor, Thomas Webster. Reducing infections through nanotechnology and nano particles. International Journal of Nanomedicine. 2011;6:1463–1473.
4. Xi Zhu, Aleksandar F, Radovic Moreno, Jun Wu, Robert Langer, Jinjin Shi. Nanomedicine in the management of microbial infection – overview and perspectives. Nanotoday. 2013;9(4):478-498.

5. Saxena A, Tripathi RM, Singh RP. Biological synthesis of silver nanoparticles using onion (*Allium cepa*) extract and their antibacterial activity. Digital Journal of Nanometer Bioscience. 2010;5(2):1427.
6. Elumalai EK, Prasad TNVKV, Hemachandran J, Theresa SV, Thirumalai TDE. Extracellular synthesis of silver nanoparticles using leaves of *Euphorbia hirta* and their antibacterial activities. Journal of Pharmacology Science and Research. 2010;2(9):549–554.
7. Khan Z, Al Thabati SA, Oband AY, Al-Youbi. Preparation and characterization of silver nanoparticles by chemical reduction methods. Colloids and Surfaces B. Biointerfaces. 2011;82:513–517.
8. Chen P, Song LY, Linn YK. Synthesis of silver nanoparticles by gamma-ray irradiation in acetic water solution containing chitosain. Radiation Physics and Chemistry. 2007;76:1165–1168.
9. Zhang WZ, Qiao XL, Chen JG. Synthesis and characterization of silver nanoparticles in AOT micro emulsion system. Chemical Physics. 2006;30:495–500.
10. Reicha FM, Sarhan A, Abdul-Hamid MI, El-sherbiny IM. Preparation of silver nanoparticles in the presence of chitosan by electrochemical method. Carbohydrate Polymers. 2012;89:236–244.
11. Abid JP, Wark AW, Brevertim DF, Girault HH. Preparation of silver nanoparticles in solution from a silver salt by laser irradiation. Chemical Communications. 2002;7:792–793.
12. Yang J, Pan J. Hydrothermal synthesis of silver nanoparticles by sodium alginate and their application in surface enhanced Raman scattering and catalysis. Acta Materialia. 2012;60:4753–4758.
13. Khan A, El-Toni AM, Alrokayan S, Alsalhi M, Allhasan M, Aldiva Yan AS. Microwave assisted synthesis of silver nanoparticles using poly-N-isopropylacrylamide /acrylic acid microgel particles. Colloids and Surfaces A. Physicochemical and Engineering Aspects. 2011;377–360.
14. Alarcin EI, Udekwu K, Skog M, Pacioni NL, StamplecosKic KG, Gonzalez Bejar. The biocompatibility and antibacterial properties of collagen-stabilised photo chemically prepared silver nanoparticles. Biomaterials. 2012;33:4947–4956.
15. Esumi K, Hosoya T, Suzuki A, Torigoe K. Formation of gold and silver nanoparticles in aqueous solution of sugar – substituted poly (amidoamine) dendrimers. J Colloid InterfSci. 2000;226:346–352.
16. Bakshi MS, Possmayer F, Peterson NO. Aqueous phase room temperature synthesis of gold nanaribbons: Soft templat effect of a Gemini surfactant. J. PhyChemC. 2008;112:8259–8265.
17. Sharma VK, RA, Linn YY. Silver nanoparticles: Green synthesis and their antimicrobial activities. Advances in Colloid and Interface Science. 2009;145:83.
18. Huang H, Yang X. Synthesis of polysaccharide – stabilized gold and silver nanoparticles. A green method carbohydrate research. 2004;330:2627–2631.
19. Lateef A, Azeez MA, Asafa TB, Yekeen TA, Akinboro A, Oladipo IC, Ajetomobi FE, Gueguim – Kana, Beukes LS. *Cola nitida* mediated biogenic synthesis of silver nanoparticles using seed and seed shell extracts and evaluation of antibacterial activities. BioNano Science. 2015;5:196-205.
20. Rajeshkumar S, Ponnanikajamideen M, Malarkodi C, Malini M, Annadurai G. Microbe mediated synthesis of antimicrobial semiconductor nanoparticles by marine bacteria. Journal of Nanostructure and Chemistry. 2014;4:96-102.
21. Simon Jackson. Baobab: The tree of life. An ethnopharmacological review. Herbal Gram. The Journal of the American Botanical Council. 2015;108:42–53.
22. Food Standards Agency, McCance, Widdowson's. The composition of foods. Royal Society of Chemistry: 6th Ed. Cambridge, UK; 2002.
23. Sidibe M, Williams JT. Baobab. *Adansonia digitata*. International Centre for Underutilised Crops: Southampton, UK; 2002.
24. Chadare F, Linneman A, Hounhouigan J, Nout M, Van Boekel MA. Baobab food products: A review on their composition and nutritional value. Critical Review of Food Science Nutrition. 2009;49(3):254–274.
25. Hussain HSN, Deeni YY. Plants in Kano ethnomedicine: Screening for antimicrobial activity and alkaloids. International Journal of Pharmacognosy. 1991;29(1):51–56.
26. Vertuani S, Braccioli E, Buzzoni V, Manfredini S. Antioxidant capacity of

Adansonia digitata fruit pulp and leaves. Acta Physiotherapeutica. 2002;2. Available:www.baobabfruitcom/pdf/Pdf/2008

27. Vimalanathan S, Hudson J. Multiple inflammatory and antiviral activities in *Adansonia digitata* (Baobab) leaves, fruits and seeds. Journal of Medicinal Plant Research. 2009;3(8):576–582.
28. Kabore D, Sawadogo – Lingani H, Diawara B, Compaore CS, Dicko MH, Jakobsen M. A review of baobab (*Adansonia digitata*) products: Effect of processing techniques, medicinal properties and uses. African Journal of Food Science. 2011;5(16):833–844.
29. Banso A, Ngbede. Phytochemical screening and *in vitro* antifungal properties of *Fagara zanthoxyloides*. Journal of Food and Agric. 2006;3,41:8–9.
30. Ngbede J, Yakubu RA, Nyam DA. Phytochemical screening for active compounds in *Camarium schl vein* furthil (Atile) leaves from Jos North, Plateau State, Nigeria. Research Journal of Biological Science. 2008;3(9):1076–1078.
31. Lateef A, Ojo SA, Azeez MA, Asafa TB, Yekeen TA, Akinboro A, Oladipo IC. Cobweb as novel biomaterial for the green and ecofriendly synthesis of silver nanoparticles. Applied Nanoscience. 2016;6(6):863–874.
32. Lino A, Deogracious O. The *In-vitro* antibacterial activity of *Annona senegalensis*, *Securidacca longipendiculata* and *Steanotaeniaaralliacea* Uganda medicinal plants. African Health Sciences. 2006;6(1):31–35.
33. Oyeleke SB, Dauda BEN, Boye OA. Antibacterial activity of *Ficus capensis.* African Journal of Biotechnology. 2005;7(10):1414–1417.
34. Chennareddy M, Kesava K, Pulicherla Y, Nataru S. *Adansonia digitalia* leaf extract mediated synthesis of silver nanoparticles; characterization and antimicrobial studies. Journals of Applied Pharmaceutical Science. 2015;5(08):082-089.
35. Kaushik R, Sarkar CK, Ghosh CK. Plant – mediated synthesis of silver nanoparticles using Parsely (*Petroselinum crispum*) leaf extract: Spectral analysis of the particles and antibacterial study. Applied Nanoscience. 2015;5:945–941.
36. Wael Mahmoud, Ahmed M, Elazzazy, Enas ND. *In vitro* evaluation, biochemical antimicrobial properties of biosynthesized silver nanoparticles against multidrug – resistant bacteria pathogens. Biotechnology and Biotechnological Equipment. 2009;31(2):373–379.
37. Klasen HJ. A historical review of the use of silver in the treatment of burns. Burns. 2000;26(2):117–130.
38. Feng QL, Wu J, Chen GO, Cui FZ, Kim TN, Kim JO. A mechanistic study of the antibacterial effect of silver ions on *Escherichia coli* and *Straphylococcus aureus*. J. Biomed. Mater Res. 2000;52(4):662–668.
39. Chen CW, Hsu CY, Lai SM. Metal nano bullets for multidrug resistant bacteria and biofilms. Advance Drug Delivery Review; 2014.
40. Pal Sukdeb, Tak Yukyung, Song JoonMyong. Does the antibacterial activity of silver nanoparticles depend on the shape of the nanoparticle? A study of the gram-negative bacterium *Escherichia coli*. Applied and Environmental Microbiology. 2007;73(6):1712–1720.
41. Danilclauk M, Lund A, Saldo J, Yamada H, Michalik J. Conduction electron spin resonance of small silver particles. Spectrochimata Acta Part A. 2006;63:189–191.
42. Kim J, Kuk E, Yu K, Kim JH, Park SJ, Lee HJ, Kim SH, Park YK, Park YH, Hwang CY, Kim YK, Lee YS, Jeong DH, Cho MH. Antimicrobial effects of silver nanoparticles. Nanomedicine. 2007;3:95–101.
43. Feng QL, Wu J, Chen GO, Cui FZ, Kim TN, Kim JO. A mechanistic study of the antibacterial effect of silver ions on *E. coli* and *Staphylococcus aureus*. J. Biomed. Mater. Res. 2008;52:662–668.
44. Matsumura Y, Yoshikata, Kunisaki S, Tsuchido T. Mode of bacterial action of silver zeolite and its comparison with that of silver nitrate. Appl. Environ. Microbiol. 2003;69:4278–4281.
45. Morones JR, Elechignerra JL, Camacho A, Holt K, Kouri JB, Ramirez JT, Yacaman MJ. The bactericidal effect of silver nanoparticles. Nanotechnology. 2005;16: 2346–2353.
46. Shahverdi Ahmad R, Fakhimi Ali, Shahverdi Hamid Q, Minaicin Sara. Synthesis and effect of silver nanoparticles on the antibacterial activity of different

antibiotics against *Staphylococcus aureus* and *Escherichia coli*. Nanomedicine. 2007;3(2):168–171.

47. Kee Jo Yur, Hyun SeoJeong, Choi Bong-Hyuk, Jin Kim Bum, Hui Shin Hwa, Hee Hwang Byeong, Joon Cha Hyung. Surface independent antibacterial coating using silver nanoparticles generating engineered mussel glue. Acs Applied Materials and Interface. 2014;6:20242–20253.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/58252