BIOSYNTHESIS OF SILVER NANOPARTICLES USING *CYNARA SCOLYMUS, LAVANDULA ANGUSTIFOLIA, ALKANNA TINCTORIA* AND ITS ANTIMICROBIAL ACTIVITIES—A COMPARATIVE STUDY

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ABSTRACT

Nanotechnology is a promising field of science that implicates use of nano size particle which anchors a prominent place in various biomedical applications. Silver is known for its antimicrobial nature. This study elucidates the qualitative phytochemical properties of three plant extracts and utilizing it in biosynthesis of silver nanoparticles. Green Silver nanoparticles (AgNPs) were synthesized from 1mM Silver Nitrate ($AgNO_3$) solution incubated with leaf extracts of Cynara scolymus (Artichoke), Alkanna tinctoria (Alkanet), and Lavandula angustifolia (Lavender), respectively. The synthesized nanoparticles were characterized visually, UV-Vis spectrophotometer and using X-ray diffraction (XRD). We further determined antimicrobial activity of these biogenic nanoparticles against pathogenic bacterial strains (Staphylococcus aureus, and Escherichia coli) and Plant pathogenic fungal strains (Aspergillus flavus and Aspergillus niger). Our results confirmed the formation of AgNPs with size <100 nm. Antibacterial activity of lavender mediated AgNP was highly significant, followed by artichoke mediated AgNP and Alkanet AgNP. However, in contrast, Artichoke mediated AgNP showed significant activity against plant fungal strains, followed by Alkanet AgNP, and finally by Lavender mediated AgNPs. We concluded that the three plants have versatile biochemical molecules responsible for wide range of AgNP and its activity against bacterial and fungal strains. Studies on combined use of AgNPs with other antimicrobial agents may solve the problem of toxicity and possible risk of drug resistance.

KEYWORDS: Silver nanoparticles, Antimicrobial activity, Medicinal Plants, phytochemical contents

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INTRODUCTION

Nanotechnology is an interdisciplinary research area responsible for creating diverse nanomaterials with wide applications in pharmaceutics, medical sciences, drug and gene delivery, cosmetic industries, food industries, chemical industries, and space industries (Abdel-Aziz *et al.,* 2014). Nanoparticles are known by their precise dimensions and accuracy. They have defined structures with sizes ranging from 1nm to 100nm. Nanoparticles are attractive resources in creating novel structures and facilitating its incorporation into biological systems. The extraordinary surface area to volume ratio of nanoparticles enforces higher reactivity than macro-size particles. Biologically synthesized nanoparticles are dynamic and depend on type of plant species, plant parts (root, stem, leaf, seed, flower etc.). The plants are the reservoirs of many vital secondary metabolites such as alkaloids, flavonoids, terpenoids, tannins, phenols, saponins, proteins, carbohydrates, and oils. These molecules possess numerous therapeutic properties and antimicrobial activities (Jain *et al.,* 2009). Metabolites extracted from plants act as reducing and stabilizing agents in the synthesis of nanoparticles. Plant mediated nanoparticles have high reputation in recent times due to their non-toxic nature, and high efficiency in biomedicines (Abdel-Aziz *et al.,* 2014).

Silver nanoparticles (AgNPs) are recognized for their uniqueness and diverse properties such as optical features, chemical stability, good conductivity, catalytic activity, electrical and thermal properties enabling their incorporation into various products. Silver nanoparticles have widely been used as antimicrobials agents due to their biocidal effect against pathogenic microorganisms and responsible for disrupting their cytoplasmic membrane, disturbing their enzymatic activities leading to its destruction. The use of silver nanoparticles as antimicrobial coatings in many textiles and fabrics, such as wound dressings, topical creams, antiseptic sprays, and biomedical devices involves continuous release of silver ions in lower levels to protect against microbial infection (Iravani *et al.,* 2014). Recently, plants are utilized in synthesizing nanoparticles by exploiting its secondary metabolites. In this study we comparatively analysed the antimicrobial activity of three biogenic silver nanoparticles using *Cynara scolymus* (Artichoke), *Alkanna Tinctoria* (Alkanet), and *Lavandula angustifolia* (Lavender) and tested its antibacterial activity (*S. aureus* and *E. coli)* and antifungal activity (*A. niger* and *A. flavus)*.

METHODOLOGY

Collection of Plant Materials

Two medicinal plants *Cynara scolymus* (Artichoke) leaves, *Lavandula angustifolia* (Lavender) leaves and a weed *Alkanna Tinctoria* (Alkanet) leaves were obtained from Baluchistan Agriculture and Research Development Centre (BARDC) Quetta. The plants were washed thoroughly thrice with normal tap water to remove dust and soil residues and further washed using distilled water to remove remaining debris. The fresh and clean plants were shade dried for 10–15 days and then finely ground using pestle and mortal.

Plant extract

The leaves extract for each plant was prepared using 5 grams of dried powdered plant leaves separately in 100 mL Erlenmeyer flask containing 50 mL of distilled water. The flask was heated at 58-60°C temperature in water bath for approximately 5 hours before decanting it. The resulting solution was filtered using 0.45µm Whatman filter paper and the extract was cooled and stored at 4^{o}C in fridge for future use (Qayyum *et al.,* 2020).

Detection of phytoconstituents:

The qualitative detection of phytoconstituents present in the extracts was also performed using standard protocols (Banu *et al.,* 2015)

Detection of Oils and Resins: Spot test: The synthesized leave extracts for plants were applied individually on filter paper. The extracts were then allowed to settle on filter paper (Banu *et al.,* 2015).

Test for Protein: Ninhydrin Test was used to estimate proteins. In controls extract was added with distilled water. About 2 ml of respective extracts were treated with 0.2 % Ninhydrin solution and heated for 5-10 minutes (Banu *et al.,* 2015).

Test for Phenol: Ferric Chloride ($FeCl_3$) Test determines presence of phenol. The controls, containing plant extracts were treated with distilled water. About 2ml of the respective plant extract were treated with 2ml of distilled water followed by adding 10% $FeCl_3$ solution into the mixture (Banu *et al.,* 2015).

Test for Saponin: Foam Test: About 2 ml of extract was taken in a test tube and 10 ml of distilled water was added and shaken vigorously (Banu *et al.,* 2015).

Test for Tannin: $FeCl_3$ Test: Around 2 ml of 5 % $FeCl_3$ solution was added in 2 ml of plant extracts individually (Banu *et al.,* 2015).

Detection of Flavonoids: Sulphuric Acid (H_2SO_4) Test: Plant extracts were treated with few drops of concentrated H_2SO_4 (Banu *et al.,* 2015).

Detection of Terpenoids: Salkowski s Test: About 5 ml of extract was mixed with two ml of chloroform and 3ml of concentrated H_2SO_4 to form a layer (Banu *et al.,* 2015).

Test for Alkaloid: Hager's Test: To execute this test a saturated solution of picric acid was prepared and added carefully in respective plant extracts, the solutions were then allowed to settle down (Banu *et al.,* 2015).

Test for carbohydrates: Benedict's Test: The three crude extracts when mixed with 2ml of Benedict's reagent and boiled until precipitates are formed (Banu *et al.,* 2015).

Synthesis of silver nanoparticle:

Approximately, 1mM concentration of $AgNO_3$ was used for synthesis of silver nanoparticles. To synthesize silver nanoparticles, 10 mL of the plant extract was taken in a burette and added drop by drop in 20 mL aqueous solution of 1mM $AgNO_3$ in a beaker covered with aluminium foil to prevent photodegradation, while keeping the beaker on the magnetic stirrer at room temperature for 2 hours respectively. The same procedure was done for all three plants to synthesize nanoparticles.

Characterization of Silver nanoparticles

Visual characterization

The synthesized silver nanoparticles were monitored constantly to assure reduction of Ag+ ions to Ag particles until the colour shifts was observed (Ahmed *et al.,* 2016).

UV-VIS Spectrophotometric analysis

The final extract containing silver nanoparticles was characterized using UV-VIS spectrophotometer (Jenway, Model no. 6305). The colloidal solution of silver nanoparticles was monitored at a wavelength ranging from 300-600nm. The initial and final reading was taken to ensure successful reduction of silver ion to silver particles (Ponarulselvam *et al.,* 2012).

X-Ray Diffraction

The silver nanoparticles were also characterized using XRD (Bruker, 2nd Generation, D2, and Phaser) which was conducted by Department of Petroleum and Gas Engineering BUITEMS. For XRD, dry powder of green nanoparticles was confirmed and matched with standard (JCPDS file No. 04-0783) of silver nanoparticles.

Antibacterial activity

The activity of all three biogenic silver nanoparticles were determined against gram-positive bacteria (*Staphylococcus aureus*) and gram-

negative bacteria (*Escherichia coli*). The identified bacterial strains were obtained from Sardar Bahadur Khan Women University. The bacterial strains were inoculated with 10mL of nutrient broth and incubated at 37°C for 24 hours. The inoculum grown overnight was matched with 0.5 McFarland solution and 100 µL of respective bacterial strains containing 10^5 CFU/mL were cultured onto Müller-Hinton Agar (MHA). The activity of silver nanoparticles was identified using four wells onto the media plate. Each well containing 100 µL (50 mg/mL) of plant extract, 100 µL of water distilled water, 100 µL (1mM) $AgNO_3$ and 50 µL (0.2 mM) silver nanoparticles, respectively. This method was repeated for all three biogenic AgNPs with three replicates in each batch. The plates were incubated at 37° C overnight and results were analysed after 18 hours of incubation (Gajbhiye *et al.,* 2009). Zone of inhibition was measured in cm using a scale.

Antifungal activity

We further determined the antifungal activity of biogenic silver nanoparticles against plant pathogenic fungal strains (*Aspergillus flavus* and *Aspergillus niger).* The fungal strains were obtained from Agriculture College Quetta and cultured onto Potato-dextrose agar for 48 hours at 24°C. The respective strain was picked and dissolve in 1ml sterile distilled water. About 50 µL of respective fungal strains containing 10^5 CFU/mL were cultured on Potato-Dextrose agar. To elucidate the activity of silver nanoparticle four wells were made with 100 µL (50 mg/mL) plant extract, 100 µL distilled water, 100 µL (1mM) silver nitrate and 50 µL (0.2 mM) silver nanoparticles, respectively. The plates were incubated at 24°C overnight and results were checked after 48 hours of incubation. This process was repeated for each biogenic AgNP synthesized using Lavender, Artichoke, and Alkanet with each batch containing three replicates. The zone of inhibition was measured in cm using a scale.

Statistical Analysis

The results for the zone of inhibition for bacterial and fungal strains in cm were analysed using GraphPad prism. The data were expressed in mean ± standard deviation (version 5.01).

RESULTS AND DISCUSSION

Qualitative analysis of phytochemical constituents

Plants are reservoirs of many essential metabolites. The presence of phytochemicals present in the extracts were analysed using different standard protocols. The oil and resin test were performed using spot tests by applying the extract on filter paper. The transparent colour was an indication of oil and resin in all the tested extracts (Banu *et al.,* 2015) (See figure no. 1). Ninhydrin test confirmed the presence of proteins in the extracts. The extract's colour changed to dark blue which indicated the presence of proteins and amino acids (Banu *et al.,* 2015) (See figure no. 2). $FeCl_3$ test confirmed the presence of phenols in all extracts. The control extracts remained unchanged, while extracts treated with phenol transformed to bluish-black which implies the presence of phenols (Banu *et al.,* 2015) (See figure no. 3). The foam test confirmed the occurrence of saponins in the respective extracts. Formation of foam upon shaking illustrated the presence of saponins while controls remain unchanged (Banu *et al.,* 2015) (See figure no. 4). $FeCl_3$ test confirmed the presence of tannins in the respective extracts. The extracts were positive for tannins as indicated by dark blue to greenish-black colour (Banu *et al.,* 2015) (See figure no. 5). The presence of flavonoids was elucidated using a sulfuric acid test. The controls remained unchanged. Whereas the tested extracts showed positive results by changing the colour to dark orange (Banu *et al.,* 2015) (See figure no. 6). These plant metabolites play vital role in reducing Ag ions into Ag particle. These components act as reducing and stabilizing agent which encapsulates the ions after the reaction. Salkowski's test confirmed the

presence of terpenoids in the respective extracts. All the three tested extracts were positive as indicated by appearance of reddish-brown coloration at the interface (Banu *et al.,* 2015) (See figure no. 7). Similarly, Hager's test confirmed the presence of alkaloids in the respective extracts as indicated by appearance of orange to yellow colour precipitates (Banu *et al.,* 2015) (See figure no. 8). Benedict's test confirms the presence of carbohydrates in the respective extracts. The controls remained unchanged whereas the tested extracts were positive as indicated by appearance of greenish-brown color. (Banu *et al.,* 2015) (See figure no. 9). Medicinal plants have been used for thousands of years and owe their importance in the field of research and medicine. They have been widely used as a traditional medicine to treat various infections. The effectiveness of medicinal plants is evident from their universal use. Nanoparticles are synthesized using medicinal plants are preferred due to their low-cost, eco-friendly, and non-toxic nature (Saji *et al.,* 2010).

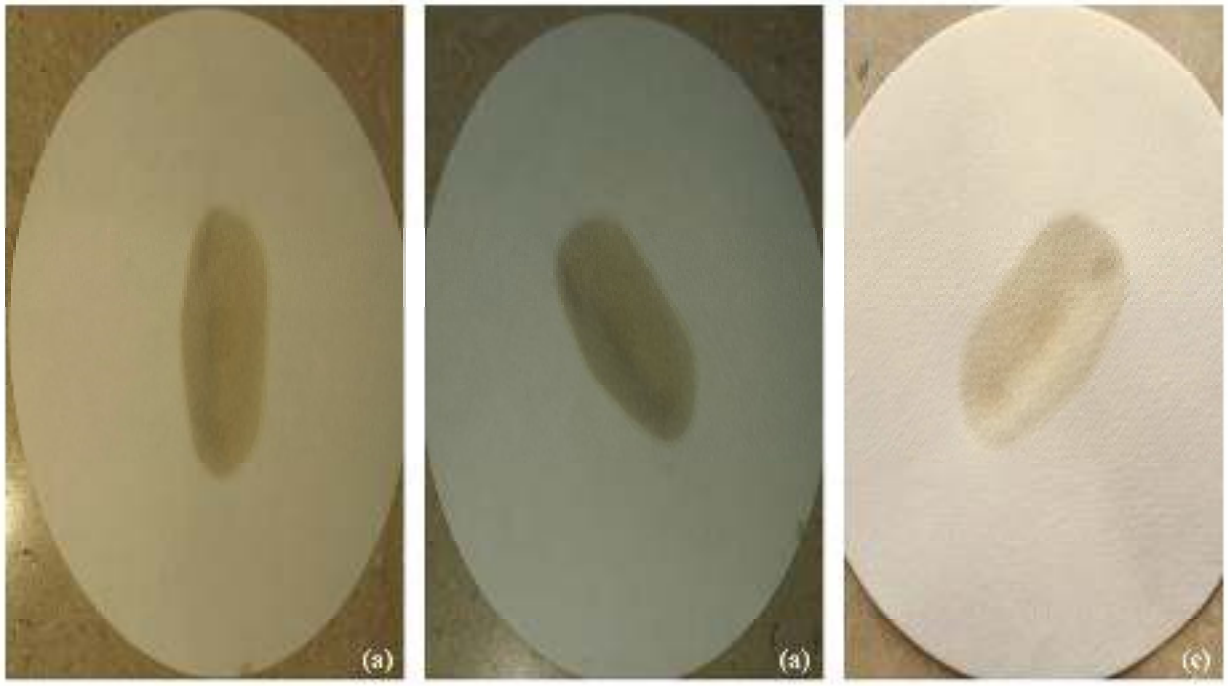

Figure No. 1 Oil and Resins Test. The transparent color is an indication of oil and resins (a) artichoke (b) lavender (c) alkanet.

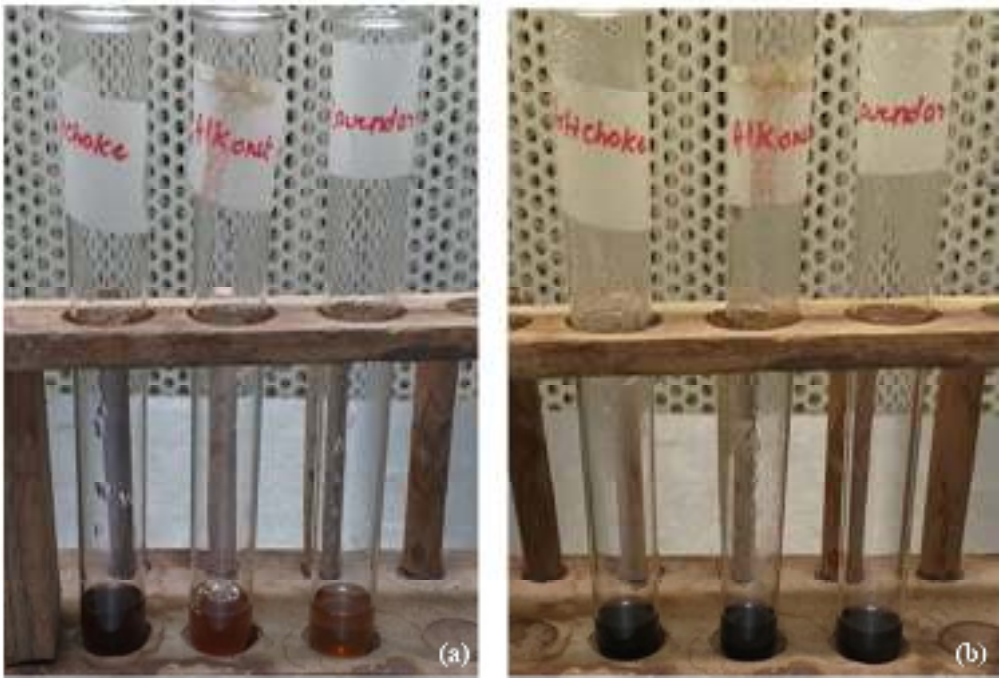

Figure No. 2. Ninhydrin test. (a) shows Ninhydrin test control for artichoke, lavender, alkanet. (b) showed dark blue color in respective plants which indicates presence of proteins and amino acids**.**

Figure No. 3. Presence of Phenols. (a) control for artichoke, lavender, alkanet. **(b) Indicates the** the extracts were positive for the presence of phenols in respective plants.

Figure No. 4. Presence of saponins. The test confirmed the presence of saponins in all extracts as indicated by foam in top layer.

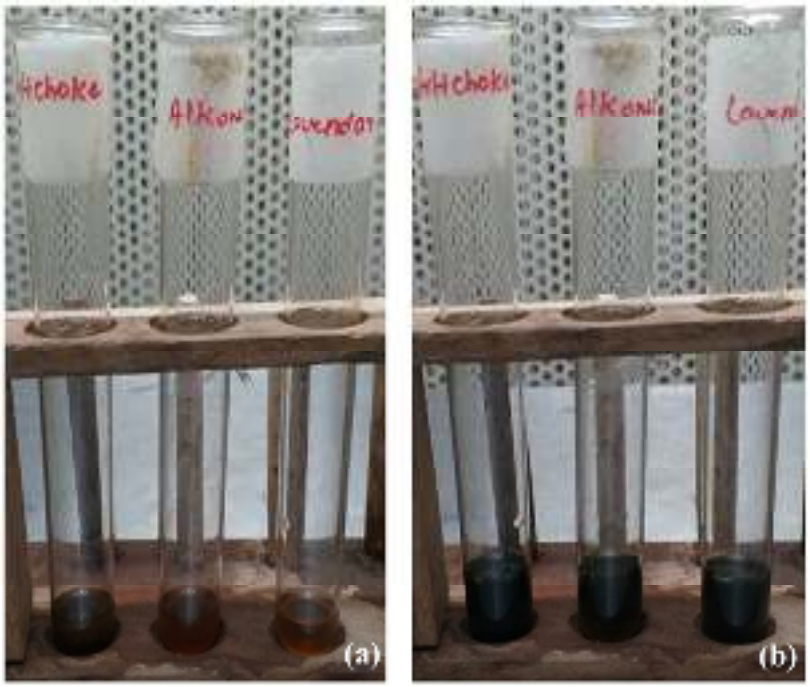

Figure No. 5. Presence of tannins. (a) controls for tannin tests. (b) The plant extracts (artichoke, lavender, alkanet) were positive for tannins as indicated by colour change.

Figure No. 6. Presence of flavonoids. (a) Controls for artichoke, lavender, alkanet (b) the test confirmed presence of flavonoids in the respective extracts.

Figure No. 7. Presence of terpenoids. (a) controls for artichoke, lavender and alkanet extracts. (b) Salkowski's test confirmed presence of terpenoids in the respective extracts.

Figure No. 8. Presence of Alkaloids. (a) controls for artichoke, lavender, and alkanet extract (b) Hager's test confirmed the presence of Alkaloids in the respective extracts.

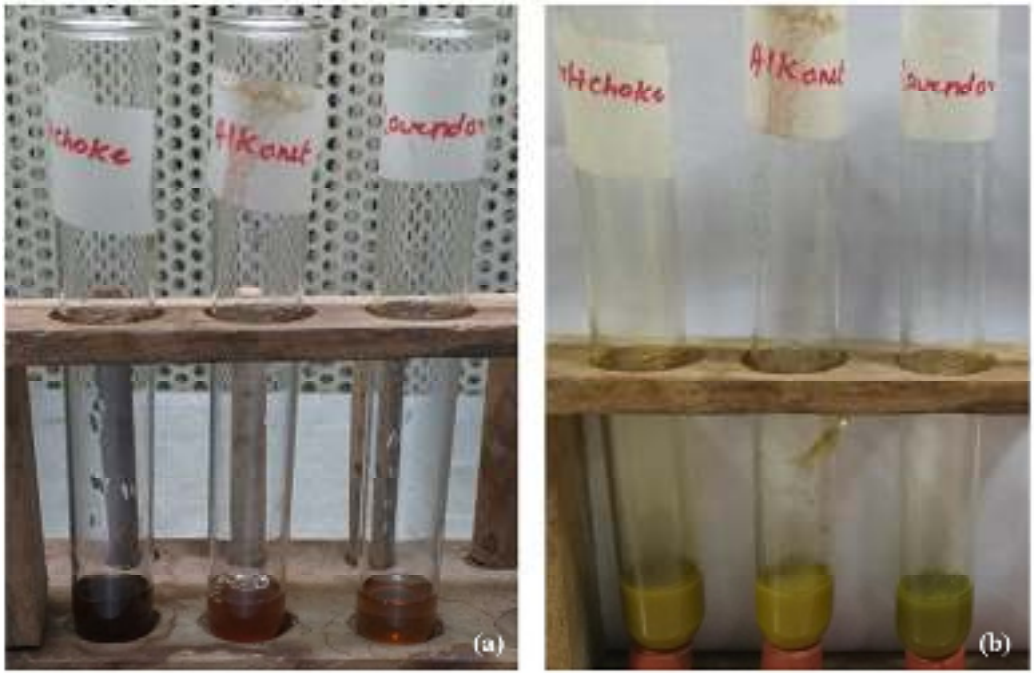

Figure No. 9. Presence of carbohydrates. (a) controls for artichoke, lavender, alkanet extracts. (b) Benedict's test confirms the presence of carbohydrates in the respective extracts.

Characterization of silver nanoparticles

The $AgNO_3$ solution was utilized to synthesize nanoparticles using plant extracts. The reaction mixture changed from pale-yellow or yellow-orange to brown due to excitation of surface plasmon vibrations of silver particles (see

figure No. 10). This colour change reflects the successful synthesis of silver nanoparticles (Veerasamy *et al.,* 2011). Plant extract comprises of reducing agents such as flavanones, phenolics, and terpenoids known to reduce silver ions to silver nanoparticles. A similar study conducted on rosemary mediated synthesis of silver nanoparticles showed chemical components such as: caffeic acids, phenolic compounds, hydrocinnamic acids and rosemarinic acid involve in reducing Ag+ to Ag particle due to high scavenging ability to suppress the formation of free radicals (Qayyum *et al.,* 2020).

UV-Vis spectrophotometer was used to characterize silver nanoparticles. The reduction of silver ions to Ag^{o} particle was confirmed by a sharp peak around 400nm for respective solutions (see figure No. 11). A similar study by Erdogan *et al* (2019) demonstrated change in colour of reaction due to the excitation of surface plasmon on metal (silver) nanoparticles. Whereas brown-orange colour of the silver nanoparticle colloidal solution was apparent and confirmed AgNP synthesis. This characteristic peak around 400–450 nm is specific for AgNPs confirming the synthesis of AgNPs owing to its range of surface plasmon resonance (SPR) (Saji *et al.,* 2010).

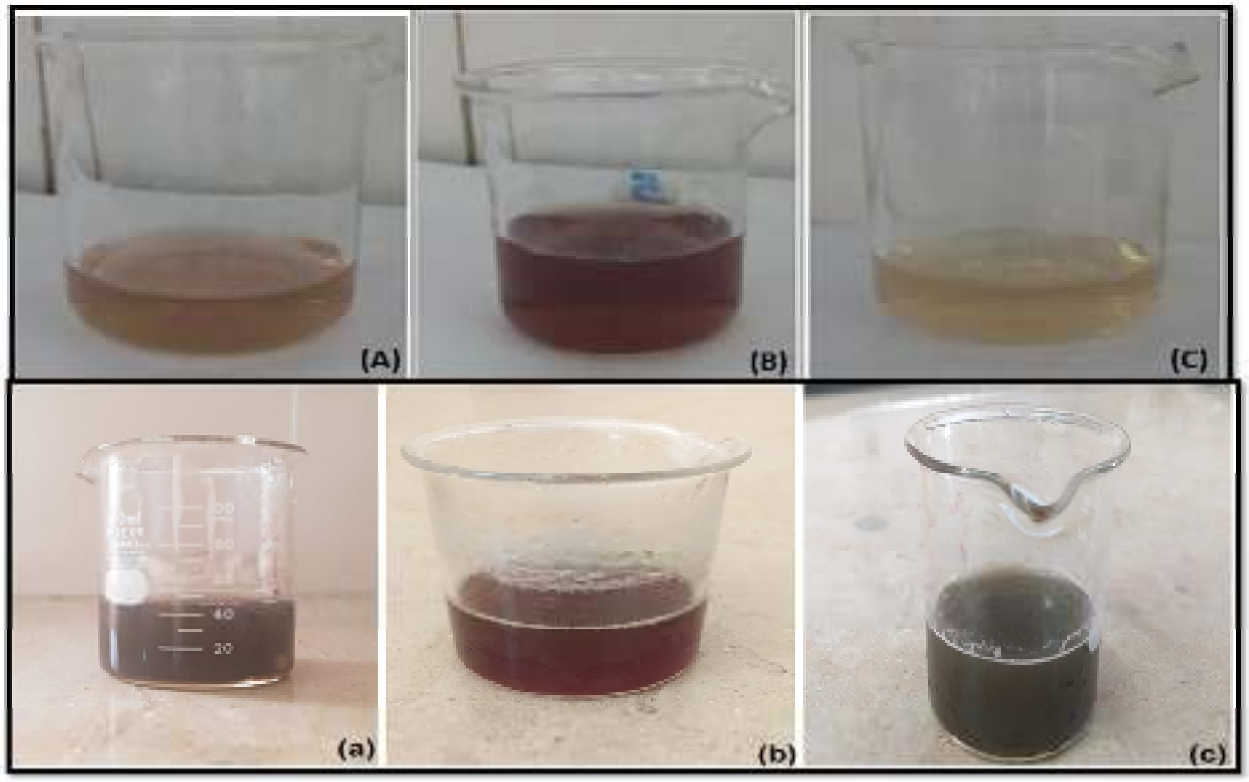

Figure. No. 10. Visual characterization of silver nanoparticles using plant extracts. Observing color change of (A) Artichoke extract to (a) Artichoke mediated silver nanoparticle, (B) Alkanet leaves extract mediated synthesis of (b) biogenic alkanet silver nanoparticle as observed by brown color of final solution (C) lavender extract converts from light yellow extract to dark brown in color of (c) solution which confirms synthesis of silver nanoparticle.

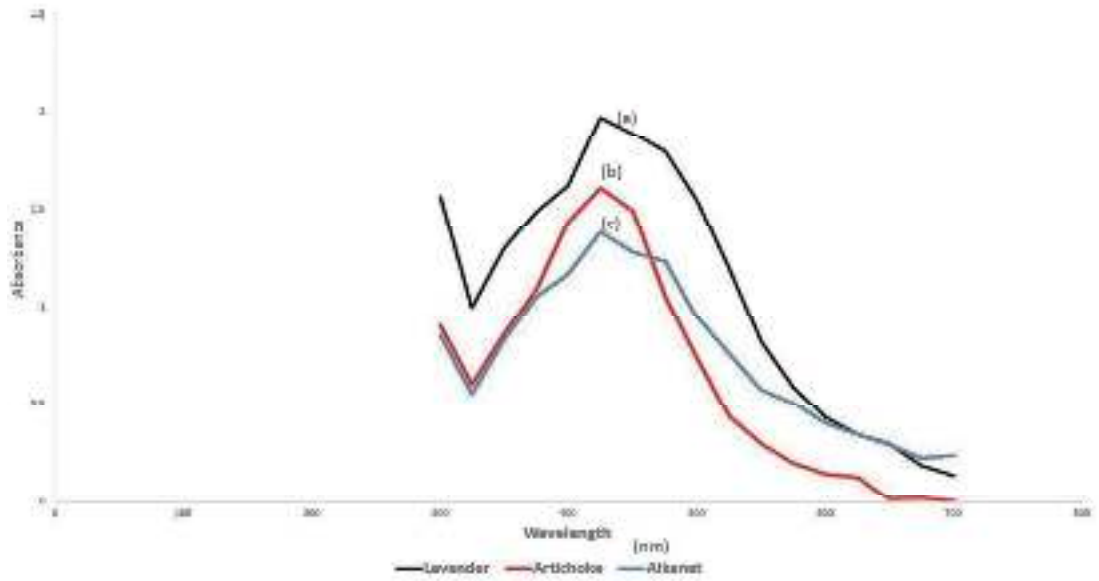

Figure. No. 11. Characterization of Silver nanoparticles using UV-VIS spectrophotometer. The colloidal solution of silver nanoparticles for respective solution was measured between 300nm to 600nm. The spectrum for (a) Lavender mediated silver nanoparticles showed peak between 320 to 370nm, (b) Artichoke mediated silver nanoparticles showed peak between 320 to 350nm and (c) Alkanet mediated silver nanoparticles showed peak between 300-350nm.

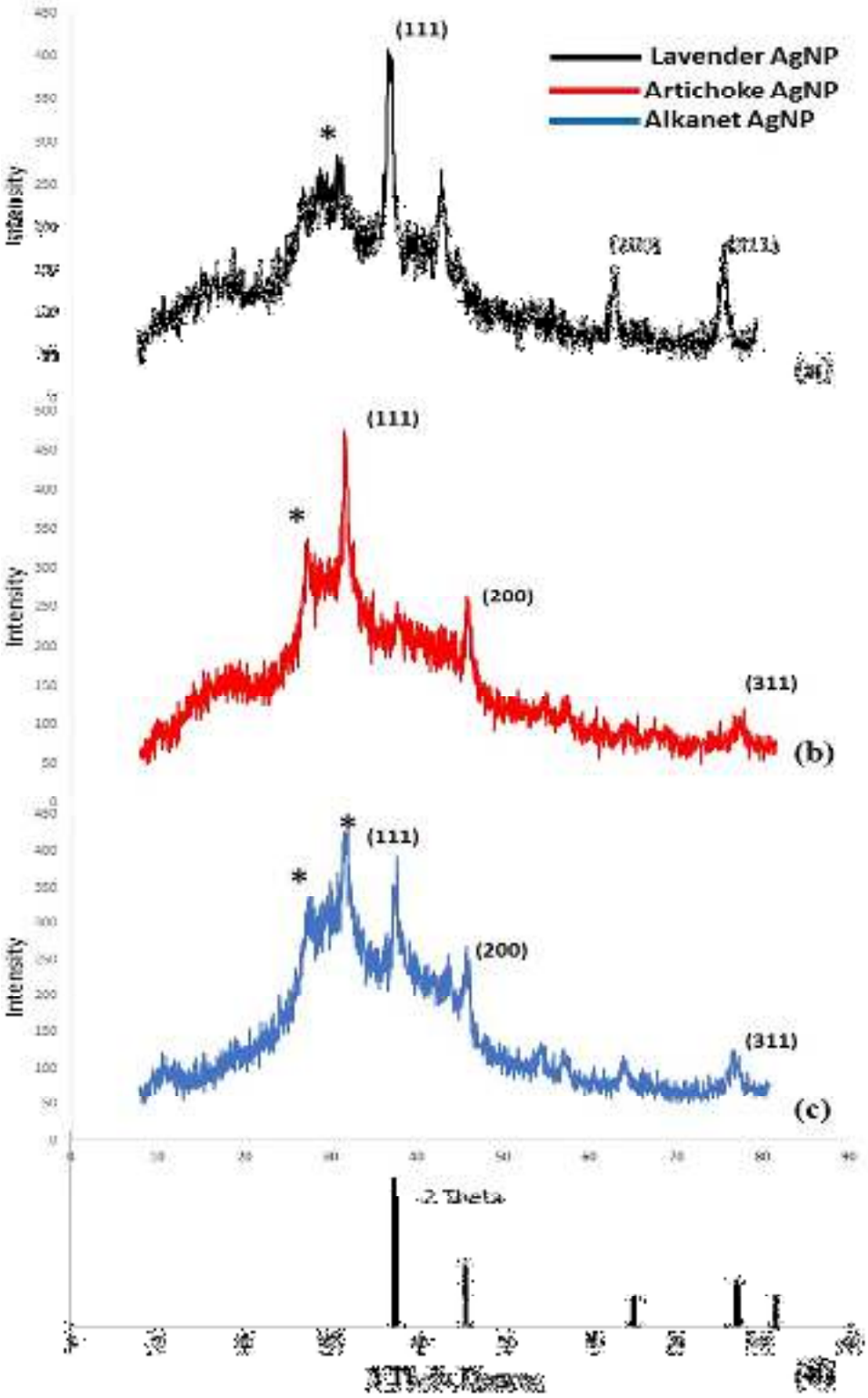

Figure. No. 12. Characterization of Silver nanoparticles using X-ray Diffraction. The XRD pattern confirms powdered particles as silver nanoparticles synthesized from the respective plant sources i.e. (a) Lavender (b) Artichoke, (c) Alkanet. The sharp fine peaks illustrate the presence of silver nanoparticles as compared and matched with (JCPDS file No. 04-0783) of silver nanoparticles.

The crystal size and nature of biogenic nanoparticles was identified using XRD in the range 30–70° at 2θ angles. The synthesized nanoparticles were confirmed with standard silver nanoparticles (JCPDS file No. 04-0783) The spectrum gives sharp peaks which confirmed silver nanoparticles synthesis via three different plant sources. XRD patterns of three biogenic silver nanoparticles showed distinct peaks at around 38°, 44° and 77° corresponding to peak positions at 111, 200, and 311 according to Bragg reflections, respectively. However, unidentified peaks marked as (*) represented the impurities in the sample of plant extract (Figure 12). These peaks indicate the presence of plant metabolite residues on the surface of AgNPs that were used as capping agents on AgNPs, also supported by Pirtarighat et al. (2019) results. Other minor peaks on the graph at Two Theta (2θ) values in AgNPs pattern can be recognized as the residues of the organic content present in the respective plant extract (Lanje et al., 2010). The average size for silver nanoparticles was obtained using Full-Width Half-Maximum (FWHM) using Debye-Scherer's formula for lavender, Artichoke and Alkanet mediated nanoparticles was 35nm, 42nm and 54 nm respectively. This result is in accordance with XRD analysis of Oves et al. (2018). The $AgNO_3$ dissociates in water and forms cation ion and anions. These cations further forms hydroxyl complexes and takes up various plant metabolites as capping agent to form Ag nanoparticles. Here plant extracts serves as reducing agent and donate its electron to the Ag-ion to complete the formation of Ag particles. Moreover, high level of plant extracts as capping and stabilizing agent ensures uniform capping of nanoparticles and prevent aggregation of nanoparticles (Makarov *et al.,* 2014)

Antibacterial activity

Silver nanoparticles synthesized using three different plant sources were tested against gram-positive (*S. aureus)* and gram-negative (*E.coli*) bacteria. These strains causes life-threatening diseases in humans such as pneumonia, urinary tract infections (UTI), and gastrointestinal infections (GIT). Artichoke mediated synthesis of silver nanoparticles showed clear zones of inhibition for *E. coli* (1.25cm ± 0.20) and *S. aureus* (1.45cm ± 0.10). Our results indicated that the effect of artichoke mediated AgNPs was greater on *S. aureus* as compared to *E. coli* (figure 13). As *S. aureus* is gram-positive and its cell wall is composed of thick peptidoglycan layer which makes them vulnerable to AgNPs. AgNPs has bactericidal and bacteriostatic effect owing to its larger surface area to volume ratio. These nanoparticles damages the cytoplasmic membrane and increases cell permeability that leaks cellular contents that leads to cell death. Bacteriostatic activity of AgNP involves the interaction of functional groups present on surface nanoparticles with bacterial membrane proteins, phospholipids, lipoproteins, and lipo-teichoic acids and reduces its colonization and surface adherence (Pereira *et al.,* 2014).

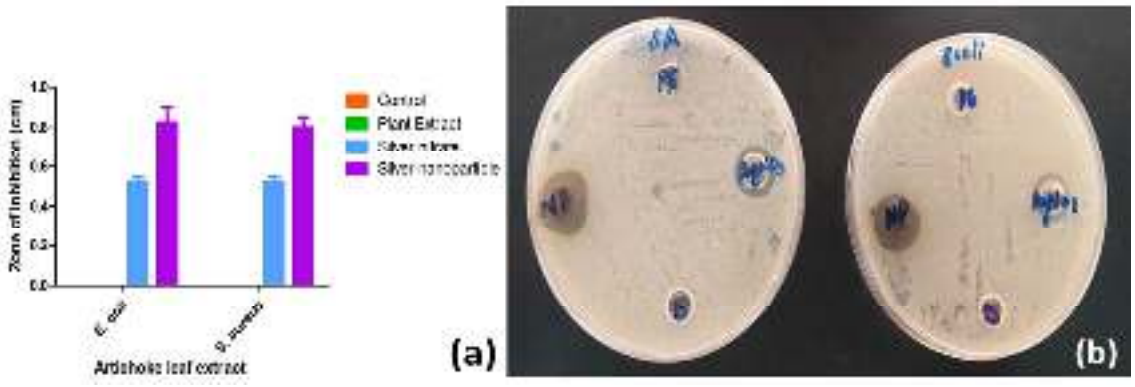

Figure no. 13. Antibacterial activity of Artichokes mediated silver nanoparticles. (a) Graphical representation showed significant effect of Artichoke mediated silver nanoparticle as compared to silver nitrate on *E. coli* and *S. aureus*. (b) illustration of AgNPs against *E. coli* and *S. aureus* as compared to its respective negative (water and Plant extract) and Positive control (Silver nitrate).

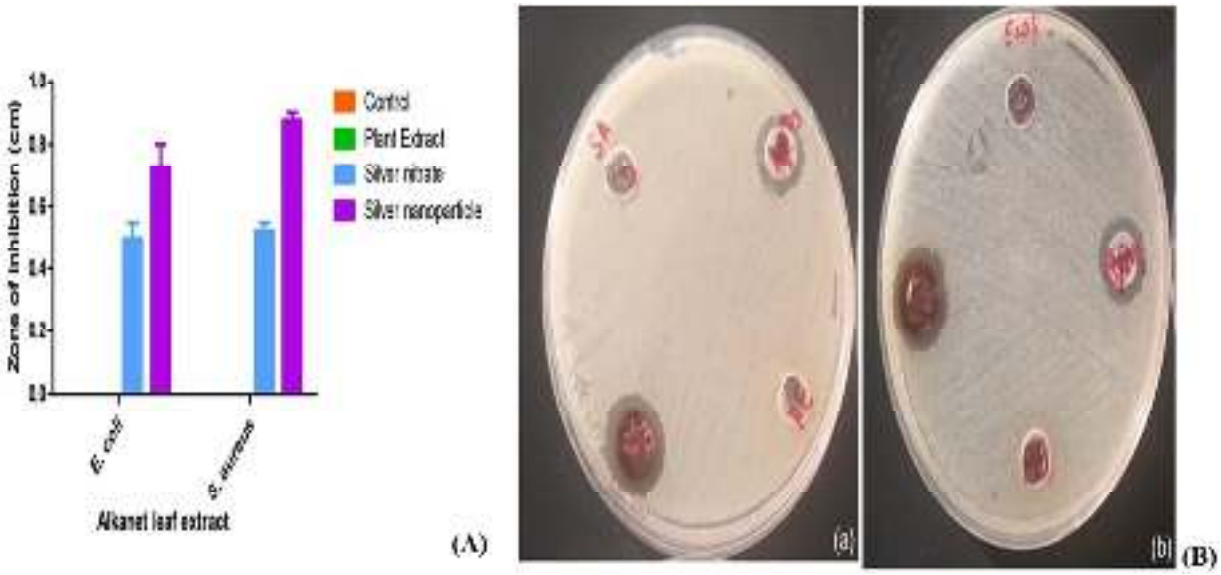

Figure no. 14. Antibacterial Activity of silver nanoparticles mediated by Alkanet. (A) Graphical representation showed significant effect of Alkanet mediated silver nanoparticle as compared to silver nitrate on *E. coli* and *S. aureus*. (B) illustration of AgNPs against (a) *S. aureus* (b) *E. coli* as compared to its controls.

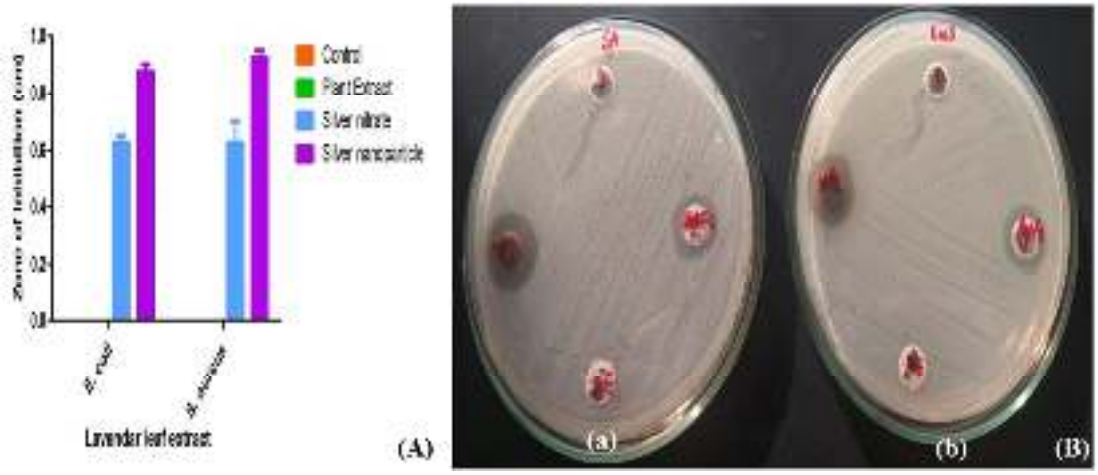

Figure no.15. Antibacterial Activity of lavender mediated silver nanoparticle. Graphical representation showed significant effect of Lavender mediated silver nanoparticle as compared to silver nitrate on *E. coli* and *S. aureus*. (B) illustration of AgNPs against (a) *S. aureus* (b) *E. coli* as compared to its controls.

Lavender mediated silver nanoparticles affected *E. coli* (1.3cm ± 0.10) significantly than *S. aureus* (1.25cm ± 0.20) as compared to its respective controls (see figure No. 15). The impact of Alkanet mediated silver nanoparticles was lower as compared to Artichoke and Lavender mediated silver nanoparticles. However, the alkanet based silver nanoparticles showed a significant effect on *E. coli* (1.2cm ± 0.0) and *S. aureus* (1.25cm ± 0.10) as compared to its respective control (see figure No. 14). Khan et al. (2015) describe bacteriostatic activity of *Alkanna tinctoria* extract that inhibits cell division of microbes. Hui et al. *(*2010) identified the antimicrobial activity of *Lavandula angustifolia* extract involved in disrupting membrane permeability by creating pores that leak its cellular contents.

Antifungal activity:

We identified the antifungal activity of biogenic nanoparticles from three different plant sources against *Aspergillus niger* and *Aspergillus flavus.* These fungal strains are known for causing aspergillosis and have a saprophytic (decaying) mode of nutrition. Our results showed a contrasting activity of biogenic silver nanoparticles as compared to its antibacterial effect. Artichoke mediated silver nanoparticles showed a significant impact on plant-pathogen as compared to other biogenic nanoparticles. This effect was followed by Alkanet mediated silver nanoparticles, whereas lavender mediated silver nanoparticles were least effective. Artichoke nanoparticles showed a greater zone of inhibition for both *Aspergillus niger* (1.2cm ± 0.0) and *Aspergillus flavus* (1.0cm ± 0.0) as compared to their respective controls (Figure no. 16). Antifungal activity of silver nanoparticles produced from Alkanet showed a prominent impact on *Aspergillus flavus* (0.9cm ± 0.0) than *Aspergillus niger* (1.8cm ± 0.0) (Figure no. 17). Lavender mediated silver nanoparticles showed lower activity against fungal strains as compared to its antibacterial activity. Moreover, biogenic silver nanoparticles from lavender showed prominent antifungal activity against *Aspergillus flavus* (0.8cm ± 0.0) followed by silver nitrate effect on *Aspergillus niger* (0.6cm ± 0.0) (Figure no. 8). A study conducted to test antifungal activity of *Cannabis sativa* against *Aspergillus flavus* confirmed high activity of n-butanol extract (Khan and javaid, 2020). Agriculture contributes to economic development of countries. There are numerous types of plant

pathogens, whereas fungi are the most common plant pathogens, and prompts crop losses. Thus, the export of high-quality fruits is reduced due to increased fungal infections of plants. A lot of natural and artificial methods are used to overcome the agricultural losses. Fungicides are commonly used to control diseases yet its residues runoff into environment posing threat for humans and animals. Therefore, an alternative use of nanoparticle instead of fungicides can open ways to control fungal infections in plants, increase crop productivity, and protect plants without harming the environment (Jo *et al.,* 2009). Silver is the most reliable metal widely to inhibit the growth of microorganisms and is also used as a disinfectant against many pathogens (Kim *et al.,* 2004).

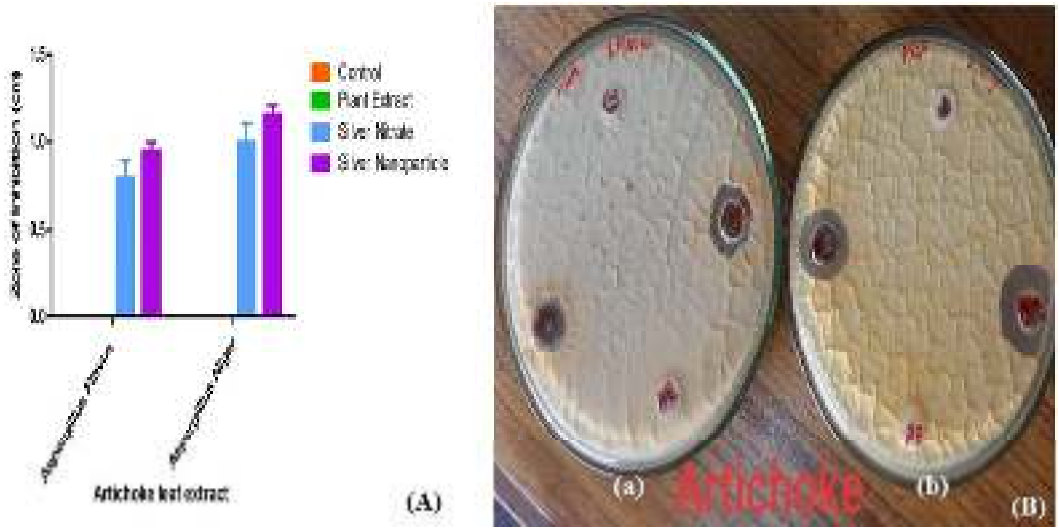

Figure no. 16. Antifungal activity of Artichoke mediated silver nanoparticles. Graphical representation showed significant effect of Artichoke mediated silver nanoparticle as compared to silver nitrate on *Aspergilus flavus* and *Aspergilus niger*. (B) illustration of AgNPs showed prominent antifungal activity against (a) *Aspergilus flavus* and (b) *Aspergilus niger* as compared to its controls.

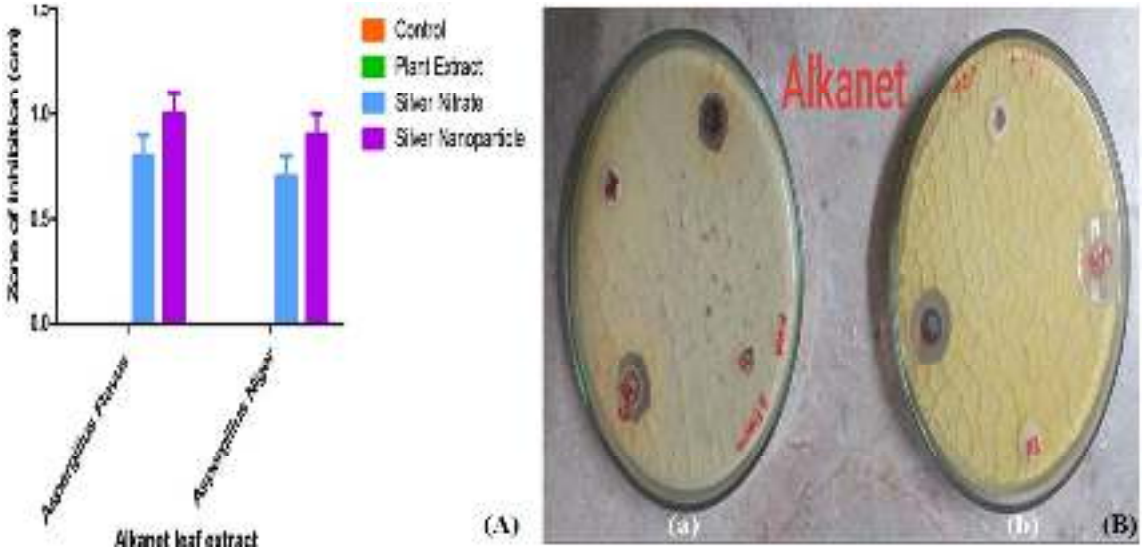

Figure no. 17. Antifungal activity of Alkanet mediated activity of nanoparticle. Graphical representation showed significant effect of Alkanet mediated silver nanoparticle as

compared to silver nitrate on *Aspergilus flavus* and *Aspergilus niger*. (B) illustration of AgNPs showed promiinent antifungal activity against (b) *Aspergilus niger* than (a) *Aspergilus flavus* as compared to its controls.

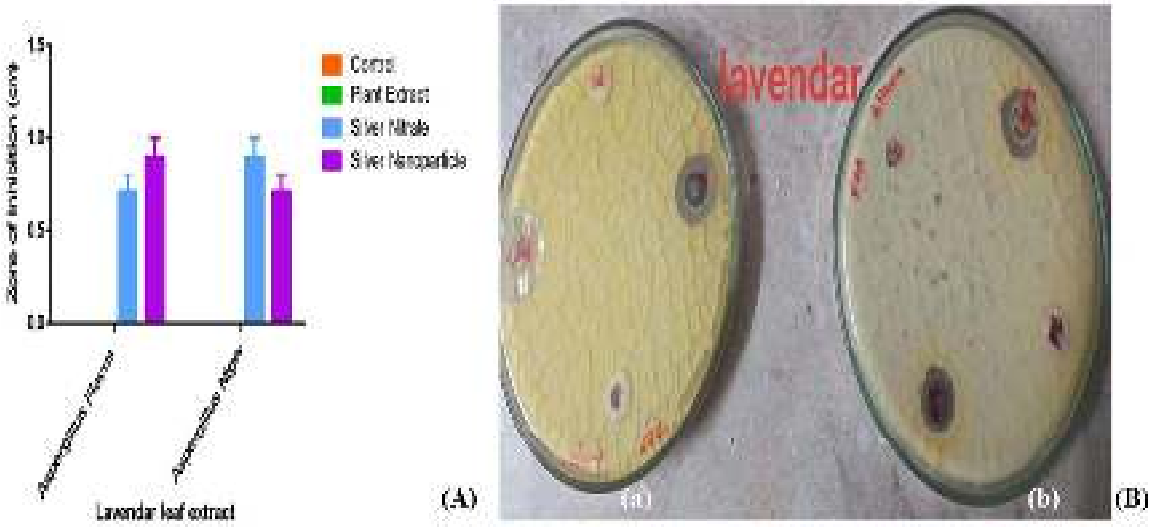

Figure no. 18. Antifungal activity of Lavender mediated silver nanoparticle. Graphical representation showed significant effect of lavender mediated silver nanoparticle as compared to $AgNO_3$ on *Aspergilus flavus* and *Aspergilus niger*. (B) illustration of AgNPs showed prominent antifungal activity against (a) *Aspergilus flavus* and (b) *Aspergilus niger* as compared to its controls.

Artichoke consists of many biomolecules such as cynarin and chlorogenic acid which exhibit great antimicrobial activities against various microorganisms (Zhu *et al.,* 2004). Alkanet has pharmaceutical important bioactive components such as Hydroxynaphthoquinones (HNQ) which possess properties like, antimicrobial activities, anti-inflammatory and wound healing etc (Terzieva *et al.,* 2019). Lavender also contains Linalool, linalyl and lavandulyl acetate which exhibits antibacterial and antifungal activities (Prusinowska *et al.,* 2016). Kim et al. *(*2012) studied the activity of silver nanoparticles against many phytopathogenic fungi such as *Alternaria alternata, Alternaria brassicicola, Alternaria solani, Botrytis cinereal, Cladosporium cucumerinum, Corynespora cassiicola, Cylindrocarpon destructans, Didymella bryoniae, Fusarium oxysporum f. sp. Cucumerinum, F. oxysporum f. sp. Lycopersici, F. oxysporum, Fusarium solani, Glomerella cingulate, Monosporascus cannonballus, Pythium aphanidermatum, Pythium spinosum, Stemphylium lycopersici* and found significant antifungal activity against these respective fungal species.

Conclusion: The current study is a comparative approach to identify the efficacy of three different biogenic silver nanoparticles synthesized from *Cynara scolymus* (Artichoke), *Alkanna Tinctoria* (Alkanet), *Lavandula angustifolia* (lavender). The phytoconstituents in plant extracts were analysed qualitatively. The silver nanoparticles were characterized visually, via UV-Vis spectrophotometer and XRD. The synthesized nanoparticles showed the size of 35nm, 42nm, and 54nm for Lavender, Artichoke, and Alkanet respectively. Among three nanoparticles, lavender nanoparticles showed significant antibacterial activity due to its smallest size as compared to other nanoparticles. In contrast, artichoke showed greater antifungal activity against *A. niger* and *A. flavus* than two biogenic nanoparticles, whereas lavender

nanoparticles showed the least effect on fungal strains. Biological synthesis of nanoparticles is an inexpensive, non-toxic, and eco-friendly procedure. Synthesis of nanoparticles using green sources (plants) are now used widely in many biomedical applications as well as in other fields also, as the plants mediated AgNPs are very effective, stable, and precise.

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Conflict of interest:

The authors have no conflict of interest

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