Lavandula angustifolia Tea Extract Mediated Biosynthesis of Silver Nanoparticles and its biomedical potential

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Abstract:

Lavandula angustifolia flowers used in Lavender Tea is a good source of phytocompounds. In the present study, Lavandula angustifolia tea extract mediated silver nanoparticles (La-AgNPs) were biosynthesized and characterized by UV-Visible spectrometer, Fourier Transform Infrared spectrophotometer (FT-IR), Energy Dispersive X-Ray analysis (EDX) and Scanning Electron Microscopy (SEM). The colour changed from pale yellow to dark brown after and characteristic Surface Plasmon resonance (SPR) peak was observed at 445 nm in UV-vis spectrophotometer. (SEM) revealed the spherical morphology and ------ nm in size. (EDX) exhibited Carbon (18.6 Wt %), Oxygen (6.8 Wt %) and Silver as predominant element (74.6 Wt %). (FT-IR) showed the presence of phyto chemicals Amines, Alkanes, Alkenes, Alkynes, Alcohols, Halogens and Fluro compounds. Better Antimicrobial activity of La-AgNPs was found against Staphylococcus aureus (G +ve), Pseudomonas (G –ve) than Escherichia coli (G –ve) and Candida albicans. Increase in concentration of La-AgNPs revealed good antioxidant activity (80.60 % in 50 µL) concentration in DPPH Assay. Significant Anti-inflammatory activity was obtained (73.70 % in 50 µL) in Egg White Albumin Denaturation Assay. The cytotoxic effect showed 60 % of live Nauplii at 80 µL concentration in Brine Shrimp Lethality Assay. Therefore, La-AgNPs may be applicable as antimicrobial, antioxidant, anti-inflammatory and cytotoxic agents in nano biomedicine applications.

Key Words: Lavandula angustifolia, Biosynthesis, Characterization, Silver nanoparticle, Bioactivity.

Introduction:

Lavandula angustifolia (L. officinalis) is a flowering plant of the Mediterranean region, belongs to Lamiaceae family. The plant has high medicinal values as it is fully loaded with different valuable phytochemicals in it. This flower is one of the main source of polyphenols and more than 100 different types of phytochemicals are identified in this flower which includes flavonoids, alkaloids, saponins, cryptone, limonene, camphene, camphor, endo-borneol, 1,8-cineole, terpinen-4-ol, α & β-pinene and p-cymene. For this reason this flower (fresh and dried) is being used in various medical applications such as Anti-cancer, anti-microbial and as analgesic (Simsek, Pehlivanoglu and Aydin Acar, 2021), anti-anxiety and

depression (Bazrafshan et al., 2020), anti-oxidant (Milea et al., 2020), wound healing (Ben Djemaa et al., 2016) from the olden days.

Recent studies gained more importance towards Nanotechnology, nano particles and its applications in the medicinal fields. Nanoparticles are synthesized usually by conventional Physical and Chemical methods. These methods, though they are significant in their biomedical values, the approach usually involves various harmful chemicals and higher costs (Moteriya and Chanda, 2017). In order to overcome this issue, Biological approaches in synthesizing nano particles are in the limelight these days as the biological approach of synthesizing silver nanoparticles gains high stability and yield (Urnukhsaikhan et al., 2021). Algae, fungi, bacteria and plants (Leaf, stem, root and flower) are widely used to synthesize nano particles. The phyto chemicals found in flower extracts are the bio reducing agents for the synthesis of different metal and metal oxide nano particles (Mandal, 2018). Biogenically synthesized silver nano particles (AgNPs) are in interest these days because of its extensive applications in nano biomedicine field like that of anti-cancer and anti-microbial (Hussain et al., 2019), (Hemlata et al., 2020), (Kalpana et al., 2019), (Samuel et al., 2020), (Raza et al., 2021), anti-oxidant and anti-inflammatory (Helmy et al., 2020), anti-fungal (Al-Otibi et al., 2021) etc. Caesalpinia pulcherrima mediated AgNPs was studied to find its cytotoxic, genotoxic, antimicrobial and antioxidant activities and very significant results were obtained (Moteriya and Chanda, 2017). It is also been found that the mechanism of antimicrobial efficacy of silver nanoparticles is that it penetrates both Gram +ve and Gram –ve bacteria and causes obstructions in various cell organelle functions and leads to the cellular death (Chugh, Viswamalya and Das, 2021). In this study we used flowers of Lavender angustifolia tea extract to biosynthesize silver nano particles from one of the least expensive salt of silver ($AgNO_3$) and efficiently characterized the biosynthesized AgNPs using double beam UV-visible spectrophotometer, X-Ray Diffraction (XRD), Fourier Transform Infrared Spectrophotometer (FT-IR), Transmission Electron Microscopy (TEM), and Scanning Electron Microscopy (SEM) to study its size, shape, phytocompounds that involve in bio reduction, stabilization and as capping materials for the AgNPs and its crystal lattice. The characterized AgNPs was then investigated for its anti-microbial (wound pathogens – Candida albicans, Staphylococcus aureus, Pseudomonas sp and Escherichia coli), anti-oxidant, anti-inflammatory activities and its cytotoxic effect.

Materials and Methods

Chemicals

Organically cultivated Sun dried Lavender flower (collected from Kashmir) tea powder was purchased from Redplum Pvt Ltd Company, Faridabad, Haryana, India. Silver nitrate and other necessary assay kits were obtained from sigma Aldrich Chemicals Pvt Ltd, Bengaluru, Karnataka, India. Agar media were obtained from Hi Media Laboratories Pvt Ltd Mumbai, Maharashtra, India. The fungi Candida albicans and the bacteria Escherichia coli, Staphylococcus aureus and Pseudomonas were obtained from microbiology Laboratory Saveetha Dental College, Chennai, India.

Preparation of Aqueous Lavender Tea extract

Lavender tea primarily consists of dried Lavandula angustifolia flower as its ingredient. 1 gram of Lavender tea powder was weighed accurately and taken in an Erlenmeyer flask. To this, 100 ml of distilled water was added, then mixed for few minutes and boiled in a heating mantle at 70^0 C for 15 minutes. The extract was filtered using a sterile Whatman No 1 filter paper in a beaker and allowed to cool until it reaches the room temperature. The extract is stored in a refrigerator for further analysis.

Biogenic synthesis of Silver nanoparticles

In another Erlenmeyer flask one milli mole of (1mM) of silver nitrate ($AgNO_3$) salt was accurately measured and 20 mL of distilled water was added to it. It was thoroughly mixed so that the silver nitrate powder was dissolved completely in the distilled water. Then 80 mL of Lavender tea extract was poured in the $AgNO_3$ solution. This is then kept in an orbital shaker at 100 rpm at room temperature for 96 hours until the characteristic dark brown colour is formed which might be because of the formation of Lavender flower tea extract mediated silver nanoparticles (La-AgNPs). To separate the nanoparticles from the extract the solution was centrifuged at 8000 rpm for 10 minutes by using Lark refrigerated centrifuge. Pellet was stored in a separate clean Eppendorf tube and stored in a refrigerator until used. The supernatant was dried in a Hot Air Oven at 70^0 C for 48 hours. The dried supernatant was also collected in a separate Eppendorf tube and stored for further analysis.

Characterization of Biosynthesized nanoparticle

The primary characterization of synthesized La-AgNPs was done in a double beam UV-vis spectrophotometer (Model Esico, 3375). The rate of bio reduction of silver ion to silver ($Ag^+ \rightarrow Ag^0$) by the L. angustifolia extract in the reaction medium and the emergence of La-AgNPs was carefully monitored from the UV-vis spectrum. In the UV-vis spectrophotometer the blank was first set with distilled water and the wavelength range for the analysis of bio reduction of silver and development of La-AgNPs was adjusted between 250 nm to 650 nm. The spectrum was plotted were wavelength is in x-axis and absorbance in y-axis.

The emerged La-AgNPs from the Lavender tea extract was further subjected to Fourier Transform Infrared spectrometer (FT-IR) to examine the functional groups of phytocompounds present in the La-AgNPs. The Oven dried pellet was obtained in the powdered form and subjected to FT-IR analysis. Absorption and emission of infrared spectra of emerged La-AgNPs was obtained as peaks between 400 cm^{-1} to 400 cm^{-1} wave number.

The morphology and elements were analysed by using Scanning electron microscope and elemental dispersive analysis.

Anti-microbial Activity of La-AgNPs – Agar well Diffusion Test

Agar well diffusion test was performed to evaluate the anti-microbial efficacy of biosynthesized La-AgNPs. Fresh bacterial and yeast cultures were used in the test. Muller Hinton Agar media was prepared to analyze the zone of inhibition of the bacteria

Staphylococcus aureus, Pseudomonas and Escherichia coli and Rose Bengal Agar was used assess the zone of inhibition for Candida albicans both the media are autoclaved at 121^0C at 120 Lbs. for 45 minutes. The sterilized media was poured in the Petri dishes when the media was at 45^0 C under aseptic conditions and allowed to solidify. Once the media in the plates are solidified, with the help of a sterile well cutter four wells were made and the test organisms were swabbed evenly on the media. La-AgNPs with different concentrations (25 µL, 50 µL, and 100 µL) were added and Amoxicillin was used as a standard drug in a separate well for the plates inoculated with bacteria and Fluconazole was used as a standard drug for yeast culture which was swabbed on Rose Bengal Agar media plates. All the microbiological procedures were done under aseptic conditions and triplicates for each plates were done. The plates were then incubated at 37^0 C for 24 hours.

In-vitro Cytotoxicity of La-AgNPs - Brine Shrimp Lethality Assay (BSLA)

The cytotoxicity of biosynthesized La-AgNPs was investigated by Brine Shrimp Lethal Assay. In a beaker 200 ml of water was taken and 2g of iodine free salt was added in it and mixed well so that the salt gets completely dissolved in the water. A clean scratch less 6 well ELISA plate was taken and 10 ml to 12 ml of saline water was filled in each well. 10 nauplii were added in each well marked with the concentration value of La-AgNPs (10 µL, 20 µL, 40 µL, 80 µL). La-AgNPs were added in each well according to the concentration mentioned. 6^{th} well was used as control were no La-AgNPs were added. The plates were then incubated for 24 hours under room temperature. After the incubation period, the wells of the ELISA plates were investigated for the number of live and dead nauplii. The percentage value of the cytotoxicity was calculated by the formula,

Number of Dead Nauplii/Number of Dead Nauplii + Number of Live Nauplii × 100 ---------- 1.

Anti-Inflammatory Assay – Egg White Albumin

The assay was performed using egg white. The egg white was separated and collected in a separate beaker. 40 ml of 1X Phosphate Buffer Solution was prepared in a separate Erlenmeyer flask. Five clean test tubes were taken and concentration (10 µL, 20 µL, 30 µL, 40 µL and 50 µL) was labelled and in each tube 200 µL of egg white was added. 2800 µL of 1X Phosphate Buffer solution was added to each tube containing egg white. These tubes were allowed to stand in room temperature for about 10 minutes. After the incubation period the tubes were kept in hot water bath at 55^0C for eight minutes. The anti-inflammatory activity of the La-AgNPs were elucidated at 660 nm wavelength.

Inhibition percentage (%) = $\frac{\text{Absorbance of control – Absorbance of test sample}}{\text{Absorbance of control}}$ × 100 ---------- 2.

Free Radical Scavenging Efficacy of La-AgNPs - DPPH (2,2-diphenyl-2-picrylhydrazyl) Assay

To analyze the free radical scavenging ability of the biosynthesized La-AgNPs, DPPH (2,2-diphenyl-2-picrylhydrazyl) assay was performed. Lavandula angustifolia tea extract mediated AgNPs were taken in different concentrations from 2 µg/ml to 10 µg/ml in respective tubes which was labeled according to the concentration. To this, 1 ml of 0.1mM of DPPH in methanol and 450 µL of 50mM of Tris Hcl buffer was added and then incubated for 30 minutes. The rate of DPPH free radical reduction was monitored at 517 nm wavelength. The control used was BHT and the inhibition percentage was calculated using the formula,

$$\text{Inhibition percentage (\%)} = \frac{\text{Absorbance of control} - \text{Absorbance of test sample}}{\text{Absorbance of control}} \times 100 \quad \text{---------- 3.}$$

Phytochemical Analysis

Alkaline Reagent Test: The phytochemicals found in the La-AgNPs are analyzed by Alkaline Reagent Test for Flavonoids. The nanoparticles are treated with few drops of NaOH solution. Formation of intense yellow colour and turns colourless on further addition of dilute acetic acid is the indication of flavonoids.

Dragondroff's Test: Dragondroff's reagent (Potassium Bismuth Iodide) is used to detect the presence of Alkaloids. Formation of permanent orange red colour is the indication of Alkaloids present in the nanoparticles.

The presence of Saponins are determined by the formation of foam in La-AgNPs after adding 2 mL of distilled water and shaking the tubes.

Ferric Chloride Test: Polyphenols are identified by adding 3 to 4 drops of Ferric Chloride solution to La-AgNPs. Formation of bluish black colour indicates presence of polyphenols.

Keller-Killari Test: this test is performed to identify the presence of Glycosides. La-AgNPs are treated with 2 mL of Glacial acetic acid containing 1 drop of ferric chloride. To this 1 mL of concentrated Sulfuric acid is added, appearance of brown ring, violet ring in acetic acid layer indicates the presence of Glycosides.

Results and Discussion

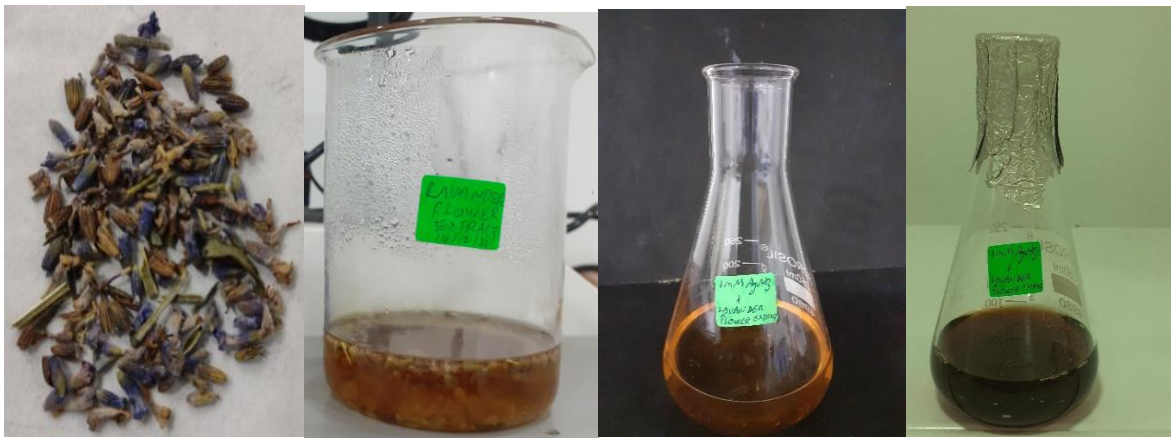
Phytochemical Analysis

The existence of phytochemicals in La-AgNPs were analyzed using alkaline reagent test for flavonoids, Dragondroff's test for alkaloids, foam formation test for saponins, ferric chloride test for polyphenols and Keller-Killari test for glycosides. Characteristic colour, foam and ring formation elucidated the presence of flavonoids, alkaloids, saponins, polyphenols and glycosides were absent. These phytochemicals are responsible for reducing, capping and stabilization of biosynthesized La-AgNPs. A study made by (Manullang et al., 2021) in Eleutherine americana bulb extract mediated silver nanoparticles revealed a comparable results for the presence and absence of phytochemicals that are responsible for reducing the

Silver ions to silver nanoparticles and for capping and stabilizing the synthesized nanoparticles.

Table 1: Phytochemical screening of lavender tea extract mediated nanoparticles

S No	Phytochemical	Present/Absent
1	Flavonoids	Present
2	Alkaloids	Present
3	Saponins	Present
4	Polyphenols	Present
5	Glycosides	Absent



(A) (B) (C) (D)

Fig 1. Visual Observation of Biosynthesized Lavendula angustifolia mediated Silver nanoparticles (A) Dried Lavender Flowers, (B) Flower Extract, (C) Initial Colour, (D) Final Colour

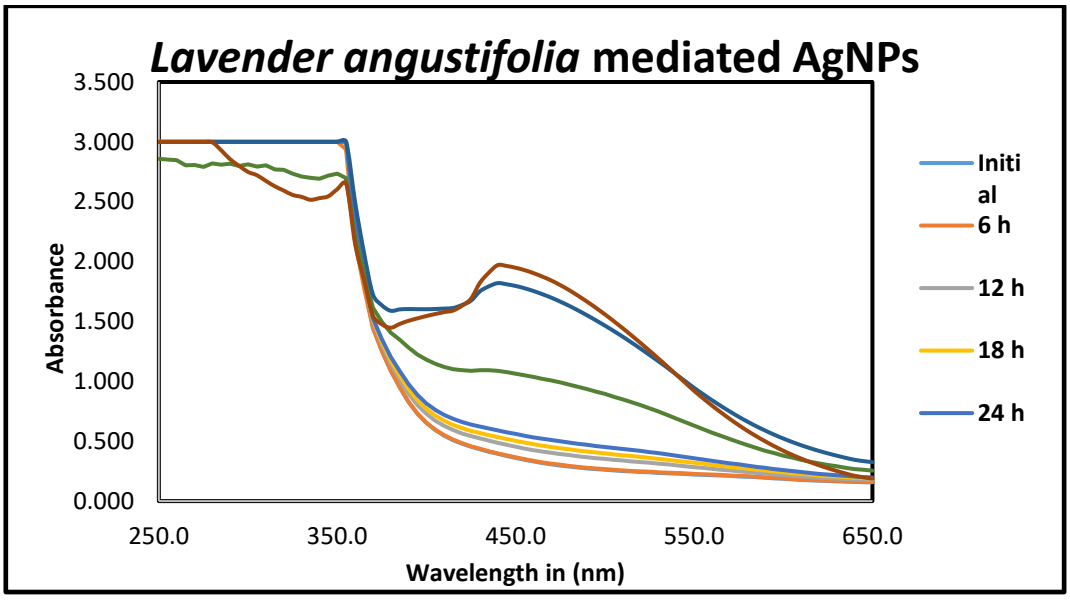


Fig 2. UV-Visible Spectrophotometric Analysis of silver nanoparticles

UV-VIS Spectrophotometric Analysis

UV-VIS spectrophotometer was used to evaluate the rate of biosynthesis of AgNPs. Fig 1 shows the initial colour of the La-AgNPs extract was deep yellow in colour and colour changed to dark brown colour (MURTHYKUMAR1 and , SANKARI MALAIAPPAN2*, 2020) after 72 hour of incubation which represents the formation of La-AgNPs. UV-visible spectrum was observed at frequent interval to analyze the bio reduction of silver ions (Ag^{+}) to silver (Ag^{0}) and formation of AgNPs. The wavelength range was adjusted between 250 nm to 650 nm and the appearance of characteristic peaks denotes the Surface Plasmon Resonance (SPR) of the particles which was observed in the band at 440 nm indicates the formation of La-AgNPs (Fig 2). The results were compared with the previous study showed the absorbance peak between 400-500 nm done in Eleutherine americana bulb extract with the similar results (Manullang et al., 2021). The position in which the (SPR) peak was formed was due to the refractive index of medium, and also the size, shape and the distribution of the AgNPs (Rizwana and Alwhibi, 2021).

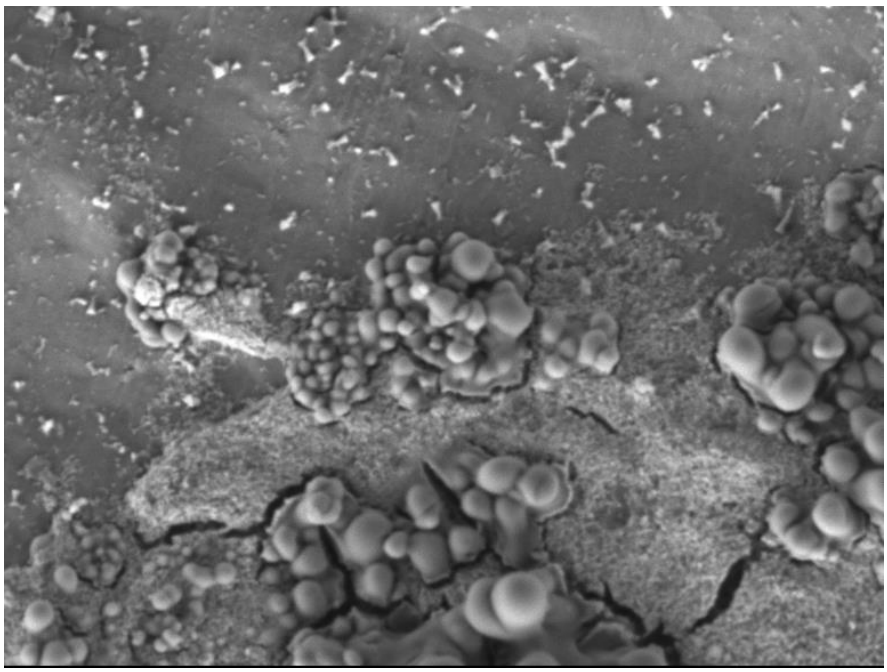


Fig 3. SEM Analysis depicts the Spherical Morphology of La-AgNPs

The Morphology and size of the biosynthesized silver nanoparticles using Lavandula angustifolia tea extract was determined by Scanning Electron Microscopy (SEM) shown in Fig 3. The nanoparticles had a spherical shape with 80 nm in average.

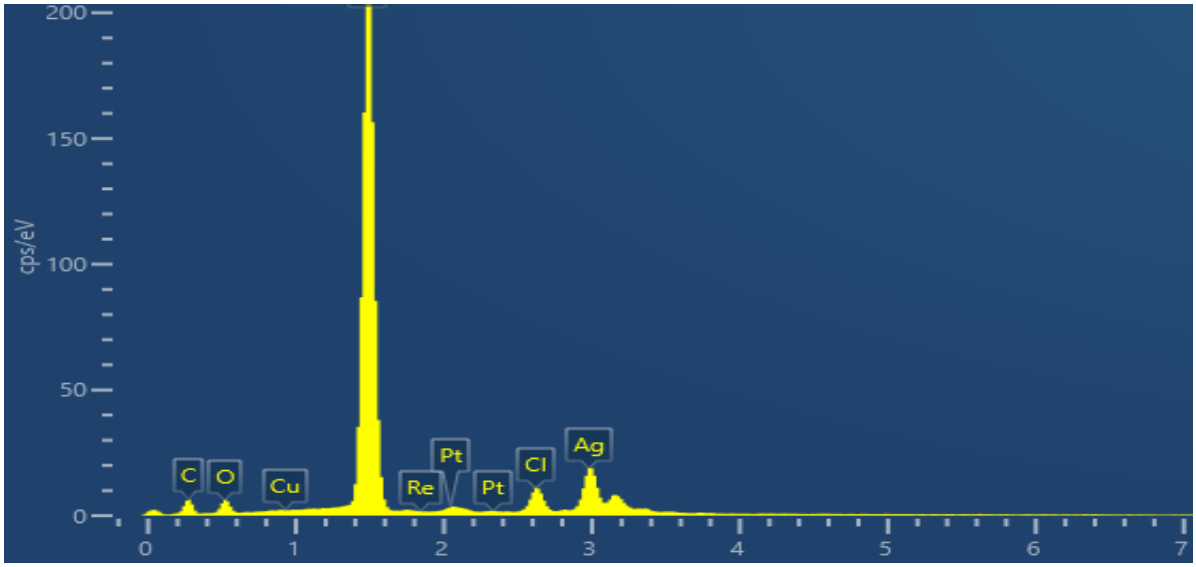


Fig 4. EDX Analysis

Energy Dispersive X-Ray (EDX) analysis was performed to analyze the elements that are present in the La-AgNPs. EDX image shown in Fig 4 exhibits the biosynthesized La-AgNPs and its atomic weight percentage. Characteristic peaks were formed for the elements Carbon, Oxygen and predominantly Silver which represents the formation of La-AgNPs. The atomic weight percentage were found to be Carbon (18.6 Wt %), Oxygen (6.8 Wt %), Silver (74.6 Wt %). The analysis proved Silver as the predominant element. Weak peaks were also observed which indicates the naturally occurring elements in the extract. Similar conclusions were made by (Khshan and Alkafaje, 2021) for elemental Silver using Calendula officinalis (L.) Extract.

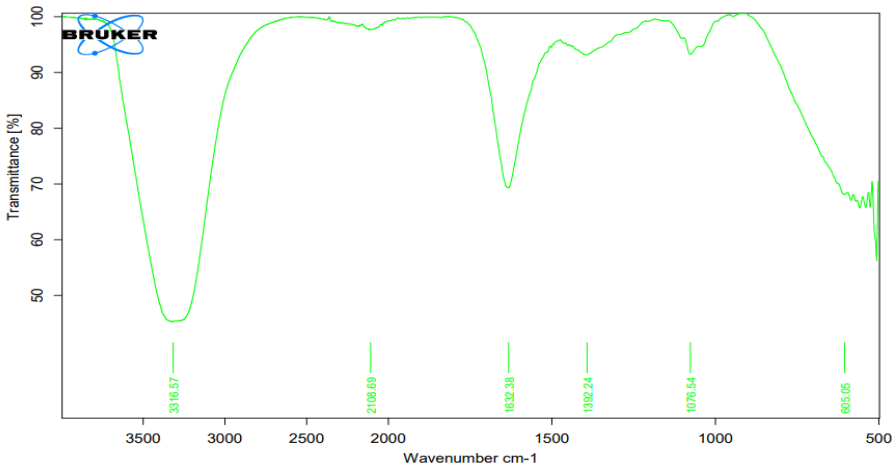


Fig 5. FT-IR Analysis

The functional groups present in the extract of L. angustifolia that are responsible for the biosynthesis of AgNPs were examined and identified by a Fourier Transform Infrared Spectrometer (FT-IR). The Absorbance bands in FT-IR spectrums were seen in the range Between 500 to 4000 cm^{-1}. Furthermore, in Fig 5 the FT-IR spectrum exhibited remarkable absorption peaks at 3316.57 cm^{-1}, 2108.69 cm^{-1}, 1632.38 cm^{-1}, 1392.24 cm^{-1}, 1076.54 cm^{-1}

and 605.05 cm^{-1}. The peak at 3316.57 cm^{-1} which is a medium and broad band denotes N-H group with stretching bond suggests Aliphatic Primary (1^0) Amines (Aguda and Lateef, 2021). At 2108.69 cm^{-1} appearance of a weak band was identified as stretching bond of C≡C indicates mono substituted or terminal Alkyne group (Bhavani et al., 2015). Medium peak at 1632.38 cm^{-1} in the spectra with stretching bond of C=C denotes di substituted Alkene, Conjugated Alkene, Cyclic Alkene and Amines with bending bonds of N-H groups (Palithya et al., 2021). Medium peak at 1392.24 cm^{-1} suggests methyl group of Alkanes with C-H bends (Okpara, 2018), O-H bend representing the Alcohols (Rizwana and Alwhibi, 2021), S=O with stretching bond shows the presence of Sulfates and Sulfonyl Chlorides (Mi ekus et al., 2020) and C-F stretching bond represents Fluro compounds (Carvalho and Oliveira, 2017). The band at 605.05 cm^{-1} shows C-Br stretching bond that shows the presence of Halo compounds (Kumar et al., 2020). The phytocompounds present in the extract may be responsible for reducing, capping and stabilization of nanoparticles. Previous study made with the extract of Jasmine flower reported that the bio molecules present in the extract may be responsible for reduction and capping of the nanoparticles (Devanesan and Alsalhi, 2021).

(A) (B) (C) (D)

Fig 6. Antimicrobial Activity – Agar Well Diffusion Assay (A) Pseudomonas (B) Candida albicans (C) Staphylococcus aureus (D) Escherichia coli

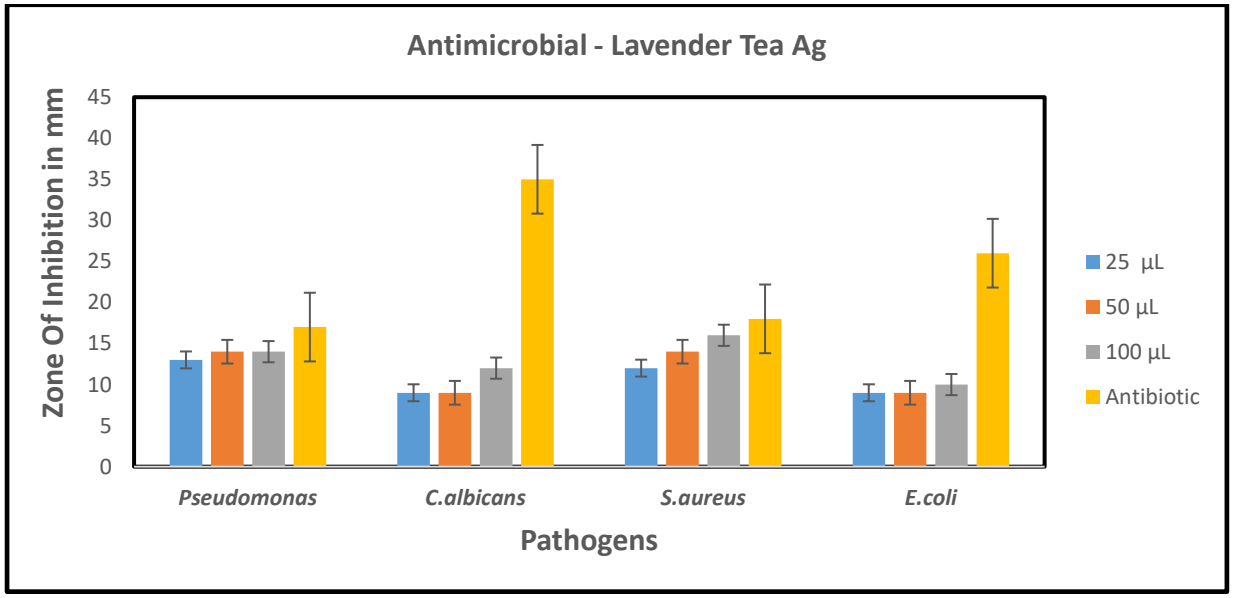
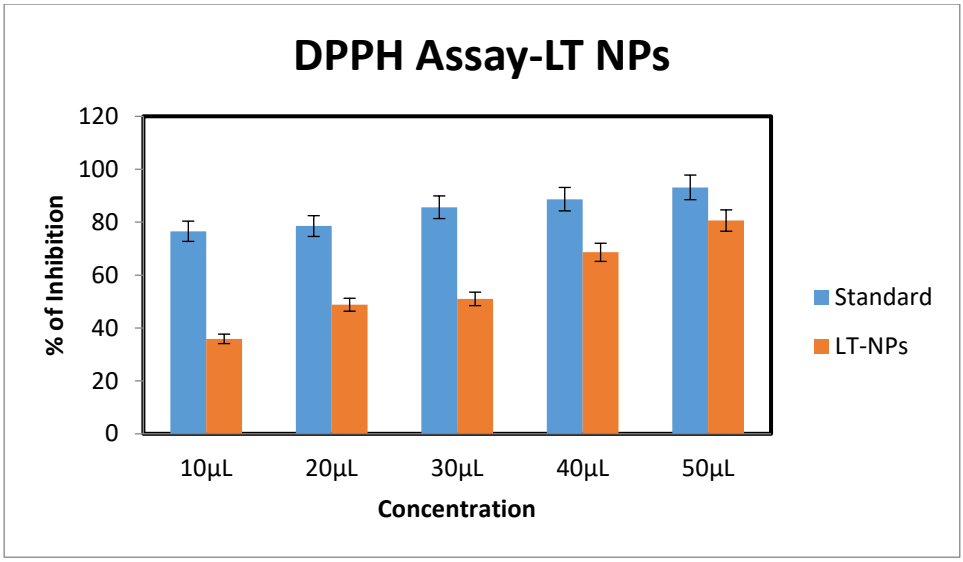


Fig 7. Antimicrobial Activity Using Graph

Antimicrobial Activity: The antimicrobial activity was performed by agar well diffusion technique in Muller Hinton Agar media shown in Fig 6 (A to D). The organisms used were Candida albicans, Pseudomonas, Escherichia coli and Staphylococcus aureus. The concentration of the La-AgNPs used was 25, 50, 100 µL and Amoxicillin was used as standard for the Bacteria and Fluconazole for fungi. The La-AgNPs revealed an average antimicrobial efficacy, the maximum zone of inhibition was found in Staphylococcus aureus when compared to other organisms which were analyzed measuring 16mm in maximum concentration of 100 µL and Pseudomonas exhibited a maximum zone measuring 13mm in least concentration of 25 µL concentration when compared to other organisms that were analyzed. The difference in the pattern of inhibition is because of the difference in the cell wall composition found in Gram +ve bacteria and Gram –Ve bacteria. Fig 7 shows the graphical representation of difference in the zone size obtained between different organisms. Furthermore the inhibition effect of La-AgNPs against microorganisms is may be due to the rupture of the cell wall and membrane, creating an obstruction in DNA replication, inhibiting the enzymatic activity. Smaller sized nanoparticles have greater surface area to volume ratio which paves them to be a good antimicrobial agent (Supraja, Avinash and Prasad, 2017). Silver is an excellent antimicrobial agent, the Lavender mediated AgNPs showed an average antimicrobial properties which was found after measuring the diameter of the zones that are formed and can be used as an antimicrobial agent against wound pathogens with increased concentrations.

(A) **(B)**



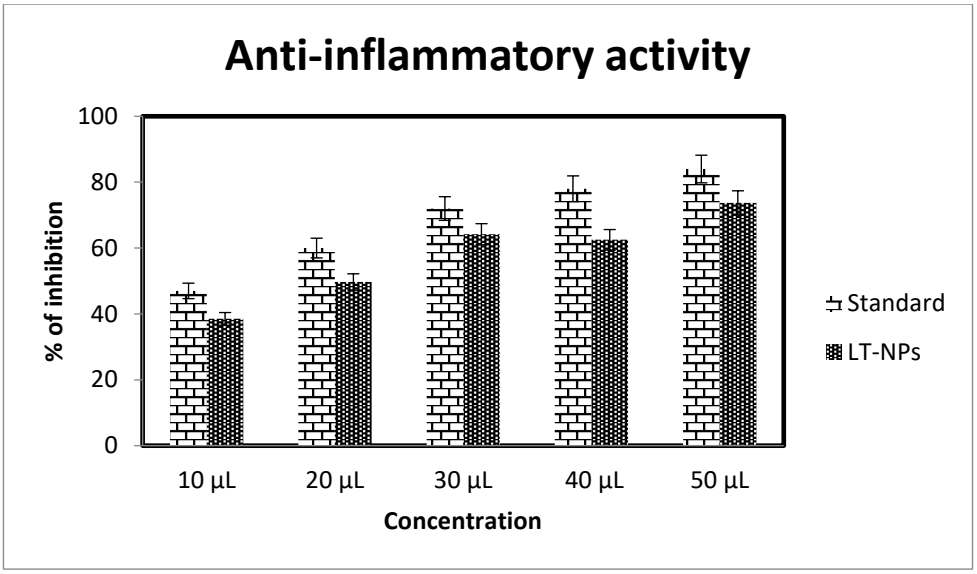
(C)

Fig 8. Antioxidant Activity – DPPH Assay – (A) DPPH with La-AgNPs before incubation (B) after 8 minutes of incubation at 55^{0}C (C) free radical scavenging efficacy of La-AgNPs at different concentrations in percent value.

DPPH (2,2-diphenyl-2-picrylhydrazyl) Assay

The assay was carried out to determine the free radical scavenging activity of the La-AgNPs. Fig 8 A and B shows the colour change before and after the dark incubation. The scavenging of free radicals increased with the increase in the concentration of La-AgNPs. At 10, 20 and 30 µL concentration the antioxidant activity was 35.9, 48.8 and 51% respectively and not correlated with the standard Ascorbic acid value which is 76.56, 78.52 and 85.63 % but as the concentration increased to 40 and 50 µL the activity was found closer which is 68.6 and 80.6 % to the standard value 88.68 and 93.15 %. Similar reports were found in a study made by (Nivethitha et al., 2020) in Hybanthus enneaspermus mediated AgNPs. The assay shows that the free radical scavenging activity of La-AgNPs increases with the increase in the concentration of nanoparticles. Further increase in the concentration may give still better antioxidant activity of the synthesized nanoparticles.

(A) **(B)**



(C)

Fig 9 Anti-Inflammatory Activity – Egg White Albumin Denaturation Assay – (A) Tubes with DPPH and La-AgNPs with different concentrations 10 µL to 50 µL before incubation (B) after 30 minutes of incubation (C) Anti-inflammatory activity of La-AgNPs

Anti-Inflammatory Activity

Egg White Albumin Denaturation Assay was carried out to estimate the anti-inflammatory efficacy of the La-AgNPs. The results were compared with the standard drug (Diclofenac). The concentration of La-AgNPs used were 10, 20, 30, 40 and 50 µL. the results confirmed the anti-inflammatory activity with increase in concentration of the La-AgNPs and near close to the standard drug value shown in Fig 9 (C). Highest anti-inflammatory activity of La-AgNPs was seen in 50 µL concentration which is 73.7 % and for standard drug it was 84%. A study performed by (Anwar et al., 2021) in Tamarix articulata leaf extract also showed a very similar results which was found to be 73.19 %. Thus the La-AgNPs confirmed to be good anti-inflammatory agent synthesized in an eco-friendly manner thereby have no side effects as that of in chemically synthesized drugs. Hence La-AgNPs may be used as an alternative for inflammatory diseases with further required and extended techniques.

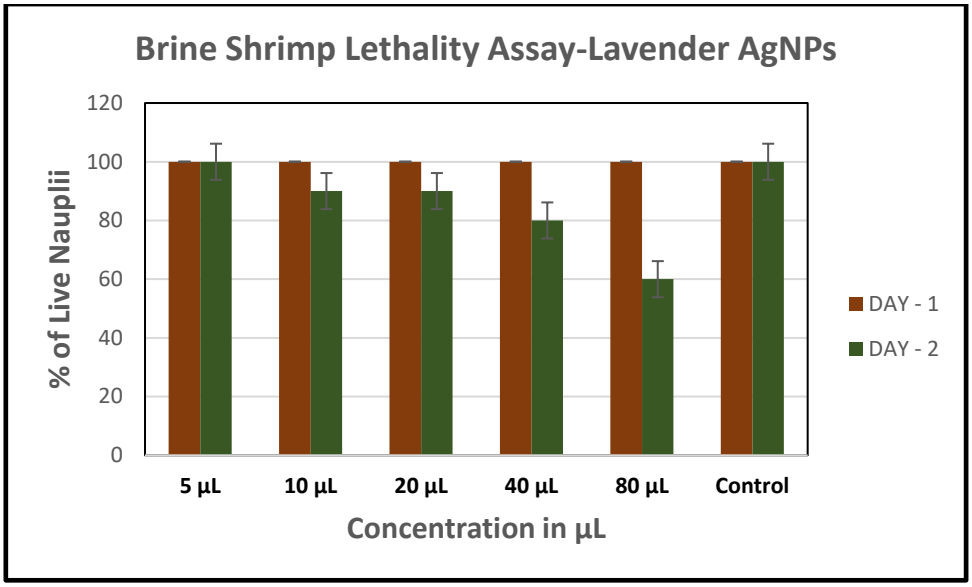


Fig 10 Depicts Cytotoxic Activity of La-AgNPs against Brine Shrimp Artemia

The cytotoxic activity of La-AgNPs was studied on Nauplii of Brine Shrimps Artemia. The assay was carried using different concentrations of La-AgNPs (5, 10, 20, 40 and 80 µL). In a six well ELISA plate ten live Nauplii were added in each well containing Iodine free salt water and La-AgNPs extract was added in each well according to the labelled concentration. The set up was incubated for 24 hours. After the incubation period the percentage of mortality was checked to estimate the cytotoxic efficacy of the synthesized La-AgNPs. It was found that 100 % of Nauplii were alive in 5 µL concentration, in 10 and 20 µL 90 % of Nauplii were alive so the mortality percentage is 10 %. In 40 µL 80 % of Nauplii were alive and in 80 µL 60 % of Nauplii were alive. The mortality percent in 40 µL is 20 % and 80 µL it was 40 %. The cytotoxic effect of La-AgNPs increased with the increase in concentration. Comparable results having 40 % mortality in 80 µL concentration was found in a cytotoxic study made in Solanum Xanthocarpum induced silver nanoparticles on Brine Shrimp Artemia by (UB, Rajeshkumar and Ramesh, 2021). Thus the La-AgNPs have significant cytotoxic effect for which it may be used in future as cytotoxic agent after adequate Cell line and other required study.

Conclusion

The present study is eco-friendly and simple for the synthesis of silver nanoparticles from Lavandula angustifolia flower tea extract in room temperature. The bio molecules found in the extract are involved in reduction, capping and stabilizing the nanoparticles. The biosynthesized silver nanoparticles expressed an average antimicrobial properties against Gram positive, Gram negative bacteria and fungi. The La-AgNPs revealed a good antioxidant, anti-inflammatory and cytotoxic properties. Hence the Lavandula angustifolia flower mediated silver nanoparticles can be efficiently used in biomedical applications in the field of nano biomedicine and other medical fields after further investigation to study the mechanism of action and other necessary advanced techniques.

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