International Journal of Innovation, Creativity and Change. www.ijicc.net
Volume 15, Issue 3, 2021

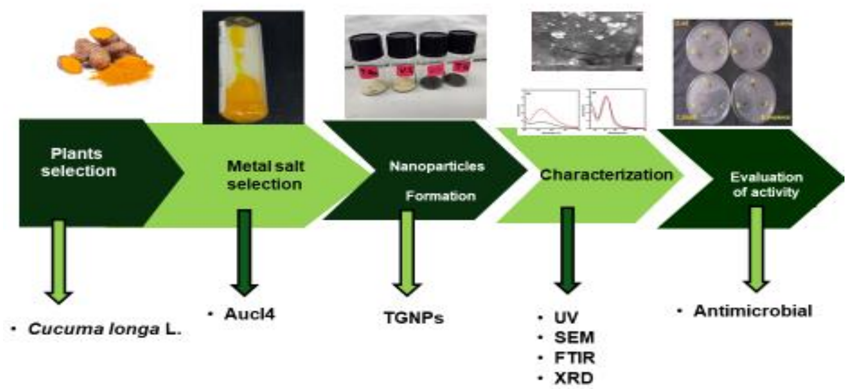
Gold Green Nanoparticles Fabrication Characterization and its Antibacterial Activity

Safia Gul[1], **Imran Khan**[1], **Farhan younas**[1], [1]Suleiman Bin Abdullah Aba Al-Khail - Center for Interdisciplinary Research in Basic Sciences(SA-CIRBS), Faculty of Basic and Applied Sciences, International Islamic University, Islamabad Pakistan. Correspondence Email: safia.phdns5@iiu.edu.pk

Nano biotechnology has opened new ways of improved materials in biomedical integrations. Green synthesis with noble metals is an enormously emerging area of research in a nano biotechnology. It acknowledged great consideration from physicists, chemists, engineers and bio scientists who wish for the development of a new world nano medicines. The current contribution deals with one pot synthesis of green nanoparticles by gold via potent and traditional medicinal plant *Curcuma longa* L. . The synthesized nanoparticles were characterized via different analytical procedures, included ultraviolet-visible spectroscopy(UV), Fourier-transform infrared spectroscopy (FTIR), X-ray diffraction(XRD) and scanning electron microscopy (SEM). The ultra violet-visible spectrum of nanoparticles e.g TGNPs peaks were recorded at 553nm. Optimization has gained at pH 8-9, 3mM concentration., high heat and 48 hours incubation period have enhanced the gold nanoparticles synthesis and small size. FTIR studies revealed some alcoholic and phenolic groups are involved in capping of Turmeric based GNPs. XRD and SEM confirmed the particles size and shape were found spherical and star like for TGNPs size varied from 100-60nm with r= 50, 30nm. TGNPs proved best all around for antibacterial activities against two bacterial strains *E.coli* and *S.aureus* . The outcome of the recent reserch could make a way in the development of value-added products from *Curcuma longa L.* with metallic salts of gold for biomedical, agriculture and nanotechnology-based productions.

Key words: Green nanoparticles, *Curcuma longa L.*, TGNPs, *E.coli* , FTIR, XRD, SEM

Graphical Abstract



INTRODUCTION

Nanotechnology is a cutting-edge scientific subject that explores materials with dimensions ranging from nanometers to 100 nanometers. Furthermore, the nanoparticles' extremely small size, structure, and surface features result in unexpected physicochemical properties not seen in bigger or bulk particles of the same matrix or substance. The electronic locations, magnetic and optical properties, and catalytic strength of materials with dimensions shorter than 5 nm differ from their bulk measure (Yu, H., et al., 2018).

When nanoparticles were first synthesised a few years ago, it marked the beginning of a new age in nanomedicine, paving the way for the development of novel methods for disease detection, prevention, and treatment based on their remarkable capabilities. There are also a variety of interesting nanoparticle technologies that may target particular cells and extracellular components in the body in order to deliver genetic materials, medications, and diagnostic agents to these specific locations (Shunmugaperumal, T., et al., 2017).

A number of studies have shown that gold nanoparticles play a critical role in the regulation of fungal activity. However, it has been discovered that fungal activity varies depending on the size of gold nanoparticles. Human fungal diseases, on the other hand, can be controlled by using gold nanoparticles of the right size and volume. The anti-protozoa, antibacterial, antifungal, and anti-cancer capabilities of these green nanoparticles were boosted, as well as the health of normal human cell lines. Mitochondrial alteration with green nanoparticles may promote cell proliferation by preventing necrosis or apoptosis, which might lead to fibrosis and tissue inflammation later on. Due to their ability to sustain their metabolism as well as some other activities, medical plants transformed by green nanoparticles are effective in animal health, which may lead to grazing in food crops, plants, or fodder labelled as that kind of green gold as medicine (Pissuwan, D., et al., 2010).

Elemental gold (in metallic form) is the most ancient medication known to dioscorides (presumably by shamanic scientists and people). Metallic gold and its derivatives have long been and continue to be utilised for therapeutic purposes. The apparent paradox of the substance's actual toxicity shows that there may be substantial gaps in our understanding of gold's physiology of action. Some modern esotericists still believe that metallic gold has therapeutic properties.

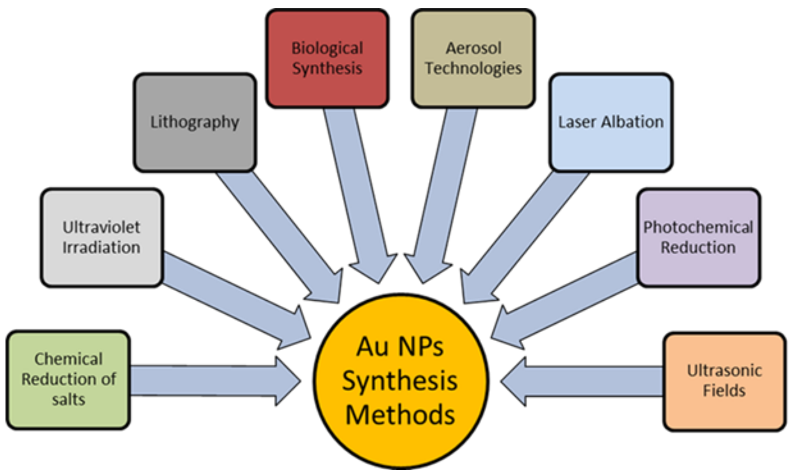


Figure:1: Synthesis approaches of gold nanoparticles.

Furthermore, in the nineteenth century, metallic gold was supposed to be nervine and used to treat neurological illnesses, depression, and glandular hitches such amenorrhea, epilepsy, migraine, and impotence, as well as alcoholism (Kean, W. F., et al., 2008).

So far, only gold salts and radioisotopes have been evaluated in terms of their potential as therapeutic agents. Sodium aurothiomalate (Gold sodium thiomalate) it is still common practise in the United States to provide gold salts that have anti-inflammatory properties, such as sodium aurothiomalate and auranofin, to patients with arthritis and other inflammatory diseases. Such gold compounds have been investigated as a way to help with rheumatoid arthritis discomfort and swelling, as well as (historically) against some parasites like tuberculosis (Jungwirth, U., et al, 2011).

The use of gold mixtures in restorative dentistry is recommended for tooth restoration procedures such as crowns and permanent bridges. With their slight malleability, these metals may be used to provide a better mating surface between molars and other teeth, resulting in more gratifying outcomes than porcelain crowns. Gold crowns, on the other hand, are preferred in certain cultures and prohibited in others, particularly in the case of incisors, which are more visible. In scanning electron microscopy, the gold as a metal and its alloys are used as a conductive coating on biological specimens, as well as on non-conductive materials such as plastics and glass. (Liu, G. 2011).

In colloidal form, gold is a expensive metal. The reduction of gold chloride with ionic citrate or ascorbate results in a highly red-colored gold suspension in water with precisely controlled particle sizes ranging from a few tens of nanometers across to a few hundred nanometers across. In the middle ages, reducing gold chloride with ethanoic extracts of plants and their constituents to form gold chloride was supported. Researchers, physicians, biologists, and materials scientists utilize colloidal gold in their work in research, health, biology, and materials science. It is possible to mark proteins with immune gold by taking advantage of the proclivity of gold particles to adsorb protein molecules to their surfaces. Certain antibodies are used as probes to detect the presence and location of antigens on the surfaces of live cells. This is accomplished by un coating specific cells on colloidal gold particles and then observing the results (Faa, G., et al., 2018). A number of gold isotopes, such as gold-198 (half-life 2.7 days), are very helpful in nuclear medicine, cancer therapy, and a variety of other conditions (Katti, K. V. et al., 2018).

In addition to pathogens such as bacteria and viruses, these nanoparticles may attach to biomolecules such as proteins, peptides, antibodies, and oligonucleotides with a strong adhesive force. These gold nanoparticles are most regularly used as biomarkers to identify illnesses and provide the right medication to treat the ailment, as well as to detect any specific pathways or genes that are responsible for any specific function in any organism.

Medicinal plants being potent are used by man long before the introduction of chemical medicines. Some favor the plants to be used for remedies due to their strong belief that plants have provided food, medical aid, and other benefits to mankind. According to WHO plants are always a way of easy and cost-effective treatment, both in the context of traditional preparations as well as in the form of active principle representation in their simplest form (Al-Snafi, 2013, Al-Snafi, 2015).

Pakistan for having a unique range of biodiversity and all climate zones. Approximately 6,000 plant species have been identified across the country. **Pakistan Plant Database (PPD)** provides account for 1,100 medicinal plant species from all over Pakistan, published in 6-10 volumes. The project has produced 217 volumes of the Flora, the last 16 co-published by the Missouri Botanical Garden and the University of Karachi. https://www.tropicos.org/project/Pakistan, hindawi is another database for medicinal plants of Pakistan, https://www.hindawi.com/journals/ecam (Jan, H. A., et al. 2020). Elementary research s shown that turmeric extract has antifungal and antibacterial properties (Ragasa et al., 2005).

Turmeric is a blossoming plant of the Zingiberaceae family, which is scientifically called (*Curcuma longa L*.), is an herbaceous plant, which is the world's supreme lucrative and important monocot crop plant, as well as one of the world's most precious and important spices. In addition to curcumin and volatile oil, it includes considerable levels of lipids (5.10 percent), proteins (6.30 percent), fiber (2.60 percent), carbs (69.40 percent), and minerals such as calcium, iron, vitamin A, and phosphorus (with a calorific value of 349 per 100 gram of rhizomes) as review by (Jansen P. C., 1981). Turmeric powder, curcumin, and its derivatives, as well as a variety of other rhizome extracts, are bioactive. Turmeric powder has a therapeutic impact on both aseptic and septic wounds and have antibacterial, antifungal, and anti-inflammatory activities (Ammon H.P. et al., 1991). Turmeric aqueous extract, leaves and rhizomes of *Curcuma longa* have been shown to have antibacterial properties has an antibacterial effect, as curcumin has been found effective against *Lactobacillus*, *Staphylococcus*, and *Streptococcus*. The effect of aqueous turmeric extracts on productiveness, on the other hand, has been studied and found to have a 100 percent antifertility effect in rats when given orally (Hatcher et al., 2008), (Sadaf F. et al., 2009).

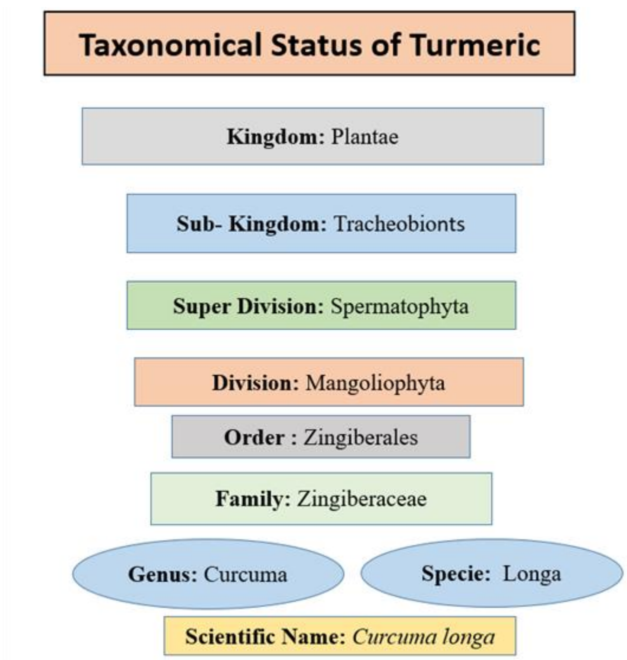


Figure: 1 : Taxonomical Status of Turmeric.

The study focused on the aggregation of beneficial compounds and the use of NPs by combining highly potent medicinal plant *Curcuma longa L*. with the benefits of non-toxic metal gold ($AuCl_4$)and testing these NPs are used for disinfection against two bacterial strains *E.coli* and *S aureus*.

METHODOLOGY

The utilized items were thoroughly sterilized, all the chemicals were of analytical grades bought from the Merck Int. and the whole experiment was conducted using fresh DD water.

Plant extraction and phytochemical tests

Two plants, turmeric (*Curcuma longa*) was chosen for experimentation. Plant extracts were used for the synthesis of green gold nanoparticles as capping agents. Powdered plants of turmeric were bought from neighboring Islamabad's standard pharmaceutical agency (Pakistan). Weighted 1 g of powder and washed twice in DD water. The powder has been soaked and was mixed at interval of 24- 48 hours. After complete soaking period the extracts were portrayed in jars and placed on a hot plate at 60C°. Mixtures were made ready for the experimentation using magnetic stirrers for the homogenious mixing. The extracts were subsequently filterd into whatman filter paper (90 mm porous size) and centrifuged for 10 minutes at 10,000 rpm to induce free redicals. The filtrate was collected in a 250 mm Erlenmeyer flasks, and the remaining were stored at 4 C° to help in the preparation for a week (Sagar R.et al, 2015 and Vidya Shilpa, 2013).the extract was used for phytochemical secondery metabolites analysis followed the procedure of (Hedge et al. 2010).

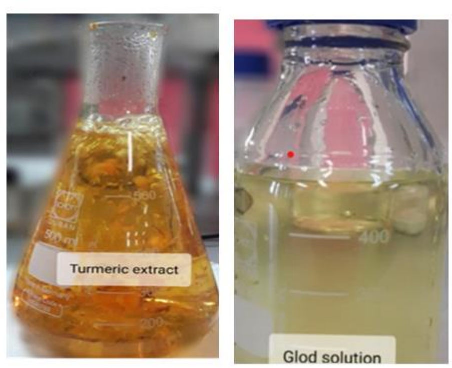


Figure: Turmeric extract and gold salt molar solutions prepared

Nanoparticles synthesis

Gold chloride ($AuCl_4.2H_2O$) was bought from Johnson Matthey Plc. The UK along with other required chemicals such as NaCl, HCl (used for stabilizing pH and particle size management). For nanoparticles production, various quantities of freshly produced extract were treated with varying concentrations of salt solution. The nanoparticles formation was indicated by the gradual color change and were confirmed by a UV spectrophotometer. Further the produced nanoparticles were optimized by different factors like time, pH, temperature, and different concentrations. In the instance of the gold solution, it was avoided to light exposure for its specific light responses, so, the initial suspension of the AuNP was kept in dark and were remained covered with aluminum foil. The color of the solutions, owing to the gold ions of the precursor, changed from yellow to ruby red or cherry red for gold, which is a feature of successful gold nanoparticle production.

The following formula was used for the molar solution preparation of metal salt of gold,

$$\text{Salt quantity g/litre} = \frac{\text{Mol. required} \times \text{Molecular wt. of salt calculated} \times \text{Volume required}}{1000 \times 1000 \text{ (per liter)}}$$

Bacterial, culture maintenance

For the bioactivity analysis (antibacterial activity) of synthesized nanoparticles, two bacterial strains, *E. coli* (ATCC25922), S.aureus (ATCC 25923) were collected from available sources. For antibacterial activities fresh colonies of all bacterial strains were grown, for antibacterial activity media was prepared, 2.8g of agar powder was dissolved in 100ml of DD water mixed well in the flask with continuous stirring and autoclaved for 1 hour and after setting it on room temperature the media is solidified in 12 plates for each of selected bacterial strains, 6cm borer was used for wells and 300µl of the sample was poured in wells (Gulzaman et al., 2012).

RESULTS AND DISCUSSION

Green nanoparticle applications have demonstrated promising results in the area of medicine. In any event, owing to a paucity of data on the physical properties of AuNPs within the physiological system, only a few gold green nanoparticles have gone through clinical studies and been proven to have useful uses. This takes into account the following integration of their in vitro investigations of these nanoparticles, their absorption by living systems, like by plants and animals for evaluation of their efficacy.

The current research used *Curcuma longa* aqueous extract to show the one-step production of green nanoparticles from gold metallic salt. Turmeric is best proven herbs utilised in this research have been used to treat fevers, stomachaches, and cancer and have stong bioactivities against vast range of pathogens in the past (Kelly K.2009). Its anticancer, antioxidant, and antibacterial effects have also been widely documented (Khan, M.A. et al.,2011). These plants include an infinite amount of phytochemicals with various medicinal actions (Asheesh et al. 2017), which may serve as a reducing agent for decreasing precursor Au ions. The antibacterial, properties of these new nanoparticles were examined after they were synthesised.

Phytochemical test results

Phytochemical tests for the secondary metabolites analysis of turmeric was analysed which have shown that many metabolites are present in vast range followed the protocol of(Hedge et al. 2010).

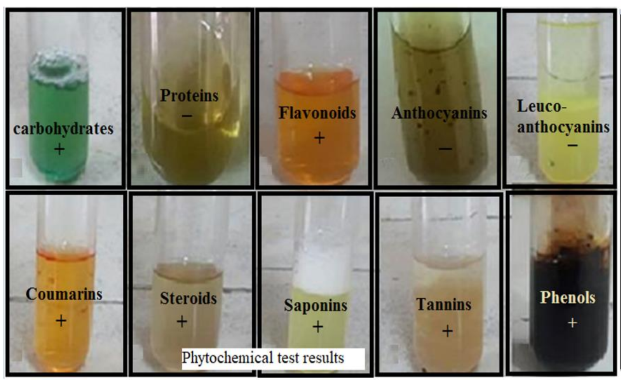


Figure: Showing phytochemical test results and Turmeric.

Table 1: Showing phytochemical tests for *Curcuma longa L.* .

S.No	Phytochemical	Test	T.Ext.
1.	Alkaloids	Dragondroff's testWagner,s reagent	+
2.	Saponins	Foam test	+
3.	Tanins	Ferric chloride test	+
4.	Terpenoids	Copper acetate test	+
5.	Amino acids	Ninhydrin	-
6.	Reducing sugars	Benedict test	+
7.	Card. Glycosides	Legal's test	+
8.	Flavonoids	HCl-Mg reaction	+
9.	Carbohydrates	Molisch'stest,Benedict test Barfored's test	+
10.	Steroids	Salkovaski method	+
11.	Proteins	Xanthoproteic test	-
12.	Carboxalic acid	Sodium hydrogen carbonate test	-
13.	Resins	Acetic anhydride test	+
14.	Coumarins	NaOH test	+
15.	Leucoanthocyanin	Isoamyl alcohol test	-
16.	Phenolic compounds	Lead acetate test	+
17.	Anthocyanins	HCl & NH3 test	-

Note: + = Present and - = Absent

The phytochemical analyses on *Curcuma longa* extract have reported to commonly contain several essential classes of phytochemical compounds, including alkaloids, terpenoids, phenols, flavonoids, tannins, steroids, saponins, resins, glycosides, etc. but the results have shown that the extract is less in protein amino acids, volatile oils carboxalic acid, leucoanthocyanins and many other which may be shown with other volatile solvent like by its ethanolic extracts (Table). These findings were in line with that of (Patil et al., 2019), (Srividya et al., 2012), (Taoheed, A. A. et al.,2017).

The extracts of *C. longa* reported that the basic plant extract /100g contained maximum amount of carbohydrates noted as 45.80 ± 0 mg/100g while in relation to phytochemicals a large number of alakaloids 538.3±10.41 mg/100g were found along with tannins 455.0 ± 13.23mg/100g. The study results are more or less in range to that of (Srividya et al., 2012) and (Umar, N. M. et al.,2020).

Thus the phytochemical tests preliminary showed the presence and percentage of various secondary metabolites found in plant extract provides an evidence for protective and disease defensive nature of the plant.

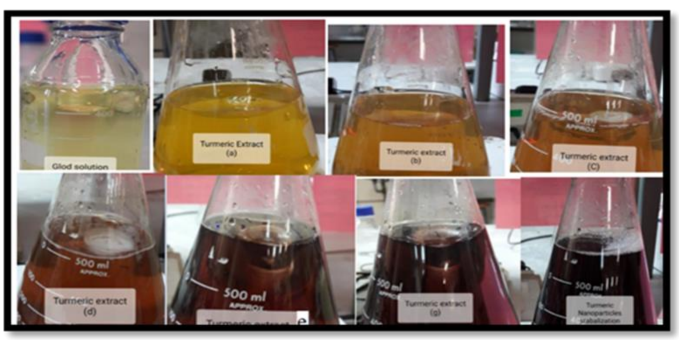


Figure: Showing color change of solution for green synthesis of TGNPs.

Characterization of TGNPs

The green nanoparticles synthesized were confirmed by the change of color which changed from shinning yellow to brown whereas in case of GNPs the colour of suspensions changed gradually from yellow to pinkish yellow and stood at dark purple. After effective synthesis the particles were optimized for best values of pH, concentation and time period. And the tests were completely checked through top affirmation, *Curcuma longa* NPs have shown peaks at 375nm which was afterward affirmed by literature (Cytodiagnostics Inc.Introduction to Gold Nanoparticle Characterization).

Nanoparticles optimization

The best reaction was observed at different concentration, pH 7, for 24 hours at 80°C, and the best reaction for enemy GNPs was observed at 3mM at pH 8-10, which gave UV absorbance peaks at, 541nm for crude extracts, UV peak settings were made at 200 to 700 nm using a UV-Vis spectrophotometer, Shimadzu, UV 1601at IIUI (CIRBS), which revealed a reduction in NPs mixtures compared to their crude extracts and pure salt solutions, such results are also noted by (Foo YY, et al., 2017).

Within 20-25 minutes of mixing 10 ml of aqueous extracts of both plants, 90 ml of 1 mM $HAuCl_4$ solution (in the case of turmeric) and 3 ml the change in colour from brown and yellow to purple violet due to reduction of Au3+ ions. comparative color changes from yellow to dull purple violet is becase of the excitation of AuNPs and surfaceplasmon resonance of gold nanoparticles synthesized by plant extract.

Characterization of the AuNPs by UV–Visible Spectrophotometer appear the best results have been observed during 24 h of incubation period. The maximum absorbance by TGNPs was noted at 553 nm. This is most similar to the findings, which confirm the arrangement of biosynthesized AuNPs from *Couroupita guianensis* extract gave absorption at 560 nm (J. Subramaniam, et al 2016) as well as the observation of sharp peaks noted at 535–565 nm for AuNP to *Amaranthus spinosus* leaf extract (M. Nicoletti, A. Canale, G. Benelli, 2016).

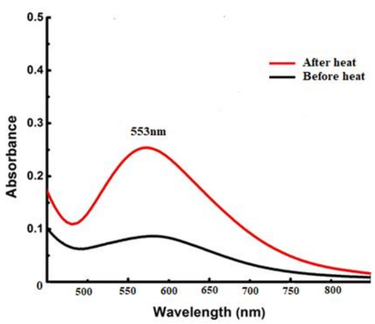


Figure: Showing TGNPs heat treatments.

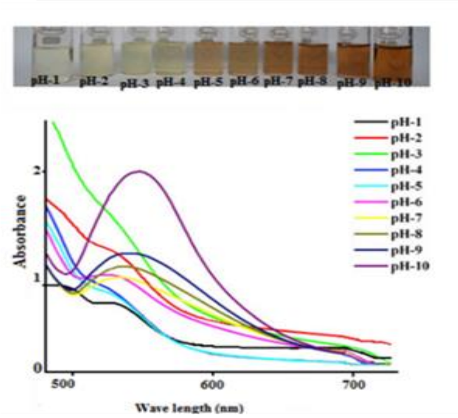


Figure: Showing results for different pH for TGNPs.

FTIR results

The alcoholic and phenolic hydroxyl bunches (O-H extending vibration) are clarified with a clear band at a wavenumber of 3342 cm1, for the TGNPs. The alcoholic and phenolic hydroxyl bunches (O-H extending vibration) are clarified with a clear band at a wavenumber of 3342 cm1. The helter kilter CH_2 extending is responsible for the clean band at 2857 cm1. Fragrant rings may be seen in the groups around 1400–1600 cm1. The fragrance ring and goodness task concentrate on the polyphenolic connection with the Au surface in this way. The C-O extension is linked to the solid band at 1049 cm1 (Methoxyl bunches). Au O was also attributed with the distinctive band at 569 cm1. All of these distinct vibrational groups point to the Curcumae Kwangsiensis Folium Functionalized Au NP once again. The above-mentioned groupings have previously been seen ponders (You et al., 2012).

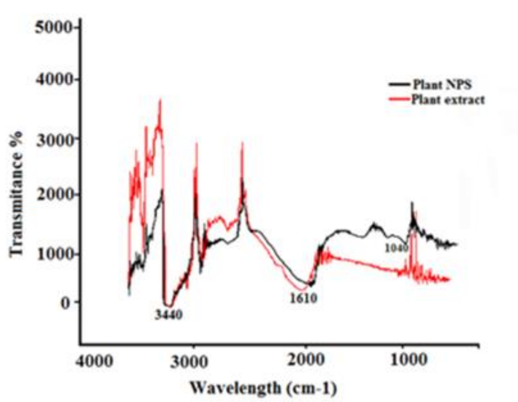


Figure: FTIR of TGNPs.

XRD results

NPs for Turmeric are round (wurtzite structure). The same results have been recorded by (Arockiya F. et al., 2014). NPS are crystalline in nature, as shown by the angle and constricted diffraction peaks. The particle's crystalline size (D) was calculated using the Scherrer equation and XRD line broadening estimate.

D = 0.89/(Cos)

Where the wave is

= The TGNPs (101) line's total width half-most extreme (FWHM) or a specific diffraction at top and bottom.

= The angle of diffraction

The peaks of T. GNPs obtained with the $AuCl_4$ were decreasing with 32°, 38°, 46°, and 57°. When can be observed in figures, since the pH of the solution rises, the breadth of the XRD data, indicating an increase in the size of produced AuNPs, which is consistent with the assimilation spectra of AuNPs at various pH. These results show similarity to that of (Alti D. et al., 2020).

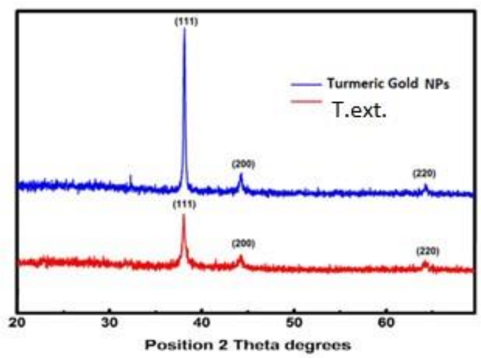


Figure: XRD results for TGNPs.

SEM results

For Au nanoparticles, the size is found to be about 100nm. TGNPs, on the other hand, are alcoholic and phenolic. The gold nanoparticles containing plant fluid extricates have been shown to have a size of less than 50 nm (Tahvilian et al., 2019).

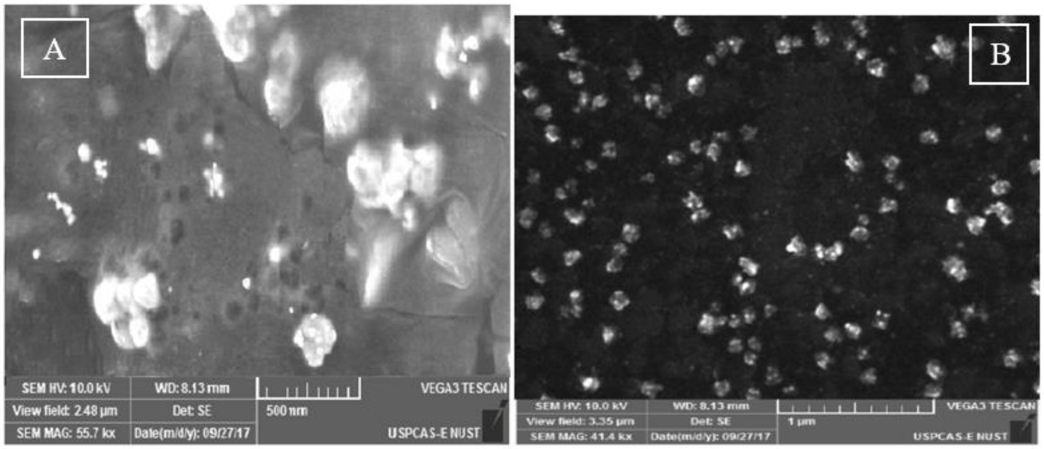


Figure: Showing SEM images of TGNPs: A at 500nm and B at 1um.

Antibacterial activity

Two bacterial species one from Gram –positive and other from Gram –negative origin were selected and tested. *E. coli* commonly known as *Escherichia coli* which is a Gram-negative bacteria and *S. aureces* commonly known as *Staphylococcus aureus* is a round-shaped Gram-positive, bacterium which were tested against different concentrations.

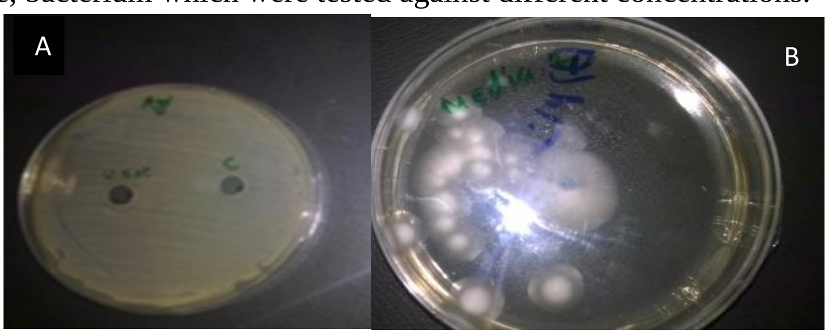


Figure: Showing, (A) *S. aureus* and *(*B) *E. coli* used in study.

Turmeric nanoparticle at different concentration 100Ug/ml,12.5Ug/ml, 1.5Ug/ml against *(E. coli)*

Modern medicines are providing enourmous ways to kills resistant infectious agent against emergence of multidrug-resistant in bacterial strains. Plant-mediated nanomaterial which were synthesized in the present study were tested (TGNPs). The maximum antibacterial activity of (*E. coli*) were found in gold nanoparticle with turmeric extracts at 100µg/ml which have shown 17mm, 11mm inhibition zone at concentrations12.5 µg/ml and 1.5µg/ml respectively. Turmeric extracts has shown 9mm, 5mm ZI (Zone of inhibition) at 12.5 µg/ml and 1.5µg/ml against *E.*

coli. Cefixime was used as positive control which had the highest 7mm ZI at 12.5µg/ml. While in control (water) no activity was found. Gold nanoparticles may enhance the antibacterial effects of loaded antibacterial medicines, as well as play a better antibacterial function in antibacterial tactics against resistant bacterial strains when used in conjunction with other antibacterial treatments (Su et al., 2020). Similar study was reported by Gulzman et al. (2012), They observed visible ZI produced by AgNPs against Gram-negative bacteria at optimum concentrations. AgNPs with tea support the result related with antimicrobial activity (Loo et al., 2018).

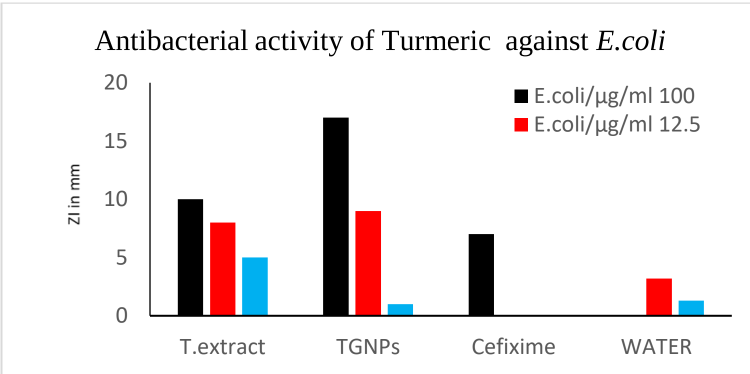


Figure: Aantibacterial activity of Turmeric against *E.coli* at 100µg/ml, 12.5 µg/ml and 1.5 µg/ml.

Teatments names (T.extract=Tumeric extract, TGNP= turmeric gold green. Cefixime =Antibiotic, Water= Negative control against). The vertical bars indicate the standard error, and the values are the averages of three replicates. At $P<0.05$, all treatments are substantially different from one another.

Turmeric nanoparticle at different concentration 100Ug/ml,12.5Ug/ml, 1.5Ug/ml against (*S. aerous*)

Antibacterial activity was exhibited by nanoparticles, which stops the growth of *S. aerous*, that canister be perceived in the form of the clear zone everywhere the hole. The most resistant of *S. aerous* with a minimum inhibition zone of 11.2mm, 13.0 mm for gold nanoparticle with turmeric extracts at 100µg/ml respectively. Turmeric extracts at 100 µg/ml was effective against *S. aerous*; inhibition zone were 12mm. In cefixime the maximum activity 15mm inhibition was found which was at par of 12.5µg/ml, 1.5µg/ml. While in control (water) there were no activity were found. The previous study concluded that NP can be, inhibit the growth of *bacteria* by releasing ROS which damage membrane (Tiwari, 2018).

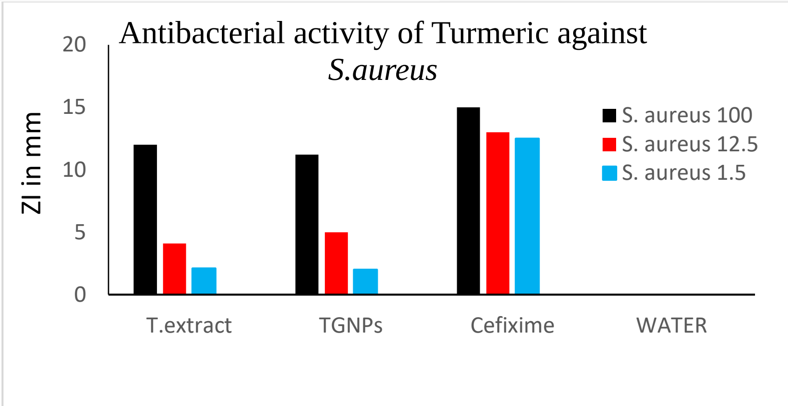


Figure: Aantibacterial activity of Turmeric against S. aureus at 100µg/ml, 12.5 µg/ml and 1.5 µg/ml.

Teatments names (T.extract=Tumeric extract, TGNP =Turmeric gold green. Cefixime =Antibiotic, Water= Negative control against). The vertical bars indicate the standard error, and the values are the averages of three replicates. At $P<0.05$, all treatments are substantially different from one another.

CONCLUSION

The drug-resistant of microorganisms is an incredible challenge for therapeutic practitioners, and unused drugs are getting focus to treat numerous diseases. Inventive progresses in nanomedicine offer an easy way of bio-imaging techniques for early discovery frameworks. Green metallic nanoparticles synthesis is growing in to an important branch of nanotechnology, moving away from typically synthesized harmful and flammable chemical medications. The present study reports about green synthesized gold nanoparticles with turmeric *Curcuma longa* L. having strong anti-microbial properties. The nanoparticles were optimized by distinctive parameters and found stabilized at pH 9-10, higher temperature ranges proved best for nanoparticles stabilization, in terms of different concentrations 3mM had sharp peaks. UV-vis spectrophotometer and FTIR affirmed the morphology as round and star shaped with size of 100-60nm. The FTIR results have revealed phenols flavonoids, alkanes and a few amines are included in capping of these nanoparticles. The neo nanoparticles have affirmed for distinctive antibacterial, ativities against *E. coli* and *S.aureces.* Overall the nanoparticles appeared distinctive activities and TGNPs demonstrated best for bioactivities analysis.

ACKNOWLEDGMENT

This research was fully funded by the HEC faculty development Programmed. We are also thankful to Centre for Interdisciplinary Research in Basic Science (CIRBS, IIUI), Faculty of Basic and Applied Sciences and Institute for Halal Research and Training (INHART, IIUM) for providing necessary facilities and support to carry out this work.

REFRENCES

Ali, T., Shakir, F. and Morton, J. (2012). Curcumin and inflammatory, bowel disease: Biological mechanisms and clinical implication. Digestion 85:249–255.

Alti, D., Veeramohan Rao, M., Rao, D. N., Maurya, R., & Kalangi, S. K. (2020). Gold–Silver Bimetallic Nanoparticles Reduced with Herbal Leaf Extracts Induce ROS-Mediated Death in Both Promastigote and Amastigote Stages of *Leishmania donovani*. ACS omega, 5(26), 16238-16245.

Ammon, H.P. and M. Wahl. (1991). Pharmacology of *Curcuma longa*. Planta Medicine, 57: 1-7.

Arockiya F., Aarthi R., V. R. M. & Subramanyam N. (2014). Phytofabrication of nano-crystalline platinum particles by leaves of *Cerbera mangas* and its antibacterial efficacy. International Journal of Pharmacology and Biological Sciences, 5, 619 – 628.

Faa, G., Gerosa, C., Fanni, D., Lachowicz, J. I., & Nurchi, V. M. (2018). Gold-old drug with new potentials. Current medicinal chemistry, 25(1), 75-84.

Gulzman, M., Dille, J., and Godet, S. (2012). Synthesis and antibacterial activity of silver nanoparticles against gram-positive and gram-negative bacteria. Nanomedicine 8, 37–45.

Hatcher, H., Planalp, R., Cho, J., Torti, F. M. and Torti, S. V. (2008). Curcumin: From ancient medicine to current clinical trials. Cell Mol Life Science. 65:1631–1652.

Jan, H. A., Jan, S., Bussmann, R. W., Wali, S., Sisto, F., & Ahmad, L. (2020). Complementary and alternative medicine research, prospects and limitations in Pakistan: A literature review. Acta Ecological Sinica, 40(6), 451-463.

Jansen, P. C. M. (1981). Spices, condiments, and medicinal plants in Ethiopia, their taxonomy, and agricultural significance. Pudoc publishers., 45-49.

Kean, W. F., & Kean, I. R. L. (2008). Clinical pharmacology of gold. Journal of Inflammo pharmacology, 16(3), 112-125.

Kelly K. (2009). History of medicine. New York: Facts on file, 29–50.

Khan, M., Khan, A. U., Bogdanchikova, N., & Garibo, D. (2020). Antibacterial and antifungal Studies of Biosynthesized Silver Nanoparticles against Plant Parasitic Nematode *Meloidogyne incognita*, Plant Pathogens Ralstonia solanacearum and Fusarium oxysporum. Molecules, 26(9), 2462.

Khan, M.A., Prakash, R., Ali, S., Aljarbou, A., Khan, M.A. (2011). Comparative study of antibacterial activity and toxicity of certain plants used in Unani medicine. Advances in Bioresearch 2(2): 10-13.

Kumar, N., & Kumbhat, S. (2016). Essentials in nanoscience and nanotechnology. John Wiley & Sons.567-568.

Li, X., Xu, H., Chen, Z. S., & Chen, G. (2011). Biosynthesis of naoparticles by microorganisms and their applications. Journal of Nanomaterials, 67-76.

Loo, Y. Y., Rukayadi, Y., Nor-Khaizura, M. A. R., Kuan, C. H., Chieng, B. W., Nishibuchi, M., & Radu, S. (2018). In vitro antimicrobial activity of green synthesized silver Nanoparticles against selected gram-negative foodborne pathogens. Frontiers in microbiology, 9, 1555.

Mishra S. & Palanivelu K. (2008). The effect of curcumin (turmeric) on Alzheimer's disease: An overview. Annals of Indian Academy Neurology, 11, 13–9.

Pissuwan, D., Cortie, C. H., Valenzuela, S. M., & Cortie, M. B. (2010). Functionalised Gold nanoparticles for controlling pathogenic bacteria. Trends in biotechnology, 28(4), 207-213.

Ragasa C., Laguardia M. & Rideout J. (2005). Antimicrobial sesquiterpenoids and diarylheptanoid from *Curcuma domestic*. ACGC Chemical Research Communications, 18, 21–24.

Rao, C. K., & Annadana, S. (2017). Nutrient biofortification of staple food crops: Technologies, products, and prospects. Phytonutritional improvement of crops, 135.

Sadaf, F., & Ahmad, S. I. (2009). Preliminary neuropharmacological studies on herbal drug Aftimooni. Pakistan Journal of Pharmacology, 26(1), 31-38

Singh R., Shitiz K., Singh S., Jha S., Singh A. (2018). Evaluation of wound dressing properties of chitin membranes containing nanosilver. Biomedical Physics and Engineering Express 4:025030.

Shunmugaperumal, T., Thenrajan, R. S., & Sharma, R. (2017). Multifunctional nanosized emulsions for theragnosis of life threatening diseases. In Nanostructures for Drug Delivery

Singh, M.D., (2017). Nano-fertilizers is a new way to increase nutrients use efficiency in crop production. International Journal of Agriculture Sciences, ISSN, pp.0975-3710.

Singh, A., & Dhariwal, S. (2018). Navneet. Traditional uses, Antimicrobial potential, Pharmacological properties and Phytochemistry of *Viola odorata*: A Mini Review. The Journal of Phytopharmacology, 7(1), 103-105.

Singh, A., Gautam, P. K., Verma, A., Singh, V., Shivapriya, P. M., Shivalkar, S., & Samanta, S. K. (2020). Green synthesis of metallic nanoparticles as effective alternatives to treat antibiotics resistant bacterial infections: A review. Biotechnology Reports, 25, 00427.

Singh, R., Gupta, A. K., Patade, V. Y., Balakrishna, G., Pandey, H. K., & Singh, A.(2019). Synthesis of silver nanoparticles using extract of *Ocimum kilimandscharicum* and its antimicrobial activity against plant pathogens. SN Applied Sciences, 1(12), 1-12.

Tahvilian, R., Zangeneh, M.M., Falahi, H. et al. (2019). Green synthesis and chemical characterization of copper nanoparticles using *Allium saralicum* leaves and assessment of their cytotoxicity, antioxidant, antimicrobial, and cutaneous wound healing properties. Applied Organometric Chemistry, 33, e5234.

Tan, N. H., & Zhou, J. (2006). Plant cyclopeptides. Chemical reviews, 106(3), 840-895.Tao, C. (2018). Antimicrobial activity and toxicity of gold nanoparticles: research progress, challenges and prospects. Letters in applied microbiology, 67(6), 537-543.

Taoheed, A. A., Tolulope, A. A., Saidu, A. B., Odewumi, O. G., Sunday, R. M., & Usman, M.

(2017). Phytochemical properties, proximate and mineral composition of *Curcuma longa Linn*. and Zingiber officinale Rosc. A comparative study. Journal of Scientific Research and Reports, 1-7.

Tiwari, V., Mishra, N., Gadani, K., Solanki, P. S., Shah, N. A., & Tiwari, M. (2018). Mechanism of anti-bacterial activity of zinc oxide nanoparticle against carbapenem-resistant *Acinetobacter baumannii*. Frontiers in microbiology, 9, 1218.

Umar, N. M., Parumasivam, T., Aminu, N., & Toh, S. M. (2020). Phytochemical and pharmacological properties of *Curcuma aromatica* Salisb (wild turmeric). Journal of Applied Pharmaceutical Science, 10(10), 180-194.

Yu, H., Park, J. Y., Kwon, C. W., Hong, S. C., Park, K. M., & Chang, P. S. (2018). An overview of nanotechnology in food science: Preparative methods, practical applications, and safety. Journal of Chemistry, 56-58.