Green Synthesis and Characterization of Gold Nanoparticles using Ethanolic Turmeric Crude Extract At Neutral Ph

Sameera Abbas, Muhammad Sohail Latif, Ida Idayu Muhamad, Faridah Kormin

Abstract*: There is a great interest in the development of green protocols to avoid environmental and health hazards. In this research, the eco-friendly and cost-effective synthesis of gold nanoparticles (GNPs) has been achieved by the green method using ethanolic turmeric crude extract at pH 7. The bioac-tive compounds of turmeric crude extract are responsible for the reduction, capping and sta-bility of the GNPs. The characterization of GNPs was carried out by ultraviolet-visible (UV-vis) spectroscopy, Fourier transforms infrared (FTIR) spectroscopy, field emission scanning electron microscopy (FESEM) and energy dispersive X-ray (EDX) spectroscopy. The UV-vis spectral study indicated the formation of GNPs with a surface plasmon resonance (SPR) band at 547 nm. FTIR analysis of turmeric crude extract and GNPs showed that phenolic groups reduced the gold ions. The FESEM analysis showed the polydisperse morphology of GNPs with average size of 26.6 nm±7.4 nm. The elemental composition determined by EDX re-vealed the presence of gold. The synthesized GNPs can be useful in a variety of applications involving medicine, cosmetics, environment and nutraceutical.

Keywords: Biosynthesis, Gold Nanoparticles,Green synthesis, pH, Turmeric crude extract.

I. INTRODUCTION

Metallic nanoparticles have unique optical, catalytic and magnetic properties. The morphology and monodispersity of the particles are main factors for tuning these properties [1]. Nanoparticles are used in a variety of felids such as biomedical, health, food, drug delivery, mechanical optics ,chemical industries and cosmetics [2-3]. Many methods have been developed for nano-synthesis like ,physical, chemical and biological [4-6].The chemical method for the synthesis of nanoparticles produces highly toxic compounds. However, synthesizing the nanoparticles by a green method is an alternative route which uses the natural ingredients [7].In green method, use of plant extracts and microorganisms for the synthesis of nanoparticles are biocompatible and do not produce toxic compounds, therefore the green method is a good alternative method for nanoparticle synthesis [8].

In recent years biomedical applications of gold nanoparticles become very active in different area of research [9] like gene and drug delivery [10],detection of proteins and pathogens, labeling of deoxyribonucleic acid, fluorescent labeling and tissue engineering [11]. The reduction of gold by the natural compounds is favorable over the chemical method by virtue of their biocompatibility, purity and non-toxicity [12-13]. For the production of gold nanoparticles the green substances such as fungus [14], algae [15] and enzyme [16] were reported successfully, however as compared to the use of microbe for gold nanoparticles synthesis ,plant-mediated synthesis is easy to manipulate the shape and size of nanoparticles. Plant-based synthesis is fast, safe and works under room conditions without any need for high physical requirements [17].

Turmeric (*Curcuma longa*) is a rhizomatous perennial herb of the ginger family. It is cultivated in tropical and subtropical region of Asia. The medicinal properties of turmeric are well known and it has been investigated for the mechanism of action and its bioactive compounds [18]. The main group of constituents of turmeric is polyphenolic curcuminoids which includes curcumin (diferuloylmethane), bisdemethoxycurcumin, demethoxycurcumin and cyclocurcumin. The curcuminoids which is yellow-pigmented composed of 85% as curcumin, 10% as demethoxycurcumin and 5% as bisdemethoxycurcumin. The most well studied compound of turmeric is curcumin. Turmeric also contain some other compounds like, sesquiterpenes (turmerone, turmeronol atlantone,,zingiberone germacrone and bisabolene). In turmeric protein carbohydrates, resins, and caffeic acid are also present [19]. The chemical structures of some important components of turmeric are given in Fig 1. It is widely used for health benefits in different countries of the world including India, Pakistan, Malaysia, Thailand, Japan, China, Korea and United State of America as a medicinal herb. Various health benefits of turmeric are attributed to its anti-inflammatory, antioxidant [20] antimicrobial, antimutagenic [21-22] and anticancer properties [23].

Revised Manuscript Received on February 15, 2020.

***** Correspondence Author

Sameera Abbas, Faculty of Applied Sciences & Technology, University Tun Hussein Onn Malaysia (UTHM), KM1 Jalan Panchor, Pagoh Educational Hub, Pagoh, Muar, Johor, Malaysia. Email: sameerasohail1314@gmail.com

Muhammad Sohail Latif, Faculty of Applied Sciences & Technology, University Tun Hussein Onn Malaysia (UTHM), KM1 Jalan Panchor, Pagoh Educational Hub, Pagoh, Muar, Johor, Malaysia. Email: slatif37@gmail.com

Ida Idayu Muhamad, Department of Bioprocess and Polymer Engineering, Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia. Email: idaidayu@utm.my

Faridah Kormin*, Department of Technology & Natural Resources, Faculty of Applied Sciences & Technology, University Tun Hussein Onn Malaysia (UTHM), KM1 Jalan Panchor, Pagoh Educational Hub, Pagoh, Muar, Johor, Malaysia. Email: faridahk@uthm.edu.my

It is used in curries, cosmetics, tea, energy drinks, in medicines, as coloring and preservating agent in cheese butter, mustard sauce and chips [18]. The rhizome has been also used for the treatment of swellings, burns, small pox, ulcer of stomach and mouth [24] it has been also used in Ayurvedic medicine to prevent water loss from the body, smoothening of skin, for the improvement of blood circulation. It is also used as an anti-microbial and anti-irritant [25-26]. It has been shown by the past 30 years' research that it plays a vital role for the prevention and treatment of various pro-inflammatory chronic conditions including cardiovascular, metabolic, neurodegenerative, malignant and autoimmune diseases [27]. Inspite of therapeutic potential of turmeric, its water solubility and bioavailability is low. Different methods have been developed to increase the bioavailability of turmeric [28], one of them being the turmeric-mediated nanoparticle synthesis. The conjugation of turmeric and metal ions in an aqueous medium to synthesize nanoparticles can increase its stability, activity, bioavailability and half-life [29-30]. In this research, we have reported the green synthesis of GNPs using ethanolic crude extract of turmeric at pH 7. The synthesis of GNPs occurred by direct reduction of gold ions ($HAuCl_4$) in an aqueous medium, so that surface of GNPs was coated by the bioactive compounds of turmeric crude extract. Green synthesis is cost effective and simple method. The process of the nano-synthesis was monitored by using UV-vis spectroscopy. The green synthesized nanoparticles were characterized by FTIR, FESEM and EDX (Energy dispersive X-ray spectroscopy) to determine the coated compounds, size and shape, and elemental composition, respectively.

II. MATERIALS AND METHODS

A. Materials

Turmeric was purchased from local market. $HAuCl_4.3H_2O$ was purchased from Sigma-Aldrich, USA, which was used as the gold precursor. Ethanol (≥ 99.4 %) was purchased from Merck, Germany.

B. Preparation of ethanolic turmeric crude extract (TCE)

Turmeric was washed with tap water to remove dirt followed by rinsing with distilled water. It was then peeled and cut into small pieces. The pieces were put into the oven at 40°C for drying. All the dried pieces were put into the electric grinder to make a fine powder that was stored at room temperature till further use. The ethanolic turmeric crude extract (TCE) was prepared by adding 4 gram of fine turmeric powder into 60 ml of absolute ethanol and kept on constant magnetic stirring for 48 hours at room temperature. The crude extract was filtered twice by using Whatmann filter paper no. 1. The filtrate was then kept in the oven at 40°C for drying [31]. The 10 mg/ml stock solution of the dried crude extract was prepared in absolute ethanol. From this stock, 2% of turmeric crude extract solution was prepared which was used for the synthesis of GNPs.

C. Synthesis of TCE-mediated gold nanoparticles

In conical flask, 2% turmeric crude extract solution was added and then the pH of the extract was adjusted to 7.0 by using 0.1 M NaOH. Turmeric crude extract and 0.25mM $HAuCl_4$ were mixed in a ratio of 1:4 at room temperature. The synthesis of nanoparticles was monitored by observing the colour change in the reaction mixture and recording the UV-vis spectra [32]. The color of the solution was changed from yellow to peach and then purplish pink indicating the formation of GNPs as shown in Figure 2.

D. Characterization of TCE-GNPs

The change in color of the reaction mixture indicates the formation of GNPs which has been observed visually and recorded through UV-vis spectra by using UV-Vis spectrometer (Biomate 3S, Thermo Scientific, USA) at regular interval within the range of 400 to 900 nm at a resolution of 1 nm. The spectra were recorded after 15, 30, 75,150 min and then after 24 and 48 hours. The reaction mixture was centrifuged at 12000 rpm for 10 min after 48 hours. The GNPs were pelleted down and the pellet was washed with distilled water three times to remove the unreacted extract material. The GNPs thus obtained were used for further characterization by FTIR, FESEM and EDX.

FT-IR spectra were recorded to identify the possible functional groups which were involved in the synthesis of Tur-GNPs. In FTIR, minute quantity of GNPs was used for characterization. The sample for FESEM analysis were prepared by placing a drop of the GNP solution on the glass slide and evaporating excess water by using a hot plate to get a thin film of GNPs. Then, the FESEM images were recorded using a JEOL JSM-7600F FESEM operating at an acceleration voltage of 10kV. The elemental analysis of the GNPs was performed using EDX on JEOL JSM-7600F FESEM.

III. RESULTS AND DISCUSSION

The turmeric crude extract acted as both reducing and stabilizing agent for $HAuCl_4$ which was the precursor of gold ions. The polyphenol from plants are effective reducing agent for gold. When this polyphenol binds with soft metals (Au^+), the concerned soft metal undergo reduction reaction and finally gold nanoparticles produced instead of complex compound formation [33]. The reduction of the $HAuCl_4$ was indicated by the colour change of reaction mixture. The yellow colour of the reaction mixture turned into peach and then pinkish purple indicating the formation of GNPs.

The formation of GNPs was indicated by the colour change after the mixing the reactants at room temperature, which was confirmed by UV-Vis spectroscopy. A strong peak was observed in the range of 540-550 nm due to the surface plasmon resonance of the GNPs. The peak steadily increased with the passage of time. UV-Vis spectroscopy analysis showed that the surface plasmons absorbance band of GNPs synthesized by using turmeric crude extract remained centered at 540-550 nm after 8 months with little decrease in its absorbance without any shift in its wavelength (Figure 3) which shows the stability of the GNPs at room temperature.

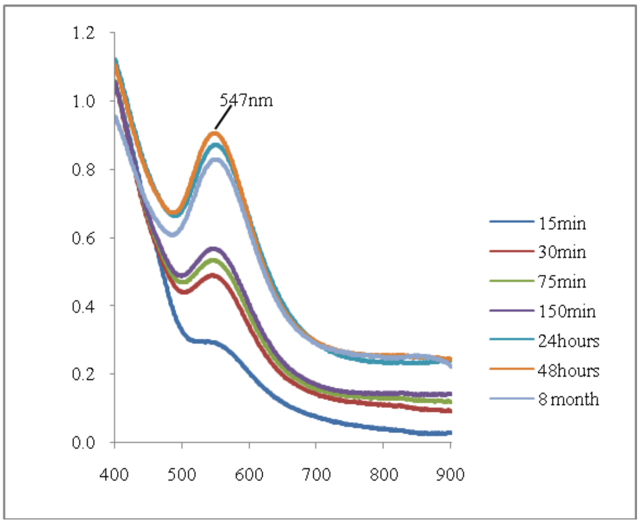


Figure 3. UV-vis spectra of TCE-GNPs synthesized at neutral pH

FTIR spectroscopy determined the functional groups that were responsible for the formation of GNPs. FTIR spectra of turmeric crude extract were recorded before and after the bioreduction of $AuCl_4$ for the formation of GNPs as shown in Figure 4. The FTIR spectra before reduction of turmeric crude extract showed peaks at 3334 cm^{-1}, 2973 cm^{-1}, 2881 cm^{-1}, 1274 cm^{-1}, 1046 cm^{-1}, 880 cm^{-1} and 632 cm^{-1}. The broadband at 3334 cm-1 represents the free hydroxyl-group of phenol (-OH). The sharp band at 2973 cm^{-1} and 2881 cm^{-1} represent the stretching of the C–H bond. The band at 1046 cm^{-1} may be considered as the –C-O group of the polyphenols such as flavones, polysaccharides and terpenoids [34-36]. The FTIR spectra after reduction of turmeric crude extract showed peak at 3334 cm^{-1} belongs to the –OH group which, in this case, can be attributed to the phenolic compounds of turmeric extract. A second important stretching vibration is recorded at 1635 cm^{-1} which, although may be considered as benzene ring containing aromatic compounds, may also be taken into account for phenolic compounds as they exhibit strong vibration on this wavenumber [37-39]. Overall, the FTIR analysis indicates that the phytochemicals present in the turmeric crude extract are responsible for the bioreduction and stability of GNPs.

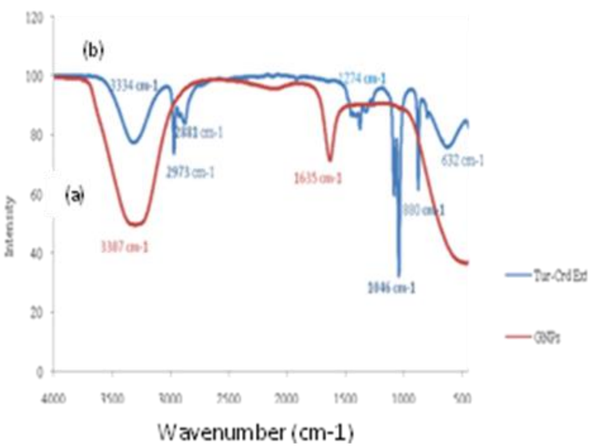


Figure 2. FTIR spectra of (a) TCE and (b) TCE-GNPs

The morphology and size of the Tur-GNPs were investigated using the FESEM as shown in Figure 5. The surface morphology of GNPs reveals the anisotropic poly dispersion of particles which are mostly irregular in shape. The histogram shows the size distribution of nanoparticles that ranges from 11 nm to 40 nm. The average size of GNPs is 26.6 nm ± 7.4 nm. This result confirms that turmeric crude extract acted as a reducing and capping agent for the synthesis of GNPs.

EDX was used for elemental analysis of GNPs by using energy dispersive X-ray microanalysis. The EDX analysis was carried out using a FESEM equipped with an energy dispersive X-ray spectrometer. The quantitative analysis EDX confirmed the elemental composition of synthesized GNPs. The gold was at its highest elementary composition while carbon, oxygen and silicon were present in trace amount as shown in Figure 6. The percentage elemental composition is given in Table I. The presence of the strong signal from gold 73.80 % atoms also explain the formation of gold particles.

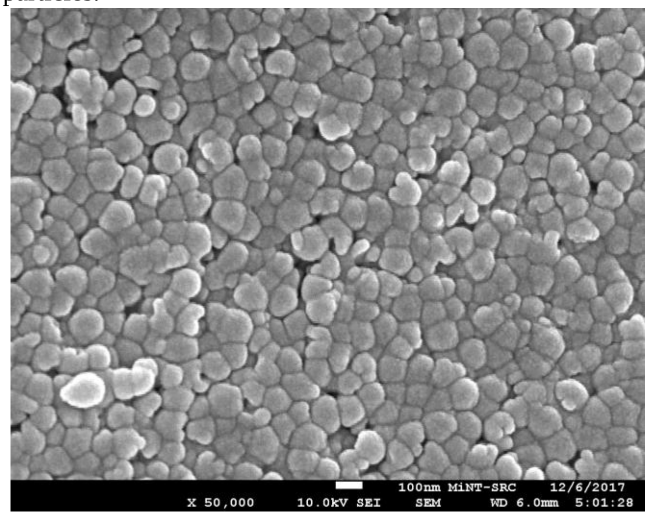
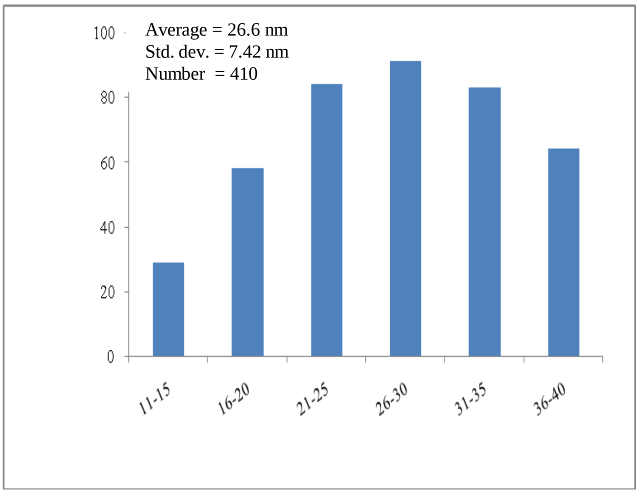


Figure 4. FESEM image of TCE-GNPs synthesized at neutral pH.



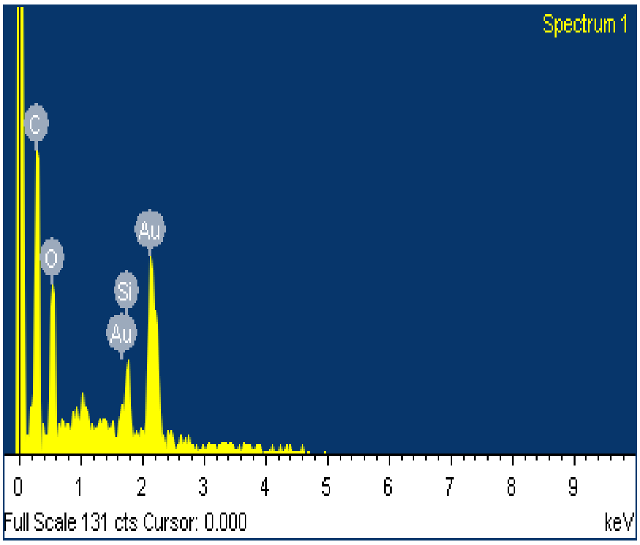


Figure 5. EDX spectrum of TCE-GNPs

Table- I. Elemental composition of TCE-GNPs

Element	Weight %	Atomic %
C	14.24	53.75
O	8.15	23.11
Si	3.80	6.14
Au	73.80	16.99

IV. CONCLUSION

In this study, GNPs were successfully synthesized by an environmentally favorable green synthesis approach using turmeric crude extract at neutral pH. The methodology is cost-effective, simple, safe and non-toxic as compared to physical and chemical methods. The turmeric crude extract acted as reducing and stabilizing agent for the nanosynthesis of gold particles. Furthermore, the adopted procedure involved *in vitro* green nanosynthesis that could be easily manipulated for large scale production of GNPs. The synthesized GNPs have the potential for application in a variety of fields including biomedicine, pharmaceutical, environment, and food and nutraceutical industries.

ACKNOWLEDGMENT

We are thankful to Research Management Centre (RMC), Universiti Tun Hussein Onn Malaysia (UTHM) for financial support through funding with Multidisciplinary Research (MDR) Vote No. H506, Geran Penyelidikan Picasiswazah (GPPS) Vote No. U489 & U602 and Fundamental Research Grant Scheme (FRGS) Vote no. K104.

REFERENCES

1. N. Suganthy, V. Sri Ramkumar, A. Pugazhendhi, G. Benelli, and G. Archunan, "Biogenic synthesis of gold nanoparticles from Terminalia arjuna bark extract: assessment of safety aspects and neuroprotective potential via antioxidant, anticholinesterase, and antiamyloidogenic effects," Environ. Sci. Pollut. Res., vol. 25, no. 11, pp. 10418–10433, 2018.
2. K. A. Khalil, H. Fouad, T. Elsarnagawy, and F. N. Almajhdi, "Preparation and Characterization of Electrospun PLGA/silver Composite Nanofibers for Biomedical Applications," Int. J. Electrochem. Sci, vol. 8, pp. 3483–3493, 2013.
3. H. Korbekandi and S. Iravani, "Silver Nanoparticles," in The Delivery of Nanoparticles, 2012, pp. 3–36.
4. V. K. R. Kumar and K. R. Gopidas, "Synthesis and characterization of gold-nanoparticle-cored dendrimers stabilized by metal-carbon bonds," Chem. - An Asian J., vol. 5, no. 4, pp. 887–896, 2010.
5. S. Deyev et al., "Synthesis, Characterization, and Selective Delivery of DARPin-Gold Nanoparticle Conjugates to Cancer Cells," Bioconjug. Chem., vol. 28, no. 10, pp. 2569–2574, 2017.
6. G. V. Khutale and A. Casey, "Synthesis and characterization of a multifunctional gold-doxorubicin nanoparticle system for pH triggered intracellular anticancer drug release," Eur. J. Pharm. Biopharm., vol. 119, pp. 372–380, 2017.
7. S. S. Shankar, A. Rai, B. Ankamwar, A. Singh, A. Ahmad, and M. Sastry, "Biological synthesis of triangular gold nanoprisms," Nat. Mater., vol. 3, no. 7, pp. 482–488, 2004.
8. S. Aswathy Aromal and D. Philip, "Green synthesis of gold nanoparticles using Trigonella foenum-graecum and its size-dependent catalytic activity," Spectrochim. Acta - Part A Mol. Biomol. Spectrosc., vol. 97, pp. 1–5, 2012.
9. A. J. Mieszawska, W. J. M. Mulder, Z. A. Fayad, and D. P. Cormode, "Multifunctional gold nanoparticles for diagnosis and therapy of disease," Molecular Pharmaceutics, vol. 10, no. 3. pp. 831–847, 2013.
10. A. Kumar, X. Zhang, and X.-J. Liang, "Gold nanoparticles: Emerging paradigm for targeted drug delivery system," Biotechnol. Adv., vol. 31, no. 5, pp. 593–606, 2013.
11. O. V. Salata, "Applications of nanoparticles in biology and medicine," Journal of Nanobiotechnology, vol. 2. 2004.
12. R.-D. Pasca, A. Mocanu, S.-C. Cobzac, I. Petean, O. Horovitz, and M. Tomoaia-Cotisel, "Biogenic Syntheses of Gold Nanoparticles Using Plant Extracts," Part. Sci. Technol., vol. 32, no. 2, pp. 131–137, 2014.
13. S. Joseph and B. Mathew, "Microwave assisted facile green synthesis of silver and gold nanocatalysts using the leaf extract of Aerva lanata," Spectrochim. Acta - Part A Mol. Biomol. Spectrosc., vol. 136, no. PC, pp. 1371–1379, 2015.
14. A. Vágó, G. Szakacs, G. Sáfrán, R. Horvath, B. Pécz, and I. Lagzi, "One-step green synthesis of gold nanoparticles by mesophilic filamentous fungi," Chem. Phys. Lett., 2016.
15. N. González-Ballesteros, S. Prado-López, J. B. Rodríguez-González, M. Lastra, and M. C. Rodríguez-Argüelles, "Green synthesis of gold nanoparticles using brown algae Cystoseira baccata: Its activity in colon cancer cells," Colloids Surfaces B Biointerfaces, 2017.
16. V. P. Venkatpurwar and V. B. Pokharkar, "Biosynthesis of gold nanoparticles using therapeutic enzyme: In-vitro and in-vivo efficacy study," J. Biomed. Nanotechnol., 2010.
17. K. Xin Lee et al., "Green Synthesis of Gold Nanoparticles Using Aqueous Extract of Garcinia mangostana Fruit Peels," J. Nanomater., 2016.
18. S. C. Gupta, S. Patchva, and B. B. Aggarwal, "Therapeutic Roles of Curcumin: Lessons Learned from Clinical Trials," AAPS J., 2013.
19. J. S. Jurenka, "Anti-inflammatory properties of Curcumin, a majorconstituent of Curcuma longa: a review of preclinical and clinicalresearch.," Altern. Med. Rev., vol. 14, no. 2, p. Jurenka, Julie S, 2009.
20. A. A. Farooqui, Therapeutic potentials of curcumin for Alzheimer disease. 2016.
21. G. B. Mahady, S. L. Pendland, G. Yun, and Z. Z. Lu, "Turmeric (Curcuma longa) and curcumin inhibit the growth of Helicobacter pylori, a group 1 carcinogen," Anticancer Res., 2002.
22. R. C. Reddy, P. G. Vatsala, V. G. Keshamouni, G. Padmanaban, and P. N. Rangarajan, "Curcumin for malaria therapy," Biochem. Biophys. Res. Commun., 2005.
23. T. S. Ramasamy, A. Z. Ayob, H. H. L. Myint, S. Thiagarajah, and F. Amini, "Targeting colorectal cancer stem cells using curcumin and curcumin analogues: Insights into the mechanism of the therapeutic efficacy," Cancer Cell International. 2015.
24. A. Al-Kashmiri, M. Al-Mutani, and A. Al-Zadjali, "Complications of hot tumeric use in acute trauma.," Oman Med. J., 2010.
25. American Cancer Society, "Turmeric," Complementary and Alternative Medicine » Herbs, Vitamins, and Minerals » Turmeric, 2014.
26. Abu Bakar et al., "Comparison Of Phytochemicals, Antioxidant And Anti-Cholinesterase Activity Of Unripe And Ripe Fruit Of Sonneratia Caseolaris," Food Research, vol. 4, no. 2, pp. 507-514, 2020.

27. S. Prasad, A. K. Tyagi, and B. B. Aggarwal, "Recent developments in delivery, bioavailability, absorption and metabolism of curcumin: The golden pigment from golden spice," Cancer Res. Treat., vol. 46, no. 1, pp. 2–18, 2014.
28. R. Nazari-Vanani, N. Sattarahmady, and H. Heli, "Nanotechnological approaches for enhancing the oral bioavailability of curcumin," J. Biol. Today's World, 2017.
29. D. K. Singh, R. Jagannathan, P. Khandelwal, P. M. Abraham, and P. Poddar, "In situ synthesis and surface functionalization of gold nanoparticles with curcumin and their antioxidant properties: an experimental and density functional theory investigation," Nanoscale, 2013.
30. C. Sreelakshmi, N. Goel, K. K. R. Datta, A. Addlagatta, R. Ummanni, and B. V. S. Reddy, "Green Synthesis of Curcumin Capped Gold Nanoparticles and Evaluation of Their Cytotoxicity," Nanosci. Nanotechnol. Lett., vol. 5, no. 12, pp. 1258–1265, 2013.
31. E. M. Tanvir *et al.*, "Antioxidant properties of popular turmeric (Curcuma longa) varieties from Bangladesh," J. Food Qual., 2017.
32. A. K. Singh and O. N. Srivastava, "One-Step Green Synthesis of Gold Nanoparticles Using Black Cardamom and Effect of pH on Its Synthesis," Nanoscale Res. Lett., 2015.
33. P. Vijaya Kumar, S. Mary Jelastin Kala, and K. S. Prakash, "Green synthesis of gold nanoparticles using Croton Caudatus Geisel leaf extract and their biological studies," Mater. Lett., 2019.
34. S. M. Kang, B. S. Lee, S. gi Lee, and I. S. Choi, "Biomimetic coating of gold nanoparticles with ultrathin silica layers," Colloids Surfaces A Physicochem. Eng. Asp., 2008.
35. S. S. Shankar, A. Ahmad, R. Pasricha, and M. Sastry, "Bioreduction of chloroaurate ions by geranium leaves and its endophytic fungus yields gold nanoparticles of different shapes," J. Mater. Chem., 2003.
36. M. S. Latif, S. Abbas, F. Kormin, and M. K. Mustafa, "Green synthesis of plant-mediated metal nanoparticles: The role of polyphenols," Asian Journal of Pharmaceutical and Clinical Research, vol. 12, no. 7, pp. 75-84, 2019.
37. P. Sathishkumar et al., Anti-acne, anti-dandruff and anti-breast cancer efficacy of green synthe-sised silver nanoparticles using Coriandrum sativum leaf extract. Journal of Photochemistry and Photobiology B: Biology, 2016. 163: p. 69-76.
38. P. Sathishkumar et al., Phyto-synthesis of silver nanoparticles using Alternanthera tenella leaf extract: An effective inhibitor for the migration of human breast adenocarcinoma (MCF-7) cells. Bioprocess and biosystems engineering, 2016. 39(4): p. 651-659.W.-K. Chen, *Linear Networks and Systems* (Book style). Belmont, CA: Wadsworth, 1993, pp. 123–135.
39. M. S. Latif et al., "Effect of temperature on the synthesis of Centella asiatica flavonoids extract-mediated gold nanoparticles: UV-vis analysis," AIP Conference Proceedings vol. 2016, no. 1, 020071 (2018); https://doi.org/10.1063/1.5055473.

AUTHORS PROFILE

Dr. Sameera Abbas is an MSc in Biochemistry and PhD in Biotechnology. Her current research interest includes the green synthesis, characterization and bioactivities of metallic nanoparticles.

Dr. Muhammad Sohail Latif is an MSc in Biochemistry and PhD in Biotechnology. His current research interests include the nanosynthesis of metallic nanoparticles and their application in pharmaceuticals, nutraceuticals and cosmaceuticals.

Dr. Ida Idayu Muhamad is a Professor and Head of the Department of Bioprocess and Polymer Engineering, Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia, and a Fellow of Institute of Food Science and Technology, United Kingdom. Currently she is the Chairman of the Scientific Advisors also Head of Biomaterial Cluster for the IJN-UTM Cardiovascular Engineering Centre, for research collaboration between National Heart Institute (Malaysia) and Universiti Teknologi Malaysia.

Dr. Faridah Kormin is Senior Lecturer in the Department of technology & Natural Reseaources, Faculty of Applied Sciences & Technology (FAST), Universiti Tun Hussein Onn Malaysia. Her research interests include food science, plant production and pharmacy products.