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Phyto-Synthesized Zinc Oxide Nanoparticles for Dengue Vector Control

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Abstract : The review focuses on the spectra of possibilities in utilizing plant-synthesized ZnONPs as larvicides against Aedes aegypti, an important vector for spreading out dengue fever. ZnONPs have also been reported as an effective larvicidal and pupicidal agent against mosquito larvae [57, 58] and pupae. ZnONPs were synthesized by using various plant extracts such as *Tarenna asiatica, Indigofera tinctoria, and Digiteria sanguinallis*. Oxidative stress, physical disruption and interference of normal physiological process in mosquito larvae and pupae are the main mechanisms of action of ZnONPs.

More research is needed to assess the ecological implications of ZnONPs although they show potential as an alternative to traditional insecticides for mosquito control. However, the potential toxicity of ZnONPs to non-target organism and environment need more deliberated evaluation. In the future research, more opportunities concentrate to on the synthesis and characterization of ZnONPs or even to studies with large field scale trials; consequently, needs carry out ecological risk assessment sing these methods. In summary, overcoming these challenges will enable ZnONPs to evolve as an important tool for sustainable dengue control.

Keywords*-ZnONPs, *Aedes aegypti, dengue fever, larvicidal activity, pupicidal activity, plant-based synthesis, ecological implications, sustainable vector control.

I. INTRODUCTION

Over the past few decades, dengue fever due to Aedes aegypti has become a neglected tropical disease with an expanding global burden. This is due to a number of factors, including urbanization, globalization and climate change that have provided ideal conditions for breeding and transmission of the mosquito. Complications Severe dengue is a potentially deadly complication due to plasma leaking, fluid accumulation, respiratory distress, severe bleeding and organ impairment.
Chemical insecticides targeting suitable mosquito vectors have been the mainstay of dengue targeted control. Yet these strategies carry difficulties — pollution, resistance to insecticides and the arrival of additional mosquito breeds. Chemical insecticides can pollute water sources, have a negative impact on non-target organisms, and contribute to the development of insecticide resistance in mosquitoes. Furthermore, the wide use of broad-spectrum insecticides could also result in a collapse of endogenous mosquito control and rebounding populations of resistant mosquitoes.
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This review performs the synthesis, characterization, and biological activity of phyto-synthesized ZnONPs against Aedes aegypti. Phyto-synthesis is a green, clean and environmentally benign method of synthesizing nanoparticles with plant extracts. Its known biocompatibility, non-toxicity, and environmental friendliness (among other benefits), compared to the traditional chemical procedures. The plant extracts are rich in bioactive compounds and most of this have a low molecular weight such as polyphenols, flavonoids which serve the dual role of reducing and capping agents, thereby yielding ZnONPs with size, shape and stability.
Therefore, it is very important to know the characterization of ZnONPs to explore the prospective biological activities and potential toxic effect due to their physical and chemical properties. UV-visible spectroscopy, Fourier-transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), scanning electron microscopy (SEM) and transmission electron microscopy (TEM) are the most common methods for characterising ZnONPs that are adopted [47].

Although there are numerous reportages on the larvicidal and pupicidal activity of ZnONPs toward Aedes aegypti, their biological functionality has been scrutinized. ZnONPs have been reported to distort the growth, development and survival of mosquito larvae and pupae. The byproducts can be both chemically reactive and physically damaging, wreaking havoc on mosquito larvae and pupae in the process of life cycle interference.

Besides their larvicidal and pupicidal utility ZnONPs might have other biological actions which are of help for vector control. ZnONPs, for instance, have been reported to disrupt mosquito oviposition, thus inhibiting the number of eggs laid by mosquitoes, thereby controlling the growth and reproduction of its population. ZnONPs were also observed to shorten the life span of mosquitoes, thereby reducing their capacity to host infectious agents [19].

Hence, phyto-synthesized ZnONPs could be an excellent alternative for bio-controlling the A. aegypti and to serve as likely-preventative to dengue fever. Future research is warranted to ascertain their ecological effects and ensure the best practices in which Wolbachia may be used as a sustainable approach to dengue vector control.

II REVIEW OF LITERATURE

2.1 Nanotechnology in Vector Control

The emerging use of nanotechnology in vector control would be a promising new approach towards innovation and sustainability in combating mosquito-borne diseases. Particles that are nanoscale in size have unique properties compared to their bulk compositions due to quantum effects. This might provide some benefits over the traditional control methods utilized, such as chemical insecticides. Efficiencies in killing mosquito larvae and pupae have been examined through several types of nanoparticles - metal oxides, metal sulfides, and polymeric nanoparticles. Among the metal oxide nanomaterials, ZnO has perhaps withstood some of the most phenomenal successes along with the others, such as TiO2 and CuO, in controlling mosquito populations.

- **Zinc Oxide Nanoparticles (ZnONPs):** ZnONPs have been widely researched concerning their toxic effects on mosquito larvae and pupae, particularly Aedes aegypti. In reality, they can influence the various growth and development processes of mosquitoes at each stage of the life cycle from the larval to the pupal stages through oxidative stress induction, physical damage, and interference with normal physiological processes.
- **Titanium dioxide nanoparticles (TiO2 NPs):** The TiO2 NPs have earlier been demonstrated to have potential in mosquito population control. It kills mosquito larvae and pupae through the generation of ROS on photoexcitation**.**
- **Copper oxide nanoparticles CuO NPs: CuO NPs** have also been tested on the larvae and pupae. These mosquitoes cause damage in their respiratory systems thus killing them.

2.2 Phyto-synthesized of Nanoparticles

This process has been found to be environmentally friendly and thus widely pursued due to its green and sustainable nature. Phyto-synthesized nanoparticles are generally more biocompatible and less toxic than chemically synthesized nanoparticles. ZnONPs has been in the center of many studies for its use in synthesizing plant extracts for vector control.

- **Type of plant extracts used for the synthesis of ZnONPs:** There are different types of plant extracts like Tarenna asiatica, Indigofera tinctoria, Digiteria sanguinallis, Azadirachta indica, and Ocimum sanctum used for ZnONPs synthesis.
- **Phytochemicals employed during the synthesis of ZnONPs:** These extracts contain phytochemicals like flavonoids, terpenoids, and alkaloids which could act as a reducing agent and capping agent thereby generating ZnONPs with unusual properties.

2.3 Ecotoxicology Involving Larvicidal and Pupicidal Activity of ZnONPs

According to several investigations conducted on the effects produced by ZnONPs, they exhibit the larvicidal and pupicidal activity against some of the mosquito species including Aedes aegypti. The mechanism of action for ZnONPs is thought to be:

- **Oxidative stress:** The action of ZnONPs can also involve the production of reactive oxygen species (ROS) which can in turn damage different components of the cell resulting in death.
- **Physical disruption:** It is also believed that ZnONPs can rupture the larval and pupal integuments leading to destruction and death.
- **Interference with physiological processes:** Essential physiological functions like respiration, nutrition, and developmental stages are obstructed by ZnONPs resulting in the death of the larvae's and pupae's. Environmental Impact of ZnONPs.

Though ZnONPs show great potential as vector control methods, their ecotoxicological risks should not be underestimated. The behavior and fate of ZnONPs in the environment and their adverse effects on non-target organisms should be properly investigated.

- **Persistence and bioaccumulation:** Constraints like persistence and bioaccumulation of the nanoparticles may lead to unfavourable accrual effects in the short and long term.
- **Toxicity to non-target organisms:** Awareness should be made of the toxicity of ZnOH and its subsequent substances to aquatic invertebrates, plants and other organisms to curb environment contamination.Future Directions

Despite the promising results obtained in both laboratory and field studies, more work is needed to be done to concentrate on the following areas; Therefore, more studies are needed in the areas mentioned below:

- **Advancement towards clinical studies of on-field large scales**: Determination of the efficacy of ZnONPs in real field settings towards control of mosquito population under different environmental conditions.
- **Synergistic effects**: Researching the introduction of ancillary vector control measures, like larvivorous fish or biological control agents with ZnONPs for optimal effect.
- **Regulatory framework:** Implementing and enforcing legislation and regulations that allow safe and effective application of ZnONPs for target vector communication control.
- **Characterization of ZnONPs and Development:** Modification of the chemical structure of ZnONPs for the preparation of larvicidal formulation that should be potent, nontoxic, and with extended shelf-life.

• **Risk assessment:** The risks and potential ecological hazards posed by use of ZnONPs to the environment and recommends remedial measures towards such risks

III AIM AND SCOPE:

This review is directed to present progress in the research of a plant synthesized zinc oxide nanoparticles (ZnONPs) for controlling Aedes aegypti, a vector who is responsible for spreading the dengue fever. This review broadly covers the following aspects**:**

• **Synthesis of ZnONPs**: Synthesis of Zinc Oxide Nanoparticles using plant camouflages and exploring other issues such as plant/chosen species and synthesis conditions.

• **Characterization of ZnONPs:** Classification of various characteristics of inert ZnO such as size, shape, morphology, and crystallinity among many others used in assessing the composition of structures to be synthesized.

• **Larvicidal and pupicidal activity:** Looking through the literature on the biological activity of nanoparticles and their structural analogs with zinc against the larvae and pupae of the 'Aedes aegypti' species with a dose-response relationship and how they act in the tissues.

• **Ecological implications:** Looking out for possible environmental concerns posed by the use of zinc oxide nanoparticles as ZnONPs in terms of nanoformulatio- fate and transport.

• **Future perspective:** Pinpointing the fruitless areas and what are the areas and challenges to be considered to make the application of ZnONPs for vector control effective.

Presenting the evidence on all these aspects, this study intends to fill in the knowledge gap on the toxicity of ZnONPs in skin cell dermal absorbers.

IV MOSQUITO-BORNE DISEASES THAT CAN BE TREATED USING ZNONPS

Although the promotion of ZnONPs in controlling Aedes aegypti mosquitoes has been centered on their larvicidal and pupicidal activities, such applications are, however, not limited to vector control. Since ZnONPs have antimicrobial activities, such nanoparticles may be directed towards the management of diseases caused by mosquitoes. Here are some examples of their possible uses:

- **Malaria:** Zinc oxide nanoparticles ZnONPs may be researched for any potential anti−malarial effect, mostly upon asexual blood phases of Plasmodium falciparum which is a most virulent malarial parasite.
- **Chikungunya:** Antiviral potential of ZnONPs may be assessed against Chikungunya virus disseminated by Aedes aegypti and Aedes albopictus to raise the virus-free virus titer.
- **Zika virus:** In light of the recent Zika virus epidemic, ZnONPs could be tested for their antiviral effects against this novel virus.
- **Yellow fever:** Further, ZnONPs can be screened to assess their ability to control yellow fever virus which is propagated by Aedes aegypti insect vector.

It is also worth noting that more studies should be done in order to assess both the safety and effectiveness of treating such diseases with ZnONPs. In vitro and in vivo studies can help deduce the proper quantity, way of administering and other side effects of these nanoparticles. Furthermore, creating a drug delivery system is necessary to direct its contents including ZnONPs to the infected.

V ECOLOGICAL IMPLICATIONS

The efficacy of ZnONPs as a novel strategy for vector control still needs to be further investigated, and their ecological consequences should also take into account. The toxicity of ZnONPs toward non-target organisms, i.e. aquatic invertebrates and plants, needs to be attentively tested. In addition to this, the examination of ZnONPs and their possible persistence in the environment could be interesting.

VI FUTURE PERSPECTIVES

While the early returns are encouraging, this remains a small study and questions remain before peanut OIT can receive FDA approval: What percentage of at-risk infants will develop food allergies;
Large-scale field trials: Testing ZnONPs for practical application
Further study: To study synergistic effects, testing the use of ZnONPs with larvivorous fish or biological control agents.
Risk assessment: Performing a full ecological risk assessments for the safe and sustainable application of ZnONPs.
Engineering ZnONPs: Synthesizing ZnONPs with superior larvicidal toxicity and minimal ecological influence.

CONCLUSION

In this regard, biosynthesized zinc oxide nanoparticles (ZnONPs) using plant extracts have been widely used as an efficient candidate for the eradication of Aedes aegypti, one of vector mosquitoes for dengue fever. These two properties together with its green synthesis method, these may be used as potent candidate for integrated vector management programs. ZnONPs has great future prospect however the longterm ecological concerns still needs to be established and applied in sustainable Dengue control with adequate further research. These include large scale field trials, impact on non-target organism and development of effective delivery system of the insecticides. Hence, combating these challenges may make ZnONPs a promising agent for the remedy of dengue and other mosquito-borne diseases.

References

[1] Milliron, D.J., Hughes, S.M., Cui, Y., Manna, L., Li, J., Wang, L., Alivisatos, A.P.: Colloidal nanocrystal heterostructures with linear and branched topology. Nature (2004). https://doi. org/10.1038/nature02695

[2] Kerker, M.: The optics of colloidal silver: something old and something new. J. Colloid Interface Sci. (1985). https://doi. org/10.1016/0021-9797(85)90304-2

[3] Zhang, S., Tang, Y., Vlahovic, B.: A review on preparation and applications of silver-containing nanofibers. Nanoscale Res. Lett. (2016). https://doi.org/10.1186/s11671-016-1286-z

[4] Chanel, T.H., Adri, H., Muhammad, D.B., Bambang, Y., Fakh- ili, G.: Green synthesis of silver nanoparticle and its antibacterial activity. Rasayan J. Chem. (2017). https://doi.org/10.7324/ rjc.2017.1041875

[5] Choudhury, R., Majumder, M., Roy, D.N., Basumallick, S., Misra, T.K.: Phytotoxicity of Ag nanoparticles prepared by biogenic and chemical methods. Int. Nano Lett. (2016). https://doi. org/10.1007/s40089-016-0181-z

[6] Kharissova, O.V., Dias, H.R., Kharisov, B.I., Pérez, B.O., Pérez, V.M.: The greener synthesis of nanoparticles. Trends Biotechnol. (2013). https://doi.org/10.1016/j.tibtech.2013.01.003

[7] Archna, H.R.: A review on green synthesis of silver nanoparticle, characterization and optimization parameters. Int. J. Res. Eng. Technol. (2016). https://doi.org/10.15623/ijret.2016.0527010

[8] Sithara, R., Selvakumar, P., Arun, C., Anandan, S., Sivashan- mugam, P.: Economical synthesis of silver nanoparticles using leaf extract of *Acalypha hispida* and its application in the detec- tion of Mn(II) ions. J. Adv. Res. (2017). https://doi.org/10.1016/j. jare.2017.07.001

[9] Mohamed, N.H., Ismail, M.A., Abdel-Mageed, W.M., Shoreit, A.A.: Antimicrobial activity of latex silver nanoparticles using *Calotropis procera*. Asian Pac. J. Trop. Biomed. (2014). https:// doi.org/10.12980/apjtb.4.201414b216

[10] Chauhan, N., Tyagi, A.K., Kumar, P., Malik, A.: Antibacterial potential of *Jatropha curcas* synthesized silver nanoparticles against food borne pathogens. Front. Microbiol. (2016). https:// doi.org/10.3389/fmicb.2016.01748

[11] Alsalhi, M., Devanesan, S., Alfuraydi, A., Vishnubalaji, R., Munusamy, M.A., Murugan, K., et al.: Green synthesis of silver nanoparticles using *Pimpinella anisum* seeds: Antimicrobial activity and cytotoxicity on human neonatal skin stromal cells and colon cancer cells. Int. J. Nanomed. (2016). https://doi. org/10.2147/ijn.s113193

[12] Jayaprakash, N., Vijaya, J.J., Kaviyarasu, K., Kombaiah, K., Kennedy, L.J., Ramalingam, R.J., et al.: Green synthesis of Ag nanoparticles using Tamarind fruit extract for the antibacterial studies. J. Photochem. Photobiol. B Biol. (2017). https://doi. org/10.1016/j.jphotobiol.2017.03.013

[13] Rashid, M.I., Mujawar, L.H., Rehan, Z.A., Qari, H., Zeb, J., Almeelbi, T., Ismail, I.M.: One-step synthesis of silver nanoparticles using *Phoenix dactylifera* leaves extract and their enhanced bactericidal activity. J. Mol. Liq. (2016). https://doi. org/10.1016/j.molliq.2016.09.030

[14] Rao, K., Aziz, S., Roome, T., Razzak, A., Sikandar, B., Jamali, K.S., Imran, M., Jabri, T., Shah, M.R.: Gum acacia stabilized silver nanoparticles based nano-cargo for enhanced anti- arthritic potentials of hesperidin in adjuvant induced arthritic rats. Artif. Cells Nanomed. Biotechnol. (2018). https://doi. org/10.1080/21691401.2018.1431653

[15] Otunola, G., Afolayan, A., Ajayi, E., Odeyemi, S.: Characteri- zation, antibacterial and antioxidant properties of silver nano- particles synthesized from aqueous extracts of *Allium sativum*, *Zingiber officinale*, and *Capsicum frutescens*. Pharmacogn. Mag. (2017). https://doi.org/10.4103/pm.pm_430_16

[16] Nazeruddin, G., Prasad, N., Prasad, S., Shaikh, Y., Waghmare, S., Adhyapak, P.: *Coriandrum sativum* seed extract assisted in situ green synthesis of silver nanoparticle and its anti-microbial activity. Ind. Crops Prod. (2014). https://doi.org/10.1016/j.indcr op.2014.05.040

[17] Nasiri, S., Nasiri, S.: Biosynthesis of Silver Nanoparticles Using *Carum carvi* Extract and its Inhibitory Effect on Growth of *Can- dida albicans*. Avicenna J. Med. Biochem. (2016). https://doi. org/10.17795/ajmb-37504

[18] Marslin, G., Dias, A.C., Selvakesavan, R.K., Gregory, F., Sar- mento, B.: Antimicrobial activity of cream incorporated with silver nanoparticles biosynthesized from *Withania somnifera*. Int. J. Nanomed. (2015). https://doi.org/10.2147/IJN.S81271

[19] Zulfiqar, H., Ayesha, Z., Rasheed, N., Ali, Z., Mehmood, K., Mazher, A., Mahmood, N.: Synthesis of silver nanoparticles using *Fagonia cretica* and their antimicrobial activities. Nanoscale Adv. (2019). https://doi.org/10.1039/C8NA00343B

[20] Dhand, V., Soumya, L., Bharadwaj, S., Chakra, S., Bhatt, D., Sreedhar, B.: Green synthesis of silver nanoparticles using *Cof- fea arabica* seed extract and its antibacterial activity. Mater. Sci. Eng. (2016). https://doi.org/10.1016/j.msec.2015.08.018

[21] Ahmed, S., Saifullah, Ahmad, M., Swami, B. L., Ikram, S.: Green synthesis of silver nanoparticles using *Azadirachta indica* aque- ous leaf extract. J. Radiat. Res. Appl. Sci. (2016). https://doi. org/10.1016/j.jrras.2015.06.006

[22] Prabhu, S., Poulose, E.K.: Silver nanoparticles: mecha- nism of antimicrobial action, synthesis, medical applica- tions, and toxicity effects. Int. Nano Lett. (2012). https://doi. org/10.1186/2228-5326-2-32

[23] Srikar, S.K., Giri, D.D., Pal, D.B., Mishra, P.K., Upadhyay, S.N.: Green synthesis of silver nanoparticles: a review. Green Sustain. Chem. 6, 34–56 (2016). https://doi.org/10.4236/gsc.2016.61004

[24] Mata, R., Nakkala, J.R., Sadras, S.R.: Biogenic silver nanoparti- cles from *Abutilon indicum*: their antioxidant, antibacterial and cytotoxic effects in vitro. Colloids Surf. B Biointerfaces (2015). https://doi.org/10.1016/j.colsurfb.2015.01.052

[25] Sulthana, R.N., Rajanikanth, A.: Green synthesis of silver nan- oparticles using seed extract of *Foeniculum vulgare* and their antibacterial activity. Int. J. Curr. Res. Biosci. Plant Biol. 5(7), 77–83 (2018). https://doi.org/10.20546/ijcrbp.2018.507.010

[26] Roy, P., Das, B., Mohanty, A., Mohapatra, S.: Green synthe- sis of silver nanoparticles using *Azadirachta indica* leaf extract and its antimicrobial study. Appl. Nanosci. (2017). https://doi. org/10.1007/s13204-017-0621-8

[27] Bhuvaneswari, T.S., Thirugnanam, T., Thirumurugan, V.: Phytomediated synthesis of silver nanoparticles using *Cassia auriculata* L.: evaluation of antibacterial and antifungal activ- ity. Asian J. Pharm. Pharmacol. 5(2), 326–331 (2019). https:// doi.org/10.31024/ajpp.2019.5.2.16

[28] Krishnan, V., Bupesh, G., Manikandan, E., Thanigai, A.K., Magesh, S., Kalyanaraman, R., Maaza, M.: Green synthesis of silver nanoparticles using *Piper nigrum* concoction and its anti- cancer activity against MCF-7 and Hep-2 cell lines. J. Antimicrob. Agents (2016). https://doi.org/10.4172/2472-1212.10001 23

[29] Singh, K., Panghal, M., Kadyan, S., Yadav, J.P.: Evaluation of antimicrobial activity of synthesized silver nanoparticles using *Phyllanthus amarus* and *Tinospora cordifolia* medicinal plants. J. Nanomed. Nanotechnol. (2014). https://doi.org/10.4172/2157- 7439.1000250

[30] Prasad, T., Elumalai, E.: Biofabrication of Ag nanoparticles using *Moringa oleifera* leaf extract and their antimicrobial activ- ity. Asian Pac. J. Trop. Biomed. (2011). https://doi.org/10.1016/ s2221-1691(11)60096-8

[31] Providence, B.A., Chinyere, A.A., Ayi, A.A., Charles, O.O., Eli- jah, T.A., Ayomide, H.L.: Green synthesis of silver monometallic and copper-silver bimetallic nanoparticles using *Kigelia africana* fruit extract and evaluation of their antimicrobial activities. Int. J. Phys. Sci. 13(3), 24–32 (2018). https://doi.org/10.5897/ijps2 017.4689

[32] Kumar, C., Yugandhar, P., Savithramma, N.: Biological synthe- sis of silver nanoparticles from *Adansonia digitata* L. fruit pulp extract, characterization, and its antimicrobial properties. J. Inter- cult. Ethnopharmacol. (2016). https://doi.org/10.5455/jice.20160 124113632

[33] Kumar, C.M.K., Yugandhar, P., Savithramma, N.: *Adansonia digitata* leaf extract mediated synthesis of silver nanoparticles; characterization and antimicrobial studies. J. Appl. Pharm. Sci. (2015). https://doi.org/10.7324/JAPS.2015.50813

[34] Ali, K., Ahmed, B., Dwivedi, S., Saquib, Q., Al-Khedhairy, A.A., Musarrat, J.: Microwave accelerated green synthesis of stable silver nanoparticles with *Eucalyptus globulus* leaf extract and their antibacterial and antibiofilm activity on clinical isolates. PLoS One (2015). https://doi.org/10.1371/journal.pone.0131178

[35] Muthu, K., Priya, S.: Green synthesis, characterization and cat- alytic activity of silver nanoparticles using *Cassia auriculata* flower extract separated fraction. Spectrochim. Acta Part A Mol. Biomol. Spectrosc. (2017). https://doi.org/10.1016/j. saa.2017.02.024

[36] Khalil, M.M., Ismail, E.H., El-Baghdady, K.Z., Mohamed, D.: Green synthesis of silver nanoparticles using olive leaf extract and its antibacterial activity. Arab. J. Chem. (2014). https://doi. org/10.1016/j.arabjc.2013.04.007

[37] Sahni, G., Panwar, A., Kaur, B.: Controlled green synthesis of silver nanoparticles by *Allium cepa* and *Musa acuminata* with strong antimicrobial activity. Int. Nano Lett. (2015). https://doi. org/10.1007/s40089-015-0142-y

[38] Sathyavathi, R., Krishna, M.B., Rao, S.V., Saritha, R., Rao, D.N.: Biosynthesis of silver nanoparticles using *Coriandrum sativum* leaf extract and their application in nonlinear optics. Adv. Sci. Lett. (2010). https://doi.org/10.1166/asl.2010.1099

[39] Venugopal, N., Mitra, A.: Influence of temperature dependent morphology on localized surface plasmon resonance in ultra- thin silver island films. Appl. Surf. Sci. (2013). https://doi. org/10.1016/j.apsusc.2013.08.062

[40] Usmani, A., Mishra, A., Jafri, A., Arshad, M., Siddiqui, M.A.: Green synthesis of silver nanocomposites of *Nigella sativa* seeds extract for hepatocellular carcinoma. Curr. Nanomater. (2019). https://doi.org/10.2174/2468187309666190906130115

[41] Kumar, B., Smita, K., Cumbal, L., Debut, A.: Green syn- thesis of silver nanoparticles using Andean blackberry fruit extract. Saudi J. Biol. Sci. 24(1), 45–50 (2017). https://doi. org/10.1016/j.sjbs.2015.09.006

[42] Sundeep, D., Kumar, T.V., Rao, P.S., Ravikumar, R.V.S.S.N., Krishna, A.G.: Green synthesis and characterization of Ag nanoparticles from *Mangifera indica* leaves for dental restora- tion and antibacterial applications. Progr. Biomater. (2017). https://doi.org/10.1007/s40204-017-0067-9

[43] Eustis, S., El-Sayed, M.A.: Why gold nanoparticles are more precious than pretty gold: noble metal surface plasmon reso- nance and its enhancement of the radiative and nonradiative properties of nanocrystals of different shapes. ChemInform (2006). https://doi.org/10.1002/chin.200625211

[44] Ajitha, B., Reddy, Y.A., Reddy, P.S.: Green synthesis and characterization of silver nanoparticles using *Lantana camara* leaf extract. Mater. Sci. Eng. (2015). https://doi.org/10.1016/j. msec.2015.01.035

[45] Usha, C., Gladys, A.R.: Biogenic synthesis of silver nanopar- ticles by *Acacia nilotica* and their antibacterial activity. Int. J. Sci. Res. 3(6), 27–29 (2012). https://doi.org/10.15373/22778 179/june2014/11

[46] Uzunuigbe, E., Mlowe, S., Revaprasadu, N., Kappo, A.P.: Synthesis, characterization and antibacterial activity of silver nanoparticles using *Acacia senegal* leaf extract. Paper Pre- sent. Past Present Res. Syst. Green Chem. (2016). https://doi. org/10.4172/2161-0401.C1.013

[47] Tan, G.: Green synthesis of silver nanoparticles using *Allium cepa* and *Allium sativum* extract: a comparative characteriza- tion study. J. Biotechnol. (2017). https://doi.org/10.1016/j.jbiot ec.2017.06.669

[48] Ahlawat, J., Sehrawat, A.R.: Nano Dimensional (1-20 nm) Sil- ver nanoparticles: stem extract of *Capparis decidua* (FORSK) EDGEW mediated synthesis and its characterization-a lab to land approach. Int. J. Curr. Microbiol. Appl. Sci. (2017).

[49] https ://doi.org/10.20546/ijcmas.2017.610.226

[50] Gondwal, M., Pant, G.J.: Synthesis and catalytic and bio- logical activities of silver and copper nanoparticles using *Cassia occidentalis*. Int. J. Biomater. (2018). https://doi. org/10.1155/2018/6735426

[51] Ponarulselvam, S., Panneerselvam, C., Murugan, K., Aarthi, N., Kalimuthu, K., Thangamani, S.: Synthesis of silver nano- particles using leaves of *Catharanthus roseus* Linn. G. Don and their antiplasmodial activities. Asian Pac. J. Trop. Biomed. (2012). https://doi.org/10.1016/s2221-1691(12)60100-2

[52] Logeswari, P., Silambarasan, S., Abraham, J.: Synthesis of silver nanoparticles using plants extract and analysis of their antimicrobial property. J. Saudi Chem. Soc. (2015). https://doi. org/10.1016/j.jscs.2012.04.007

[53] Syafiuddin, A., Salmiati, Hadibarata, T., Kueh, A.B., Salim, M.R.: Novel weed-extracted silver nanoparticles and their antibacterial appraisal against a rare bacterium from river and sewage treatment plan. Nanomaterials (2017). https://doi. org/10.3390/nano8010009

[54] Gomathi, M., Rajkumar, P., Prakasam, A., Ravichandran, K.: Green synthesis of silver nanoparticles using *Datura stramo- nium* leaf extract and assessment of their antibacterial activity. Resour. Effic. Technol. (2017). https://doi.org/10.1016/j.reffi t.2016.12.005

[55] Thovhogi, N., Diallo, A., Gurib-Fakim, A., Maaza, M.: Nano- particles green synthesis by *Hibiscus Sabdariffa* flower extract: main physical properties. J. Alloys Compd. (2015). https://doi. org/10.1016/j.jallcom.2015.06.076
[56] Patil, S.P., Kumbhar, S.T.: Antioxidant, antibacterial and cyto- toxic potential of silver nanoparticles synthesized using terpenes rich extract of *Lantana camara* L. leaves. Biochem. Biophys. Rep. (2017). https://doi.org/10.1016/j.bbrep.2017.03.002
[57] Gupta, A., Ingle, A., Gade, A.K., Gaikwad, S., Rai, M., Bonde, S.R.: *Lawsonia inermis*-mediated synthesis of silver nano- particles: activity against human pathogenic fungi and bacte- ria with special reference to formulation of an antimicrobial nanogel. IET Nanobiotechnol. (2014). https://doi.org/10.1049/ iet-nbt.2013.0015
[58] Bharathi, V., Jannathul, F., Noorzaid, M., Resni, M.: Green syn- thesis of *Mangifera indica* silver nanoparticles and its analysis using Fourier transform infrared and scanning electron micros- copy. Natl. J. Physiol. Pharm. Pharmacol. (2017). https://doi. org/10.5455/njppp.2017.7.0725428082017
[59] Khatoon, A., Khan, F., Ahmad, N., Shaikh, S., Rizvi, S.M., Shakil, S., et al.: Silver nanoparticles from leaf extract of *Mentha piperita*: Eco-friendly synthesis and effect on acetylcho- linesterase activity. Life Sci. (2018). https://doi.org/10.1016/j. lfs.2018.08.046
[60] Moodley, J.S., Krishna, S.B., Pillay, K., Sershen, Govender, P.: Green synthesis of silver nanoparticles from *Moringa oleif- era* leaf extracts and its antimicrobial potential. Adv. Nat. Sci. Nanosci. Nanotechnol. (2018). https://doi.org/10.1088/2043- 6254/aaabb2
[61] Ajitha, B., Reddy, Y.A., Jeon, H., Ahn, C.W.: Synthesis of silver nanoparticles in an eco-friendly way using *Phyllanthus amarus* leaf extract: antimicrobial and catalytic activity. Adv. Powder Technol. (2018). https://doi.org/10.1016/j.apt.2017.10.015
[62] Ojha, S., Sett, A., Bora, U.: Green synthesis of silver nanopar- ticles by *Ricinus communis* var. carmencita leaf extract and its antibacterial study. Adv. Nat. Sci. Nanosci. Nanotechnol. 8(3), 035009 (2017). https://doi.org/10.1088/2043-6254/aa724b
[63] Gopinath, V., Mubarakali, D., Priyadarshini, S., Priyadharsshini, N.M., Thajuddin, N., Velusamy, P.: Biosynthesis of silver nano- particles from *Tribulus terrestris* and its antimicrobial activity: a novel biological approach. Colloids Surf. B Biointerfaces (2012). https://doi.org/10.1016/j.colsurfb.2012.03.023
[64] Rajesh, P., Swati, W., Sandesh, M., Sangita, J., Kulkarni, S.: Green synthesis of silver nanoparticles by *Withania somnifera* and evaluation of its antimicrobial potential. J. Empir. Biol. 1(2), 38–48 (2013). https://doi.org/10.13074/jent.2013.02.121028
[65] Ynalvez, R., Compean, K.: Antimicrobial activity of plant sec- ondary metabolites: a review. Res. J. Med. Plant (2014). https:// doi.org/10.3923/rjmp.2014.204.213
[66] Jain, S., Mehata, M.S.: Medicinal plant leaf extract and pure flavonoid mediated green synthesis of silver nanoparticles and their enhanced antibacterial property. Sci. Rep. (2017). https:// doi.org/10.1038/s41598-017-15724-8
[67] Ahmad, S., Munir, S., Zeb, N., Ullah, A., Khan, B., Ali, J., et al.: Green nanotechnology: a review on green synthesis of silver nanoparticles—an ecofriendly approach. Int. J. Nanomed. 14, 5087–5107 (2019). https://doi.org/10.2147/ijn.s200254
[68] Siddiqi, K.S., Husen, A.: Fabrication of metal nanoparticles from fungi and metal salts: scope and application. Nanoscale Res. Lett. (2016). https://doi.org/10.1186/s11671-016-1311-2
[69] Adeeyo, A.O., Odiyo, J.O.: Biogenic synthesis of silver nano- particle from mushroom exopolysaccharides and its potentials in water purification. Open Chem. J. 5(1), 64–75 (2018). https:// doi.org/10.2174/1874842201805010064
[70] Ghorbani, H.R.: Biosynthesis of silver nanoparticles by *Escheri- chia coli*. Asian J. Chem. (2013). https://doi.org/10.14233/ajche m.2013.12805
[71] Ilavarasan, R., Vadivelu, L.: Phytochemical and quality assess- ment of *Acacia nilotica* Linn and *Acacia leucophloea* willd flow- ers. Pharmacogn. J. (2017). https://doi.org/10.5530/pj.2017.6.113
[72] Okoro, S.O., Kawo, A.H., Arzai, A.H.: Phytochemical screen- ing, antibacterial and toxicological activities of *Acacia senegal* extracts. Bayero J. Pure Appl. Sci. 5(1), 163–170 (2012). https://doi.org/10.4314/bajopas.v5i1.29
[73] Eltayeb, I.M., Elhassan, I.A., Elrasoul, J.H., Eldind, E.S.: A com- parative study of chemical composition of *Acacia Seyal* stem, stem wood and stem bark dry distillates used by sudanese women as cosmetic and medicine. Int. J. Pharm. Pharm. Sci. (2017). https://doi.org/10.22159/ijpps.2017v9i11.21802
[74] Arora, E., Sharma, V., Khurana, A., Manchanda, A., Sahani, D., Abraham, S., Jomy, S.: Phytochemical analysis and evaluation of antioxidant potential of ethanol extract of *Allium cepa* and ultra- high homoeopathic dilutions available in the market: a compara- tive study. Indian J. Res. Homoeopath. 11(2), 88 (2017). https:// doi.org/10.4103/ijrh.ijrh_13_17
[75] Yasmin, H., Anbumalarmathi, J., Sharmili, S.A.: Phytochemical analysis and antimicrobial activity of garlic (*Allium sativum* L.) and onion (*Allium cepa* L.). Res. Crops 19(2), 245 (2018). https://doi.org/10.5958/2348-7542.2018.00035.9
[76] Offor, C.: Comparative chemical analyses of *Vernonia amygda- lina* and *Azadirachta indica* leaves. IOSR J. Pharm. Biol. Sci. 9(5), 73–77 (2014). https://doi.org/10.9790/3008-09527377
[77] Oke, D.G.: Proximate and phytochemical analysis of *Cajanus cajan* (Pigeon Pea) leaves. Chem. Sci. Trans. (2014). https://doi. org/10.7598/cst2014.785
[78] Morsy, N., Sherif, E.A., Abdel-Rassol, T.M.: Phytochemical analysis of *Calotropis procera* with antimicrobial activity inves- tigation. Main Group Chem. (2016). https://doi.org/10.3233/ mgc-160206
[79] Zia-Ul-Haq, M., Ćavar, S., Qayum, M., Imran, I., Feo, V.D.: Compositional studies: antioxidant and antidiabetic activities of *Capparis decidua* (Forsk.) Edgew. Int. J. Mol. Sci. (2011).
[80] https://doi.org/10.3390/ijms12128846
[81] Nascimento, P., Nascimento, T., Ramos, N., Silva, G., Gomes, J., Falcão, R., Silva, T.: Quantification, antioxidant and antimi- crobial activity of phenolics isolated from different extracts of *Capsicum frutescens* (*Pimenta Malagueta*). Molecules (2014). https://doi.org/10.3390/molecules19045434
[82] Barkat, M.Q., Mahmood, H.K.: Phytochemical And Antioxi- dant Screening Of *Zingiber officinale*, *Piper nigrum*, *Rutag raveolanes* and *Carum carvi* And Their Effect On Gastrointes- tinal Tract Activity. Matrix Science Medica (2018). https://doi. org/10.26480/msm.01.2018.09.13

[83] Asgarpanah, J.: Phytochemistry, pharmacology and medicinal properties of *Coriandrum sativum* L. Afr. J. Pharm. Pharmacol. (2012). https://doi.org/10.5897/ajpp12.901

[84] Murugan, M., Murugan, T., Wins, J.: Antimicrobial activ- ity and phytochemical constituents of leaf extracts of *Cassia auriculata*. Indian J. Pharm. Sci. 75(1), 122 (2013). https://doi. org/10.4103/0250-474x.113546

[85] Srividya, S., Sridevi, G., Manimegalai, A.G.: Phytochemical screening and in vitro antioxidant activity of ethanolic extract of *Cassia occidentalis*. Int. J. Pharm. Clin. Res. (2017). https://doi. org/10.25258/ijpcr.v9i3.8327

[86] Rajalakshmi, B.G., Komathi, S.K.S., Poongodi, N., Sasikala, T., Banuraviganesh, B.: Antimicrobial activity and phytochemical screening of *Catharanthus roseus*. Int. J. Sci. Res. 2(10), 1–2 (2012). https://doi.org/10.15373/22778179/oct2013/156

[87] Favela-Hernández, J., González-Santiago, O., Ramírez-Cabrera, M., Esquivel-Ferriño, P., Camacho-Corona, M.: Chemistry and pharmacology of *Citrus sinensis*. Molecules 21(2), 247 (2016). https://doi.org/10.3390/molecules21020247

[88] Block, S.: Diterpenes from the leaves of *Croton zambesicus*. Phy- tochemistry 65(8), 1165–1171 (2004). https://doi.org/10.1016/j. phytochem.2004.02.023

[89] Lawal, O., Oyedeji, A.: Chemical composition of the essen- tial oils of *Cyperus rotundus* L. from South Africa. Molecules (2009). https://doi.org/10.3390/molecules14082909

[90] Soni, P., Siddiqui, A.A., Dwivedi, J., Soni, V.: Pharmacologi- cal properties of *Datura stramonium* L. as a potential medicinal tree: an overview. Asian Pac. J. Trop. Biomed. 2(12), 1002–1008 (2012). https://doi.org/10.1016/s2221-1691(13)60014-3

[91] Saeed, M.A., Sabir, A.W.: Effects of *Fagonia cretica* L. con- stituents on various haematological parameters in rabbits. J. Eth- nopharmacol. 85(2–3), 195–200 (2003). https://doi.org/10.1016/ s0378-8741(02)00365-3

[92] Badgujar, S.B., Patel, V.V., Bandivdekar, A.H.: *Foeniculum vul- gare* Mill: a review of its botany, phytochemistry, pharmacol- ogy, contemporary application, and toxicology. Biomed. Res. Int. (2014). https://doi.org/10.1155/2014/842674

[93] Tomar, N.S., Sharma, M., Agarwal, R.M.: Phytochemical analy- sis of *Jatropha curcas* L. during different seasons and devel- opmental stages and seedling growth of wheat (*Triticum aes- tivum* L.) as affected by extracts/leachates of *Jatropha curcas* L. Physiol. Mol. Biol. Plants 21(1), 83–92 (2014). https://doi. org/10.1007/s12298-014-0272-0

[94] Bello, I., Shehu, M.W., Musa, M., Asmawi, M.Z., Mahmud, R.: *Kigelia africana* (Lam.) Benth. (Sausage tree): phytochemistry and pharmacological review of a quintessential African tradi- tional medicinal plant. J. Ethnopharmacol. 189, 253–276 (2016). https://doi.org/10.1016/j.jep.2016.05.049

[95] Verma, R.K., Verma, S.K.: Phytochemical and termiticidal study of *Lantana camara* var. aculeata leaves. Fitoterapia (2006). https ://doi.org/10.1016/j.fitote.2006.05.014

[96] Li, Q., Gao, W.Q., Zhao, Y.Q.: Advances in studies on chemi- cal constituents and biological activities of *Lawsonia inermis*. China J. Chin. Mater. Med. (2013). https://doi.org/10.4268/ cjcmm20130604

[97] Adesegun, S., Ayoola, G., Coker, H., Adepoju-Bello, A., Obaw- eya, K., Ezennia, E., Atangbayila, T.: Phytochemical screening and antioxidant activities of some selected medicinal plants used for malaria therapy in Southwestern Nigeria. Trop. J. Pharm. Res. (2008). https://doi.org/10.4314/tjpr.v7i3.14686

[98] Sujana, P., Sridhar, T.M., Josthna, P., Naidu, C.V.: Antibacterial activity and phytochemical analysis of *Mentha piperita* L. (Pep- permint)—an important multipurpose medicinal plant. Am. J. Plant Sci. (2013). https://doi.org/10.4236/ajps.2013.41012