Characterization and biomedical application of phytosynthesized gold nanoparticles from *Datura stramonium* seed extract

IC Oladipo*1, A Lateef2, MA Azeez2, TB Asafa3, TA Yekeen2, SB Ogunsona1, HM Irshad4, and SH Abbas5

1Department of Science Laboratory Technology, Ladoke Akintola University of Technology, Ogbomoso, Oyo State Nigeria.

2Department of Pure and Applied Biology, Ladoke Akintola University of Technology, Ogbomoso, Oyo State Nigeria.

3Department of Mechanical Engineering, Ladoke Akintola University of Technology, Ogbomoso, Oyo State Nigeria.

4Faculty of Materials and Chemical Engineering, Ghulam Ishaq Khan Institute of Engineering, Science and Technology, Pakistan.

5Center for Excellence in Nanotechnology, King Fahd University of Petroleum and Minerals, Saudi Arabia

*corresponding author: icoladipo@lautech.edu.ng

Abstract

This study describes characterization and some biological evaluation of gold nanoparticles synthesized using aqueous seed extract of *Datura stramonium*. The phytosynthesized AuNPs was characterized by UV-Vis spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), Energy Dispersive X-ray (EDX) and Scanning Electron Microscopy (SEM) and evaluated for antifungal, antioxidant, thrombolytic and anticoagulant activities. The AuNPs were nearly spherical, and agglomerated in nature with size ranges of 75.1-156.5 nm. Gold was the most occurring metal noted on EDX analysis, while the AuNPs showed face-centred crystalline pattern. The UV-visible spectrum of the AuNPs synthesized displayed clear peak at 536 nm. The FTIR peaks at 3423.76, 2920.32, 2360.95 and 1635.69 cm\(^{-1}\) attributed to the involvement of proteins in the AuNPs biofabrication and capping. The AuNPs showed potent antifungal activity through inhibitions of mycelia by 57.9, 60.7, 64.5, 69.6 and 80.6 % against *Fusarium solani*, *Candida albicans*, *Aspergillus niger*, *A. flavus* and *A. fumigatus* at 250 µg/ml respectively.
The AuNPs synthesized showed scavenging properties of 28.9, 37.3, 42.5 and 52.4 % at 250, 500, 750 and 1000 µg/ml against 2,2-diphenyl-1-picrylhydrazyl. Furthermore, the synthesized AuNPs also showed free radical scavenging properties against nitric oxide at 250 (52.20 %), 500 (55.73 %), 750 (56.71 %) and 1000 (59.51 %) µg/ml respectively using sodium nitroprusside as positive control. Blood coagulation was prevented by the AuNPs at 250 (54 %), 500 (55 %), 750 (56 %) and 1000 (59 %) µg/ml. Also, AuNPs showed thrombolytic potential by causing lysis of blood clot thus, showing potential for biomedical applications. An inexpensive and environmental-friendly synthesis of AuNPs from *Datura stramonium* seed has been presented for various nano-biotechnological applications.

**Keywords**: Antifungal, Antioxidant, Biomedical, Nanoparticles.

1 Introduction

Nanotechnology is the science that involves the manipulation of materials/matters to produce nanoparticles with dimension size between 1 and 100 nanometer [1, 2]. Nanotechnology has shown unprecedented innovations in history as it has opened doors for many feats of discoveries in science and technology. For over two decades, researchers have exploited avenues in nanotechnology that have in turn made the world a better place [3-7]. The indispensability of nanotechnology to man is getting more stronger as many intricate problems in areas of medicine [8,9], biochemistry, microbiology/molecular biology [3, 4, 8], engineering [10] and materials science [10, 11] have been proffered solutions to.

Many methods have been used in the synthesis of nanoparticles and most of these methods have one or two short comings when it comes to the application of the synthesized nanoparticles in biomedical. However, considering the residual and side effects, among all the approaches/methods used in synthesizing nanoparticles, the green method is the cheapest, eco-friendly, safe and easy to carry out. The green synthesis of nanoparticles is commonly used and it has been shown to be useful in biomedical application [3, 4, 13] than any other approach.

Plant/plant materials as a result of their abundance in bio-reductant molecules have been pivotal in the green synthesis of nanoparticles. Phytochemicals present in plants played major roles in reduction of metals, a feature highly useful in nanobiotecnology. Many common and uncommon plants/plants materials have been exploited in the green synthesis of nanoparticles yielding sterling and beneficial applications in all fields especially biomedical [3, 4, 5, 14, 15,
16]. In this study, Jimson weed (*Datura stramonium*); popularly called the Devil’s trumpet was evaluated for its nanobiotechnological potentials. It is an annual, herbaceous plant that grows to a height of 1 to almost 2 meters with white/violet trumpet-shaped flowers and spiny fruit [17, 18].

Jimson weed grows indiscriminately around in gardens, road sides and farmlands in Western Africa especially in Nigeria. It is locally called “Gegemu” by the Yoruba tribe and it is popularly known for its intoxicating power and also could be planted explicitly to ward off poisonous snakes. In Nigeria, *D. stramonium* is very important to the locals and also in many countries around the world. It is highly medicinal and it is used for treating asthma/cough, bronchitis, goiter, ulcer and wound dressing [19]. It also possesses abortifacient and antimicrobial activities against *E. coli* and *Pseudomonas aeruginosa* and all these properties could be due to its abundance in phytochemicals such as alkaloids [18].

On the evidence of phytochemical contents and medicinal importance, this study was aimed at establishing the possibility of synthesizing gold nanoparticles using aqueous seed extract of Jimson weed as reducing/capping agents and also evaluating biomedical properties of the synthesized nanoparticles.

2 Materials and Methods

2.1 Sample Collection and Preparation

The Jimson weed fruit was collected from Isale General Area, Ogbomoso, Oyo State by plucking and then conveyed to the laboratory in sterile polythene bag. The seeds were separated from the husk and were examined closely to ensure no sign of infection. The seeds were washed with sterilized distilled water, drained aseptically, air-dried and blended aseptically after two weeks. The seed powder (0.1 g) was weighed and suspended in 10 ml of distilled water, and placed in water bath at 60 °C for 1 h. The extract was filtered and centrifugation was carried out at 4000 rpm for 15 min. The scheme of sample preparation is depicted in Figure 1.

2.2 Biofabrication and Characterization of Gold nanoparticles

Exactly 1 ml of the seed extract was reacted with 40 ml of 1mM HAuCl₃ under ambient condition. The synthesis was monitored through the colour change and measurement of the absorption spectrum carried out by UV-vis spectrophotometry (B-UV1800PC spectrophotometer); and also for the determination of biomolecules responsible for the
biofabrication, capping and stabilization of the AuNPs, the IR spectroscopy spectral was obtained using IR Affinity-1s spectrophotometer (Shimadzu, UK). The AuNPs was also subjected to Scanning Electron Microscope and Energy-Dispersive X-ray spectroscopic analyses for the determination of the elemental composition and size of the AuNPs. The micrograph was taken by using FESEM 6100 Zeiss Ultra Plus (Germany) working at a voltage of 20.0 kV with secondary electrons in low vacuum mode.

2.3 Biomedical Application of the AuNPs

2.3.1 Antifungal Activity

The antifungal activities of the AuNPs were determined using mycelial growth inhibition test [21]. AuNPs were included in potato dextrose agar (PDA) at concentration of 200 μg/ml. Agar plug of 6 mm of 48 h-old cultures of Aspergillus niger, A. fumigatus, Fusarium solani, Candida albicans and A. flavus were used to inoculate the PDA plates at the centre. The control plates contained no nanoparticles. Incubation was done at 28 ± 2°C for 72 h. Measurement of the fungal radial growths in all the plates were taken and the percentage growth inhibitions were calculated using the formula:

\[ \text{DPPH scavenging (\%)} = \left( \frac{D_{\text{control}} - D_{\text{test}}}{D_{\text{control}}} \right) \times 100 \]

Where D is the diameter of fungal growth on the plates.

2.3.2 Antioxidant Activities of Biosynthesized Gold Nanoparticles

The 2, 2-diphenyl-1-picrylhydrazyl is widely used for testing preliminary radical scavenging activity of a compound or nanoparticles. Antioxidant activity was measured by the use of the modified DPPH method as reported by Lateef et al. [22]. Methanolic solution of DPPH was prepared using 0.04 g of DPPH into 1 liter of methanol and the optical density of the solution was read at 517 nm. To determine the antioxidant activity, 1.0 ml of varied concentrations of the synthesized gold nanoparticles (250, 500, 750 and 1000 µg/ml) were challenged with 4 ml of methanolic DPPH. The reaction was allowed in the dark for 30 min. The absorbance was measured at 517 nm in UV-visible spectrophotometer. Calculation was done using the formula below:

\[ \text{DPPH scavenging (\%)} = \left( \frac{\text{Absorbance of sample} - \text{Absorbance of control}}{\text{Absorbance of control}} \right) \times 100 \]
2.3.3 Anticoagulant and Thrombolytic Activities of Synthesized Gold Nanoparticles

The anticoagulant activity of the gold nanoparticles was investigated as earlier described by Lateef et al. [23]. Exactly 100 μl of the gold nanoparticles (100 μg/ml) was added to 0.5 ml of freely donated human blood, while blood in EDTA served as positive control and blood in clean tube served as negative control. Also, Datura stramonium seed extract and aqueous gold solution were used to treat blood samples, which were held at 30 ± 2 °C for 30 min. These were then examined for anticoagulation.

Determination of the thrombolytic activity was done by utilizing the strategies of Azeez et al. [24]. Quantification of the thrombolytic activity was carried out in this case [25]. For blood clotting to occur, tubes with 0.5 ml of blood were kept at 37 °C for 30 min and then examined. The weight of clean tube (W1) was subtracted from the weight of tube and blood clot (W2) to obtain the weight of blood clot (W3). Subsequently, 100 μl of the gold nanoparticles, gold chloride solutions, and Datura stramonium aqueous seed extract were placed in each blood clot tube. Incubation was done at 37 °C for 90 min, and the tubes were inverted to confirm lysis of blood clot [26, 27]. The tubes were drained, and the weight of the tube left over clot was taken (W4) to obtain the weight of clot that was not lysed (W5). The percentage thrombolytic activity was obtained as:

\[
\frac{W_3 - W_5}{W_3} \times 100
\]

3 Results and Discussion

3.1 Biosynthesis and Characterization of AuNPs

The phytosynthesis of the AuNPs using aqueous seed extract of Datura stramonium (Plate 1) as the stabilizing /reducing agent brought about change in the colour of the salt solution from pale yellow to light pink within the first 5 min and later stabilized turning to dark pink 22 min later (Figure 2); this similar colour change was reported by Abirami et al. [28] and Alaa et al. [29]. Furthermore, colours like ruby red, purple, blue-black and light blue have also been observed for gold nanoparticles by many authors [13, 30, 31, 32, 33]. The change in colour is the result of excitation of surface plasmon vibration, which is indicated by the reduction of Au$^{3+}$ ions to Au$^0$ ions at different time interval [28]. In the interim of each time interval, the peak became
clear, unique and rising; this unique peak clearly indicates the increase in synthesis of nanoparticles as the time increases till the capping of the reaction, these facts were lent credence to by Reddy et al. [34] and Jayaseelan et al. [35].

**Figure 1.** Sample preparation

---

**Figure 2.** Photoactivation of the gold nanoparticles by *Datura stramonium* seed (DSS) extract
The UV-vis spectrum of the AuNPs displayed maximum absorbance at the wavelength of 536 nm as shown in Figure 3C and this is within the reported absorption properties of AuNPs i.e surface plasmon resonance in range of 510-614 [13, 26, 36, 37]. The spectra for the aqueous gold chloride which was the precursor (Figure 3A) and the aqueous crude extract of the *Datura stramonium* seed (Figure 3B) that serves as the reducing/capping agents were also presented to establish the occurrence of new reaction in Figure 3C at the mixture of the precursor (HAuCl₃) and the reducing/capping agent (aqueous crude extract of the *Datura stramonium* seed) that brought about the reduction of Au³⁺ ions to Au⁰.

The AuNPs FTIR spectrum showed prominent peaks at 3423.76, 2920.32, 2360.95 and 1635.69 cm⁻¹ (Figure 4). The vibrational peak around 3423 cm⁻¹ is assigned to O-H and N-H stretching vibration in amines and amides. Furthermore, the peak at 2920.32 is ascribed to C-H stretch of the alkyl group, the peak around 2360.95 cm⁻¹ which is likely to correspond to C≡C from alkyne and the peak at 1635.69 cm⁻¹ suggested conjugation effects of C=O stretching of carbonyl groups [33] or esters and N-H binding of proteins. The appearance of these peaks in the AuNPs FTIR spectrum suggested that macromolecules like proteins, carbohydrates and some phytochemicals like phenolic compounds in the *Datura stramonium* seed extract may be responsible for the stabilizing and capping of the AuNPs. Hamed *et al.* [33] reported that phytochemicals from plant extract putatively make a coating that shields metal nanoparticles.

The Energy Dispersive X-ray (EDX) patterns (Figure 5) showed gold as the prominent element showing the yield of 86.00%. Also, the SEM (Figure 6) micrograph shows the fabrication of nearly spherical shaped and agglomerated AuNPs with size range of 75.1-156.5 nm.
Figure 3. A, UV-vis spectrum of aqueous gold chloride; B, UV-vis spectrum of *Datura stramonium* seed extract; 1C, UV-vis spectrum of biosynthesized gold nanoparticles
Figure 4. FTIR spectrum of the biosynthesized gold nanoparticles

Figure 5. EDX spectrum of the biosynthesized gold nanoparticles
Figure 6. SEM micrograph of the biosynthesized gold nanoparticles

3.2 Antifungal Activities of AuNPs

The biosynthesized AuNPs showed significant effect on the growth of *C. albicans* (60.7%), *A. niger* (64.5%), *A. flavus* (69.6%), *A. fumigatus* (80.6%) and *F. solani* (57.9%) in relation to the abundant growth of the control and aqueous *D. stramonium* seed extract embedded (Figure 7). Mycotoxins are one out of many to reckon with as they are produced by toxigenic fungi under appropriate environmental conditions making them almost impossible to avoid and are considered the key factor in contamination and foodstuffs spoilage [39, 40]. When the environmental conditions are right, the toxigenic fungi grow and release the mycotoxins into the food materials and later cause severe health problems. Some food-borne mycotoxins are very acute and severe that they start affecting the body system almost immediately, while other food-borne mycotoxins have longer severe accumulative impacts on health, which could even result in cancer or immune deficiency over time [40, 41]. *Fusarium* sp., followed by *Aspergillus* sp. are
the most common and largest mycotoxin-producing fungi [42, 43, 44]. Nigeria has suffered huge losses because of the poor standard of farm produce as a result of mycotoxins contamination. Due to the reduction in yield, health and market value of the crops, exportation has been affected drastically over the years [45]. This work might provide solution to the infestation of these fungi as the test organisms used in this study has proven susceptible to the bio-fabricated AuNPs. A green synthesized, eco-friendly AuNPs might be a good replacement to poisonous fumigating chemicals that cause deadly poisoning yearly in Nigeria [46]. *Candida albicans* was also found to be susceptible to the bio-fabricated AuNPs, suggesting that the problem of superficial mycosis caused by this yeast could be possibly mitigated.

3.3 Anticoagulant and Thrombolytic Activity

Clots formation was prevented by the addition of EDTA (which served as positive control) whereas coagulation was noticed in the negative control (blood clot). The synthesized gold nanoparticles on the other hand showed tremendous anticoagulant activities; at 250 µg/ml (54%), 500 µg/ml (55%), 750 µg/ml (56%) and 1000 µg/ml (59%) (Figure 8 and Table 1). The results obtained are in agreement with anticoagulant potentials of metallic nanoparticles synthesized from diverse biomolecules as previously recorded by Azeez *et al.* [24]. Similarly, the gold nanoparticles generated clot dissolution within 5 min of reaction when reacted with previously formed blood clot. The control experiment performed with the aqueous gold chloride and the *D. stramonium* seed extract showed lesser dissolution of blood clot (Figure 9). The AuNPs showed thrombolytic activities of 33%, 46%, 48% and 52% at 250, 500, 750 and 1000 µg/ml respectively (Table 2). Therefore, the thrombolytic activities of the synthesized gold nanoparticles demonstrated fair thrombolytic properties. Though clotting of blood is essential to inhibition of bleeding, yet its dissolution is similarly crucial in inhibiting thrombolysis and sustenance of hemostasis, where nanoparticles assume significant roles in rendering effective lysis of blood clots. The thrombolytic and anticoagulant potentials of gold nanoparticles have been recently reported [13].
Figure 7. Antifungal activities of the bio-fabricated AuNPs
**Figure 8.** Anticoagulant activities of gold nanoparticles by *Datura stramonium* seed extract {A, control; B, Blood + EDTA; C, Blood + AuNPs (250 µg/ml); D, Blood + AuNPs (500 µg/ml); E, Blood + AuNPs (750 µg/ml); F Blood + AuNPs (1000 µg/ml)}

| Treatments | $W_3$ (g) | $W_5$ (g) | $\frac{W_3 - W_5}{W_3} \times 100$ % |
|------------|-----------|-----------|----------------------------------|
| Extract    | 2.32      | 1.24      | 46                               |
| HAUCl$_3$  | 2.32      | 1.10      | 52                               |
| AuNPs (µg/ml) |            |            |                                  |
| 250        | 2.32      | 1.07      | 54                               |
| 500        | 2.32      | 1.05      | 55                               |
| 750        | 2.32      | 1.02      | 56                               |
| 1000       | 2.32      | 0.95      | 59                               |

Table 1. Anticoagulant activities of the biosynthesized AuNPs
Figure 9. Thrombolytic activities of gold Nanoparticles by *Datura stramonium* seed extract {A, control; B, *D. stramonium* seed extract + blood; C, AuCl$_3$ + blood; D, Blood + AuNPs (250 µg/ml); E, Blood + AuNPs (500 µg/ml); F, Blood + AuNPs (750 µg/ml); G, Blood + AuNPs (1000 µg/ml)}

Table 2. Thrombolytic activities of the biosynthesized AuNPs

| Treatments        | $W_3$ (g) | $W_5$ (g) | $\frac{W_3-W_5}{W_3} \times 100$ % thrombolysis |
|-------------------|-----------|-----------|-----------------------------------------------|
| Extract           | 2.32      | 1.61      | 31                                            |
| AuCl$_3$          | 2.32      | 1.65      | 29                                            |
| AuNPs (µg/ml)     |           |           |                                               |
| 250               | 2.32      | 1.56      | 33                                            |
| 500               | 2.32      | 1.24      | 46                                            |
| 750               | 2.32      | 1.20      | 48                                            |
| 1000              | 2.32      | 1.10      | 52                                            |
The phytosynthesized gold nanoparticles demonstrated significant free radical scavenging properties against 2, 2-diphenyl-1-picrylhydrazyl (DPPH) by 28.9, 37.3, 42.5 and 52.4% at 250, 500, 750 and 1000 µg/ml (Table 3). Furthermore, gold nanoparticles demonstrated significant radical scavenging properties against nitric oxide by 52.20, 55.73, 56.71 and 59.51% at 250, 500, 750 and 1000 µg/ml (Table 4). The scavenging activities of gold nanoparticles were compared to those recorded by Oladipo et al. [13], in which biosynthesized AuNPs synthesized using the cell-free extract of Enterococcus species showed free radical scavenging against DPPH at 33.24-51.47% at 1-40 µg/ml. On the evidence of the free radical scavenging properties of the AuNPs in this study, it could be established that the biosynthesized AuNPs has a very potent antioxidant properties. The activity shown by the phytosynthesized gold particles mean that they may be relevant in scavenging for free radicals in the environment as well as in biomedical applications. The free radical scavenging potentials of nanoparticles is because of the functional groups of bioreductant molecules, whose capacity to adhere to the surface of the nanoparticles may bring about amplified surface areas of activity.

Table 3. Antioxidant activities of the AuNPs

| Stages          | DPPH Free radical scavenging (%) |
|-----------------|----------------------------------|
| Control         | 82.3                             |
| Ascorbic acid   | 62.7                             |
| Quercetin       | 58.8                             |
| AuNPs (µg/ml)   |                                  |
| 250             | 28.9                             |
| 500             | 37.3                             |
| 750             | 42.5                             |
| 1000            | 52.4                             |
| DSS Extract     |                                  |
Table 4. Antioxidant activities of the AuNPs (Nitric Oxide)

| Stages         | Free radical scavenging (%) |
|----------------|-----------------------------|
| Control        | 82.0                        |
| Sodium nitroprusside | 52.20                     |
| AuNPs (µg/ml)  |                             |
| 250            | 52.20                       |
| 500            | 55.73                       |
| 750            | 56.71                       |
| 1000           | 59.51                       |
| DSS Extract    | 59.50                       |

4 Conclusion

This study demonstrated the biofabrication of AuNPs using *Datura stramonium* seed extract as the reducing and capping agent. The deep pink colored AuNPs were slightly agglomerated with sizes between 71.5 and 156.5 nm with near spherical morphology. The particles displayed varied degrees of activities as antifungal, antioxidant, anticoagulant and thrombolytic agents. Supposedly, this is the first documentation of the phytosynthesis of AuNPs from *Datura stramonium* seed extract with potential biomedical applications.
Reference

[1] Roco MC 2001 From vision to the implementation of the US National Nanotechnology Initiative. J. Nanopart. Res. 3 (1) pp 5-11.

[2] Lövestam G, Rauscher H, Roebben G, Klüttgen B S, Gibson N 2010 Considerations on a definition of Nanomaterial for regulatory purposes. Joint Research Centre (JRC) Reference Reports. 80 pp 00-41.

[3] Gupta V K, Gupta M and Sharma S 2001 Process development for the removal of lead and chromium from aqueous solution using red mud – an aluminum industry waste. Water Res. 35 (5) pp 1125-1134.

[4] Shanmugavadivu M, Selvam K and Ranjithkumar R 2014 Synthesis of pomegranate peel extract mediated silver nanoparticles and its antibacterial activity. Am. J. Adv. Drug Deliv. 2 (2) pp 174-182.

[5] Lateef A, Azeez M A, Asafa T B, Yekeen T A, Akinboro A, Oladipo I C, Ajetomobi F E, Gueguim-Kana E B, Beukes L S 2015 Cola nitida-mediated biogenic synthesis of silver nanoparticles using seed and seed shell extracts and evaluation of antibacterial activities. BioNanoSci. 5 (4) pp 196-205.

[6] Lateef A, Ojo S A, Folarin B I, Gueguim-Kana E B, Beukes L S 2016 Kolanut (Cola nitida) mediated synthesis of silver-gold alloy nanoparticles: antifungal, catalytic, larvicidal and thrombolytic applications. J. Clust. Sci. 27 (5) pp 1561-1577.

[7] Oladipo I C and Ogunsona S B 2019 The Utilization of Agro Waste: A nanobiotechnology Point of View. Recent Advances in Biological Research Vol. 5; Chapter 10 Print ISBN: 978-93-89246-84-1, eBook ISBN: 978-93-89246-85-8.

[8] Salta O V 2004 Applications of nanoparticles in biology and medicine. J. Nanobiotechnol. 2 (1) 3. https://doi.org/10.1186/1477-3155-2-3.

[9] Caruthers S D, Wickline S A and Lanza G M 2007 Nanotechnological applications in medicine. Curr. Opin. Biotechnol. 18 (1) pp 26-30.

[10] Khorami M and Ganjian E 2011 Comparing flexural behavior of fibre-cement composites reinforced bagasse: Wheat and eucalyptus. Constr. Build. Mater. 25 (9) pp 3661-3667.
[11] Karademir A, Aydemir C and Yenidogan S 2011 Sound absorption and print density properties of recycled sheets made from waste paper and agricultural plant fibres. *Afr. J. Agric. Res.* 6 (28) pp 6073-6081.

[12] Morais M G, Vilásia G M, Daniela S, Patricia P and Jorge A V C 2014 Biological applications of nanobiotechnology. *J. Nanosci. Nanotechnol.* 14 (1) pp 1007-1007.

[13] Oladipo I C, Lateef A, Elegbede J A, Azeez M A, Asafa T B, Yekeen T A, Akinb oro A, Gueguin-Kana E B, Beukes L S, Oluyide T O and Atanda O R 2017 *Enterococcus* species for the one-pot biofabrication of gold nanoparticles: Characterization and nanobiotechnological applications. *J. Photochem. Photobiol. B: Biol.* 173 pp 250-257.

[14] Van H L, Chi N H T and Huy H T 2013 Synthesis of silica nanoparticles from Vietnamese rice husk by sol–gel method. *Nanoscale Res. Lett.* 8 (1) 58. https://doi.org/10.1186/1556-276X-8-58.

[15] Lee K X, Kamyar S, Mikio M, Noriyuki K, Nurul B A K, Shaza E B and Yen P Y 2016 Green synthesis of gold nanoparticles using aqueous extract of *Garcinia mangostana* fruit peels. *J. Nanomater.* Article ID 8489094, http://dx.doi.org/10.1155/2016/8489094.

[16] Sharma K, Sanket K and Anupam J 2016 Green synthesis of silver nanoparticles by using waste vegetable peel and its antibacterial activities. *J. Pharm. Sci. Res.* 8 (5) pp 313-316.

[17] Dethier M, Cordier Y and Demeyer K 1993. Cultivation of *Datura* species for scopolamine and hyoscyamine production in Burundi. *ISHS Acta Hortic.* 331. https://doi.org/10.17660/ActaHortic.1993.331.6.

[18] Mairura FS and Setshogo MP 2008 *Datura stramonium* L. Schmelzer GH, Gurib-Fakim A (Editors). pp 221-225.

[19] Burkill HM 2000 The useful plants of West Tropical Africa. 2nd Edition. Volume 5, Families S–Z, Addenda. Royal Botanic Gardens, Kew, Richmond, United Kingdom. 686 pp
[20] Philipov S, Berkov S and Doncheva T S 2007 GC-MS survey of Datura stramonium alkaloids. Comptes Rendus de l’Académie Bulgare des Sciences 60 (3) pp 239-250.

[21] Lateef A, Folarin BI, Oladejo SM, Akinola PO, Beukes LS and Gueguim-Kana EB 2018 Characterization, antimicrobial, antioxidant and anticoagulant activities of silver nanoparticles synthesized from Petiveria alliacea L. leaf extract. Prep. Biochem. Biotechnol. 48 (7) pp 646-652.

[22] Lateef A, Azeez MA, Asafa TB, Yekeen TA, Akinboro A, Oladipo IC, Azeez L, Ojo SA, Gueguim-Kana EB and Beukes LS 2016 Cocoa pod extract-mediated biosynthesis of silver nanoparticles: its antimicrobial, antioxidant and larvicidal activities. J. Nanostruct. Chem. 6 pp 159-169.

[23] Lateef A, Ojo SA, Elegbede JA, Azeez MA, Yekeen TA and Akinboro A 2017 Evaluation of some biosynthesized silver nanoparticles for biomedical applications: hydrogen peroxide scavenging, anticoagulant and thrombolytic activities. J. Clust. Sci. 28 (3) pp 1379-1392.

[24] Azeez M A, Lateef A, Asafa T B, Yekeen T A, Akinboro A, Oladipo I C, Gueguim-Kana EB and Beukes L S 2017 Biomedical applications of cocoa bean extract mediated silver nanoparticles as antimicrobial, larvicidal and anticoagulant agents. J. Clust. Sci. 28 (1) pp 149-164.

[25] Lateef A, Akande M A, Ojo S A, Folarin B I, Gueguim-Kana E B and Beukes L S 2016 Paper wasp nest-mediated biosynthesis of silver nanoparticles for antimicrobial, catalytic, anti-coagulant and thrombolytic applications, 3 Biotech. 6 140. http://dx.doi.org/10.1007/s13205-016-0459-x.

[26] Ojo S A, Lateef, A Azeez M A, Oladejo S M, Akinwale A S, Asafa T B, Yekeen T A, Akinboro A, Oladipo I C, Gueguim-Kana E B and Beukes L S 2016 Biomedical and catalytic applications of gold and silver-gold alloy nanoparticles biosynthesized using cell-free extract of Bacillus safensis LAU 13: antifungal, dye degradation, anticoagulant and thrombolytic activities, IEEE Trans. NanoBiosci. 15 (5) pp 433-442
[27] Lateef A, Ojo S A, Oladejo S M 2016 Anti-candida, anti-coagulant and thrombolytic activities of biosynthesized silver nanoparticles using cell-free extract of Bacillus safensis LAU 13. Process Biochem. 51 (10) pp 1406-1412.

[28] Abirami H, Tajuddin N B, Mohamed H M I, Hussain S J, Premkumar K, Shilu M, Archunan G and Ishtiaq Q 2016 Synthesis of plant mediated gold nanoparticles using Azima tetracantha Lam. leaves extract and evaluation of their antimicrobial activities. Pharmacogn. J. 8 (5) pp 507-512.

[29] Alaa A A, Aljabali I D, Yazan A, Mazhar S A, Zoubi I D, Khalid M A, Bahaa A I D, Osama A A, Alaaldin M A, Mourad B and David J E 2018 Synthesis of gold nanoparticles using leaf extract of Ziziphus zizyphus and their antimicrobial activity. Nanomater. 8 (3) 174 https://doi.org/10.3390/nano8030174.

[30] Inbakandan D, Venkatesan R and Khan S A 2010 Biosynthesis of gold nanoparticles utilizing marine sponge Acanthella elongata (Dendy, 1905). Colloids Surf. B: Biointerf. 81 (2) pp 634-639.

[31] Ahmad T, Wani I A, Manzoor N, Ahmed J and Asiri A M 2013 Biosynthesis, structural characterization and antimicrobial activity of gold and silver nanoparticles. Colloids Surf. B: Biointerf. 107 pp 227-234.

[32] Ramakrishna M, Babu D R, Gengan R M, Chandra S and Rao G N 2016 Green synthesis of gold nanoparticles using marine algae and evaluation of their catalytic activity. J. Nanostruct. Chem. 6 (1) pp 1-13.

[33] Hamed A G, Khalid A K, Essam H I and William N S 2019 Synthesis of gold nanoparticles (AuNPs) using Ricinus communis leaf ethanol extract, their characterization, and biological applications. Nanomater. 9 (5) 765 https://doi.org/10.3390/nano9050765.

[34] Reddy G R, Jayakumar C, Morais A B, Sreenivasn D and Gandhi N N 2012 Green synthesis characterization and in-vitro antibacterial activity of polycrystalline gold nanoparticles by using Senna siamea (Lam.) Plant leaf extract. Int. J. Green Chem. Bioprocess 2 (1) pp 1-5.

[35] Jayaseelan C, Ramkumar R, Rahuman A A and Perumal P 2013 Green synthesis of gold nanoparticles using seed aqueous extract of Abelmoschus esculentus and its antifungal activity. Ind. Crops Prod. 45 pp 423-429.
[36] Mishra A, Kumari M, Pandey S, Chaudhry V, Gupta K C and Nautiyal C S 2014 Biocatalytic and antimicrobial activities of gold nanoparticles synthesized by Trichoderma sp. Bioresour. Technol. 166 pp 235-242.

[37] Malathi S, Ezhilarasu T, Abiraman T and Balasubramanian S 2014 One pot green synthesis of Ag, Au and Au-Ag alloy nanoparticles using isonicotinic acid hydrazide and starch. Carbohydr. Polym. 111 pp 734-743.

[38] Bennett J W and Klich M 2003 Mycotoxins. Clin. Microbiol. Rev. 16 pp 497-516.

[39] Bhat RV and Miller JD. Mycotoxins and food supply. Food, Nutrition and Agriculture-Food for the Future., FAO. 1991. https://www.fooddiagnostics.dk/seekings/uploads/FAO-Mycotoxins_and_Food_Supply.pdf. Accessed on 25 January, 2020.

[40] Sokefun E, Ayepola O O and Olasehinde G I 2018 Mycotoxins: Food production and exportation in Nigeria. Earth Environ. Sci. 210 (1) 012018. https://doi.org/10.1088/1755-1315/210/1/012018.

[41] Ahmed A I and Jutta P 2015 Mycotoxins: Producing fungi and mechanisms of phytotoxicity. Agricult. 5 (3) pp 492-537.

[42] Yazar S and Omurtag G 2008 Fumonisins, Trichothecenes and Zearalenone in Cereals. Int. J. Mol. Sci. 9 pp 2062-2090.

[43] Alexandra H H and Lewis E H B 2015 Comparative Ochratoxin toxicity: A review of the available data. Toxins 7 pp 4253-4282.

[44] Travis R B and Felicia W 2015 Ochratoxin A and human health risk: A review of the evidence. Crit. Rev. Food Sci. Nutr. 55 (13) pp 1860-1869.

[45] Bankole S A and Adebanjo A 2003 Mycotoxins in food in West Africa: current situation and possibilities of controlling it. Afri. J. Biotechnol. 2 (9) pp 254-263.

[46] Asogwa E U and Dongo L N 2009 Problems associated with pesticide usage and application in Nigerian cocoa production: a review. Afr. J. Agric. Res. 4 (8) pp 675-683.