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Phyto-synthesis of Silver Nanoparticles and Their Application to Bioactive Products Development

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Abstract: A proprietary technique of biosynthesis of silver nanoparticles using banana trunk fibres is reported for the first time. In this study the potential applications of silver nanoparticles to three products: filter paper, shoe in-sole and egg crates by exploiting the bioactive properties of silver nanoparticles was demonstrated. The nanoparticles were phyto-synthesized by the reduction of silver nitrate solution using banana trunk fibres as both reducing and capping agents. The presence of silver nanoparticles was confirmed by the Plasmon resonance frequency absorption of silver at 420 nm; scanning electron microscopy and electron diffraction spectroscopy of the materials also showed the position of the nanoparticles within the fibre matrix and appreciable elemental signal level, respectively.

Key words: Banana trunk fibres, silver nanoparticles, phyto-synthesis, plasmon resonance, frequency absorption, bioactive products, nanotechnology

INTRODUCTION

Nanotechnology is a fast-growing research field in science and technology. Research has already led to significant breakthroughs and value-added products in nanoforms are commercially available (Ostiguy *et al*., 2008). Most high-value nanotechnology products are outstanding and very innovative. They thus command a credible market presence and robust acceptance. Almost all of these products are manufactured in developed countries and subsequently marketed in the less developed countries. Thus, the relevance of this technology has been minimal on the social lives of a large segment of residents of these developing countries since, such countries harbor a large percentage of low-income earners.

Nanomaterials of gold, silver, platinum and copper among others have been documented to exhibit a wide range of applications ranging from electrical to biomedical (Hussain *et al*., 2003; Kearns *et al*., 2006; Mohanraj and Chen, 2006; Sathyavathi *et al*., 2010). Furthermore, nanotechnology is directly relevant to improving water sanitation, disease diagnosis and treatment as well as new product development. Improving these indices would have more direct impact on the populace who in turn can contribute to the development of such products and thus reap financial benefits accruing from nanotechnology. Thus this attempt is made to focus on true-nanotechnology: nanotechnology that has direct impact on the immediate community.

Improving water sanitation leads to a concomitant improvement in wellness and health in most communities. Likewise, early detection and improved surveillance help stem the tide of debilitating disease (Lee *et al*., 2007; Kim *et al*., 2007; Ahmad *et al*., 2011). There are generally two genres of water sanitation strategies: sterilization and filtration. The ultimate aim of the current effort is to combine the two in a cost effective way using nano-particle technology, commencing with a green synthetic method of nanoparticle production. Silver nanoparticles due to their large charge to particle ratio have been implicated in microbicidal activities (Lee *et al*., 2007; Kim *et al*., 2007; Ahmad *et al*., 2011). Chemical synthesis of silver nanoparticles is the most common method which employs use of potentially hazardous chemicals, raising toxicological fears (Sathyavathi *et al*., 2010). However,

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other much safer methods such as microwave assisted process, irradiation and electrochemical have not become cottage technologies available to resource poor communities. Green synthesis of nanoparticles is a fairly recent phenomenon. It offers the twin advantages of environmental control as well as simplicity. Microbial and plant mediated silver nanoparticles synthesis have been reported (Saifuddin *et al*., 2009; Ankanna *et al*., 2010; Ali *et al*., 2011). Plants are relatively available and cheaper than microorganisms as their use would not require culture preparation and maintenance of aseptic conditions (Singh *et al*., 2011). However, the use of an agricultural waste to generate highly valuable nanoparticles is being reported here for the first time. About >90% of the biomass produced by banana plantations could be regarded as agricultural waste hence, the importance of deploying the fibres to nanoparticle synthesis.

Plant by products are a great source of renewable biomass, chiefly unexploited and relatively inexpensive. Agricultural by products considered as wastes can potentially be converted into various value added products. Harnessing these resources to product applications and applying nanotechnology to make bioactive products is thus considered worthwhile. Thus, the potentials of banana (*Musa acuminata*) trunk fibres in the synthesis of silver nanoparticles and its application to bioactive product development were investigated.

MATERIALS AND METHODS

Plant material and synthesis of silver nanoparticles: Banana trunk wastes were collected from the pilot farm of Biotechnology Advanced Laboratory, Sheda Science and Technology Complex, Abuja, Nigeria. Silver nitrate was purchased from Sigma-Aldrich. The trunks were cut into pieces and soaked in water for 1 h. The softened trunk was filtered and employed for the synthesis of silver nanoparticles. $AgNO_3$ (1 mM) solution was added to banana trunk fibres until the trunk was inundated with the solution. The whole mixture was put into a rotary shaker operating at 150 rpm at 27°C and maintained in dark conditions for 24 h. It was observed that addition of silver nitrate solution led to colour changes. The colour changes were monitored at periodic intervals. The dark fibres were allowed to dry in a vacuum oven set at 60°C for 12 h. Another set of banana fibres were cut, soaked in water under similar conditions, washed and dried as control. The fibres produced were then used in the production of paper, egg-crates and shoe-insoles according to proprietary methodologies developed by the SHESTCO biomaterials group.

UV-Vis spectra analysis: The formation of silver nanoparticles was monitored by sampling an aliquot (2 mL) of the solution and measuring the UV-VIS spectra of the reaction medium at 1, 3, 5 and 24 h intervals. Absorption measurements were carried out on CECIL 7500 UV-Vis spectrophotometer. UV-VIS scans were taken in the range 200-1100 nm.

SEM and EDS analyses: Scanning Electron Microscopic (SEM) analysis of banana trunk-mediated biosynthesized silver nanoparticles were investigated using Hitachi S-4500 SEM instrument equipped with Thermo EDS attachments. Thin films of the sample were allowed to dry and a small amount was dropped on a carbon coated copper grid. Elemental analysis was performed using Electron Dispersive Spectroscopy (EDS).

RESULTS AND DISCUSSION

Silver nanoparticles exhibit characteristic features. Addition of 1 mM $AgNO_3$ to *Musa acuminata* trunk resulted in progressive changes of colour (colourless-yellow-brown-black) within the 24 h experimental period (Fig. 1) (Ankanna *et al*., 2010). This may be due to excitation of the Surface Plasmon Resonance (SPR) vibrations of silver nanoparticles formed (Ahmad *et al*., 2011) from bioreduction of aqueous Ag^+. The reaction was subsequently monitored and established by UV-VIS spectroscopy. Figure 2 shows UV-VIS spectra of the silver nitrate treated banana trunk. Surface absorbance plasmon (SPR) energy of Ag is located far away from the intraband transition (Singh *et al*., 2011). The reaction media displayed peak absorbance between 420-443 nm within 24 h with relative absorbance increase with time and this probably due to increase in SPR. The highest absorbance readings were obtained after 5 h. The absorbance however, dropped after 24 h. It was therefore,

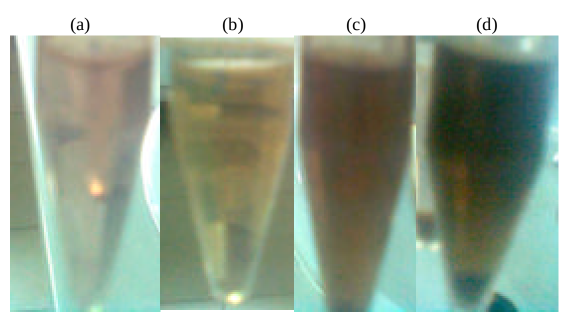

Fig. 1: Colour changes observed in solutions of *Musa acuminata* trunk treated with silver nitrate after treatment for 1 (a), 2 (b), 5 (c) and 24 h (d), respectively

hypothesized that the drop is due to absorption of silver by the banana trunk fibres. This result correlates with previous documented studies on plant-mediated synthesis of AgNPs with reported characteristic absorption range between 400 and 440 nm

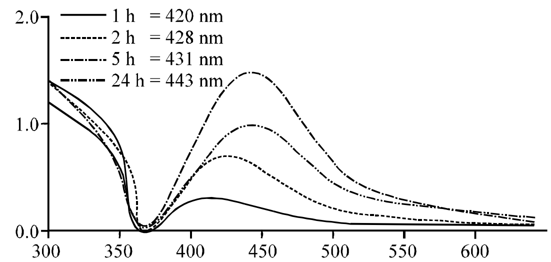

Fig. 2: UV-Vis spectrophotometric analysis of aliquot of the solutions of *Musa acuminata* trunk treated with silver nitrate after treatment for 1, 2, 5 and 24 h

(Sathyavathi *et al*., 2010). Various organic constituents that serve as reducing agents in plant have been implicated to reduce Ag^{+} to Ag^{0} (Ahmad *et al*., 2011). Absorbance recorded between 190-350 nm after 1 h may be due to release of proteins or probably reducing enzymes to aid the synthesis and capping of reduced AgNPs. Interestingly, *Musa acuminata* trunk not just possesses the ability to synthesize AgNPs but also absorbed it. Figure 3 and 4 shows SEM analysis of phyto-synthesized AgNPs entrapped in the banana trunk, the images clearly depict agglomerated shiny spherical structure of AgNPs. These results explains the drop in absorbance observed in the UV/Vis results. The Elemental Diffraction Spectroscopic analysis (EDS) is shown in Fig. 5 indicative of the presence of silver nanoparticles (Ag^{0}) in the dried banana trunk fibre. The relative abundance was determined to be 5% by the equipment. Figure 6 shows a comparative banana trunk fibre that was

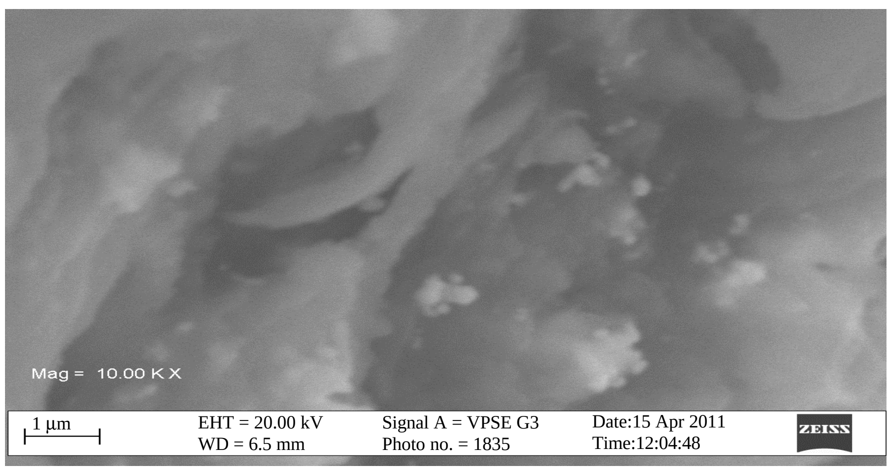

Fig. 3: SEM micrographs showing agglomerated AgNPs entrapped in banana fibres

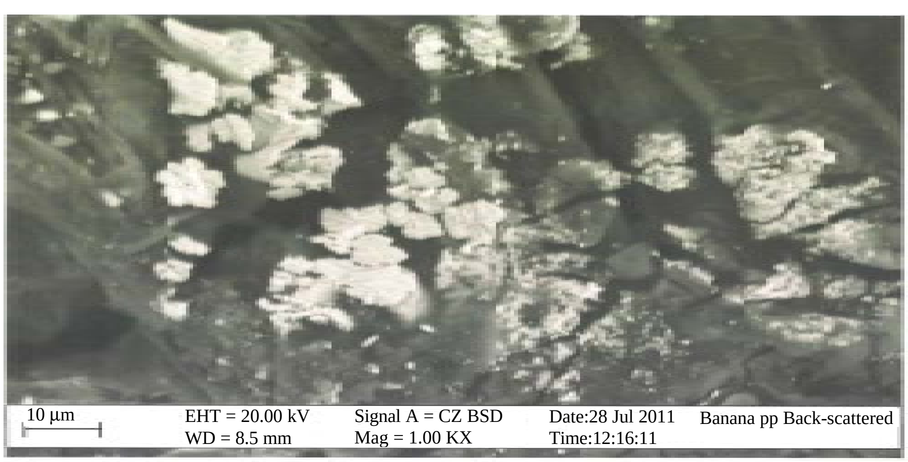

Fig. 4: Back-scattered images of AgNPs entrapped in banana trunk. The brighter sections in the micrograph represent the highly relective Ag^{0} images

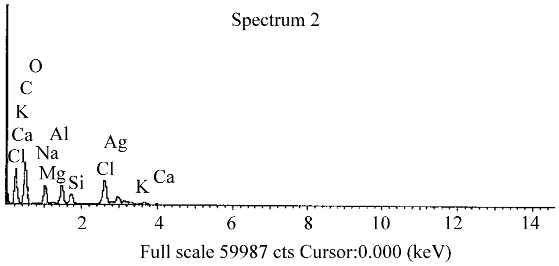

Fig. 5: EDS signals of the elements present in banana trunk fibres showing the presence of Ag^0

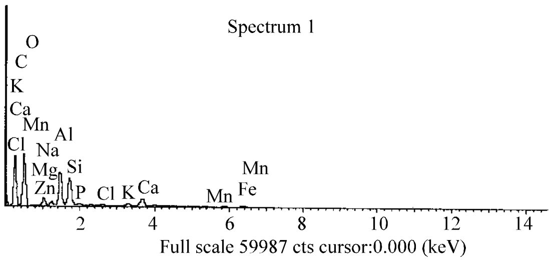

Fig. 6: EDS signals showing the elements present in the control sample

soaked in water and not incubated with silver nitrate solution. There was no evidence of the formation of elemental silver particles in this sample.

The use of silver for centuries as antiseptic and antimicrobial agents has been widely documented but constrained by difficulties in the production of pure silver and its toxicological effect on consumption (Ostiguy *et al*., 2008). Whereas silver nanoparticles engineered via nanotechnology have been shown to reproduce similar/enhanced biological activity (Kim *et al*., 2007; Lee *et al*., 2007) with no net deleterious effect. Entrapment of AgNPs in banana trunk showed prospects of the use in development of banana trunk-based value added products especially in water purification thus exploiting biological properties of silver.

To demonstrate the product opportunities achievable with banana trunk fibres, the biomaterials research group of the Sheda Science and Technology Complex (SHESTCO) have made filter paper from banana trunk fibre as well as shoe in-sole and egg crates (Fig. 7) with potential bioactive application through AgNPs addition. Comparative studies are on-going to establish if nanoparticle egg-crates would increase its shelf life or offer protection to the eggs. Other experiments are underway to examine if these waste derived shoe-insole with incorporated nanoparticles will prevent the growth of microbes that inhabit damp shoes and cause offensive smells. Other efforts are currently on to use nanoparticle

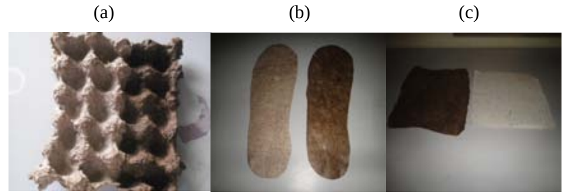

Fig. 7: Bioactive products made from banana fibre. a) shows an egg-crate half of the material (dark portion) was made with banana fibre incorporating AgNPs, b) shoe-insole and c) filter paper that was incorporated with AgNPs

silver infiltrated banana trunk fibres in the manufacture of ceramic water filters where the simple technique described above could be used to the profit of a great majority of rural communities.

CONCLUSION

Phytosynthesis of silver nanoparticles led to dark colouration of the fibres as demonstrated when fibres incorporating silver nanoparticles were used to make egg-crates, shoe insole and filter paper.

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