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Biogenic synthesis of silver nanoparticles using a pod extract of *Cola nitida*: Antibacterial and antioxidant activities and application as a paint additive

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Abstract

This work reports the biogenic synthesis of silver nanoparticles (AgNPs) using the pod extract of *Cola nitida*, the evaluation of their antibacterial and antioxidant activities, and their application as an antimicrobial additive in paint. The AgNPs were characterized with UV–Vis spectroscopy, Fourier-transform infrared (FTIR) spectroscopy, and transmission electron microscopy (TEM). The AgNP solution was dark brown with a maximum absorbance occurring at 431.5 nm. The FTIR spectrum showed strong peaks at 3336.85, 2073.48, and 1639.49 cm^{-1}, indicating that proteins acted as the capping and stabilization agents in the synthesis of the AgNPs. The AgNPs were spherical, with sizes ranging from 12 to 80 nm. Energy dispersive X-ray (EDX) analysis showed that silver was the prominent metal present, while the selected area electron diffraction pattern conformed to the face-centred cubic phase and crystalline nature of AgNPs. At various concentrations between 50 and 150 μg/ml, the AgNPs showed strong inhibition of the growth of multidrug resistant strains of *Klebsiella granulomatis*, *Pseudomonas aeruginosa*, and *Escherichia coli*. In addition, at 5 μg/ml, the AgNPs completely inhibited the growth of *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Aspergillus niger*, *A. flavus* and *A. fumigatus* in a paint-AgNP admixture. The AgNPs exhibited a potent antioxidant activity with an IC_{50} of 43.98 μg/ml against 2,2-diphenyl-1-picrylhydrazyl and a ferric ion reduction of 13.62–49.96% at concentrations of 20–100 μg/ml. This study has

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demonstrated the biogenic synthesis of AgNPs that have potent antimicrobial and antioxidant activities and potential biomedical and industrial applications. To the best of our knowledge, this work is the first to use the pod extract of *C. nitida* for the green synthesis of nanoparticles.
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Keywords: *Cola nitida* pod; Silver nanoparticles; Antimicrobial activity; Multi-drug resistance; Paint; Antioxidant

1. Introduction

The numerous potential applications of nanoparticles have played a prominent role in the search for eco-friendly processes for generating nanoparticles using different biological materials because conventional nanoparticles syntheses involve the use of toxic solvents, high pressure, and high energy, all of which may be harmful to the environment. Such syntheses are capable of yielding nanoparticles that have unique attributes and properties that may influence their utility. Because of the rich biodiversity of microbes and plants, the potential for using biological materials in the synthesis of nanoparticles has yet to be fully explored. In this regard, several biological resources of the tropics, particularly those of Nigeria, have not been adequately evaluated for their potential use in synthesizing nanoparticles.

The green synthesis of nanoparticles has continued to receive unprecedented attention due to the simplicity of the processes, the minimal chemical handling needed, and the eco-friendliness [1]. In addition, the availability of several biological macromolecules/substances that can serve as capping and stabilization molecules for the green synthesis of nanoparticles has also contributed to the steady rise of this synthesis route. Various authors have reported using bacteria, fungi, algae, spider cobwebs and plant extracts for the green synthesis of different types of nanoparticles [1–13].

Kola is a caffeine-containing nut, and the two most common species are *Cola nitida* and *Cola acuminata* [14]. The nut is chewed in many West African countries, as it is known to ease hunger pangs. It also has ethnomedicinal values, with reports of its use to treat whooping cough and asthma, and it contains not only caffeine but also essential oils, phenolic compounds and alkaloids [15–17]. It is also a flavouring ingredient that is used in the production of flavoured beverages and chocolates, as well as in the production of dyes [18]. *Cola* sp., an evergreen plant originally endemic to West Africa, mainly Cote d'Ivoire, Ghana, Liberia, Nigeria, and Sierra Leone, has been introduced to many tropical countries [19]. The exotic species can now be found in countries such as Jamaica, India, and the United States. The world production of kola nuts from *C. nitida* and allied species has been estimated to be approximately 180,000 t, of which approximately 120,000 t is produced in Nigeria and used either internally or in neighbouring countries [20]. Despite the large potential that kola offers, it has not been fully exploited for applications in the food and pharmaceutical industries. This work therefore seeks to extend the frontiers of the potential applications of the pod extract of kola nut with a particular interest in nanobiotechnology. The work presented here pioneers the effort of evaluating the kola nut pod for use in the green synthesis of nanoparticles. Most recently, we established the possibility of using seed shells and seed extracts of *C. nitida* to form AgNPs that have potent antibacterial activities against multi-drug resistant bacteria [21].

Metal nanoparticles and their alloys made of some combination of silver, iron, cadmium, zinc, platinum, gold, graphene, among others have diverse applications in different aspects of human endeavours, with catalytic [8,22,23], optical [24], electronic [25], magnetic, antimicrobial [3,6,9,12,26] and biomedical utility [27,28]. Silver nanoparticles, for instance, are of interest because of their unique properties (size- and shape-dependent optical, electrical, and magnetic properties), which can be incorporated into coating materials, antimicrobial applications, biosensor materials, composite fibres, and electronic components [29]. In this work, we report the green synthesis of AgNPs using the pod extract of *Cola nitida* and the evaluation of its antibacterial activities towards several drug-resistant strains of bacteria. The study also assessed the application of the nanoparticles as an antimicrobial additive in emulsion paint and included an evaluation of their antioxidant activity. To the best of our knowledge, this is the first report of the green synthesis of nanoparticles using the fruit pod of *C. nitida*.

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