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Biogenic synthesis of palladium nanoparticles using *Pulicaria glutinosa* extract and their catalytic activity towards the Suzuki coupling reaction

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Green synthesis of nanomaterials finds the edge over chemical methods due to its environmental compatibility. Herein, we report a facile and eco-friendly method for the synthesis of palladium (Pd) nanoparticles (NPs) using an aqueous solution of *Pulicaria glutinosa*, a plant widely found in a large region of Saudi Arabia, as a bioreductant. The as-prepared Pd NPs were characterized using ultraviolet-visible (UV-vis) spectroscopy, powder X-ray diffraction (XRD), transmission electron microscopy (TEM), energy-dispersive X-ray spectroscopy (EDX), and Fourier transform-infrared spectroscopy (FT-IR). The hydroxyl groups of the plant extract (PE) molecules were found mainly responsible for the reduction and growth of Pd NPs. FT-IR analysis confirmed the dual role of the PE, both as a bioreductant as well as a capping ligand, which stabilizes the surface of Pd NPs. The crystalline nature of the Pd NPs was identified using XRD analysis which confirmed the formation of a face-centered cubic structure (JCPDS: 87-0641, space group: *Fm3m* (225)). Furthermore, the as-synthesized Pd NPs demonstrated excellent catalytic activity towards the Suzuki coupling reaction under aqueous and aerobic conditions. Kinetic studies of the catalytic reaction monitored using GC confirmed that the reaction completes in less than 5 minutes.

Introduction

Recently, the green synthesis of metallic nanoparticles (NPs) has attracted tremendous attention in the scientific community, due to the growing environmental contamination caused by the conventional chemical methods.[1–5] Usually, NPs have been synthesized using various chemical and physical methods based on the availability and feasibility of protocols to achieve the required applications.[6,7] However, many of these methods either involve expensive equipment or hazardous chemicals which have harmful effects on the environment as well as on the human health.[8] Additionally, during the chemical synthesis, the residuals of some toxic chemicals may adsorb on the surfaces of the NPs, which prevents their application in biomedical equipment.[9] Therefore, there is immense interest in the development of environmentally friendly and sustainable methods for the preparation of NPs.[10]

Several green methods have been applied for the preparation of NPs, including the application of natural materials such as microorganisms, marine organisms, biomolecule extracts and plant materials as bio-reductants or mimicking the biochemical processes leading to the formation of complex biominerals.[11–14] However, among these methods plant extracts have attracted significant attention, due to easy and simple sampling, and cost effectiveness of this method facilitates the large scale biosynthesis of NPs.[15–17] Several metallic and bimetallic NPs, such as Au, Ag, Pd, Pt, Cu, Ag/Au, Au/Pd and Cu/Au, having potential applications in various fields including optoelectronics, SERS based detection of small molecule analytes, biological labeling and catalysis, have been successfully synthesized using different kinds of plant materials.[18–25]

Among the metallic NPs, Pd has a variety of applications in the field of both homogeneous and heterogeneous catalysis.[26–28] Various catalytic reactions explored using Pd NPs include hydrogenations, oxidations, carbon–carbon coupling as well as electrochemical reactions.[29–32] Especially, stable colloidal Pd NPs supported by conventional and non-

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