

# Antibacterial activity of Co, Ni, and Pd-infused $\text{CaO}_{0.85}\text{ZrO}_{0.15}$ : a novel nanocomposite with broad-spectrum

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## Abstract

In the present study, a Co–Ni–Pd/ $\text{CaO}_{0.85}\text{ZrO}_{0.15}$  trimetallic nanocomposite was synthesized and characterized using Fourier transform infrared spectroscopy (FTIR), x-ray diffraction (XRD), and transmission electron microscopy (TEM) to characterize its structural and morphological properties. The antibacterial activity of the synthesized nanocomposite was also evaluated against selected gram-positive and gram-negative bacterial strains. The results of FTIR confirmed the formation of acetylacetonate ligands and metal–oxygen bonds in the nanocomposite. XRD patterns confirmed the crystalline structure with identified diffraction peaks of cubic CaO and  $\text{ZrO}_2$  phases. TEM images showed agglomerated nanoparticles with sizes ranging from 45 to 85 nm. The novelty of this study focuses on the incorporation of Co, Ni, and Pd into the CaO– $\text{ZrO}_2$  matrix, which leads to the generation of multiple active surface sites and enhances synergistic interactions, thereby improving the antibacterial performance. The antibacterial activity of the prepared nanocomposite was assessed against gram-positive and gram-negative bacteria. Increased inhibition zones were noted at higher concentrations, recorded 9.80 mm for *Staphylococcus lentus*, 9.73 mm for *Bacillus subtilis*, 11.33 mm for *Pseudomonas aeruginosa*, and 11.65 mm for *Escherichia coli* at 10 000 ppm. The nanocomposite showed higher antibacterial activity against gram-negative bacteria (*P. aeruginosa* and *E. coli*) than the gram-positive one (*Staphylococcus lentus* and *Bacillus subtilis*). These results provide a preliminary indication of the antibacterial potential of the nanocomposite, particularly against gram-negative bacteria. Nevertheless, further biological studies are necessary to comprehensively evaluate and confirm its antibacterial efficiency.

Keywords:  $\text{CaO}_{0.85}\text{ZrO}_{0.15}$ , bacteria, antibiotic, cytotoxicity, TEM, FTIR

## 1. Introduction

In response to expanding antibiotic resistance, nanocompounds have attracted significant attention as alternative antimicrobial agents due to their advanced physicochemical properties. Unlike conventional antibiotics, nanomaterials exhibit antibacterial activity through multiple mechanisms,

including destruction of the bacterial membrane and cell wall, formation of reactive oxygen species (ROS), DNA and protein damage, and release of metal ions, ultimately leading to bacterial cell death [1, 2]. The ROS generated are highly effective in disrupting biofilms, which are typically resistant to the conventional antibiotics. Additionally, nanoscale particles enable them to penetrate bacterial cell membranes, resulting in direct physical damage or disruption of essential cellular processes [3]. The application of nanocomposites as antibacterial agents requires thorough characterization of

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