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EDITORIAL

Advancements in the Nanobiotechnological Applications

Sanjay K. S. Patel[1] · Vipin C. Kalia[1]

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A significant development in the field of nanobiotechnology is proving beneficial for sustainable development. Chemical, physical, and biological approaches are employed to synthesize nanomaterials and nanoparticles (NPs). Synthesis of NPs through spray pyrolysis is helpful for bulk production, especially with well-regulated morphology and size [1–3]. The structural (size, shape, distribution, and porous nature) and chemical (composition, functional, active groups on their outer surface, and catalysis) properties vary with method [4–6]. Biologically NPs can be synthesized using plant extracts and microbes at ambient conditions [7–9]. The scope for employing NPs for industrial bioetchnological applications has been feasible due to their high biocompatibility and biocatalytic activities [10–16]. Protein engineering techniques and immobilization strategies have helped to circumvent the following limitations of NPs: low stability, and limited reusability [1, 6, 17–19].

Adsorption, encapsulation, covalent and cross-linking is effectively used for immobilizing free cells or enzymes. Relative activity (RA) of biocatalysts during biotransformation varies depending upon the properties of immobilization support and methods and the immobilization yields [1, 19–21]. The amount of biocatalysts loading also varies with the morphology and porous nature of the support material [1, 2]. Compared to bulk synthetic solids, NPs have shown more benefits during immobilization, such as uniform morphology and porous nature (useful for internal immobilization within a pore, especially to enzymes or a cavity, especially for whole cells. The high surface area allows higher binding of the catalysts [1, 2, 4]. The immobilization of biocatalysts on extensive supports and magnetic NPs is proving economical because of their easy separation by filtration and applying a magnetic field [22–24]. In general, the immobilization of biocatalysts has resulted in lower activity due to the inactivation of cells or enzymes through undesirable changes such as in the protein structure (enzyme) and mass transfer limitations [1–4]. A unique approach for enzyme immobilization through simple encapsulation using metals and enzymes has been developed as metal-protein hybrids—known as nanoflower due to their flower-like morphology [25, 26]. In a nanoflower-based system, the RA of enzymes after immobilization varies with the types of metal ions, enzymes, and synthesis conditions. A high RA of β-glucosidase (207%) nanoflower was noted using zinc metal ions [20]. The use of bi-metals (copper and zinc) and cross-linking of nanoflower by glutaraldehyde for laccase immobilization improved the catalytic efficiency (up to 2.7-fold) and structural stability, respectively [25, 26].

Microbial and infectious diseases can potentially influence health management and the economy [27–29]. The microbes and materials, including NPs can counter pathogenic infections and critical health issues such as cancers [30–33]. TiO_2/CdS/ZnS NPs has potential to induce the cell death of *Bacillus subtilis* [34]. The curcumin hydrophilicity was improved ~ 1000-folds through encapsulation by polyethylene glycol as nanoliposomes that can be employed for treating different diseases and antimicrobials towards *Escherichia coli*, *B. subtilis*, *Chromobacterium violaceum*, *Klebsiella pneumoniae*, and *Mycobacterium smegmatis* [35]. The orange peel extract

✉ Sanjay K. S. Patel
sanjaykspatel@gmail.com

✉ Vipin C. Kalia
vckaliaku@gmail.com

[1] Department of Chemical Engineering, Konkuk University, Seoul 05029, Republic of Korea

copper nanoflower showed antimicrobial against fish pathogen *Yersinia ruckeri* [9]. Silver nanoparticles (Ag-NPs) inhibits the biofilms of *Candida albicans* and *Streptococcus* mutans successfully [36]. Eco-friendly leaf extract (*Azadirachta indica*) mediated AgNPs was highly effective against phytopathogens, including *Penicillium*, *Fusarium*, *Aspergillus*, and *Ralstonia* spp. [37]. Similarly, *Manilkara zapota* aqueous extract-derived Ag-NPs proved beneficial for environmental and biomedical applications [38]. The gold NPs (Au-NPs) synthesized with flower-like morphology by *B. subtilis* exhibited increased surface area that can be potentially employed for regulated drug delivery [7]. In contrast, Au-NPs synthesized using *Terminalia bellerica* fruit parts showed the high capability to eradicate clinical pathogens, such as *Acinetobacter pneumonia*, *B. subtilis*, and *Enterococcus faecalis* [8]. NPs based on *Bacillus* spp. can be used for the restoration of concrete crack [39].In addition, chitosan-based NPs were found to be effective for developing analytical measurements techniques [40].

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