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Engineering Magnetic Nanobiocatalytic Systems Functionalities for Biocatalysis, Applications of Biotechnology and Bioprocess

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Abstract

Enzymes are powerful natural biological catalysts with numerous uses in the culinary, medicinal, agricultural, and environmental industries. However, the most difficult obstacles preventing biocatalytic systems from being used in industry are their ineffective recovery, reusability, and expensive soluble form of enzymes. Immobilization looks to be a great method for improving the stability and catalytic effectiveness of enzymes, as well as permitting their separation and reusability in continuous reaction batches, in order to address these deficiencies. Due to their significant surface area, higher surface-to-volume ratio, modifiable surface, and adjustable surface particle size, stability, and high mass transferring ability, magnetic nanomaterials have attracted the most attention among other nanostructures as support matrices for immobilising biomolecules and enzymes. They can also be rapidly healed from and the synthesis of artificial benzylisoquinoline alkaloid, butanol production, lignocellulosic biomass hydrolysis, glucose monitoring, fruit juice extraction and clarifying, and so on are thoroughly examined with illustrative examples. Finally, the summary and potential directions in this developing field are also addressed.

Keywords: Nanobiocatalysis; Magnetic nanoparticles; Enzyme immobilization; Wastewater treatment; Biodiesel; Lignocellulosic biomass

Introduction

The usage of Biocatalysis has dramatically increased in recent years across a variety of industries, including the biomedical, food, energy, pharmaceutical, and drug industries [1]. It also plays a critical role in environmental protection [2]. Enzymatic processes are seen to be a more competitive, cost-effective, and promising technology than chemical ones because of crucial characteristics including selectivity, specificity, low toxicity, and the absence of secondary reactions [3]. The use of free enzymes is often restricted on a wide scale due to low operating efficiency, although having many potential applications. Because of their magnetic characteristics, ease of handling, biocompatibility, reuse, and recovery, Fe3O4 magnetic nanoparticles are intriguing materials for protein and enzyme attachment among other supporting matrices. Their capacity to transport significant quantities of enzymes due to their increased surface area and enzyme stability has recently attracted extraordinary interest in enzyme Biocatalysis [4]. Here, great care has been taken to demonstrate the most recent and cutting-edge developments in the development and application of multifunctional magnetic nanobiocatalytic systems for a variety of biotechnological applications. Have lately been used to immobilise enzymes one at a time [5]. Magnetic nanoparticles provide a number of advantages over these supporting materials, including vast surface areas that allow the immobilisation of several enzymes and ease in separating from the digested peptides with only a few simple steps. Excellent biocompatibility, renewability, and a magnet [6]. For instance, by reacting the azlactone functionals with the amine groups of the enzyme, Mu et al. effectively generated magnetic Fe3O4 NPs with polyfunctionalities and used them to covalently immobilise L-asparaginase [7]. Because it inhibited the changes of native L-asparaginase, this substance was utilised to simulate the treatment of acute lymphoblastic leukaemia [8]. A magnetic enzyme Nano system with a polydopamine cover and a Fe3O4 magnetic core was created by Cheng and colleagues. PDA's ability to adhere to this support allowed trypsin to become immobilised on it. The adoption of this magnetic enzymatic technique reduced the protein digesting process to 30 minutes [9]. In addition to the properties of the solid supports, the immobilisation process has a substantial impact on digestion using immobilised enzymes. the extensive literature that Adsorption, encapsulation, and other physical techniques as well as chemical strategies such as van der Waals force, chelating with metals, and covalent bonding can all be used to immobilise proteolytic enzymes [10]. Although encapsulation and enclosing techniques are widely employed to immobilise items, they have drawbacks, such as the advantages of using magnetic nanoparticles as supports for enzyme immobilisation [11]. Inside the support matrix, there is enzyme leakage and a delay in the mass transfer of the products and substrates [12]. Van der Waals forces-based approaches and physical adsorption are straightforward but come with dangers from non-specific binding affinity and enzyme function degradation [13].

Discussion

The greatest effective strategy for avoiding enzyme separation from the supports during operation is covalent contact [14]. The cost of changing the protein's 3D structure through multiple access binding is likely denaturation and deactivation. To get payment for this benefit additionally, the typical solid supports used for covalent immobilisation are difficult to renew if the immobilised enzyme loses function. Therefore, it is crucial to develop novel immobilisation processes and auxiliary elements that provide strong yet reversible enzyme attachment. Porcine lipase was designed using thiol functionals generated inside the confines of a fused silica capillary and immobilised on a monolithic polymer substrate. Their novel method utilised stronger but reversible Au-NH2 and Au-S interactions in contrast to

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conventional physical or chemical immobilisation techniques. The last application for this bioreactor that demonstrated its potential to produce biodiesel was the transesterification of triacylglycerides from cooking oil to fatty acid methyl esters. Cao and co. suggested using magnetic Fe3O4 nanoparticles coated with AuNPs as a sustainable support for enzyme immobilisation. The reversible immobilisation of trypsin was accomplished by the AuNPs acting as an intermediate ligand. The enzyme was immobilised by the strong but reversible Au-S and Au-NH2 binds. Traditional protein digestion was carried out in this immobilised trypsin bioreactor, and it took 15 minutes to finish. Following digestion, the trypsin-loaded NPs were extracted from the reaction liquid using a magnet. A prominent source of pollution is dye factory wastewater. It takes the enzyme peroxidase to degrade phenolic compounds like azo dyes. The peroxidase enzyme was immobilised on Fe3O4 MNPs, and the modification was carried out by co-precipitating glutaraldehyde to make the enzyme stable, effective, and recyclable. According to studies, peroxidase-MNPs are remarkably stable in a pH- and temperature-variable environment. Accordingly, researchers discover a possible use for peroxidase-MNPs in the bio-remediation of red and green azo dyes from wastewater from the textile sector. Because of its wide variety of possible applications, which range from the creation of pure optical molecules to actions pertaining to the environment, chloroperoxidase is relevant in both ecological and sociological perspectives. The molecular arrangement of CPO on the surface of Fe3O4 MNPs was achieved by layer-by-layer guided assembly thanks to a site-specific connection between avidin and biotin. Enzymatic oxidative decolorization of soluble aniline blue was performed in order to evaluate the catalytic effectiveness of immobilised CPO. Within 10 minutes, I-CPO had a decolorization efficiency of more than 90%. The process of enzyme-assisted extraction involves As a viable, effective, and efficient replacement for conventional solvent methods. The quickest and least quantity of solvent required to extract biological components is provided by EAE Additionally, this may be done with mild conditions, which is helpful for extracting chemicals that are sensitive to heat, such as oil, flavours, pigments, etc. Numerous studies have been done to look at EAE for different bioactive substances in the food industry. Recently, researchers used glutaraldehyde as a bridging agent to co-immobilize the enzymes -amylase and glucoamylase on MNPs during the processing of Curcuma longa powder. Additionally, the turmeric-root powder was pre-treated with generated biocatalyst and low power ultrasound in order to extract the curcuminoids. The cumulative effect raises the extraction efficiency under the ideal solvent extraction technique by compared to the solo strategy by the curcuminoids were recovered via crystallisation, resulting in 54% (w/w) separation and purification of Site-specific and covalent bond immobilisation techniques are excellent; nevertheless, traditional procedures can need the production of complicated materials or genetic engineering, which increases the complexity and difficulty of operations. A novel site-specific and covalent method for immobilisation, developed by Tang, is based on carefully selected immobilisation sites on lipase.

Conclusion

Natural polyphenol epigallocatechin Gallate modified Fe3O4 NPs were created for the lipase site-specific immobilisation. Comparing the immobilised lipase to unbound and randomised immobilised lipases, the immobilised lipase had a biodiesel yield of 92.1%. The results showed that synthetic site-specific immobilisation carriers were useful for maintaining the conformation of the naturally charged catalytic site and enhancing the rigidity of the immobilised lipase. Eight iterations later, CL biosensing has good stability, strong catalytic activity, and rapid magnetic separation capabilities. In the past 10 years, bioassays have paid a lot of attention to CF-NMs because to their high CL content, ease of construction, and good biocompatibility. Using a post functionalization and solvothermal approach, CuFe2O4 MNPs were functionalized with N-(4-aminobutyl)-N-ethylisoluminol to produce ABEI/CuFe2O4 with improved catalytic performance. Without the need of an organic stabilising agent or surfactant, spinel cobalt ferrite MNPs with an estimated diameter of 40–50 nm have been made using sonochemical and co-precipitation procedures. In alcoholic or aqueous solutions, nanoparticle dispersions are stable. The uncapped nanoparticles were then employed as a reusable catalyst in the Knoevenagel reaction in an aqueous solution containing ethanol. an external magnet was utilised to aid in the catalyst's separation from the reaction medium and collection. High yields of the proper Knoevenagel compounds were readily produced at just 5 mol% of the catalytic concentration at 50 °C. Phenolic compounds are serious pollutants released in wastewater from many industrial units, such as petrochemicals, metallurgy, pesticides, pulp and paper industry, medicines, resin, and plastic synthesis. With a maximum removal efficiency of and, respectively, the immobilised magnetic nanobiocatalyst efficiently removed phenol, 4-chlorophenol, and 2,4-dichlorophenol throughout a wide pH and temperature range. It maintained more than 80% of its original catalytic activity after 6 successive cycles, demonstrating an effective and cutting-edge method for biodegrading phenolic pollutants. To covalently immobilise Rhus vernicifera laccase, 3-aminopropyltriethoxysilane, glutaraldehyde, and Fe3O4 nanoparticles were created.

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Conflict of Interest

None

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