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Review

Biosensors in Food and Healthcare Industries: Bio-Coatings Based on Biogenic Nanoparticles and Biopolymers

Melania Popescu [1] and Camelia Ungureanu [2,*]

[1] National Institute for Research and Development in Microtechnologies—IMT Bucharest, 126A Erou Iancu Nicolae Street, 077190 Bucharest, Romania
[2] General Chemistry Department, University "Politehnica" of Bucharest, Gheorghe Polizu Street, 1-7, 011061 Bucharest, Romania
* Correspondence: ungureanucamelia@gmail.com or camelia.ungureanu@upb.ro

Abstract: Biosensors use biological materials, such as enzymes, antibodies, or DNA, to detect specific analytes. These devices have numerous applications in the health and food industries, such as disease diagnosis, food safety monitoring, and environmental monitoring. However, the production of biosensors can result in the generation of chemical waste, which is an environmental concern for the developed world. To address this issue, researchers have been exploring eco-friendly alternatives for immobilising biomolecules on biosensors. One solution uses bio-coatings derived from nanoparticles synthesised via green chemistry and biopolymers. These materials offer several advantages over traditional chemical coatings, such as improved sensitivity, stability, and biocompatibility. In conclusion, the use of bio-coatings derived from green-chemistry synthesised nanoparticles and biopolymers is a promising solution to the problem of chemical waste generated from the production of biosensors. This review provides an overview of these materials and their applications in the health and food industries, highlighting their potential to improve the performance and sustainability of biosensors.

Keywords: bio-coatings; nano/biosensors; green-chemistry; biogenic nanoparticles; biopolymer composites; surface modifications; eco-friendly coatings

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1. Introduction

In the digital era, regardless of all the scientific advancements, we are witnessing profound climate change, the emergence of new diseases, and the extinction of many animal and plant species due to household and industrial pollution [1,2]. The use of nanoparticles and polymers in developing biosensors has improved their performance and sensitivity [3,4]. However, their chemical synthesis generates by-products in the environment [5,6]. The green-chemistry and white biotechnology domains explore alternatives to reduce the environmental impact across the whole value chain, including food and medical industries [7,8]. Figure 1 presents the elements of a biosensor, with emphasis on the coating choice, which is the main subject of this review.

Briefly, biosensors are devices used to analyse the concentration of a specific target component with the help of a sensitive biological element. They can detect, record, and transmit selective, quantitative, or semi-quantitative analytical information about biochemical reactions [9]. A biosensor includes a substrate, typically paper, glass, or silicon. The substrate must be chemically modified to ensure an effective immobilisation of the biorecognition elements. The biorecognition elements can be organic components (enzymes, antibodies, hormones, or nucleic acids), biological material (microorganisms, cellular organelles, tissues, or receptor cells), biologically derived material, or biomimetic components. Analyte detection is possible with a transducer which translates the biological response into a quantifiable signal (optical, electrochemical, amperometry) [10,11].

4. Conclusions and Future Perspectives

The choice of functionalisation strategy to attach the biorecognition element to the active element is fundamental in biosensing to achieve the desired performance. This strategy also ensures reusability with a limited impact on the environment. Nowadays, alternatives to conventional functionalisation strategies are being explored to obtain ecologically friendly and sustainable biosensors. This review gives an overview of bio-coatings derived from nanoparticles synthesised via green chemistry, biopolymers, and biopolymer composites and their role in biosensing applications with usage in the health and food sectors.

Substantial research efforts have been made to develop environment-friendly biosensors for smart packaging to increase food safety and quality by detecting pathogens promptly and inhibiting the 'microorganisms' growth. In this regard, biopolymers, biogenic nanoparticles, and biopolymer composites as bio-coatings in biosensors and smart packaging represents a milestone. However, biosensors must meet the market demands in terms of specificity, sensitivity, and detection limit. Moreover, the potential risks for human health posed by the integration of biosensors into smart packaging will need to be addressed before commercialisation. The possible migration of nanoparticles from packaging into food and their toxic effect on the human body and the environment are of great importance and are given special attention from regulatory bodies.

In healthcare, particularly in developing biosensors, the use of bio-coatings minimises their impact on the surrounding environment. Moreover, the switch towards sustainable, biocompatible, and eco-friendly biosensors opens the path towards wearable biosensors for continuous monitoring of various health parameters. The biosensors will be expected to play a big part in human well-being as they are expected to detect infections and life-threatening diseases in a fast manner. Improvements and tests need to be done to ensure their best performance and safety, especially for biosensors coming directly into contact with the human body. Thus, toxicity assessments for various bio-coatings employed in biosensors must be accomplished before taking them a step forward toward commercialisation.

The future direction of research in this field is likely to be focused on the following areas: (a) improving the sensitivity and stability of bio-coatings: researchers will continue to work on developing bio-coatings that have improved sensitivity and stability, allowing for more accurate and reliable biosensor readings; (b) expanding the range of applications: eco-friendly bio-coatings are expected to expand into new applications, such as wearable biosensors and real-time monitoring systems; (c) developing alternative materials: researchers will continue exploring alternative materials, such as biodegradable polymers and natural products, for synthesising bio-coatings; (d) enhancing biocompatibility: efforts will be made to improve bio-coatings' biocompatibility further, ensuring their safe and effective use in biomedical applications; (e) improving the sustainability of biosensor production: bio-coatings synthesised via green-chemistry methods are expected to reduce biosensor production's environmental impact, making it more sustainable.

Overall, future research in this field will likely focus on improving biosensors' performance and sustainability using eco-friendly bio-coatings.

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