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Review Article

Biosensors and their applications – A review

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ABSTRACT

The various types of biosensors such as enzyme-based, tissue-based, immunosensors, DNA biosensors, thermal and piezoelectric biosensors have been deliberated here to highlight their indispensable applications in multitudinous fields.

Some of the popular fields implementing the use of biosensors are food industry to keep a check on its quality and safety, to help distinguish between the natural and artificial; in the fermentation industry and in the saccharification process to detect precise glucose concentrations; in metabolic engineering to enable in vivo monitoring of cellular metabolism. Biosensors and their role in medical science including early stage detection of human interleukin-10 causing heart diseases, rapid detection of human papilloma virus, etc. are important aspects. Fluorescent biosensors play a vital role in drug discovery and in cancer. Biosensor applications are prevalent in the plant biology sector to find out the missing links required in metabolic processes. Other applications are involved in defence, clinical sector, and for marine applications.

1. Introduction

Biosensors are analytical devices that convert a biological response into an electrical signal. Quintessentially biosensors must be highly specific, independent of physical parameters such as pH and temperature and should be reusable. The term ''biosensor'' was coined by Cammann,[1] and its definition was introduced by IUPAC.[2–4]

Fabrication of biosensors, its materials, transducing devices, and immobilization methods requires multidisciplinary research in chemistry, biology, and engineering. The materials used in biosensors are categorized into three groups based on their mechanisms: biocatalytic group comprising enzymes, bioaffinity group including antibodies and nucleic acids, and microbe based containing microorganisms.

2. Material and methods

The term ''biosensors'' was searched in Pubmed, Sciencedirect, and google, and all articles based on its applications were selected.

3. Review of literature

3.1. Types of biosensors

Biosensors started in the 1960s by the pioneers Clark and Lyons. Various types of biosensors being used are enzyme-based, tissue-based, immunosensors, DNA biosensors, and thermal and piezoelectric biosensors.

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The first enzyme-based sensor was reported by Updike and Hicks in 1967. Enzyme biosensors have been devised on immobilization methods, i.e. adsorption of enzymes by van der Waals forces, ionic bonding or covalent bonding. The commonly used enzymes for this purpose are oxidoreductases, polyphenol oxidases, peroxidases, and aminooxidases.[5–7]

The first microbe-based or cell-based sensor was actualized by Diviès.[8] The tissues for tissue-based sensors arise from plant and animal sources. The analyte of interest can be an inhibitor or a substrate of these processes. Rechnitz[9] developed the first tissue based sensor for the determination of amino acid arginine. Organelle-based sensors were made using membranes, chloroplasts, mitochondria, and microsomes. However, for this type of biosensor, the stability was high, but the detection time was longer, and the specificity was reduced.

Immunosensors were established on the fact that antibodies have high affinity towards their respective antigens, i.e. the antibodies specifically bind to pathogens or toxins, or interact with components of the host's immune system.

The DNA biosensors were devised on the property that single-strand nucleic acid molecule is able to recognize and bind to its complementary strand in a sample. The interaction is due to the formation of stable hydrogen bonds between the two nucleic acid strands.[10]

Magnetic biosensors: miniaturized biosensors detecting magnetic micro- and nanoparticles in microfluidic channels using the magnetoresistance effect have great potential in terms of sensitivity and size.[11]

Thermal biosensors or calorimetric biosensors are developed by assimilating biosensor materials as mentioned before into a physical transducer.

Piezoelectric biosensors are of two types: the quartz crystal microbalance and the surface acoustic wave device. They are based on the measurement of changes in resonance frequency of a piezoelectric crystal due to mass changes on the crystal structure.

Optical biosensors consist of a light source, as well as numerous optical components to generate a light beam with specific characteristics and to beeline this light to a modulating agent, a modified sensing head along with a photodetector.[12]

Green fluorescent protein and the subsequent autofluorescent protein (AFP) variants and genetic fusion reporters have aided the development of genetically-encoded biosensors.[13–20] This type of biosensor is user-friendly, easy to engineer, manipulate and transfer into cells. Single-chain FRET biosensor is another example. They consist of a pair of AFPs, which are able to transfer fluorescence resonance energy between them when brought close together. Different methods may be used to regulate changes in Förster resonance energy transfer (FRET) signals based on intensity, ratio or lifetime of AFPs. Peptide and protein biosensors are easily manufactured through synthetic chemistry followed by enzymatic labelling with synthetic fluorophores. Due to their independence of genetically-encoded AFPs, they are readily utilized to control target activity and constitute attractive alternatives and have an added advantage of being able to enhance signal-to-noise ratio and sensitivity of response through introduction of chemical quenchers and photoactivatable groups.

3.2. *Applications of biosensors*

Biosensors have been applied in many fields namely food industry, medical field, marine sector etc., and they provide better stability and sensitivity as compared with the traditional methods.

3.2.1. *In food processing, monitoring, food authenticity, quality and safety)*

An arduous quandary in food processing industry is of quality and safety, maintenance of food products and processing. Traditional techniques performing chemical experiments and spectroscopy have shortcomings due to human fatigue, are expensive and time consuming. Alternatives for food authentication and monitoring with objective and consistent measurement of food products, in a cost effective manner, are desirable for the food industry. Thus development of biosensors in response to the demand for simple, real-time, selective and inexpensive techniques is seemingly propitious.[21]

Ghasemi-Varnamkhasti et al.[22] worked on the monitoring of ageing of beer using enzymatic biosensors, based on cobalt phthalocyanine. These biosensors evinced a good capability to monitor the ageing of beer during storage.

Biosensors are used for the detection of pathogens in food. Presence of *Escherichia coli* in vegetables, is a bioindicator of faecal contamination in food.[23,24] *E. coli* has been measured by detecting variation in pH caused by ammonia (produced by urease–*E. coli* antibody conjugate) using potentiometric alternating biosensing systems. Washing the vegetables such as sliced carrots and lettuce with peptone water provides us with the liquid phase. It is then separated by amalgamating it in a sonicator, to disaffiliate bacterial cells from food items.[25]

Enzymatic biosensors are also employed in the dairy industry. A biosensor, based on a screen-printed carbon electrode, was integrated into a flow cell.[26] Enzymes were immobilized on electrodes by engulfment in a photocrosslinkable polymer. The automated flow-based biosensor could quantify the three organophosphate pesticides in milk.

One of the popular food additives extensively used today are sweeteners, which are adversely causing undesirable diseases including dental caries, cardiovascular diseases, obesity and type-2 diabetes. It is believed that artificial sweeteners are addictive and coax us to eat more high-energy food unconsciously, inadvertently causing weight gain. Thus their detection and quantification are of prime importance. Traditional methods to distinguish the two types of sweeteners are ion chromatographic methods, which are complicated and laborious.

A more efficacious method, which combined lipid films with electrochemical techniques as biosensors for speedy and sensitive screening of sweeteners has been explored by multichannel biosensor, which detect the electrophysiological activities of the taste epithelium. The signals are analyzed using spatiotemporal techniques, on MATLAB, where glucose and sucrose represent natural sugars while saccharin and cyclamate comprise artificial sweeteners. Since all sweeteners are mediated by heterodimeric G-protein coupled receptors in Type-II cells in the bud, they have a plurality of binding sites to identify sweet stimuli of different structures respectively. Studies suggest two types of sweet stimuli: cyclic adenosine