

Biosensors – the mini laboratory

*Pa.Raajeswari, **S.Sindhu

*Assistant Professor, **M.Phil Research Scholar
Department of Food Science and Nutrition

Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore – 43

Abstract: There has been a considerable interest in developing new assays for food analysis to meet the demands of the different regulatory health agencies. Biosensors offer a new alternative due to their inherent specificity, simplicity and quick response. A biosensor is an analytical device for the detection of an analyte that combines a biological component with a physicochemical detector component. Depending on the nature of the transducers and the transduced parameter, there are different types such as Electrochemical, Piezoelectric, and Thermometric and Optical biosensors in the analytical field. As a result of the development of the microprocessor applied technology and rapid growth of biotechnology, production and application of biosensors expanded dramatically. Although human sense organs are sensitive, instruments provide better quantitative results than them. However conventional instrumental methods are incompatible in cases where quick results are needed. In addition to this, biosensors have various advantages as compared to conventional analytical methods. They are relatively cheap, easy to handle, portable and the user does not require special skills.

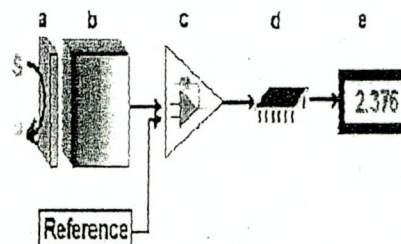
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1. INTRODUCTION

The term biosensor is used for a whole class of sensors that utilize a biochemical reaction to determine a specific compound. Multidisciplinary skills of biologists, physicists, chemists and engineers have been combined to produce biosensors. The analytical devices composed of a biological recognition element directly interfaced to a signal transducer which together relates the concentration of an analyte (or group of related analytes) to a measurable response. In a biosensor the analyte or the sensing element could be a bio catalyst such as an enzyme, organism, tissue or an affinity system such as an antibody, or a nucleic acid.

2. PRINCIPLE

In a biosensor, the bio-reaction (a) converts the substrate to product when a bio-receptor molecule is immobilized in a suitable matrix to form a bio-layer which is then placed in the immediate vicinity of a transducer (b).



The transducer then converts the bio-reaction to electrical signal. The output from the transducer is amplified (c), processed (d) and displayed (e).

2.1. Parts of a Biosensor

It consists of 3 parts:

- **The sensitive biological element** - biological material (e.g. tissue, microorganisms, organelles, cell receptors, enzymes, antibodies, nucleic acids, etc.) or a biologically derived material or bio mimic component that interacts (binds or recognises) the analyte under study. The biologically sensitive elements can also be created by biological engineering.
- **The transducer (detector) element** - transforms the signal resulting from the interaction of the analyte with the biological element into another signal that can be more easily measured and quantified.
- **The biosensor reader device** with the associated electronics or signal processors that are primarily responsible for the display of the results in a user-friendly way. The readers are usually custom-designed and manufactured to suit the different working principles of biosensors.

An important part in a biosensor is to attach the biological elements to the surface of the sensor (be it metal, polymer or glass). The simplest way is to functionalize the surface in order to coat it with the biological elements. This can be done by polylysine, aminosilane, epoxysilane or nitrocellulose in the case of silicon chips/silica glass. Subsequently the bound biological agent may be for example fixed by Layer by layer deposition of alternatively charged polymer coatings

Alternatively three dimensional lattices (hydrogel / xerogel) can be used to chemically or physically entrap these (where by chemically entrapped it is meant that the biological element is kept in place by a strong bond, while physically they are kept in place being unable to pass

through the pores of the gel matrix).

The most commonly used hydrogel is sol-gel, glassy silica generated by polymerization of silicate monomers (added as tetra alkyl orthosilicates, such as TMOS or TEOS) in the presence of the biological elements (along with other stabilizing polymers, such as PEG) in the case of physical entrapment.

2.1.1 Basic Characteristics of a Biosensor Linearity

Maximum linear value of the sensor calibration curve. Linearity of the sensor must be high for the detection of high substrate concentration.

- **Sensitivity:** The value of the electrode response per substrate concentration.
- **Selectivity:** Interference of chemicals must be minimised for obtaining the correct result.
- **Response Time:** The necessary time for having 95% of the response

2.2. Types of Biosensors

Depending on the nature of the transducers and the transduced parameter, there are different types such as Electrochemical, Piezoelectric, and Thermometric and Optical biosensors in the analytical field.
Electrochemical biosensors

An electrochemical biosensor is a self-contained integrated device, which is capable of providing specific quantitative or semi-quantitative analytical information using a biological recognition element (biochemical receptor) which is retained in direct spatial contact with an electrochemical transduction element.

Piezoelectric Biosensor

The development of a piezoelectric biosensor based on nucleic acids interaction is presented focusing on the methodology for probe immobilization. This is a key step in any DNA biosensor development. Often, the detection limits and, in general, the analytical performances of the biosensor can be improved by optimizing the immobilization of the receptor on the transducer surface.

Thermometric Biosensors

Thermometric biosensors are constructed by combining enzymes with temperature sensors. When the analyte is exposed to the enzyme, the heat of reaction of the enzyme is measured and is calibrated against the analyte concentration.

Optical biosensors

Optical Biosensors provides the most comprehensive analysis of optical biosensors and relevant technologies to date. According to the optical configuration, optical sensors have classified into two modes. When light is reflected at an optical interface where there is a change of

refractive index, there is a decay of energy from the point of reflection into the surrounding medium. This energy field which extends into the medium depends upon the medium in which the wave guide is dipped. The resultant changes of luminescence, absorption or fluorescence can hence be determined. When the glass surface of the biosensor is coated with a thin layer of metal (silver, gold), the intensity of the resonance angle changes depending on the concentration of the medium in which electrode is immersed. This phenomenon is called the surface plasma resonance (SPR).

2.3. Applications

There are many potential applications of biosensors of various types. The main requirements for a biosensor approach to be valuable in terms of research and commercial applications are the identification of a target molecule, availability of a suitable biological recognition element, and the potential for disposable portable detection systems to be preferred to sensitive laboratory-based techniques in some situations. Some examples are given below:

2.3.1 Glucose monitoring in diabetes patients

Commercially available glucose monitors rely on amperometric sensing of glucose by means of glucose oxidase, which breaks blood glucose down. In doing so it first oxidizes glucose and uses two electrons to reduce the FAD (a component of the enzyme) to FADH₂. This in turn is oxidized by the electrode (accepting two electrons from the electrode) in a number of steps. The resulting current is a measure of the concentration of glucose. In this case, the electrode is the transducer and the enzyme is the biologically active component.

2.3.2 Other medical health related targets

Detection of pathogens and toxic metabolites such as mycotoxins

In food industry optic coated with antibodies are commonly used to detect pathogens and food toxins. The light system in these biosensors has been fluorescence, since this type of optical measurement can greatly amplify the signal.

- Environmental applications e.g. the detection of pesticides and river water contaminants
- Remote sensing of airborne bacteria e.g. in counter-bioterrorist activities
- Determining levels of toxic substances before and after bioremediation
- Detection and determining of organophosphate
- Routine analytical measurement of folic acid, biotin, vitamin B12 and pantothenic acid as an alternative to microbiological assay