Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 04, Issue: 04 (JULY-AUG, 2024)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

Biosensors: A Rapid Sensing Technology for Food Processing Industry

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Abstract
Biosensors are versatile tools used for various applications, including food analysis, biomolecular studies, medical diagnostics, environmental monitoring, quality control, industrial process control, pharmaceutical manufacturing, and organ replacement. They have significant potential in agriculture and food processing. For example, optical biosensors rapidly identify and quantify *Escherichia coli (E. coli)* in water in food industry, while colorimetric biosensors detect *E. coli* in milk via pH-regulated transformations, photoelectrochemical biosensor detects organophosphate pesticide and amperometric biosensors detects aflatoxin B1 by inhibiting acetylcholinesterase (AChE) activity. Various methods for immobilizing biomolecules on metal oxide-coated surfaces have been explored, such as modifying metal-oxide coated surfaces with amino-terminated silane and glutaraldehyde cross-linking for covalent protein attachment. Biosensors are advantageous due to their speed and sensitivity, capable of detecting minute quantities of pesticides and aflatoxins, which are associated with numerous diseases.

Keywords: Aflatoxin, Bioreceptor, Biosensor, *Escherichia coli*, Transducer.

Introduction
Bioelectronics involves applying electronics to biology and medicine, with biosensors being a key bioelectronic device used in bioanalysis. The biosensors are a subset of chemical sensors, converts an input variable into a measurable signal. These analytical devices combine a biological recognition element (such as an enzyme, antibody, receptor, or microorganism) with a transducer (electrochemical, mass, optical or thermal). Biosensors are advantageous for food analysis because they can meet demands unmet by classic methods, and monitoring biomolecular interactions in real time. Typically, one component of a biosensor is immobilized on a solid surface (the sensor chip), while the other component to be detected is in the solution phase. The immobilized component is known as the 'ligand' or 'receptor,' and the solution component that binds to it is the 'analyte'. Technological advances over the past decade have enhanced the tools and materials needed to build biosensor devices. Since the invention of the Clark oxygen electrode sensor, improvements in sensitivity, selectivity, and multiplexing capacity have been significant. A biosensor operates on two fundamental principles: biological recognition and sensing. It comprises three components: (1) a biological recognition system (bioreceptor), (2) a transducer, and (3) microelectronics. The recognition system provides high selectivity for the analyte, and the transducer converts the molecular recognition into a measurable signal. According to IUPAC, a biosensor is an integrated receptor-transducer device that provides selective quantitative or semiquantitative analytical

information using a biological recognition element. The goal of a biosensor is to offer rapid, real-time, accurate, and reliable information about the analyte, ideally responding continuously and reversibly without perturbing the sample. Biosensors have been envisioned to play a significant analytical role in medicine, agriculture, food safety, bioprocessing, environmental and industrial monitoring (Luong *et al*., 2008).

The history of biosensors began with Professor Leland C Clark Jr., known as the father of the biosensor. In 1956, Clark published a definitive paper on the oxygen electrode, and in 1962 he proposed making electrochemical sensors more intelligent by adding enzyme transducers. Guilbault and Montalvo first detailed a potentiometric enzyme electrode with a urea sensor based on urease immobilised at an ammonium-selective liquid membrane electrode. Clark's concepts became commercially viable in 1975 with the Yellow Springs Instrument Company's glucose analyzer, using amperometric detection of hydrogen peroxide.

Thermal transducers for biosensors emerged in 1974, leading to the development of thermal enzyme probes and enzyme thermistors. Lubbers and Opitz coined the term 'optode' in 1975 to describe a fiber-optic sensor with an immobilized indicator to measure carbon dioxide or oxygen, later extended to alcohol biosensors. Despite enzyme optodes not being widely available, commercial optodes perform well for in vivo pH, pCO_2, and pO_2 measurements. incorporated an electrochemical glucose biosensor into an artificial pancreas, marketed by Miles (Elkhart) as the Biostator. There are three biosensor generations: first-generation biosensors rely on the normal reaction product diffusing to the transducer to cause an electrical response; second-generation biosensors use specific mediators between the reaction and the transducer for an improved response; and third-generation biosensors have the reaction itself causing the response without product or mediator diffusion.

Basic Principle of a Biosensor

The working principle of biosensor depends upon type of transducer used for detection, therefore different types of biosensors include calorimetric (heat absorbed or released), electrochemical (change in electric output), amperometric (redox reaction), optical (light output/absorbance), and piezoelectric (based on mass of reactant or products). The biological material is immobilized and interacts with the analyte to form a bound analyte to produce a measurable electronic response (Fig. 1).

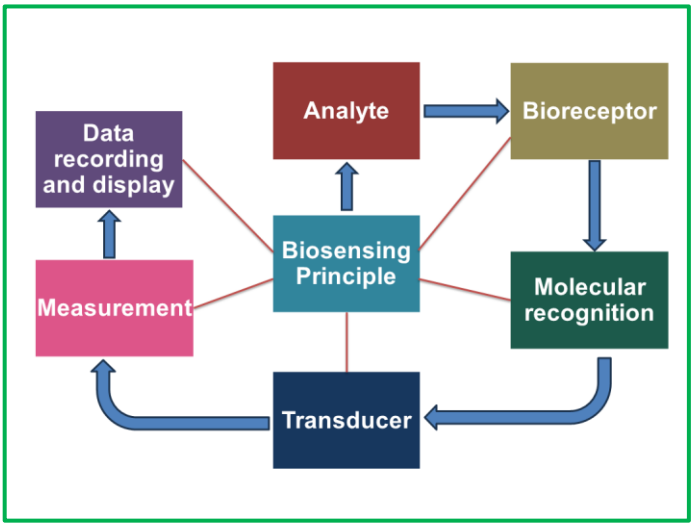

Figure 1. Basic principle of biosensor

Components of Biosensor

A biosensor comprises three main elements: a bioreceptor, a transducer, and a signal processing system. Biosensors are classified as affinity sensors (binding to analyte), metabolic sensors (chemical change measurement), or catalytic sensors (converting to an auxiliary substrate). Broadly, biosensors can be classified based on their bioreceptor or their transducer types (Fig. 2).

Bioreceptors: Bioreceptors are the key distinguishing feature, responsible for binding the target analyte to the sensor surface for measurement. They are responsible for binding the analyte of interest to the sensor surface for the measurement. They can be classified into five

major categories, (a) Antibody-antigen interactions, (b). Nucleic acid interactions, (c). Enzymatic interactions, (d). Cellular interactions (i.e., microorganisms) and (e) Interactions using biomimetic materials (i.e., synthetic bioreceptors). Enzymes and antibodies are the most widely used bioreceptors in biosensor applications.

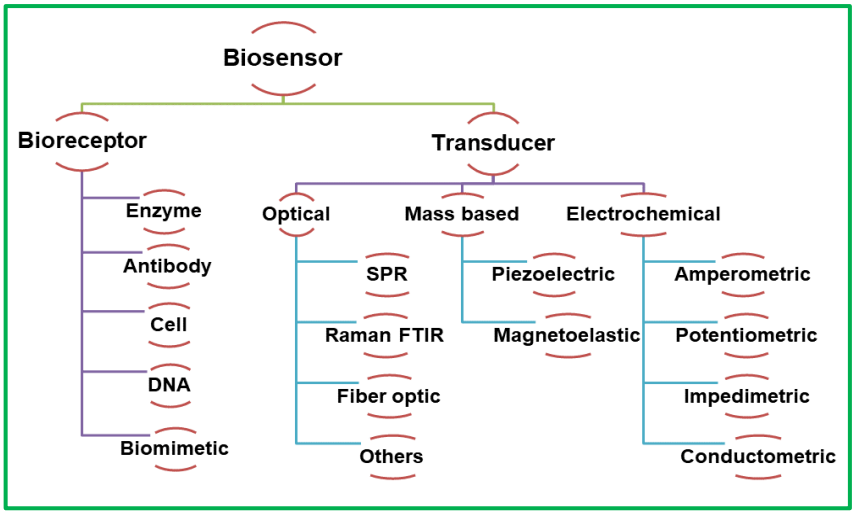

Figure 2. Biosensor classification based on bioreceptor and transducer

Transducers: The transducer in biosensors converts biorecognition events into detectable signals. These signals can be electrochemical (potentiometry, conductometry, amperometry, voltammetry, impedimetry), optical (colorimetric, fluorescence, luminescence, interferometry), calorimetric (thermistor), mass change (piezoelectric/acoustic wave), or magnetic. One of the most common transducers is optical based, in optical detection it involves optoelectronics, which interacts with light, including invisible radiation like gamma rays and infrared. Whereas, these optoelectronic systems include components like waveguides, optical fibres, LEDs, laser diodes, photodetectors, solar cells, and display instruments such as LCDs and LED displays.

Applications of Biosensors in Food Industry

Use of biosensors is extensively increasing in various fields due to their miniaturization and reduced cost enhance analytical capabilities. Biosensor research is expanding globally in diverse fields, with applications in medical to agricultural sectors. In the food processing industry, they provide quick, cost-effective detection of microbes, aflatoxin, allergens, and pathogens.

Microbial detection: Rapid detection of bacteria, such as *E. coli*, is essential for ensuring food safety and preventing foodborne diseases. An optical biosensor utilizing a nanostructured, oxidized porous silicon (PSi) thin film functionalized with *E. coli* specific antibodies is used for this purpose. These biosensors can identify and quantify *E. coli* present in water used in food industries. This process involves collecting reflectivity spectra in real time from water samples having high microbial loads, soil particles and debris. The sensor's thin-film optical interference spectrum changes predictably upon exposure to *E. coli*, confirmed by real-time PCR. The biosensor selectively identifies and quantifies *E. coli* at very low concentrations without needing pre-enrichment or prior processing. Such biosensors are prepared using *E. coli* antibodies (IgG) grafted onto the neat $PSiO_2$ Fabry-Pérot thin films via salinization and biotin-streptavidin coupling. The binding was verified using fluorescence microscopy and quantified by image analysis (Massad *et al.*, 2016).

Pesticide residual detection: Organophosphorus, carbamates, and pyrethroid pesticides, despite their low toxicity and rapid degradation are being extensively used and leave residues in soil and water, therefore posing health risks. Traditional methods like gas chromatography–mass spectrometry is expensive and time-consuming method. Biosensors, with high specificity due to enzyme-based reactions, are ideal for detecting these residues. They work by immobilizing catalytic enzymes on the sensor, which normally produce detectable signal followed by amplification if required. When pesticides are present, they

bound with enzymes results in inhibiting their catalytic activity, causing chemical or physical changes. These changes indicate presences and concentration of pesticides and need to be collected, amplified, and visualized by the signal transducer, providing a rapid and efficient detection method.

Aflatoxin detection: Aflatoxins are toxic and carcinogenic compounds produced by molds *Aspergillus flavus* and *Aspergillus parasiticus*, contaminate various plant products like cereals, nuts, and fruits. These toxins are potent carcinogens, teratogens, genotoxins and mutagens, poses significant health risks to humans as well as animals. To detect aflatoxins, biosensors based on modified screen-printed electrodes with Prussian Blue are being used. Enzyme immobilization can be achieved through a crosslinking method, and to preserve the efficacy, these sensors should be kept in a phosphate buffer solution until used. The detection method involves amperometric measurement of acetylcholinesterase (AChE) activity, utilizing a secondary enzyme, ChO_x, to convert acetylcholine to an electrochemically active product, H_2O_2 (Gong *et al*., 2013). This method is simpler, faster, and less expensive than traditional methods like HPLC or ELISA, allowing for the detection of low concentrations of aflatoxin B1 without the need for dilution steps required in spectrophotometric methods.

Conclusion

Biosensors presents a real time and cutting-edge technology for the food industry for the detection and quantification of physical, chemical, and biological quality hazards occurring in food ecosystem. The online monitoring and detection of various quality parameters by biosensors relies on target specific recognition of analyte by recognition element followed by its conversion into spectrum through transducer (electrochemical or thermal or optical or piezoelectric) that can be analysed by precise data processing. The selectivity, specificity, responsivity, and reproducibility of fabricated biosensors plays a critical role in food industry aimed at strengthening the quality assurance which thereby increases the confidence and trust of the consumers.

References

1. Gong, J., Guan, Z., and Song, D. (2013). Biosensor based on acetylcholinesterase immobilized onto layered double hydroxides for flow injection/amperometric detection of organophosphate pesticides. *Biosensors and Bioelectronics*, 39(1), 320-323.
2. Luong, J. H., Male, K. B., and Glennon, J. D. (2008). Biosensor technology: technology push versus market pull. *Biotechnology advances*, 26(5), 492-500.
3. Massad-Ivanir, N., Shtenberg, G., Raz, N., Gazenbeek, C., Budding, D., Bos, M. P., and Segal, E. (2016). Porous Silicon-Based Biosensors: Towards Real-Time Optical Detection of Target Bacteria in the Food Industry. *Scientific reports*, 6.