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Rapid Method of Detection: Biosensor

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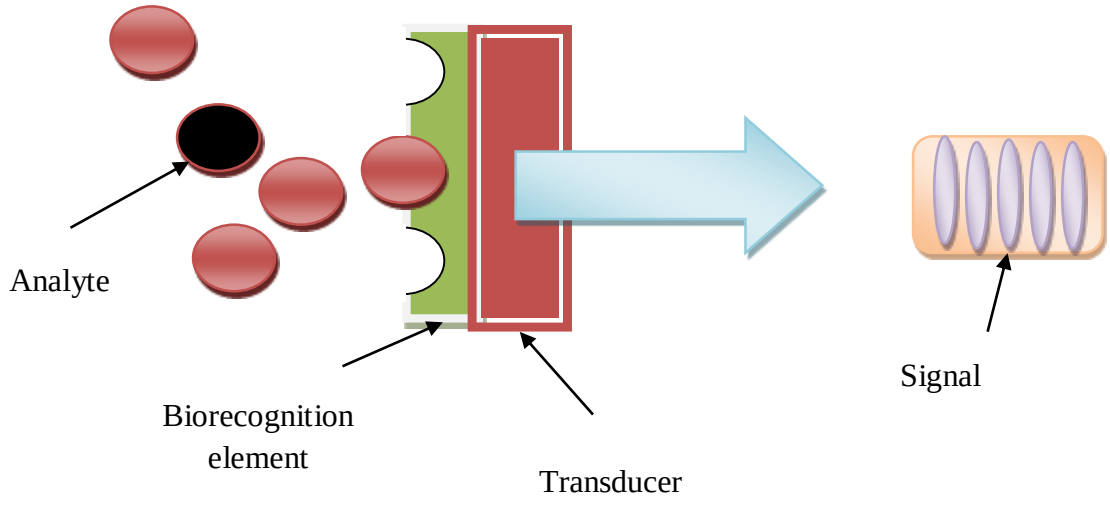
ABSTRACT

Biosensors are the technique used to detect analytes with the combination of biorecognition element and transducer. The worldwide biosensor marketplace is currently really worth over 10 billion dollars annually and is a growing field of interdisciplinary studies that is addressed as a potential revolution in purchaser, healthcare, and business. A key barrier to the large acceptance of biosensors, however, is their price. One manner to reduce the cost this is suitable for sure structures is to enable their reuse, for this reason decreasing the fee in step with take a look at. Regenerating biosensors is a way that could frequently be used along with low cost which boost up the commercialization process. This article discusses the various biosensor, principle of detection and their application on dairy industry.

INTRODUCTION

Food contaminants such as pathogens, toxins, heavy metals etc. are threat to food safety, leading to various health problems. This necessitates their detection in foods. Conventional methods for monitoring food safety have primarily relied on time-consuming enrichment steps, followed by biochemical identification, having a total assay time of up to 1 week in certain cases. Over the last two decades, a great deal of research has focused on the development of biological sensors for monitoring of food safety, allowing rapid and “real-time” identification. A biosensor is a self-contained integrated device that is capable of providing specific quantitative or semi-quantitative analytical information using a biological recognition element, which is in direct contact with a transduction element. There are various biosensor systems based on their transducer properties, which include electrochemical, optical, thermometric and piezoelectric. Electrochemical biosensors are one of the most explored biosensors for detection of food contaminants Regarding major developments in bioreceptors and transducers during the past ten years (Reverté *et al*. 2016; Seok Kim *et al*. 2016; Xia et al. 2016; Zhang and Liu 2016), it is time to present an up-to date-comprehensive review, covering the main recent advances in the design and production of biosensors for antibiotic residue detection in many different types of foodstuffs (milk, meat, eggs, honey, seafood). Various electrochemical biosensors are developed recently using various bio-recognition elements for rapid detection of food contaminants. These methods are more specific, due to their principle. Moreover, analytical techniques based on the

physico-chemical properties of antibiotic molecules have been developed in parallel (Thin-Layer Chromatography (TLC), High-Performance Liquid Chromatography (HPLC).

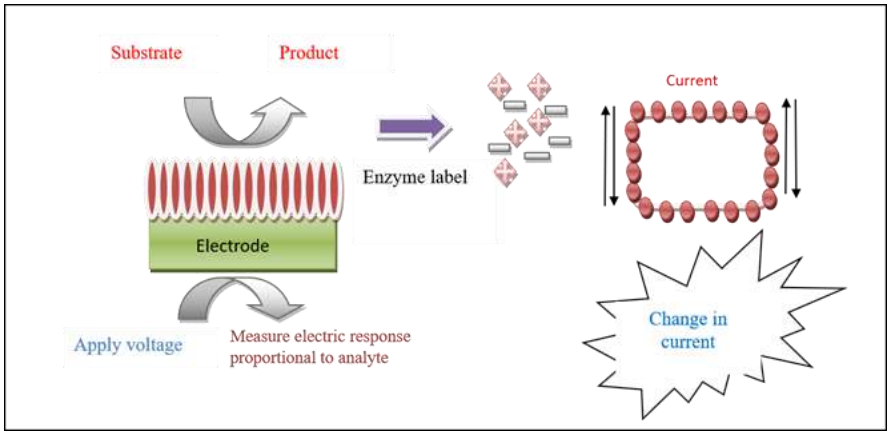


Biosensor

Biosensors are analytical devices composed biological component with physicochemical detector that convert a biological response into an electrical signal. Typically, 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 (Thevenot *et al*., 1999; Thévenot *et al*., 2001). The touchy organic detail, e.g. Tissue, microorganisms, organelles, cellular receptors, enzymes, antibodies, nucleic acids, and many others., is a biologically derived cloth or biomimetic thing that interacts with, binds with, or acknowledges the analyte below study. The biologically touchy factors also can be created through biological engineering. The transducer or the detector detail, which transforms one signal into another one, works in a physicochemical way: optical, piezoelectric, electrochemical, electrochemiluminescence and many others., as a consequence of the interaction of the analyte with the organic element, to effortlessly degree and quantify.

Principle of electrochemical biosensor

The desired biological material (usually a specific enzyme) is immobilized by conventional methods (physical or membrane entrapment, non- covalent or covalent binding). This immobilized biological material is in intimate contact with the transducer. The analyte binds to the biological material to form a bound analyte which in turn produces the electronic response that can be measured. In some instances, the analyte is converted to a product which may be associated with the release of heat, gas (oxygen), electrons or hydrogen ions. The transducer can convert the product linked changes into electrical signals which can be amplified and measured.



Classification of Biosensor

Biosensors are classified on the type of bioreceptor and transducer used.

A. On the basis of bioreceptor (biorecognition element)

Bioreceptors are the protein molecules that are embedded in the cellular membrane to which target analytes specifically bind. Bioreceptors can be classified into five different types on the basis of bioreceptor

1. Enzyme-based bioreceptor

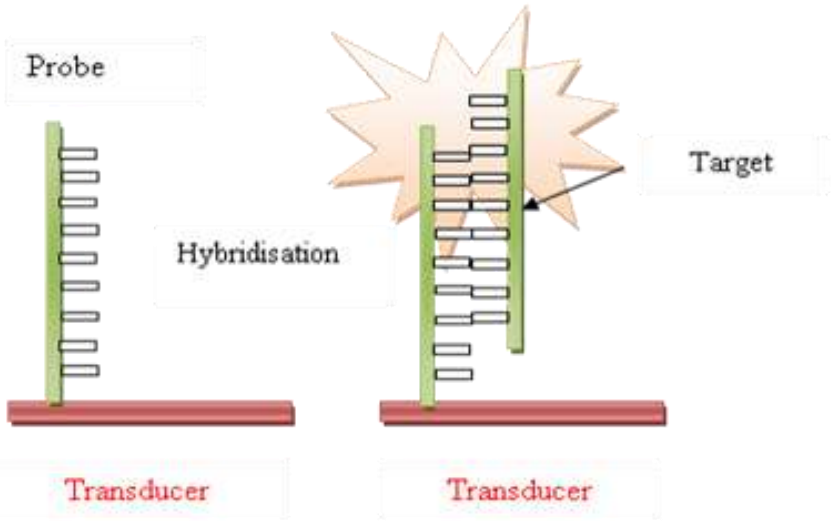
An enzyme is a large, complex macromolecule consisting largely of proteins that act as powerful catalysts to convert substrates into products. The enzymes used in the biosensor and their mode of action, which involve oxidation or reduction, can be detected electrochemically. The main reason for the popularity of bioreceptors is the catalytic activity of enzymes and their specific binding capacity. These biosensors utilize enzymes that are specific for the desired molecules. Different types of enzymes were used for the fabrication of biosensors. For example, fructose dehydrogenase enzymes were used for fructose, alcohol oxidase enzyme for alcohol, amino acid oxidase for amino acid, and glucose dehydrogenase for glucose. The lifetime of a sensor is limited by the stability of the enzyme. The five basic methods of enzyme immobilization are adsorption, microencapsulation, entrapment, cross-linking, and covalent bonding.

2. Antibody- or antigen-based bioreceptor

Antibodies are common bioreceptors used in biosensors. The antibodies may be monoclonal, polyclonal, or recombinants depending on the properties and synthesis. Antibody–antigen-based biosensor is also known as immunosensor. This type of interaction is similar to lock-and-key interaction in which the antigen will bind to the antibody if it has corrected conformation. Some of the disadvantages of using antibodies in the biosensors are the binding capacity of antibodies affected by the pH and temperature conditions; and the irreversible antibody–antigen interaction binding they may interrupt.

3. Nucleic acid-based bioreceptor

A biosensor that uses nucleic acid as a bioreceptor is known as genosensor. Nucleic acid analysis has become an important tool for the identification of microorganisms such as pathogens, bacterium, and so on, which are commonly present in food and the environment. The process is based on the principle of complementary base pairing, adenine-thymine, and cytosine-guanine in DNA. If the target nucleic acid sequence is known, complementary sequences can be synthesized, labeled, and then immobilized on the sensor. The hybridization probes can then base pair with the target sequences, generating an optical signal.



4. Molecular-imprinted polymers-based bioreceptor

It is a technique of producing artificial recognition sites by forming a polymer around a molecule that can be used as a template. Molecular-imprinted polymers (MIPs) can be synthesized for any analyte molecule and are capable of binding target molecules with affinities. MIPs possess many disadvantages such as the fact that it is very difficult to completely remove the template from MIPs and the imprinted polymer is insoluble.

5. Bacteriophages-based bioreceptor

Bacteriophages are viruses that are made of an outer protein coat and inside genetic material (DNA or RNA). Bacteriophages are considered as biorecognition elements for the identification of various microorganisms present in food and environment. The viruses can bind to specific receptors and inject their genetic material inside the bacteria. Researchers reported the use of phages as a biorecognition substance for the identification of various pathogens such as *Escherichia coli*, *Staphylococcus aureus*, and *Bacillus anthracis* on sensing platforms.

B. On the basis of transducers

Transducer plays an important role in the detection process of the biosensor and converts the biological or chemical signal into an electrical signal. Depending upon the type of transducer used, they are classified into optical, electrochemical, and mass-based biosensors.

1. Optical biosensor

These types of biosensors are based on measuring the changes in the intensity of light and convert light signal into an electrical signal that can be recorded in the form of current or potential. Optical biosensors have gained considerable interest for bacterial pathogen detection due to their sensitivity and selectivity. The most commonly used technique of optical detection is surface plasmon resonance (SPR) for pathogen detection. Now a days An Optical Biosensor use for Continuous Glucose Monitoring in Animal Cell Cultures.

SPR-based optical biosensor

SPR is based on the phenomena of optical illumination of metal surface for the detection of food-borne pathogens. To capture the optical illumination, certain antibodies were immobilized on a thin gold film. The interaction of light with the electrons presents in the metal leads to the generation of strong resonance. When the pathogen is bound to the metal surface, there is a shift in the resonance to the higher wavelength and the concentration of bound pathogen is directly proportional to the amount of shift in the resonance. With the help of SPR technique, diagnosis of pathogens such as *E. coli* O157:H7 and *S. aureus* using bacteriophage as bioreceptor has been reported. A modified technique was developed for the detection of *E. coli* O157:H7 at a low concentration of 50 colony forming unit (CFU)/mL called long-range surface plasmons in which magnetic NPs were used. Many researchers use commercially available SPR biosensor for the identification of food-borne pathogens. BIACORE 3000 was used for the detection of *Listeria monocytogenes* and *Salmonella*, and Spreeta^{TM} was used for *E. coli* O157:H7 (Sharma *et al*., 2013).

2. Electrochemical biosensor

The present popularity of the electrochemical biosensor over other biosensors is due to advantages such as low cost, good sensitivity and selectivity, use in turbid media, and miniaturization potential for the detection of food-borne pathogens.[53] In the electrochemical biosensor, when there is an interaction between the sensor electrodes and the sample analyte, then the changes in the current and potential values are measured. They are classified into amperometric (current), potentiometric (potential), and impedimetric (impedance), which depend on the type of transducer used.

3. Amperometric biosensor

Amperometric transduction is most common in the electrochemical method for the detection of food-borne pathogens.[55] In an amperometric biosensor, current is produced by the oxidation or reduction of electroactive species at the working electrode (ie, gold, carbon, platinum). The value of current magnitude produced at the surface of working electrode is proportional to the quantity (concentration) of analyte present in the test solution. Chu *et al.*, 2012 fabricated an amperometric glucose biosensor in which they immobilized GOx on the ZnO nanotubes using cross-linking method and further detected the amount of glucose in blood samples. Concentration of glucose was found to be 50 μM–12 mM within 3 seconds response time. The sensitivity of the biosensor was found to be 21.7 μA/mM cm^2, and its experimental detection limit was found to be 1.0 μM.

4. Potentiometric biosensor

In a potentiometric biosensor, the biorecognition process is converted into a potential signal. This sensor uses ion-selective field effect transistors (ISFETs) and light-addressable potentiometric sensors (LAPSs).In order to increase electrical conductivity in ISFETs, an electric field is used to generate excess charge in semiconductor substrate.[67] In a potentiometric immunosensor, enzyme-labeled antibodies such as GOx, urease, or alkaline phosphatases are used, which are able to change either pH or ionic strength during the detection of microorganisms present in food sample. LAPS evolved from ISFET by combining potentiometry with optical sensor for the detection of food-borne pathogens. Kumar and Naalam (2016) developed a potentiometric urea biosensor based on bovine serum albumin embedded on the surface of modified polypyrrole film. The electrode shows a linear response of 6.6×10^{-6} to 7.5×10^{-4} M urea in 70–90 seconds.

5. Conductometric biosensor

Conductometric biosensor is generally based on the conductance measurement, that is, whenever a change in the ionic concentration of an analyte occurs, there is a subsequent change in the electrical conductivity of the solution or changes in the flow of current. The microbial metabolism changes occur in the medium or analyte, which result in an increase in both capacitance and conductance, causing a decrease in impedance. Therefore, conductance, capacitance, impedance and resistance are interrelated with each other, but they only differ in ways of monitoring the test system. Wang and Li (2017), developed a conductometric biosensor for the detection of *E. coli* O157:H7 and *Salmonella* food pathogens in 10 minutes with an LOD of 81 CFU/mL.

Application in Dairy and Food Industry:

Development of biosensor is being carried out in dairy and food industry for determination of quality of milk and milk products and food materials. It is used to detect various metabolites like heavy metal, antibiotics and pesticides etc. These metabolites are very hazardous to our health. So, the earlier screening of milk and milk products is needed. It can also use to detect pathogenic bacteria *like*

Clostridium, E. coli, salmonella and Listeria monocytogens present in milk. Biorecognition element for used to detect pesticide present in milk are *Bacillus megaterium* and for antibiotic *bacillus stearothermiphillus* spores. Detection of above metabolites and pathogen observed using the color change of substrate.

It can also determine the quality of modified atmosphere packages of fruits, vegetable and processed food. Damages in the food packaging leads to worsen the quality of food, also promote the growth of pathogenic microorganism and cause huge losses to food and dairy industry. Biosensor can detect the damages in packaging material by changes in color. Its analysis the freshness of food component like change in odor of sea foods. Bio check method also use to analysis the meat and meat products. Quality of wine can also analysis by newly isolated biorecognition element *Gluconobacter spp and Erwinia spp*.

CONCLUSION

We have summarized the types of biosensor and their application in dairy and food industry for rapid detection of analyte. This era is demanding for rapid detection technique for determination of different analytes present in food for further processing. Various biosensor like nanomaterial, electrochemical, optical, surface plasma resonance and piezoelectric biosensor are led out with advanced technique for rapid detection of hazardous metabolites. However, detecting low number of analytes is stilled hurdle in the path of biosensor.

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