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Biosensor: Use in Agriculture

Biotechnology

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Vishal L. Bagde	Ph.D. Scholars, Biotechnology Centre, Botany Department. Dr. PDKV Akola-444104
Dipali B. Borkar	Ph.D. Scholars, Biotechnology Centre, Botany Department. Dr. PDKV Akola-444104

ABSTRACT

Biosensor technology is a powerful alternative to conventional techniques, harnessing the specificity and sensitivity of biological systems in small, low cost devices. Despite the promising biosensors developed in research laboratories, there are not many reports of applications in agricultural monitoring. Biosensor research and development has been directed mainly towards health care, environmental applications and the food industry. The most commercially important application is the hand-held glucose meter used by diaberics. The agricultural/veterinary testing market has seen a number of diagnostic tests but no true biosensor systems have made an impact. The need for fast, on-line and accurate sensing opens up opportunities for biosensors in many different agricultural areas -in situ analysis of pollutants in crops and, detection and identification of diseases in crops and livestock, on-line measurements of important food processing parameters, monitoring animal fertility and screening therapeutic drugs in veterinary testing. Further challenges in the commercial development of biosensors are also addressed.

INTRODUCTION

Humankind has been performing bioanalysis since the dawn of time, using the sensory nerve cells of the nose to detect the scents or the enzymatic reactions in the tongue to taste food. As time has progressed, so has our level of understanding about the function of living organisms in detecting trace amounts of biochemical in complex systems. Because biological organisms are some of the most efficient machines ever created, scientist have sought to apply and copy their efficiency for use in man made creations. In particular, the recognition abilities of biological organisms for foreign substances is unparalleled. Using bioreceptors from biological organisms or receptors that have been patterned after biological systems, scientist have developed a new means of chemical analysis that often has the high selectivity of biological recognition systems. These biorecognition elements in combination with various transduction modes have helped to create the rapidly expanding fields of bioanalysis and related technologies known as biosensors (Tuan Vo-Dinh, 1999).

A biosensor can be defined as an analytical device with a biological sensing element in close proximity or integrated with a signal transducer inorder to quantify a compound or conditions. In the past two decades, the biological and medical fields have seen great advances in the development of biosensors and biochips capable of characterizing and quantifying biomolecules.

What is Sensor?

Sensors are the electronic device which uses the physical changes of the reaction to produce an effect. According to the nature of input signals they can be broadly classified as

1. Physical sensor
2. Chemical sensor (Sultana Afrin, 2004).

Biosensor

A biosensor is an analytical device which converts a biological signal into electrical signal. Leland C. Clark Jr. known as the father of the biosensor. The term biosensor is often used to cover sensor devices used in order to determine the concentration of substances and other parameters of biological interest. It is an analytical device where immobilized layer of biological material is in contact with sensor which analyses the biological signal & convert it in to electrical signal (Gronow,1984). Biosensors combine the selectivity of biological system with the processing power of modern microelectronics and optoelectronics. Biosensor offers a new analytical tool with major application in environmental diagnostics, medical field, industries and in agriculture.

Principle of Biosensor

1. Immobalization of biological material

The biological components is suitably immobilized on the transducer surface. Enzymes are usually immobilized by gluteraldehyde onto a porous sheet like lens tissue paper or nylon net fabric and the enzyme membrane thus produced is affixed to transducer.

2. Surface treatment to transducer

The transducer surface may be treated with 3-aminopropyltriethoxysilane. The biological components may now covalently linked to this cross-linked silane via the reactive amino group remains free. This method yield non reproducible results and often causes a large reduction in the activity of the biological components.

3. Interaction of analyte with biological material

The biological component interacts specifically to the analyte, which produces a physical change close to the transducer surface. This physical changes may be heat released or absorbed by the reaction, production of electrical potential due to change distribution of the electrons, movement of electrons due to redox reactions, light produced or absorbed by the reaction, change in the mass of biological components as a result of the reaction.

4. Convertion of biological signal

The transducer detects the signal and convert into the electrical signals.

5. Amplification of signal

This signal is necessarily very small, and is amplified by the amplifier before it is fed into the microprocessor. The signal is then processed and interpreted and is displayed into the suitable units. (Singh, 2004).

Components of the Biosensor

A) Biological components

1. Enzymes
2. Antibody
3. Microorganisms
4. Cell etc.

B) Physical components

1. Transducer
2. Detector
3. Signal processing unit
4. Amplifier

Methods of detection

1. Electrochemical method of detection-

Production of electrical potential due to change distribution of the electrons.

2. Amperometric method of detection-

Movement of electrons due to redox reactions.

3. Thermistor method of detection-
Heat released or absorbed by the reactions.

4. Optical method of detection-
Light produced or absorbed by the reaction.

5. Piezoelectric method of detection-
Change in the mass of biological components as a result of the reaction. (www.dddmag.com)

Types of Biosensors
1. Electro-chemical biosensor
Electrochemical biosensors are normally based on enzymatic catalysis of a reaction that produces or consumes electrons (such enzymes are rightly called redox enzymes). The sensor substrate usually contains three electrodes; a reference electrode, an active electrode and a sink electrode. An auxiliary electrode (also known as a counter electrode) may also be present as an ion source. The target analyte is involved in the reaction that takes place on the active electrode surface, and the ions produced create a potential which is subtracted from that of the reference electrode to give a signal.

2. Potentiometric biosensor
Such biosensors are screenprinted, conducting polymer coated, open circuit potential biosensors based on conjugated polymers immunoassays. They have only two electrodes and are extremely sensitive and robust. They enable the detection of analytes at levels previously only achievable by HPLC and LC/MS and without rigorous sample preparation. The signal is produced by electrochemical and physical changes in the conducting polymer layer due to changes occurring at the surface of the sensor. Such changes can be attributed to ionic strength, pH, hydration and redox reactions, the latter due to the enzyme label turning over a substrate.

3. Amperometric biosensor:-
It measure the reaction of analyte with enzyme and generate electrons directly or through mediator. It consists of either enzyme-electrode or without mediator. The best example is glucose oxidase biosensor.

4.Thermistor containing biosensor:-
Use to record temperature changes during biochemical reaction using enzymes like cholesterol oxidase, invertase , tyrosinase. Also use to study antigen-antibody with very high sensitivity in ELISA (Gronow et al.,1984). It shows a very high sensitivity.

5. Whole cell biosensor
In this biosensor whole cell or organelles use as a biological component. The cells are cheaper, have longer active lifetime, and are less sensitive to inhibition, pH, temperature variations than enzymes. In this biosensor whole cell of micro-organisms is use for the study.

6. Colorimetric test strips
The most simplest form of biosensor is the colorimetric test strips. In this biosensor strips of cellulose is use which coated with appropriate enzyme and suitable reagents which gives colour change in the reaction. An example of such strips is the one used to detect glucose in blood or urine of diabetic patients.

$$\textbf{Chromogen(2H)} + H_2O_2 = \textbf{Dye} + H_2O$$

7. Optical biosensor
It detect how much light is produced or absorbed during the biochemical reaction. A most promising biosensor is luminescence biosensor for detection of bacteria in food and clinical samples. Bacteria is also used as a biosensor it get fluoresces in presence of specific pollutants which they like to eat and detect the oil spills area. (Dubey, 2006).

8. Acoustic wave biosensor
In this biosensor piezoelectric crystals are used to assay the mass of analyte that bind to the biological components immobilized on the crystal suface. This biosensor detect the change in the mass of the biological components. (www. moleular-plant-biotechnology. Info).

Biosensors in Agriculture
Agriculture includes the production of crops and the rearing of livestock producing various products which are used in daily life. These elements have always been susceptible to damage in the form of pests and diseases causing a loss in the profits (Fletcher et al., 2006). Hence, a way of increasing profits would be to reduce the loss of crops and livestock by such natural threats. With the advancement in bioterrorism, the need for biosecurity becomes very necessary. There have been cases where bacteria such as anthrax and virus such as the small pox have been deliberately propagated through livestock in order to infect the nation's population and inflict damage (O'Toole and Inglesby, 2003). Also, the need for biosecurity is essential when agricultural produce or any living object is to be transported across the international borders. Biosensors may play a major role in this field as they provide rapid and specific detection compared to the older techniques. A biosensor has been developed for the detection of the fungus *Phakopsora pachyrhizi* that causes Asian rust or Soybean rust, using the SPR technique. In this case, antibody against *Phakopsora pachyrhizi* was used as the biological recognition element. The biosensor had a response range of 3.5–28 mg/ml of antigen solution (leaf extract) and a detection limit of 800 ng/ml (Mendes et al., 2009). The non-specific binding to the antibody was prevented by blocking the reactive sites with BSA. Such rapid and simple methods can be developed for world's most acute crop diseases thus preventing damage and spread. It is also important to develop biosensors for monitoring agricultural by-products. A biosensor for the detection of aflatoxin in olive oil has been developed (Amine et al., 2006). Aflatoxins produced by molds *Aspergillus flavus* and *Aspergillus parasiticus* are carcinogenic to humans. Aflatoxin has inhibitory effect on acetylcholinesterase (AchE) and its detection is coupled with the decrease in the activity of AchE which is measured using a choline oxidase amperometric biosensor. The choline oxidase enzyme is immobilized on screen printed electrodes. The residual activity of the enzyme is calculated after the application of sample and is used for the indirect detection of aflatoxin that may be present in the sample (Ben Rejeb et al., 2009). The AchE activity is highly pH dependent with best results obtained at pH 7.4. Amperometric method allows the detection of low aflatoxin concentration that cannot be detected by the classical spectrophotometry because of the omission of the dilution step used in the classical method (Ben Rejeb et al., 2009).

Concentrations of herbicides, pesticides and heavy metals in agricultural lands is increasing and this is a matter of concern. Biosensors can be used to measure the levels of pesticides, herbicide and heavy metals in the soil and ground water. Biosensors can also be used to forecast the possible occurrence of soil disease, which has not been feasible with the existing technology. The biological diagnosis of soil using biosensor means opening the way to reliable prevention and decontamination of soil disease at an earlier stage.

The basic principle of soil diagnosis with the biosensor is to estimate the relative activity of "good microbes" and "bad microbes" in the soil on the basis of quantitative measurement of differential oxygen consumption in the respiration of tow types of soil microorganisms. The measurement proceeds through the following steps: two sensors impregnated with "good microbes" and "bad microbes", respectively, are immersed in a suspension of soil sample in buffer solution. Half an hour later, the oxygen consumption data by two microbes are displayed on a PC screen. By comparing two data it may be possible to quantitatively decide which microbe favors the soil. It is feasible, therefore, to predict whether or not soil disease is ready to break out in the tested soil beforehand. It is to be emphasized that the biosensor offers an innovative technique of diagnosing soil condition based not on experience but on numerical data. Nitrate biosensor has been developed for the detection of amount of nitrate present in soil. (www.aist.go.jp).

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Other applications of Biosensors

1. Use in health and medicine

The initial impetus for advancing sensor technology came from health care area, where it is now generally recognized that measurements of blood gases, ions and metabolites are often essential and allow a better estimation of the metabolic state of a patient. In intensive care units for example, patients frequently show rapid variations in biochemical levels that require an urgent remedial action. Also, in less severe patient handling, more successful treatment can be achieved by obtaining instant assays. At present, the list of the most commonly required instant analyses is not extensive. In practice, these assays are performed by analytical laboratories, where discrete samples are analyzed, frequently using the more traditional analytical techniques.

2. Use in Industrial Process

Biosensor monitored the pH, temperature, gases in bioreactor and improve the quality of the product, increase product yield because it maintain the optimum condition throughout process. Improved plant performance, processing rate and line speed automated. Optimized energy efficiency. The use of biosensors in industrial process in general could facilitate plant automation, cut analysis costs and improve quality control of the product.

3. Environmental Monitoring

Biosensor is use for air and water monitoring. The primary measurement media here will be water or air, but the variety of target analytes is vast. The possible analytes include biological oxygen demand (BOD) which provides a good indication of pollution, atmospheric acidity, and river water pH, detergent, herbicides, and fertilizers (organophosphates, nitrates, etc.).

4. Military Application

Biosensor detect the toxic gases including the chemical warfare agents. (*www.*gatewaycoalition.org).

Advantages of biosensor

Biosensors are sophisticated tools for detection and monitoring. Biosensors are moré specific and provide more accurate readings. It is very easy to use. They can measure non-polar molecules that do not respond to most measurement devices. No need of continous monitoring.

Disadvantages of biosensor

Heat sterilization is not possible as this would denature the biological part of the biosensor. Cost is high. Reproducibility- it is not possible the same type of biosensor gives the same result. Its sensitivity sometimes may be a problem. Reusability- Some type of biosensor such as colorimetric test strips has single use. Cell intoxication - the cells in the biosensor can become intoxicated by other molecules that are capable of diffusing through the membrane.

Current biosensor Research

1. Abnormal sulphur in gastrointestinal disease. Mucins are the proteins that lie in gastrointestinal tract and contain sulphate group as the part of their structure.
2. Identification of volatile marker compounds for biosensors.
3. Microsensor array for mycotoxin analysis. Mycotoxin are toxic fungal metabolites that occur in food and feed products due to fungal contamination.
4. Food pathogen biosensor scientist are inventing a new ways to protect the food supply from potentially deadly food pathogens.
5. Phosphate ion biosensor.
6. Agricultural agent sensor. These biosensor has been developed for detection of insecticide, herbicide and their influence on the environment.
7. Wheat flour quality sensor to determined the starch damage and diastitic activity of wheat flour by the use of FIA biosensor. (Nakamura Hideaki and Karube Isao, 2003).

Future prospects

Though a lot of research activity has been involved in developing biosensors for various purposes the time has come to bring this technology to the forefront and make it commercially available. Efforts and funds need to be mobilized to manufacture biosensors on a large scale so as to benefit and be of use to the general public. With exposure to the commercial market the applications of this technology would be greatly enhanced. Real time monitoring of dairy products and breweries might help foster a cleaner and hygienic environment and experiment with different tastes imparted by specific microorganisms in specific concentrations giving rise to new products. A farfetched and plausible use of this technology could be in space exploration where if present the concentration of the living organisms would be very low and might lead to answering many of the long standing questions regarding the presence of life in space and the most elusive question to date vis-à-vis life on earth.

Conclusions

A biosensor is a device that detects, records, and transmits information regarding a physiological change or the presence of various chemical or biological materials in the environment. Biosensors combine the selectivity of biological system with the processing power of modern microelectronics to offer powerful new analytical tools with major applications in medicine , environmental diagnostic, food industries and agriculture. Inputs are required from biology, chemistry, electronics and physics for the efficiency of biosensor and its wide application in different field.

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