Applications of Biosensors in Food Industry

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Food processing industry faces various challenges; one of the foremost challenges is the need for quick and cost effective methods to detect the presence of allergenic components and pathogens in the food. Biosensors pave way for the rapid detection of pathogens, allergens as well as pesticide residues in food. Detection of contaminants, verification of product contents, product freshness and monitoring of raw materials conversion are the areas of potential biosensor applications. Generally in the food and the agricultural industries, chemical and microbiological analyses are done periodically by trained operators, which are expensive and require steps of extraction or sample pretreatment, increasing the time of analysis. Biosensors can overcome all these disadvantages by offering rapid, non-destructive and affordable methods for quality control. Biosensors have the potential to produce an analytical revolution to resolve the challenges in the agricultural and the food industries. This review gives an overview of various types of biosensors used in the food industry and outlines its future prospects.

Key words: Quality Control, Food Industry, Optical biosensor, Biolumesent bisosensor.

Biosensors act as analytical devices employing a biological material or biomimic as a recognition molecules integrated within a physicochemical transducer or transducing microsysytems. The outcome of this is a digital electronic signal proportional to the concentration of a specific analyte or analytes. Biosensors are used in various fields, with miniaturization and reduced cost has further increased the analytical capabilities of such device. Biosensors research is booming around the world and the area of applications range from medical to agriculture. The types of instruments required for the agro-food diagnostics market can be divided into large multi-analysers, bench-top portable instruments and one-shot disposable sensors. Many of the instrumentations developed to date were for the medical diagnostics market[1]. Fish and meat freshness instruments, based on the determination of nucleotide-related compounds, to indicate whether the product is fit for human consumption, have been introduced to the market[2]. Biosensors are very useful in food-borne pathogen detection. For instance, they have sensitivity in the range of ng/ml for microbial toxins; provide fast or real- time detection; and, the miniaturization of biosensors allow for integration in food production equipment and machinery[3]. The main disadvantage of biosensors is the instability of the biological sensing component, which tends to degrade and lose its effectiveness over a short period of time. This is due to the various stresses encountered within an environment, including pH, temperature or ionic strength.

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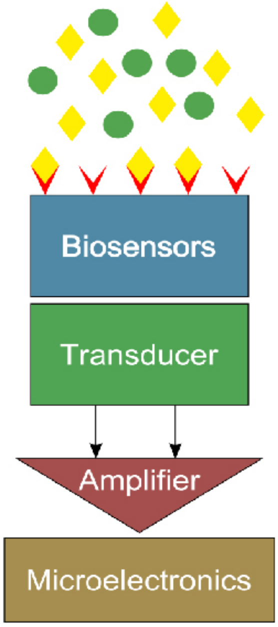

Fig. 1. Principal of Biosensors

Receptor Molecules

The characteristics of biomolecules in selective binding are exploited in biosenor devices, using this either an affinity or catalytic sensor can be developed. A varied range of naturally produced molecules such as nucleic acids, protein lipids and their derivatives, enzymes, antibodies, cell receptors etc. can all be used as the sensing element in biosensors. Enzymes catalyze many biochemical reactions, and they are vastly used in biosensors as the catalytic component. Many enzymes are unsuitable for use in such devices due to their lack of stability and enzyme modification or other means of improving stability is desirable[4]. This is achieved by manipulation of various factors including chemical stabilisation, immobilisation procedures that confer stability. The other important approach is sourcing enzymes from thermophilic organisms. Whole cells (bacteria, yeast, fungi, plant and animal cells) are also used as recognition component by interrogating their general metabolic status. This usually involves detecting oxygen or substrate consumption, the production of carbon dioxide or metabolites, detecting of bacterial luminescence or direct electrochemical sampling of the electron transport chain[5].

Affinity sensors mainly depend on antigen-antibody reaction. Polyclonal antibodies (Pabs) and Monoclonal antibodies (Mabs) may lead to development and future growth of immune sensors, which will deal with antibody fragments and molecularly engineered antibodies. The major stumbling block in biosensor technology is the poor stability of biological molecules. Research dealing with improving stability is a potent area and various methods were devised to achieve the desired results, methods such as the use of soluble, positively-charged polymers, such as diethyl amino ethyl (DEAE) dextran, lacitol, and sugar derivatives are being tested.

Transducers and sensor fabrication

The major types of transducers used in biosensors are electrochemical (electrodes), optical (optrodes), mass (piezoelectric or surface acoustic wave devices) and calorimetric (thermistor or heat sensitive sensors). Research on transducers design focus on the mergers of different technologies. Electrochemical devices usually monitor the current at a fixed voltage (amperometry), the voltage at zero current (potentiometry), or measure conductivity or impedance changes. Impedance is the total electrical resistance to the flow of an alternating current being passed through a given medium. Typically during measurement impedance decreases while conductivity and capacitance increase. Optical transducers use a number of principles, such as the effect of the biological event on light absorption, fluorescence, refractive index or other optical parameters[2]. Thermometric devices operate by measuring enthalpy changes during the biological reaction. Sensors based on piezoelectric principles use the change in the resonant frequency of wave propagation through a piezoelectric material. These principles can be used to measure mass, viscosity or density changes at the sensor surface. Further information on transducers used in biosensor devices can be acquired from Kress-Rogers[6].

Mass production of sensors is carried out using silicon fabrication technology. This is also a potent area of research and the use of silicon microfabrication for both electrochemical and optical sensors is expanding and the capability of on-chip electronic signal amplification and data processing are very attractive.

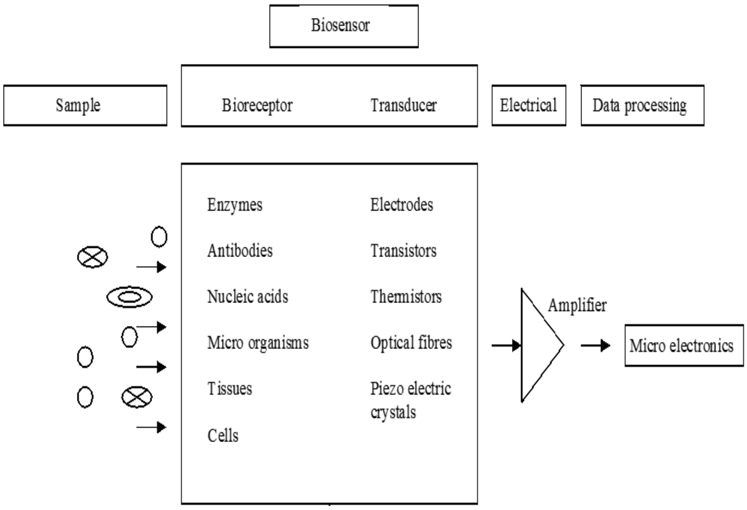

Fig. 2. Principle of operation of food biosensors[7]

Food Biosensors

Biosensors in food industry are used for mainly two purposes. First is enzyme biosensor, which is mainly used in liquor and beverages industry for detecting or measurement of carbohydrates from alcohol, amino acids, amines, amides, phenol etc. The table below lists the food component and the enzymes sensed by the biosensors to measure or detect the specified components.

The second type of biosensor used in food industry is for the detection of microorganisms. They are detected by two methods: Direct detection and Indirect detection.

Direct Detection

Specific reactions are directly measured in real time by measuring the physical changes induced by the complex formation.

Optical Biosensor

These are used for the direct detection of bacteria in food products. These sensors detect changes in refractive indices when cell bind to receptor which are immobilized on the transducer[9]. Examples for optical biosensors are Elapsometric, Ewascent wave interferometer, resonant mirror, and piezoelectric biosensor.

Bioluminesent Biosensor

A cell is genetically modified with the introduction of a reporter gene, whose expression is regulated by a receptor or regulatory protein. When the analyte enters the cell, it binds the protein receptor. This activates the expression of the reporter gene, with synthesis of mRNA and consequently of reporter protein. The measurement of the reporter protein provides the analytical signal. E.g. Luciferase reporter phage in which the gene encoding Luciferase incorporated into the genome of bacterial viruses.

Electrical impedance biosensor

Impedance biosensors measure the electrical impedance of an interface in AC steady state with constant DC bias conditions. The biosensor is based on impedance measure of adherently growing cells on inter digitized electrode structure. Cell density, growth of cells on electrode changes the impedance of the biosensor.

Fluorescence labeled biosensor

A fluorescence biosensor consists of a receptor component to capture a target ligand and a signal transduction component to convert the ligand-binding event into measurable signals, such as fluorescence, chemiluminescence, colorimetric, electrochemical, and magnetic responses. Especially, fluorescence detection is currently the most widely utilized method in the biomolecular imaging due to its high sensitivity and selectivity, sufficient temporal and spatial resolution, and low cost for use[10]. Microbial metabolism based biosensors: Microorganism is able to transducer their metabolic Redox reaction in to quantify electric signals by using

Table 1. Enzymes sensed by food biosensors[8]

Food Components	Enzyme Used
Glucose	Glucose oxidase
Fructose	Fructose -5-dehydrogenase
Sucrose	Glucose Oxidase, Mutarotase,Invertase
Lactose	Galactose oxidase & Peroxidase
Glutamate	Glutamate Oxidase
Malate	Malate dehydrogenase, Diaphorase
Glycerol	Glycerol Dehydrogenase
Cholesterol	Cholesterol Oxidase
Essential fatty acids	Lipoxygenase
Ehanol	Alcohol Dehydrogenase
Choline	Choline Oxidase

Oxidoreductase reaction and mediator[8]. Flow immune sensors: Nowadays, many of the assays for microbes are based on Elisa using micro titration plates on completion of Chromogenic reaction, the quantitative determination is done using Elisa reader e.g. *E.coli* detection[8].

CONCLUSION

Biosensor is a rapidly growing field encompassing various fields like medicine, agriculture and environmental science. Biosensors application in medical field is highly advanced especially in the area of medical diagnostics. In the food industry quality control is a major thrust area, the need for fast methods to monitor the quality of food is urgent. Conventional methods are expensive, time consuming and labour intensive. Development of efficient sensors will not only speed up the process but will be also cost effective. Biosensor is an interdisciplinary field involving many areas; research in material science, microfabrication and nanofabrication will enhance the development of suitable sample preparation steps, such as extraction, concentration, and isolation. Future sensors developments must focus on provide multi-analyte detection combined with signal transmitters for remote sensing.

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