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Biosensors in Food Industry

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Abstract. One of the main challenges the food industry has to deal with is the growing need for fast and cost-effective methods of detecting allergens and pathogens in foods. Biosensors provide an express method of detecting pathogens, allergens, and pesticide residues in food products. In addition, they can detect contaminants, verify food composition, and define its freshness. As a rule, only qualified experts in food science and agriculture can conduct chemical and microbiological analyses, which are expensive and time-consuming because of long sampling or pre-treatment procedures. Biosensors can optimize this process: they are fast, non-destructive, and affordable. In general, biosensors can advance digital agriculture and food production. This article provides an overview of biosensors used in the food industry and their prospects.

1 Introduction

Biosensors are analytical devices that use biological material or biomic as receptor molecules and integrate them into a physicochemical transducer or a transducer microsystem. The resulting digital electronic signal correlates with the concentration of a particular analyte or analytes.

Biosensors in the modern world are used in various fields of industry, agriculture and medicine, and their application is huge. Biosensor research is currently at the top worldwide. The best modern sensors are meant for medical diagnostics [1]. Hi-tech sensors that determine the freshness of fish and meat detect compounds associated with nucleotides. Biosensors also detect foodborne pathogens and microbial toxins in the ng/mL range. Minute biosensors provide express or real-time agri-food diagnostics. Unfortunately, biosensors have one serious disadvantage: its main active component degrades fast, which makes its effectiveness short-lived. As a rule, it happens as a result of various environmental stresses, e.g., changes in pH or temperature. An example of a biosensor sensor is shown in figure 1.

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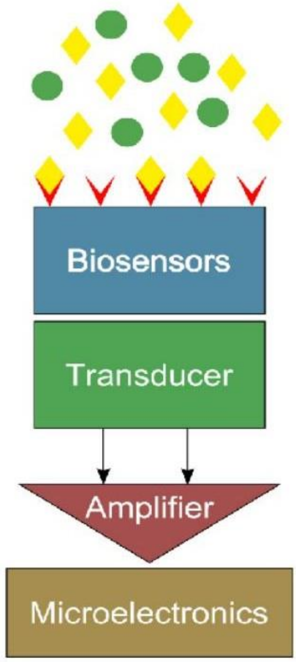

Fig. 1. Schematic diagram of biosensors

2 Study objects and methods

This research covered ten years of open-access research publications in Russian and English registered in the PubMed databases of the National Center for Biotechnology Information (USA), Elsevier (Scopus, ScienceDirect), the Web of Science platform, and the Russian electronic library eLibrary.ru.

3 Results and discussion

Receptor molecules

Catalytic biosensors exploit some selective-binding properties of biomolecules. A wide range of natural molecules, e.g., nucleic acids, protein lipids and their derivatives, enzymes, antibodies, etc., can be used as a sensitive element. Enzymes catalyze many biochemical reactions and are widely used as a catalytic component in biosensors. Many enzymes are unstable, which makes them unapplicable without modifications. The list of possible modifications includes chemical stabilization or immobilization to impart stability. Enzymes obtained from thermophilic organisms represent another important approach [2].

It is also possible to use bacteria, yeast, fungi, plant and animal cells to detect a common metabolite.

Sensors depend on the antigen-antibody reaction. Polyclonal antibodies (Pabs) and monoclonal antibodies (Mabs) may one day yield immune sensors that will interact with antibody fragments and molecularly engineered antibodies. As it was mentioned before, the main disadvantage of biosensor technology is the low stability of biological molecules. Biosensor stability is a promising area, which has developed various methods, e.g., such soluble positively charged polymers as diethylaminoethyl (DEAE) dextran, lacitol, and sugar derivatives [3].

Transducers and sensor production

Biosensors include various transducers: electrodes are electrochemical transducers, optical transducers are called optrodes, mass transducers are piezoelectric devices or devices with surface acoustic waves, and calorimetric transducers are thermistors or temperature-sensitive sensors. Fusion is the most promising direction of transducer design [4].

Electrochemical devices typically monitor current at a fixed voltage, and this process is known as amperometry. Those devices that monitor voltage at zero current are part of potentiometry. Other devices can measure changes in conductance.

Impedance is the total electrical resistance to the flow of alternating current through a medium. Optical converters can use a number of indicators, such as light absorption, fluorescence, refractive index, etc.

Thermometric devices measure enthalpy changes during a biological reaction. These principles can also be used to measure mass, viscosity or density [4].

Biosensor manufacturing sensors are mainly used for silicon production. This direction is promising for research, covering the use of silicon in optical sensors, as well as data processing.

Food biosensors

The food industry applies biosensors for two purposes. Enzyme biosensors are used to detect and measure carbohydrates, amino acids, amines, amides, phenol, etc., in alcohol drinks and soft beverages. Table 1 shows food components and enzymes detected by biosensors [5].

Table 1. Enzymes detected by food biosensors

Food component	Enzyme
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

Biosensors of the second type report microorganisms by direct or indirect detection. The principle of operation of the food biosensor sensor is shown in figure 2

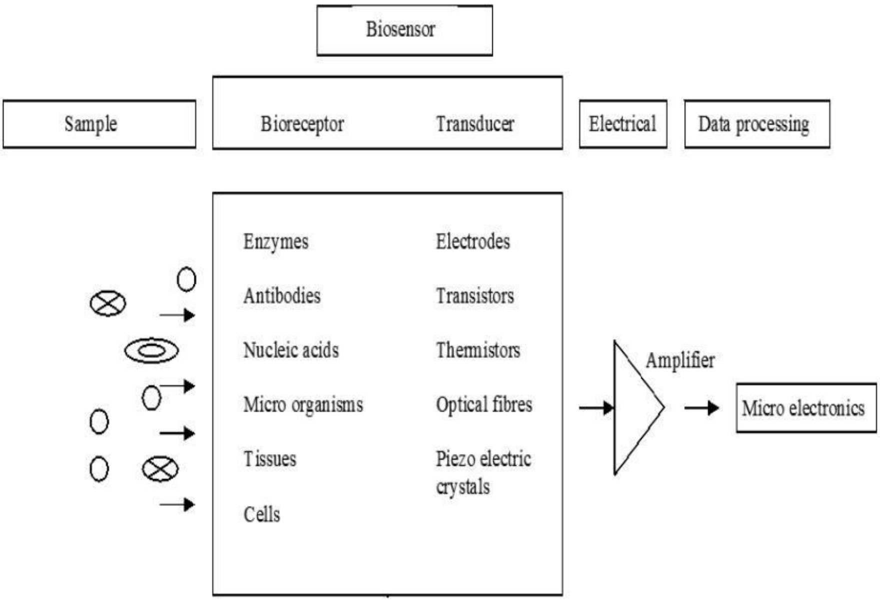

Fig.2. Food biosensors in operation

Direct detection

Specific responses are measured directly in real time by registering the physical changes caused by complex formation.

Optical biosensors

Optical biosensors detect bacteria directly as changes in refractive index when cells bind to receptors immobilized on the transducer. Optical biosensors are elastometric or piezoelectric, e.g., Ewascent wave interferometer.

Bioluminescent biosensors

A cell is genetically modified by introducing a reporter gene. Its expression is regulated by a receptor or regulatory protein. When an analyte enters this cell, it binds to the protein receptor. This process activates the expression of the reporter gene with the synthesis of mRNA and hence the reporter protein: its detection triggers an analytical signal.

Electrical impedance biosensors

Such biosensors are capable of measuring the electric charge in direct and alternating currents, and are also able to measure adhesively growing cells on the structure of the created electrode, cell density and growth.

Fluorescent biosensors

A fluorescent biosensor is capable of measuring signals, fluorescence, chemiluminescence, colorimetric, electrochemical, or magnetic waves. Fluorescence detection is currently the most popular biomolecular imaging technique: in addition to its excellent temporal and spatial resolution, it is cheap, highly sensitive, and selective [5].

Microbial biosensors

Microorganisms use the oxidoreductase reaction to convert their metabolic redox reaction into a quantification of electrical signals.

Flow immune sensors

Many microbial assays are based on ELISA, i.e., an enzyme-linked immunosorbent assay: they use microtiter plates after the chromogenic reaction is completed. The quantification involves an ELISA reader, e.g., detecting E. coli8 [5].

4 Conclusion

Biosensors are used in many areas, such as medicine, agriculture, and environmental science. Modern medical diagnostics relies on highly advanced sensors. However, the food industry also needs such fast tools to provide food quality control. While traditional methods remain expensive and labor-intensive, sensors speed up the test process and reduce its cost. Materials science, microprocessing, and nanotreatment are other prospective areas of biosensor application that will contribute to the development of sampling procedures, such as extraction or concentration [6]. Sensors of the future will probably combine multi-analyte detection with remote sensing.

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