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BIOSENSORS USED IN THE FOOD INDUSTRY

Abstract: *Food safety is one of the most pressing issues directly related to ensuring public health and welfare in any state. The article is devoted to biosensors used in the food industry. Biosensors are devices used to analyze and diagnose substances by converting a biological response into a signal. Depending on the type of biomaterial, there are biosensors based on enzymes, microbial cells, tissue cultures, DNA, immunocomponents, and organelles. Biosensors and analytical procedures based on them have long gone beyond the scope of laboratory research and have occupied a stable niche in everyday practice. Biotechnology, food industry, medicine, ecology – this is not a complete list of possible areas of their application for civilian purposes.*

Potentially, biosensors are capable of performing sensitive and specific detection of harmful effects, which in general determines the prospects for the development of this direction. An analysis of various detection methods, parameters and types of the described biosensors and the possibility of their practical use are given in the review.

Key words*: Food safety, biosensors, biomaterial, enzymes, food control.*

Food safety is one of the most pressing issues directly related to ensuring public health and welfare in any state.

Currently, there are many methods for analyzing food products for the content of certain toxic substances, or for detecting the excess of their maximum permissible concentration in products. Most of them have disadvantages, which are the high cost of research, mandatory sample preparation, the duration of obtaining results, and the need for analysis directly in the laboratory.

All this makes it necessary to search for and modernize methods for testing food products for the content of controlled toxic substances.

One of the promising directions in this area is the development of biosensors. To date, biosensor technologies are widely used in medicine, agriculture, ecology and other industries. Food control is a wide field for finding new methods based on the use of biosensors, since you can find a biodetector for almost any analyte.

Biosensors are devices used to analyze and diagnose substances by converting a biological response into a signal. Depending on the type of biomaterial, there are biosensors based on enzymes, microbial cells, tissue cultures, DNA, immunocomponents, and organelles. To record the biosensor signal, electrochemical (ampero-, potentio- and conductometric), optical, calorimetric, and acoustic transducers are used, which record such parameters of biochemical reactions as the appearance of electrochemically active products, temperature changes, and enhancement or weakening of luminescence [1].

Biosensors make it possible to carry out continuous monitoring of biochemical processes in biotechnology, to determine the quality of food products, their composition, the content of toxins, antibiotics, and to carry out environmental monitoring.

Enzyme biosensors have found wide application in monitoring low molecular weight compounds such as glucose, amino acids, and antibiotics. Immunosensors are actively used to determine pesticides, toxins, pathogenic bacteria in food products.

It is promising to use cells of microorganisms as a biological material in biosensors, because they are available, cheap, easy to cultivate and maintain in pure culture. To date, microbial sensors are known for the determination of alcohols, sugars, organic acids, antibiotics, and inorganic compounds (ammonia, nitrates, nitrites, sulfides, sulfates, phosphates) [2, 3].

Scientists have developed and are using an amperometric type biosensor integrated with a personal computer. The sensors in this setup are oxygen electrodes with immobilized yeast preparations of alcohol oxidase and glucose oxidase. The equipment used allows high-precision measurements in the nanoampere range of currents and the use of small amounts of biomaterial. Signal processing in the setup is performed using specialized IPC software (Kronas , Russia). Biosensor analyzers of the amperometric type have been developed for the analysis of the content of ethanol, glucose and starch in fermentation intermediates, and their characteristics have been determined. Scientists have found that a biosensor based on the enzyme glucose oxidase allows the analysis of glucose in the range of 0.5-2.5 mm , and a biosensor based on alcohol oxidase allows the analysis of ethanol in the range of 0.7-12.3 mm [4].

Among the various electrodes used in biosensor technologies, an important place is occupied by printed graphite electrodes. They have the advantages of compactness, versatility, low cost and the possibility of modification. All this makes it possible to create on their basis various biosensors suitable for industrial production.

The determination of starch content by the biosensor method is carried out using a bienzymatic receptor element, which includes glucose oxidase and amylase (GO+Am). In the literature, there are examples of the development of biosensors of this type [5], but there are not so many of them. The advantages of printed electrodes are fully manifested when several biosensors are combined into a single analytical system capable of simultaneously determining the content of several components of fermentation media. It is this problem, traditionally difficult for physicochemical methods of analysis, that can be successfully solved using biosensors. As for biosensor systems for the selective analysis of the composition of multicomponent samples, such systems are still quite rare. A system of amperometric biosensors is known that allows simultaneous selective determination of glucose and lactate using a flow-injection system that includes an electrode with immobilized glucose oxidase and lactate oxidase [6]. A system of amperometric biosensors for the analysis of ethanol, lactate and glucose in wine samples has been described (operating ranges are 0.3-20 mm for ethanol, 0.04-2.5 mm for glucose, and 0.008-1 mm for lactate) [7].

There is an enzymatic conductometric biosensor for the determination of lactose. The bioselective element is a trienzyme membrane (glucose oxidase ,mutarotase, β-galactosidase) immobilized on the surface of a conductometric transducer. The time for determining the lactose concentration in a solution by this biosensor is 1-2 min, the linear range of the biosensor operation is from 0.01 mm to 0.75 mm for glucose and from 0.01 mm to 1.25 mm for lactose. The scientists studied the dependence of the biosensor response to the introduction of the substrate on pH, ionic strength and buffer capacity of the working solution and presented data on the selectivity of the biosensor and its stability during storage. This conductometric biosensor is characterized by high operational stability and signal reproducibility.

As a conductometric transducer, the scientists used a differential pair of planar gold comb electrodes deposited on a glass-ceramic lining. The role of the bioselective element was performed by a three- enzyme system (invertase, mutarotase, glucose oxidase) immobilized on the transducer surface. The developed biosensor was characterized by high signal reproducibility . The optimal concentration of sucrose for inhibitory analysis was 1.25 mm , the incubation time in the test solution was 10-20 min. The biosensor was characterized by the highest sensitivity to Hg 2+ and Ag + ions. The principal possibility of biosensor reactivation with an EDTA solution after inhibition with silver ions or with a cysteine solution after inhibition with mercury ions is shown. The results of the analysis of real water samples positively correlated with the results of traditional methods for the determination of toxicants [8].

Potentially, biosensors are capable of performing sensitive and specific detection of harmful effects, which in general determines the prospects for the development of this direction. An analysis of various detection methods, parameters and types of the described biosensors and the possibility of their use in military practice are given in the review. The expediency of using biosensor sensors in military practice is due to the following considerations:

– it is possible to develop systems for early warning of the use of chemical or biological weapons;

– biosensors for the detection of biological and chemical weapons can be based on enzymes, antibodies and tissue material, which makes it possible to imitate the complex functions of multicellular human organs and evaluate the damaging effect with high sensitivity;

– advantages of biosensor analysis include the possibility of detecting not only known, but also previously unused substances;

– biosensors make it possible to distinguish physiologically active substances from inactive chemical compounds;

– small size and compactness of analyzers [9].

Describing the biosensor as an analyzing system, let us briefly note the main functions of the biomaterial. Biological material can be paired with various types of transducers that provide the most efficient signal recording when interacting with the analyzed compound.

In biosensors of the electrochemical type, in combination with potentiometric electrodes, enzymes, receptors, microorganism cells, plant and animal tissues, enzyme-labeled antibodies are used. In combination with amperometric electrodes, it is known to use enzymes, microorganisms, plant and animal tissues, antibodies labeled with enzymes.

Optical types of biosensors are based on the measurement of fluorescence, luminescence, surface plasma resonance effects, evanescent waves.

In biosensors based on acoustic transducers, it is known to use antibodies, antigens, enzymes, and nucleic acids.

Measurement of the amount of heat released during the interaction of the analyzed compound with the bioreceptor material is used in calorimetric type biosensors; the basis of the bioreceptor can serve as enzymes, cells of microorganisms, animals. For further acquaintance with biosensors of various types, one can refer to monographs [10].

There are a huge number of principles for classifying biosensors, which depend on:

– The nature of the biochemical component.
– Analytical tasks.
– Signal converter.
– Areas of potential application.
– Features of the generated signal.

The most common classification is as follows:

According to the biochemical component:

– sensors based on cellular tissues and microorganisms;
– DNA sensors;
– immunosensors ;
– enzyme sensors;
– sensors based on supramolecular cellular structures;

By the method of measuring the signal;

– physical;
– optical;
– electrochemical;
– hybrid;

On signal;

– stationary (equilibrium);
– dynamic (kinetic);

By area of application;

– food industry;
– biotechnology;
– the medicine;
– ecology.

Classification by biochemical component:

Enzyme sensors involve biological enzyme preparations that exhibit a specific biological activity.

Immunosensors use immunoglobulins as a biochemical receptor – these are protective proteins that are secreted by the body's immune system in response to exposure to foreign biological compounds (antigens). DNA sensors include nucleic acids (DNA) as a biochemical component.

Microbial sensors involve microorganisms that are able to carry out the transformation of a certain substance with the help of enzymes.They differ from enzyme sensors in that during the transformation of the substrate, a combination of enzymes can be used, and not just one.

Biosensors based on supramolecular cell structures are in an intermediate position between DNA sensors, enzyme and microbial sensors, since they are based on intracellular structures that have a very complex hierarchical structure.

Classification by measurement method:

Electrochemical biological sensors operate on the principle of measuring the electric current, which occurs due to the reduction or oxidation of electrochemically active substances on the working electrode, or on measuring the potential difference between the reference electrode and the working electrode at direct current.

Piezoelectric devices are sensitive to changes in mass, density on the surface of a physical carrier, as well as the frequency of acoustic waves and the viscosity of the medium.

Optical sensors respond to physical-optical parameters, and not to the chemical interaction of the component with the sensing element. It can be absorption intensity, object luminescence, light reflection and so on.

Any biosensors constructively represent a combined device, which consists of two fundamental functional elements: physical and biochemical, they are in close contact.

Biochemical element is represented by a bioselective structure, which acts as a biological recognition element. All types of biological structures can be used as it: nucleic acids, receptors, antibodies, enzymes, and even living cells.

The physical signal converter converts the determined component, i.e. the concentration signal , into an electrical one. For the purpose of reading and writing information, electronic amplification systems are used, as well as signal registration.

The principle of operation of the device is quite simple:

At the first stage of the device operation, the bioelement «recognizes» a specific substance contained in a multicomponent mixture.

At the second stage, information about the course of a particular biochemical reaction is converted into the form of an electrochemical signal.

The electrical signal at the last stage from the transducer is converted into a waveform that is acceptable for processing [11].

These are a kind of detectors, the action of which is based on the specificity of molecules and cells. They are used to measure and identify the amount of the smallest concentrations of a wide variety of substances. When a biological component is bound to the desired substance, the transducer generates an optical or electrical signal, the power of which is proportional to the concentration of the substance. Thus, in enzymatic devices, the analyte diffuses through a semipermeable membrane into a thin layer of a biocatalyst, where the enzymatic reaction takes place. Since the product of the enzymatic reaction in this case is determined using an electrode on the surface of which there is an enzyme, such a device is often called an enzyme electrode. In microbial sensors consisting of immobilized microorganisms, as well as an electrochemical sensor, the principle of operation is the assimilation of organic compounds by microorganisms. This action is recorded by electrochemical sensors.

References

1. Тернер Э., Карубе И., Уилсон Дж. Биосенсоры: основы и приложения. – М.: Мир, 1992. – 614 с.

2. Toward the development of smart and low cost point-of-care biosensors based on screen printed electrodes / M. U. Ahmed, M. M. Hossain, M. Safavieh [et al.] // Critical reviews in biotechnology. – 2016. V. 36. – P. 495- 505.

3. Sato N., Okuma H. Development of single-wall carbon nanotubes modified screen-printed electrode using a ferrocene-modified cationic surfactant for amperometric glucose biosensor applications // Sens. Actuators B. 2008. V. 129. – P. 188-194.

4. Абашкина С.С., Каманин С.С., Арляпов В.А. Биосенсорные анализаторы для определения содержания этанола, глюкозы и крахмала в бродильных средах. // Материалы III Международной студенческой научной конференции «Студенческий научный форум» / <p> БИОСЕНСОРНЫЕ АНАЛИЗАТОРЫ ДЛЯ ОПРЕДЕЛЕНИЕ СОДЕРЖАНИЯ ЭТАНОЛА, ГЛЮКОЗЫ И КРАХМАЛА В БРОДИЛЬНЫХ СРЕДАХ // Материалы III Международной студенческой научной конференции «Студенческий научный форум» URL: https://scienceforum.ru/2011/article/2011000924?ysclid=lemb0pw65u168263725 (дата обращения: 16.02.2021).

5. Co-immobilization of glucoamylase and glucose oxidase for electrochemical sequential enzyme electrode for starch biosensor and biofuel cell / Q. Lang, L.Yin, J. Shi [et al.] //Biosensors and Bioelectronics. 2014. V. 51. P. 158-163.

6. Simultaneous monitoring of glucose and L-lactic acid during a fermentation process in an aqueous two-phase system by on-line FIA with microdialysis sampling and dual biosensor detection / R. W. Min, V. Rajendran, N. Larsson [et al.] // Analyticachimicaacta. – 1998. V. 366. – № 1–3. P. 127–135.
7. Goriushkina T. B., Soldatkin A. P., Dzyadevych S. V. Application of amperometric biosensors for analysis of ethanol, glucose, and lactate in wine // Journal of Agricultural and Food chemistry. 2009. V. 57. – P. 6528-6535.
8. Пешкова В.М.,Саяпина О.Я., Солдаткин О.О., Кукла О.Л., Дзядевич С.В. Ферментный кондуктометрический биосенсор для определения лактозы [Электронный ресурс] https://cyberleninka.ru/article/n/fermentnyy-konduktometricheskiy-biosensor-dlya-opredeleniya-laktozy/viewer (дата обращения 12.01.2021).
9. Paddle B.M. Biosensors for chemical and biological agents of defense inferest // Review article. Резюме. Biosensors and Bioelectronics, 1996, v. 11. – № 11.
10. Libby J.M., Wada H.G. Detection of Nesseria meningitidis and Yersinia pestis with a novel silicon-based sensor/ / J. Clin. Microbiol. 1989, № 27.
11. Starodub N.F., Arenkov P.Y., Starodub A.N. & Berezin V.A. Construction and biomedical application of immunosensors based on fiber optics and enhanced chemiluminescence // Opt. Eng., 1994. – № 33.

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БИОСЕНСОРЫ, ПРИМЕНЯЕМЫЕ В ПИЩЕВОЙ ПРОМЫШЛЕННОСТИ

Аннотация: *Безопасность пищевой продукции – одна из наиболее актуальных проблем, напрямую связанная с обеспечением здоровья населения и благосостояния в любом государстве. Статья посвящена биосенсорам применяемым в пищевой промышленности. Биосенсоры представляют собой устройства, используемые для анализа и диагностики веществ путем преобразования биологической реакции в сигнал. В зависимости от типа биоматериала различают биосенсоры на основе ферментов, микробных клеток, тканевых культур, ДНК, иммунокомпонентов и органелл. Биосенсоры и аналитические процедуры на их основе уже давно вышли за рамки лабораторных исследований и заняли устойчивую нишу в повседневной практике. Биотехнология, пищевая промышленность, медицина, экология – далеко не полный перечень возможных областей их применения в гражданских целях.*

Потенциально биосенсоры способны выполнять чувствительную и специфическую детекцию вредных воздействий, что обусловливает в целом перспективность развития данного направления. Анализ различных методов детекции, параметров и типов описанных биосенсоров и возможности их использования в практике приведены в обзоре.

Ключевые слова: *Безопасность пищевых продуктов, биосенсоры, биоматериалы, ферменты, пищевой контроль.*

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ТАҒАМ ӨНДІРІСІНДЕ ҚОЛДАНЫЛАТЫН БИОСЕНСОРЛАР

Аңдатпа: *Азық-түлік қауіпсіздігі кез келген мемлекетте халықтың денсаулығы мен әл-ауқатын қамтамасыз етумен тікелей байланысты ең өзекті мәселелердің бірі болып табылады. Мақала тамақ өнеркәсібінде қолданылатын биосенсорларға арналған. Биосенсорлар – биологиялық жауапты сигналға түрлендіру арқылы заттарды талдау және диагностикалау үшін қолданылатын құрылғылар. Биоматериал түріне қарай ферменттерге, микроб жасушаларына, ұлпа дақылдарына, ДНҚ-ға, иммунокомпоненттерге және органеллаларға негізделген биосенсорлар бар. Биосенсорлар және оларға негізделген аналитикалық процедуралар зертханалық зерттеулердің шеңберінен әлдеқашан шығып кетті және күнделікті тәжірибеде тұрақты орынды иеленді. Биотехнология, тамақ өнеркәсібі, медицина, экология – бұл азаматтық мақсатта оларды қолданудың ықтимал салаларының толық тізімі емес.*

Потенциалды түрде биосенсорлар зиянды әсерлерді сезімтал және спецификалық анықтауды орындауға қабілетті, бұл жалпы алғанда осы бағыттың даму болашағын анықтайды. Шолуда әртүрлі анықтау әдістеріне, сипатталған биосенсорлардың параметрлері және оларды тәжірибеде пайдалану мүмкіндігіне талдау берілген.

Түйін сөздер: *Азық-түлік қауіпсіздігі, биосенсорлар, биоматериалдар, ферменттер, тағамдық бақылау.*

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COMPACT VIDEO SURVEILLANCE AND SECURITY SYSTEM BASED ON A SINGLE-BOARD MULTI-PURPOSE COMPUTER

Abstract: *Ensuring the security of facilities today is a priority for many companies and manufacturing enterprises. Security video surveillance systems carry out constant monitoring of any residential, office space, as well as industrial facilities and the territories adjacent to them. Despite the wide variety of security systems and complexes currently on the market, a very small part may well be relevant for use in apartments and small offices for a number of reasons, including financial ones. The solution that is proposed in this article, in fact, provides for the possibility of using those hardware components that were originally involved in solving a different range of tasks. So, for example, the functions of the security system could be taken over by a multimedia server, which is used at home for storing and distributing videos, musical compositions and photographs.*

Key words: *single-board computer, security system, video surveillance, video sequence, browser.*

Hardware configuration. The single-board computer of the “Raspberry” family, or rather one of its latest modifications “2B”, was not chosen by chance as the central link of the system. It is relatively easy to operate, has 4 "Cortex A7" cores with a frequency of 900 MHz, which is quite enough for the problem being solved, 1 GB of RAM and, not least, 4 USB ports. In addition, it is