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Biosensor: An Emerging Tool for the Diagnosis of Animal Diseases

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Abstract

Infectious diseases caused by microbes are important causes of morbidity as well as mortality in humans and animals worldwide. A biosensor is an analytical instrument with a bio-recognition factor immobilized on its surface and linked to a transducer that transmits and interprets the signal. Many biotechnological breakthroughs have resulted in the development of biosensors for bacterial and viral detection and tracking over the last three decades. Some antibody-based biosensors for detecting viral pathogens of veterinary significance have been developed using electrochemical and optical transducers. The principle of a biosensor is based on the detection of a biomarker molecule in the clinical sample. Since biosensors have been demonstrated to be an efficient analytical tool for animal disease detection, meat quality control, and milk quality control, this application is of great relevance in the veterinary field.

Keywords: Animal Health; Biosensor; Infectious Disease; Microbes; Veterinary Significance

Introduction

Microbes, which are ubiquitously prevalent in our environment, are responsible to affect the health of animals and humans by causing infections and diseases [1]. The health of animals plays a vital role as it affects the country's economy as well as health of the people [1]. Since the 1990s, when researchers in Gary Sayler's laboratory engineered the first genetically modified microbial biosensor, the field of bio reporters or biosensors has evolved exponentially. When exposed to carcinogenic and toxic substances, a broad variety of biological materials produce a measurable signal through a suitable transducer, which is referred to as a biosensor [2].

A biosensor is an analytical system that has a bio-recognition factor (enzymes, hormones, nucleic acid, and cells) immobilized on the surface of a sensor that is connected to a transducer that transmits and interprets the signal. Biosensors are made up of two parts: a bio-recognition element or a bio-receptor that recognizes the desired analyte and a transducer that produces a digital electronic signal proportional to the concentration of a particular analyte [3].

Updike and Hicks are credited to publish the first enzyme-based sensor in 1967. Enzyme biosensors have been developed based on immobilization methods, such as enzyme adsorption via van der Waals forces, ionic bonding, or covalent bonding. Oxidoreductases, polyphenol oxidases, peroxidases, and amino oxidases are some of the most widely used enzymes for this function. Furthermore, viral infections in animal populations pose global public health threats such as intermittent human zoonotic infections or the development of a pandemic viral strain. Animals are believed to be the source of more than 70% of all emerging infections [4].

Virus replication and separation from culture are traditional approaches for viral detection. These methods are efficient and responsive, but they are also expensive, labor-intensive, and time-consuming (typically, results are available in 2–10 days). Alternative molecular methods based on polymerase chain reaction (PCR), real-time polymerase chain reaction (RT PCR) are more specific, sensitive, and take less time, but they require isolated genetic materials, careful manipulation, and specialized equipment, making them unsuitable for on-site monitoring. As a result, developing a valid diagnostic assay with high sensitivity and selectivity for rapid pathogen detection and identification is a challenge for researchers all over the world [5].

Several biotechnological breakthroughs in the last 30 years have resulted in biosensors for bacterial and viral detection and tracking. Some emerging systems have yielded promising prototypes that achieved rapid pathogen detection without requiring extensive sample manipulation, which is inconvenient for contaminated samples. Different animal infectious disease biomarkers (as proteins, DNA, and RNA) are widely used in biosensing technologies, especially for virus detection [6]. The present communication delineates the growing importance of biosensors in diagnosis of infectious diseases of animals.

Principal of Biosensing Technology

A biosensor recognizes a target biomarker, which is specific to a pathogen, using an immobilized sensing element known as a bioreceptor (monoclonal antibody, RNA, DNA, glycan, lectin, enzyme, tissue, and whole-cell) [7]. The bio-receptor is an important component because its biochemical properties ensure high sensitivity and selectivity of biomarker detection and allow for the avoidance of interferences from other microorganisms or molecules present in the tested sample. The transductor transforms the unique biochemical interaction between the biomarker and the bio-receptor into an observable [6].

The development of a biosensor for pathogen detection faces two major challenges: (i) developing a bioassay for biomarker detection, and (ii) improving the robustness of the bioassay to adapt it for applications in the field and/or on complex biological samples [7]. Many bioassays that work well on the bench with purified biomarker molecules fail to detect them in complex media, such as blood or serum. Furthermore, diagnosis of infectious diseases necessitates high sensitivity because pathogens will spread quickly before any clinical sign occurs in animals [8].

Biosensors in Diagnosis of Animal Diseases

The viruses and bacteria are the living microbes that may be harmful to humans as it may sometimes cause life threatening disease [1]. They are commonly dispersed in food and the atmosphere, and they enter the human gastrointestinal tract through the ingestion of infected food [9]. Many of these microbs are important to life; however, some of them are pathogenic and harm human health because they can cause infections and several diseases. Any of these microorganisms can survive harsh environmental conditions, causing serious diseases with a high fatality rate [10].

Several antibody-based biosensors have been developed for the detection of veterinary viral pathogens, such as avian influenza virus (AIV) subtype H5N1, bovine viral diarrhea virus (BVDV), rabies virus, duck hepatitis virus serotype 1 (DHV1), foot and mouth disease virus (FMDV), infectious bursal disease virus (IBDV), porcine totavirus using optical transducers, Coxsackie virus B4 using mass-based transducers, and swine-origin influenza virus (S–OIV) subtype H1N1 using electrochemical and optical transducers [11].

The detection of pathogen by biosensing approaches are focused on four fundamental physiological or genetic properties of microorganisms: metabolic patterns of substrate use, phenotypic expression analysis of signature molecules by antibodies, nucleic acid analysis, and analysis of pathogen interactions with eukaryotic cells [12]. The biosensor has the benefit of producing more specific and responsive results in a shorter period. It can also be used for a wide range of analytes and in complex sample matrices (such as blood, serum, urine, or food) with minimal sample pre-treatment [13].

The pathogen identification is very imperative, primarily for the health and safety purposes. The traditionally based methods like culture and colony counting processes, polymerase chain reaction technique, and immunology-based procedures are the most widely used pathogen detection techniques [14]. They are DNA analysis, bacterial counting, and antigen-antibody interactions, in that order. Despite drawbacks, such as the time taken for research or the sophistication of their application, they still reflect an area in which progress is possible. Biosensors are analytical instruments that contain a biological material that is inextricably linked to or integrated into a physicochemical transducer or transducing microsystem that may be optical, electrochemical, thermometric, piezoelectric, magnetic, or micromechanical [13].

Eshcherichia coli, Salmonella typhi, Clostridium perfringens, and *Shigella* spp. are examples of common pathogenic bacteria that can cause many diseases in humans as well as in animals including poultry [1]. However, *Staphylococcus aureus* is regarded as one of the most lethal bacteria, capable of causing fatal infections in a matter of minutes, and is often immune to several antibacterial active substances [11,15].

As a result, new approaches for easier and faster detection are needed, since traditional culture methods take 3–5 days to produce results, and other nucleic acid-based methods are costly and require qualified personnel [16]. Antibody based biosensors employ antibody as a bio-recognition element and herein we will be focusing only on them as they are well suited for the development of point of care diagnostics and on site diagnostics [10].

Conclusion and Recommendations

Biosensors can be proved as an efficient analytical tool for animal disease diagnosis, and quality control of meat, and milk. This review summarizes the present developments in the field of veterinary science. Since the inception of biosensors, its commercialization in the field of pathogen detection for the diagnosis of animal diseases is still lacking. The advantage of the biosensor is that it offers higher specific and sensitive results in a quick time. Lots of laboratory work has been done on the development of biosensors for the detection of veterinary viral pathogens but hardly any find its market value and it can be concluded that biosensing for veterinary pathogens is still a distant dream. As biosensors are fast, simple, have an on-site application and cost. Based on the above conclusion, the following recommendation was provided:-

- Biosensors can be proved as an efficient analytical tool for animal disease diagnosis, quality control of the meat, and milk, hence, this should be practiced widely in veterinary field.
- A lot of researches had been done in the biosensor, in case of medical field especially in food microbiology. However, it is not well studied or exploited in the case of veterinary field; therefore, additional research on biosensor on the application in veterinary medicine must be conducted.

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Contribution of Authors

All the authors contributed equally. They read the final version, and approved it for the publication.

Conflict of Interest

The authors declare that they do not have conflict of interest.

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