VETERINARY TODAY
INTERNATIONAL
ISSN 2583-8288

Basics of Application of Biosensors in Veterinary Medicine

Anindita Sandilya[1], Udipta Bhuyan[1], Chandramita Das[1]
[1]Veterinary Officer, Animal Husbandry & Veterinary Department, Govt. of Assam

DOI:10.5281/Vettoday.15743506

Abstract

Biosensors have emerged as a transformative technology in veterinary medicine, offering rapid, sensitive, and specific detection of pathogens, biomarkers, and contaminants relevant to animal health and food safety. These analytical devices integrate biological recognition elements with physicochemical transducers to convert biorecognition events into measurable signals. Recent technological advances have enhanced biosensor performance, enabling point-of-care diagnostics, real-time monitoring, and multiplex detection. In veterinary practice, biosensors are applied across a broad spectrum of areas, including disease diagnosis, metabolic and reproductive health monitoring, animal welfare assessment, and the detection of foodborne pathogens and veterinary drug residues in animal-derived products. Electrochemical, optical, piezoelectric, and thermal biosensors, coupled with various bioreceptors such as enzymes, antibodies, and nucleic acids, have been developed to identify a wide range of bacterial, viral, and parasitic agents. As biosensor technologies continue to evolve, they are expected to play an increasingly vital role in improving diagnostic precision, enhancing animal health and welfare, and ensuring the safety of the food supply chain.

Introduction

Veterinary medicine has witnessed significant advancements in diagnostic technologies, which have substantially enhanced animal health and welfare. Among these innovations, biosensors have emerged as a powerful platform for the rapid, sensitive, and specific detection of diverse biological markers. A biosensor integrates a biological recognition element such as enzymes, antibodies, or nucleic acids with a physicochemical transducer to convert a biological interaction into a quantifiable electrical signal. The miniaturization of components, reduction in manufacturing costs, and enhanced data processing capabilities have collectively advanced the analytical potential of these devices. Biosensors are characterized by high specificity, ease of use, minimal sample requirements, rapid response times, accuracy, stability, and the ability to deliver real-time, on-site results.

Basics of Biosensor Technology

Biosensors consist of three main components: the bioreceptor, the transducer, and the signal processor. The bioreceptor is the biological element that interacts specifically with the target analyte. Common bioreceptors include enzymes, antibodies, nucleic acids, and whole cells. The transducer converts the biorecognition event into a measurable signal, which is subsequently processed into a user-readable output.

Biosensors can be classified based on the type of bio-receptor or transducer used. These are classified based on methods of detection. Biosensors namely electrochemical, piezoelectric, optical, acoustic, calorimetric etc. are included in the preliminary stage of categorization, which itself is based on signal output. Electrochemical biosensors, which measure changes in electrical properties such as current, potential, or impedance resulting from the interaction between the bioreceptor and the analyte. Optical biosensors detect changes in light properties such as absorption, fluorescence, or refractive index upon analyte interaction. Piezoelectric biosensors detect changes in mass or acoustic waves resulting from the binding of the analyte to the bioreceptor. Thermal biosensors measure changes in heat production or absorption during the biorecognition event. Enzymatic, immunological, microbiological, and cellular biosensors are all included in the second tire of categorization based on the method of detection. The operation of biosensors involves several key mechanisms, including affinity binding, which is based on the specific binding between an antibody and an antigen or between nucleic acids (e.g., DNA-DNA hybridization). Catalytic activity involves the use of enzymes that catalyze specific reactions, producing detectable products. Molecular recognition refers to the specific interaction between molecules, such as the binding of receptors to ligands.

Recent Advancements in Biosensor Technology

Recent advancements in biosensor technology have focused on improving sensitivity, specificity, and portability. The use of nanomaterials, such as nanoparticles, carbon nanotubes, and nanowires, has significantly improved biosensor performance by increasing surface area and electrical conductivity, thereby lowering detection limits. The integration of microfluidic systems allows for the manipulation of small fluid volumes, enabling high-throughput analysis and point-of-care (POC) testing. The emergence of wearable biosensors designed for continuous monitoring of physiological parameters in animals offer real-time data on health status. Lab-on-a-chip systems, which integrate multiple laboratory functions on a single microchip, have enabled rapid and multiplexed detection of analytes.

Applications of Biosensors in Veterinary Medicine

Biosensors have a wide range of applications in veterinary medicine, including disease diagnosis, health monitoring, and food safety. Biosensors have emerged as valuable tools in disease diagnostics, enabling the rapid and sensitive detection of a wide range of pathogens, including bacteria, viruses, and parasites, thereby facilitating timely diagnosis and appropriate therapeutic intervention. Electrochemical biosensors, for instance, have been engineered for the detection of Brucella spp., a pathogen of major concern in livestock. Numerous antibody-based biosensors have also been developed to detect veterinary-relevant viral pathogens. These include devices employing electrochemical and optical transducers for the identification of Avian Influenza Virus (AIV) subtype H5N1, Bovine Viral Diarrhoea Virus (BVDV), Rabies Virus, and Swine-Origin Influenza Virus (S-OIV) subtype H1N1. Additionally, optical transducer-based biosensors have been utilized for the detection of Duck Hepatitis Virus serotype 1 (DHV1), Foot and Mouth Disease Virus (FMDV), Infectious Bursal Disease Virus (IBDV), and Porcine Rotavirus, while mass-based transducers have been applied in the detection of Coxsackie Virus B4. Biosensors can also monitor biomarkers associated with metabolic disorders, such as glucose and ketone levels, aiding in the management of diseases like diabetes in companion animals. Additionally, they can measure hormones such as progesterone and estradiol, helping in the monitoring of reproductive cycles and the management of breeding programs. In health monitoring, wearable biosensors can continuously monitor vital signs such as heart rate, respiration rate, and body temperature, providing real-time data on an animal's health status. Biosensors can also detect biomarkers of stress, such as cortisol, allowing for the assessment of animal welfare and the implementation of stress-reducing interventions. In the field of food safety, biosensors play a critical role in the detection of foodborne pathogens in animal-derived products, such as *Salmonella* spp. and *E. coli* O157:H7, thereby contributing to the protection of public health. Cell-based biosensor platforms have been employed for the detection of a variety of pathogens and toxins. Notably, piezoelectric immunosensors have been developed for the specific identification of *Vibrio cholerae, Candida albicans, Salmonella typhimurium,* and *Listeria monocytogenes*. In addition to pathogen detection, biosensors are also utilized to monitor the presence of veterinary drug residues, particularly antibiotics, in animal products such as milk, thereby ensuring compliance with food safety standards and regulatory guidelines.

Challenges and Future Prospects

Despite their immense potential, the application of biosensors in veterinary medicine faces several challenges. Achieving high sensitivity and specificity is crucial for accurate diagnosis, and interference from complex biological matrices can affect sensor performance. The lack of standardization in biosensor design and validation can hinder their widespread adoption in veterinary practice. High costs associated with the development and production of biosensors can limit their accessibility, especially in resource-limited settings. Additionally, obtaining regulatory approval for new biosensor technologies can be time-consuming and complex.

The future of biosensors in veterinary medicine looks promising, with ongoing research focusing on addressing current challenges and exploring new applications. Development of biosensors for personalized health monitoring and tailored treatment plans in veterinary patients is an area of interest. Integration of biosensors with telemedicine platforms can provide remote monitoring and consultation services. The use of biosensors to monitor environmental contaminants and their impact on animal health is another potential application. Exploration of advanced materials, such as graphene and quantum dots, can enhance biosensor performance and expand their capabilities.

Conclusion

Biosensors represent a transformative innovation in veterinary diagnostics, offering rapid, sensitive, and specific diagnostic capabilities. Recent advancements in nanotechnology, microfluidics, and wearable devices have further enhanced their potential applications. While several challenges remain, ongoing research and development efforts are paving the way for the broader adoption of biosensors in veterinary practice. As the technology continues to evolve, biosensors are poised to play a critical role in improving animal health and welfare, ensuring food safety, and advancing veterinary medicine.

References

Bhalla, N., Jolly, P., Formisano, N., & Estrela, P. (2016). Introduction to biosensors. *Essays in Biochemistry*, 60(1), 1-8.

Damborsky, P., Svitel, J., & Katrlik, J. (2016). Optical biosensors. *Essays in Biochemistry*, 60(1), 91-100.

Dincer, C., Bruch, R., Kling, A., Dittrich, P. S., & Urban, G. A. (2017). Multiplexed point-of-care testing – xPOCT. *Trends in Biotechnology*, 35(8), 728-742.

Turner, A. P. F. (2013). Biosensors: sense and sensibility. *Chemical Society Reviews*, 42(8), 3184-3196.

Hnaiein, M., Boujday, S., & Raouafi, N. (2019). Nanobiosensors: trends in health and environmental diagnostics. *Sensors and Actuators B: Chemical*, 293, 126-142.

Vasylieva, N., Maucler, C., Meiller, A., & Marinesco, S. (2015). Wearable biosensors for monitoring the physiological and pathological state of the body: present and future. *Frontiers in Bioengineering and Biotechnology*, 3, 63.

Zhang, A., & Lieber, C. M. (2016). Nano-bioelectronics. *Chemical Reviews*, 116(1), 215-257