Popular Article

Trends in Agriculutre Science

Vol.2 Issue 8 August 2023, Page: 692-697

Role of biosensors in livestock production management: A Review

Atul Singh Rajput[1] & Divya Rajawat[2]

[1]Livestock Production Management Section, [2]Division of Animal Genetic, ICAR- Indian Veterinary Research Institute, Bareilly, Uttar Pradesh - 243122, India

https://doi.org/10.5281/zenodo.8290674

Abstract

Biosensors serve as specialized monitoring tools designed to precisely measure a wide range of variables related to an animal's physiology and its surrounding environment. The integration of innovative biosensors in livestock management offers several benefits, including the ability to detect diseases, monitor health, regulate reproduction, and assess an animal's physiological state. These biosensors come in various types, such as enzyme-based, tissue-based, immune-sensors, thermal, and piezoelectric biosensors. They operate by identifying a specific target biomarker through a bioreceptor. The unique biochemical interaction between the biomarker and the bioreceptor is then transformed into a measurable signal by a transducer. This recorded signal is subsequently displayed, enabling both qualitative and quantitative identification of biomolecules.

Keyword: - Biosensors, Bio-receptor, Livestock, Health, Reproduction

1. Introduction

Biosensors serve as innovative tools within Precision Livestock Farming, combining biochemical molecules with physical signals to provide indications. These devices offer speed, sensitivity, selectivity, affordability, and portability in various procedures, presenting themselves as promising alternatives to conventional techniques (Newman et al., 2005). The interaction between biomarkers and bioreceptors is translated into measurable signals through a transduction system, subsequently presented as a readout. These biosensors boast specificity, sensitivity, reliability, and user-friendliness, expediting monitoring processes. In the realm of livestock management, emerging biosensors offer substantial advantages, aiding in disease detection, health monitoring, reproductive cycle tracking, and assessment of animal well-being via environmental analysis (Singh et al., 2020).

The integration of biosensors with systems such as the Internet of Things holds the promise of making continuous monitoring devices more accessible. The data harnessed from comprehensive livestock monitoring is poised to empower farmers and the agricultural industry to enhance animal productivity. As biosensors advance, they are positioned to play a pivotal role in the agricultural 4th revolution. By amalgamating innovative technologies into cost-effective diagnostic approaches, these biosensors can effectively mitigate the potentially disastrous consequences of infectious outbreaks in livestock.

2. Components and working principle of biosensors

Biosensors consist of three essential components: a biological element, a transducer, and a signal processing system. The biological element is designed to strongly bind with target molecules, which can include microorganisms, nucleic acids, enzymes, receptors, and antibodies. This element exhibits specific interaction with the desired compound for detection. The transducer functions as an intermediary, capturing the physical changes occurring at the bioreceptor and subsequently converting this energy into quantifiable electrical output. The signal processing system then amplifies and analyzes the signal originating from the transducer. These processed signals are directed to a microprocessor, where the data is converted into measurable units and subsequently conveyed to a display or stored in a data storage device (Pohanka *et al.,* 2008)

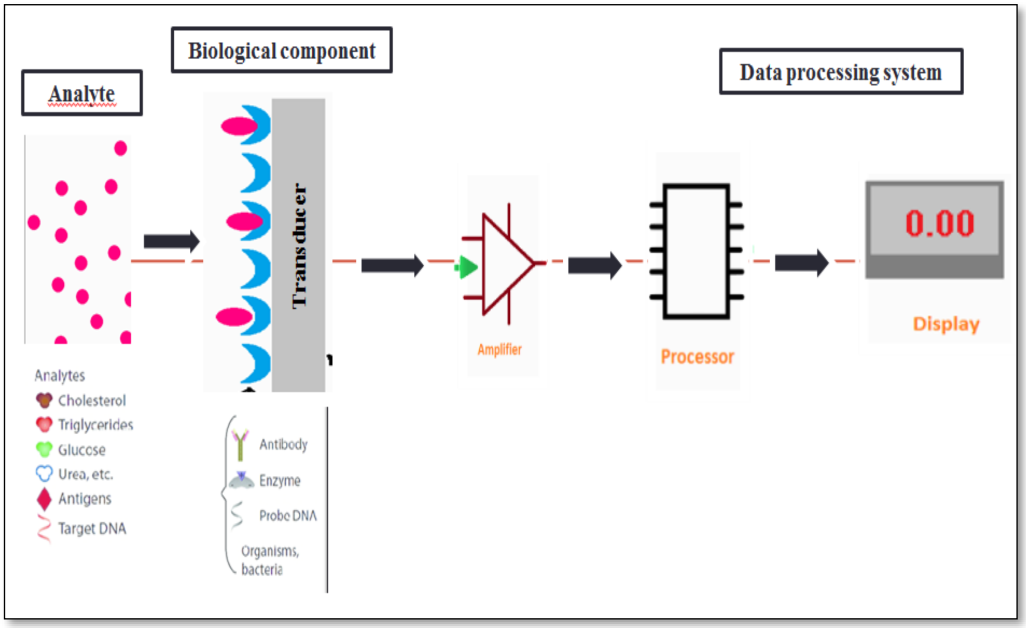

Figure 1 Working of biosensors

3. Types of biosensors

Electrochemical biosensors: These devices employ diverse electrochemical reactions to gauge alterations in the electrical attributes of the biological recognition component.

Piezoelectric biosensors: Functioning on the basis that modifications in mass due to a biochemical reaction led to frequency shifts in an oscillating quartz crystal.

Optical biosensors: Utilizing linear optical phenomena, such as fluorescence, phosphorescence, surface Plasmon resonance (SPR), and total internal reflection (TIR), to detect and quantify biochemical interactions.

4. Characteristics of a biosensor

Selectivity: Biosensors exhibit the ability to exclusively detect a particular analyte and refrain from responding to additional mixtures.

Precision: Biosensors demonstrate remarkable precision, ensuring accuracy across repeated measurements.

Sensitivity: Biosensors possess the capability to detect minute quantities of analytes within a sample.

Working Range: These sensors have the capacity to detect a broad spectrum of analyte concentrations, encompassing the operational span of the sensor.

Regeneration Time: Biosensors promptly regain their functional state after interacting with a sample, minimizing downtime.

5. Biosensors in livestock management

5.1 Biosensors for breath analysis

Breath metabolites encompass gases such as methane, hydrogen, and volatile organic compounds (VOCs), serving as biomarkers indicative of metabolic and pathological occurrences. These compounds hold potential as biomarkers for both metabolic and pathological processes. The utilization of volatile organic compounds (VOCs) for disease diagnosis presents a non-invasive approach. In the case of cattle, the analysis of VOCs has been investigated as a means to diagnose various conditions, including bovine respiratory disease, brucellosis, bovine tuberculosis, Johne's disease, ketoacidosis, and normal rumen physiology (Mottram et al., 1999).

5.2 Biosensors analysing metabolites in perspiration

These techniques have been employed to assess sodium concentration and lactate levels. In the realm of sweat analysis, flexible printed tattoos featuring electrochemical sensors are utilized to monitor animal sweat. Additionally, adhesive radio-frequency identification (RFID) sensor patches are employed, enabling potentiometric measurement of surface temperature and the evaluation of metabolites like glucose and lactate. Furthermore, these patches are capable of determining electrolyte composition, encompassing sodium and potassium ions. The acquired data can then be conveniently accessed and interpreted through a smartphone application (Rose *et al.,* 2015).

5.3 Biosensors for detection of ovulation

Breeding constitutes a fundamental aspect of livestock husbandry. Identifying the ovulation cycle in cattle holds paramount significance to ascertain the optimal timeframe for artificial insemination. Traditional estrus detection methods, reliant on visual observation, are both costly and inefficient. Ovulation biosensors tackle this challenge by identifying the progesterone hormone, a pivotal player in female reproductive functions. To achieve this, surface plasmon resonance imaging (SPRi) emerges as a label-free optical detection method. This technique is adept at monitoring an array of biomolecules present in both milk and blood samples, facilitating the precise detection of ovulation cycles. (Zeidan *et al.,* 2016).

5.4 Automated detection of mastitis

Mastitis stands as a significant infectious ailment with economic implications in dairy cattle. Within this context, catalase activity emerges as a potential bio-indicator for mastitis detection. This enzyme, catalase, permeates milk through somatic cells, leading to a direct correlation between its activity in raw milk and the somatic cell count. In cases of mastitis, the heightened catalase activity, induced by infective microorganisms, accelerates the breakdown of hydrogen peroxide added to milk. Biosensors play a pivotal role in determining the optimal hydrogen peroxide concentration to be introduced into milk samples and the requisite incubation period for effectively diagnosing infected milk (Neitzel *et al.,* 2014).

5.5 Biosensors for subclinical ketosis

Subclinical ketosis stands as a metabolic disorder linked to unfavorable energy balance in the transitional phase. Indicative of this condition, β-hydroxybutyrate (βHBA) serves as a marker. Within this context, diaphorase catalyzes the reaction between NADH and the colorimetric indicator WST-1, generating a formazan dye proportionate to the concentration of βHBA. The foundation of the biosensor relies on the ability of the ensuing complex to absorb ultraviolet light. As a result, the intensity of transmitted light signal is contingent upon the βHBA concentration present in the examined samples (Weng *et al.,* 2015).

5.6 Biosensors for salivary uric acid and cortisol

Deviant levels of uric acid are recognized as biomarkers for various disorders, including metabolic syndrome, renal dysfunction, and irregular purine metabolism. A sensor incorporating the urease enzyme leverages uric acid in saliva, which is subsequently quantified through an amperometric sensor. Meanwhile, salivary cortisol has proven to be an effective stress indicator for animals housed in confined settings. Employing a cortisol immunosensor, the current detected stems from a competitive

trendsinagriculturescience.com
trendsinagriculturescience@gmail.com

Published: 28 Aug 2023

reaction between cortisol within the sample and a glucose oxidase (GOD)-labeled cortisol conjugate. This recorded current is inversely correlated with the cortisol concentration present in the sample solution (Yamaguchi *et al.,* 2013).

5.7 Biosensor for disease detection

Escherichia coli (E. coli) is a type of gram-negative bacterium known to cause gastroenteritis. In the context of disease detection, biosensors have introduced an innovative approach through stacked membranes, where each layer serves a distinct purpose. As the analyte migrates, it binds with the corresponding antibody, which is linked to horseradish peroxidase (HRP), thereby generating a detectable signal.

In the case of detecting influenza virus in birds, a lateral flow test is employed. This involves the complexation of influenza viruses with immune-gold nanoparticles, followed by their interaction with specific antibodies. This interaction results in the appearance of a visible red line, providing a clear indication of the presence of the targeted influenza virus in the sample. (Wu *et al.,* 2017)

6. Advantages & disadvantages of biosensors

Advantages	Disadvantages
They can measure the non-polar molecules that do not respond to most measurement devices	Heat sterilization is not possible because of denaturation of biological material
Rapid and continuous control is possible with biosensors	Stability of biological material depends on the natural properties of the molecule
Biosensors are specific due to the immobilized system used in them	Cells in the biosensors can become intoxicated by another molecule
Response time is short	

Conclusion

Biosensors are geared towards establishing a comprehensive management system that hinges on self-governing, uninterrupted, and real-time monitoring across various domains of livestock management. This encompasses aspects such as reproduction, animal well-being, health, and the ecological repercussions of livestock farming. Essentially, biosensors function as cost-effective and high-performance tools suitable for seamless integration into daily livestock management practices. Their capability to swiftly, precisely, and consistently identify issues contributes to heightened productivity and enhanced reproduction rates. The wealth of data generated by biosensors has the

trendsinagriculturescience.com
trendsinagriculturescience@gmail.com
Published: 28 Aug 2023

potential to be harnessed as a valuable resource for informed decision-making within the realm of livestock management.

References

Mottram, T., Dobbelaar, P., Schukken, Y., Hobbs, P., Bartlett, P., 1999. An experiment to determine the feasibility of automatically detecting hyperketonaemia in dairy cows. *Livestock production science* **61**(1), 7-11.

Neitzel, A.-C., Stamer, E., Junge, W., Thaller, G., 2014. Calibration of an automated California mastitis test with focus on the device-dependent variation. *Springer Plus* **3**, 760.

Newman, J. D., & Setford, S. J. (2005). Enzymatic biosensors. *Molecular biotechnology*, **32**(3), 249-268.

Pohanka, M., & Skládal, P. (2008). Electrochemical biosensors--principles and applications. *Journal of applied biomedicine*, **6**(2).

Rose, D.P., Ratterman, M.E., Griffin, D.K., Hou, L., Kelley-Loughnane, N., Naik, R.R., Hagen, J.A., Papautsky, I., Heikenfeld, J.C., 2015. Adhesive RFID Sensor Patch for Monitoring of Sweat Electrolytes. *IEEE Transactions on Biomedical Engineering* **62**(6), 1457-1465.

Singh, R. (2020). Application of Biosensors Technology For Monitoring Of Animal Health Care & Livestock Management, **2**, 1-25.

Weng, X., Zhao, W., Neethirajan, S., Duffield, T., 2015b. Microfluidic biosensor for β-Hydroxybutyrate (βHBA) determination of subclinical ketosis diagnosis. *Journal of Nanobiotechnology* **13**(1), 13.

Wu, S., Zhu, Y., Cai, Q., Zeng, K., Grimes, C.A., 2017. A wireless magnetoelastic α-amylase sensor. *Sensors and Actuators B: Chemical* **121**(2), 476-481.

Yamaguchi, M., Matsuda, Y., Sasaki, S., Sasaki, M., Kadoma, Y., Imai, Y., Niwa, D., Shetty, V., 2013. Immunosensor with fluid control mechanism for salivary cortisol analysis. *Biosensors & bioelectronics* **41**, 186-191.

Zeidan, E., Shivaji, R., Henrich, V.C., Sandros, M.G., 2016. Nano-SPRi Aptasensor for the Detection of Progesterone in Buffer. *Scientific Reports* **6**, 26714.