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Recent advances in wearable sensors for animal health management

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ABSTRACT

Biosensors, as an application for animal health management, are an emerging market that is quickly gaining recognition in the global market. Globally, a number of sensors being produced for animal health management are at various stages of commercialization. Some technologies for producing an accurate health status and disease diagnosis are applicable only for humans, with few modifications or testing in animal models. Now, these innovative technologies are being considered for their future use in livestock development and welfare. Precision livestock farming techniques, which include a wide span of technologies, are being applied, along with advanced technologies like microfluidics, sound analyzers, image-detection techniques, sweat and salivary sensing, serodiagnosis, and others. However, there is a need to integrate all the available sensors and create an efficient online monitoring system so that animal health status can be monitored in real time, without delay. This review paper discusses the scope of different wearable technologies for animals, nano biosensors and advanced molecular biology diagnostic techniques for the detection of various infectious diseases of cattle, along with the efforts to enlist and compare these technologies with respect to their drawbacks and advantages in the domain of animal health management. The paper considers all recent developments in the field of biosensors and their applications for animal health to provide insight regarding the appropriate approach to be used in the future of enhanced animal welfare.

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1. Introduction

The use of biosensors and wearable technologies is becoming increasingly important for animal health management. These devices, if built precisely and used correctly, can provide timely diagnosis of diseases in animals, eventually decreasing economic losses. Such devices are particularly useful for dairy cattle and poultry farms. Instead of relying solely on farmers' senses and knowledge, on-site sensors can provide reliable data about the physical condition of the animals. Due to the superior performance of wearable technologies and sensors, they can make a breakthrough in livestock development, and promises to become one the most impactful and practicable technology in the animal health market. New wearable technologies are being customized to meet the needs of animals, pets and livestock. Products such as medication patches, tracking collars, and electronic saddle optimization are being purchased at higher rates [1] and harnessed for the healthier upbringing of farm animals. These wearable technologies are multifunctional and efficient, allowing animal owners to do more in less time. Global growth of this sector in the next ten years has been predicted to soar from $0.91 billion to $2.6 billion [1].

Sensors and wearable technologies can be implanted on animals to detect their sweat constituents [2–4], measure body temperature [5–7], observe behavior and movement [8,9], detect stress [10], analyze sound [11–16], detect pH [17], prevent disease [18], detect analytes and detect presence of viruses and pathogens [19–23]. Wearable sensors help farmers catch disease early, and thereby prevent deaths of animals. Farmers can also cull diseased animals in time to prevent the spread of disease in whole cattle herds through prediction.

Apart from collecting useful data regarding animal health, general farm monitoring can also be made easier and more reliable by using biosensors integrated with cellphones and handheld devices instead of conventional methods, such as writing notes, keeping a farm diary, or using simple equipment without data-sharing functions. A number of systems have been developed on cellphones and handheld devices to reduce the effort of recording data manually [24]. Solar-powered receivers mounted on livestock can collect data that is transmitted to a central server. The final data can easily be viewed on a custom dashboard or office computer, which makes this technology very convenient for farmers.

A biosensing device that attaches to ears to measure the body temperature of animals now costs $100,000 for 10,000 cattle. Commercially available biosensor collars are also being used in cows for detection of estrus period [25–27]. An innovative robotic grazing system uses electronic leg bands that interact with sensors mounted on the animal to record data on its feeding and milking behavior and pattern [28].

It's a big challenge to provide good quality, safe meat to meet the increasing global demand for meat and poultry products. With rising demand comes growing concerns relating to animal health [29]. Devices that can be integrated inside the body of animal, patched under its skin, or remain in its stomach give animal owner's useful information regarding their behavior and medical conditions. These electronic devices are expected to be used for the medical treatment of animals, detection of heating and cooling needs, iontophoretic drug delivery, and even conservation of wild species [1].

Another important use of biosensors is antibiotic detection. With the unhampered and frequent use of antibiotics in the animal industry, antibiotic resistance has become a major threat for farmers. Ecological instability is caused by the uncontrolled use of sub-therapeutic antibiotics in concentrated animal feeding operations (CAFOs), which in turn causes antibiotic resistance in animals. There is a dire need for farmers to switch to alternatives to avoid animals becoming immune to antibiotic treatment. The amount of antibiotics administered in the blood serum and muscles of farm animals should be kept in a certain range, and there should be a proper system to detect the antibiotic levels in the animal body. It is nearly impossible to put a ban on the use of antibiotics in the livestock health management, since antibiotics help cure the most common ailments, like enteric and respiratory infections. The use of antibiotics in sub-therapeutic concentrations for increasing development and growth of farm animals is also well recognized. To address this prevailing issue, the European Union set up a standard to prevent the antibiotic resistance. This principle, which has been suggested as precautionary measure, focuses on banning certain antimicrobial growth promoters. Maximum Residue Limits (MRLs) have been set up for those antibiotics that are still allowed to be administered in animals in the United States and European countries. MRL is that amount of pharmacologically active substances, and their derived metabolites, which is legally acceptable. Biosensors have been identified as being helpful in this regard; they can easily detect antibiotic levels and warn the farmer if the antibiotics level exceeds a maximum range [19].

The international market for wearable technology for animals is expected to grow from around $1 billion to $2.5 billion in the next decade, increasing more than 2.5 times [1]. The highest percentage of manufacturers of this unique technology is in China, which is providing these products at a very cheap price, followed by the USA.

A significant amount of money is spent every year on agricultural research and animal health management. However, this does not necessarily translate to better productivity or increased health of animals. More often than not, the funding is aimed to provide newer solutions to the problems, rather than bridging the gap between research and industry. Banhazi and Black [30] have suggested that a rigorous procedure be carried out to ensure that agricultural practices are correct and consistent in accordance with the current knowledge and research findings [30]. This ambitious standard can only be accomplished by integrating data measurements and data acquisition systems through novel biosensing technologies.

To meet the current and emerging challenges of farmed animal disease surveillance, diagnostics and control, it is imperative that a paradigm shift occurs in how diseases are identified. This shift involves replacing the shipping samples from farms to labs with rapid diagnosis on the farm itself. The world organization for animal health (OIE) has warned that the zoonotic diseases from farmed animals can have devastating impacts on public health if there is spill over from the farmed animal reservoir, and the livestock industry is under heavy pressure to improve its biosecurity protocols and enhance animal traceability and

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