The Pharma Innovation Journal 2022; 11(10): 298-300

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(10): 298-300

www.thepharmajournal.com
Received: 01-08-2022
Accepted: 05-09-2022

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A review on smart technologies in dairy farming

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Abstract
The current digital technologies will have a profound effect on delivery of animal health services and management of animal health systems. The sensor-based system can effectively and correctly detect the illness of the cow, before it effects the milk production. The farm owner can place the sensor onto the cow's neck, tail, or leg for acquiring real time data to examine numerous factors like cow's behavior, activity, health, feed consumption, milk production, and fertility management. The biosensors, can provide timely diagnosis of diseases, and ultimately decrease the economic losses in dairy farming. Biochips are also called as 'laboratory-on-a-chip' or microfluidics having the capacity to be used as diagnostics. Geofencing uses GPS network and other related means like Wi-Fi nodes and Bluetooth beacons to create a geofence in the defined grazing areas. Unmanned Aerial Vehicle (UAV) technology, drones are now commonly used for animal surveillance on the dairy farm. Lastly, automated cattle traffic management system has computer-controlled gates which open and close electronically to control the movement of cattle in the dairy farm.

Keywords: Biosensors, biochips, geofencing, drones, cattle management

Introduction
Recent science and technological advances have been major drivers for change in the livestock farming and animal health industry. Over the past decade, veterinary medicine has seen many changes with respect to diagnosis, treatment, and animal care. The field of veterinary medicine has witnessed much advancement, enabling veterinary practitioners to make faster diagnosis, more accurate prognosis to ultimately reduce the mortality rate. The current digital technologies will have a profound effect on delivery of animal health services and management of animal health systems.

With increase in size of dairy herds, reduced availability of skilled work foce and technologization of on-farm tasks, identification of sick animals by visual observation is becoming more difficult [1, 2]. Early detection of health disorders is crucial to restore health and to reduce the disease related costs. In this matter, Internet of things (IoT) can support farmers with wearable sensor devices to keep them aware of the status of every cow. The sensor-based system can effectively and correctly detect the illness of the cow, before it effects the milk production [3]. The farm owner can place the sensor onto the cow's neck, tail, or leg for acquiring real time data to examine numerous factors like cow's behavior, activity, health, feed consumption, milk production, and fertility management [4]. Thus, IoT and data-driven techniques are creating greater opportunities for smart dairy farming. IoT can sustain farmers with wearable sensor devices to keep a track of the physiological status of each and every cow in the farm. Some of the smart technologies that are proposed for monitoring the dairy farm activities are presented here under:

1. Biosensors
Many health disorders in lactating dairy cows altered the behavioural patterns (e.g. physical activity, feeding and drinking behaviour and rumination) with reduction in fertility and milk yield [5, 6, 7]. Instead of relying solely on awareness and knowledge of farmers, on-site sensors could provide reliable data about the physical condition of the animals.

The use of biosensors and wearable technologies are gaining importance at a faster pace in animal health management systems. These devices, if designed precisely and used correctly, can provide timely diagnosis of diseases, and ultimately decrease the economic losses in dairy farming. Due to the superior performance of wearable technologies and sensors, they can become one the most impactful and practicable technology in the animal health market. Based on signal transduction, biosensors can be classified as electrochemical, optical, piezoelectric,

magnetic, thermal, radioactive, and mechanical sensors [8].
The wearable wireless biosensor system is composed of a battery, a data transmitter, and one or more sensors (tri-axis accelerometer, thermometer, pH electrode, microphone, etc.), which are placed in contact with the cow's body (ear tags, halters, neck collars, reticulo-rumen bolus, leg tags, tail tags, tail head tags, and vaginal tags) to measure and transmit the biometric data at specified time intervals. The raw data from the sensors are then computed into physiological and behavioral parameters (such as the number of steps, activity level, time spent for eating, ruminating, or lying) by algorithms in the sensor, by the PC software, or by clouding computing [1]. Additionally, these parameters are used as the predictor variables for the diagnosis model for detecting physiological and health status of the animal (e.g., estrus events, calving, and illness) [9].

2. Biosensors for detection of metabolic diseases
Early detection of metabolic diseases in transition cows is challenging, especially in large sized dairy herds. Automatic health control makes it possible for early detection of diseases, to monitor the outcome of treatment and health status of the dairy cow in a more efficient way. The currently used sensors for detection of metabolic disorders in cows are Accelerometers to measure the behavioural pattern of walking, eating and rumination. Others are Temperature sensors, BCS cameras and Real time location systems that allow the farmers to track the movements of individual cows. These are some of the excellent tools that provide an early warning for occurrence of a metabolic disease [10].

3. Biosensors for detecting bovine mastitis
Mastitis is one the most important disease for dairy producers with economic impact. Existing diagnostic methods are complicated with limited application at farm level. Automated detection of mastitis can be an integral part of automatic milking to ensure milk quality and maintain animal welfare with prompt attention to cows affected with clinical mastitis. Biosensors combined with bio-receptors like antibodies, nucleic acid, enzymes etc. produced signals through a transducer system. Several types of transducers are used, but for pathogen detection the widely used ones are electrochemical, optical, fiber optic surface plasmon resonance (SPR), piezoelectric, gravimetrical, magnetic, and acoustic sensors. Currently, a large number of sensors are commercially available to measure colour changes, electrical conductivity (EC) and enzymatic reactions (Lactate dehydrogenase) [11, 12].

4. Biochips for detecting mastitis
Biochips are also called as 'laboratory-on-a-chip' or microfluidics having the capacity to be used as diagnostics [13]. These have the capacity to revolutionize the diagnostics and the technology had already been applied for the detection of mastitis. The disposable microchips were used with a portable reader system to measure milk somatic cell counts in mastitis affected cows.

5. Geofencing
Livestock monitoring is another important aspect of farming. Traditionally, cattle were monitored manually and confined in farms by erection of physical fences. However, advanced technologies have made it possible to track and monitor the cattle automatically. Navigation satellites and Global Positioning System (GPS) are extensively used for tracking the position of cattle [14]. Geofencing uses GPS network and other related means like Wi-Fi nodes and Bluetooth beacons to create a geofence in the grazing area; subsequently the geofence is paired with animal collar and the software application so that the animal does not leave that specific area, which is designated for grazing and any deviation would tigger alert to the farmer.

6. Cattle monitoring by drones
Unmanned Aerial Vehicle (UAV) as a tool of farming has attracted the interests of many researchers. Monitoring a large herd in open field is a challenging task in the agricultural industry but is essential for the welfare of cattle. With the advancement of Unmanned Aerial Vehicle (UAV) technology, drones are now commonly used for animal surveillance on the open fields of the dairy farm [15, 16].

7. Automated cattle traffic management
It is an extremely tedious task to manage and move cattle across the dairy farm especially to milking parlour and back to barns, which also includes the risk of injuries to cows. Automated cattle traffic management system has computer-controlled gates which open and close electronically. The system can sort the dairy cows on the basis of their readiness for milking. The cows, which are ready for milking, are moved to the milking area while the others are either put in the waiting area or returned to the barns [17].
Future prospectives of veterinary technology include development of practice management tools such as computer programs, 3D printing, Telemedicine, minimal invasive surgical procedures, and so on. Technology has helped to alleviate some of the shortfalls on veterinary profession by offering more innovative ways of treating animals and providing efficient and cost-effective treatment regimens. Other advancements in veterinary medicine include microchip fracture detection for broken bones, surgical monitoring devices, corrective laser eye surgeries and oral pill camera to obtain 360-degree internal images of the digestive tract.

Implications
Achieving the full potential benefits and desired outcomes of the digital transformation is challenging in all sectors. There are hurdles to overcome before digital technologies could be widely adopted by animal health sectors especially in the developing world. These challenges had been extensively reviewed from different perspectives *viz*., infrastructure requirements, interoperability of digital systems, policies and regulations, digital skills and competencies and the digital divide. As such, the ongoing digital transformation and its challenges will have important implications for the Veterinary Services, which must be considered from the perspectives of technology users, policy-makers, regulators, partners and other stakeholders [18, 19]. Implications include developing a legal and policy enabling digital environment, fostering public-private partnerships, building national and global robust system for data management and governance.

Conclusion
Preparing the current and future veterinary workforce to stay up to date and aware of digital innovations in animal health should be a driving force for future of veterinary services.

There is a need for research, development, and commercialization of complex bimolecular based sensors for various health applications and daily health monitoring. It is therefore crucial for veterinary services to be proactive and adapt to the ongoing digitalization. Investment in new technologies and preparing the veterinary professionals with the necessary digital skills and knowledge should be a priority for the years to come.

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