APPLICATIONS OF INTERNET OF THINGS FOR SUSTAINABLE ANIMAL AGRICULTURAL PRODUCTION

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ABSTRACT
The animal agriculture industry is expected to increase productivity match the population explosion experienced now. However, technological tools are the drivers for experiencing such transformative shift in livestock farming. Internet of things (IoT) has been identified as one of such tools. The aim in this paper is to explore the multifaceted applications of IoT in livestock production and management, focusing on efficiency and sustainability. Sensors and wearable devices are presently available to provide real-time data on early detection of diseases, efficient reproduction management and improved overall welfare. Internet of Things driven automated feeding systems, optimizes nutritional delivery, enhanced resource efficiency and reduced waste (feed and water). Dairy production activities were efficiently and profitably by deployment of IoT devices. In conclusion, Internet of Things in present day animal agriculture is applicable to all production and management of farm animals for enhanced productivity and efficiency.
Keywords: Animal management, Deployment, Sensors and Technological tools

INTRODUCTION

Agriculture contributes 40% to the Gross Domestic Product (GDP) and employs about 70% of the working population in Nigeria (CIA, 2013). Agriculture is also the largest economic activity in rural areas, where almost 50% of the population lives (Odetola and Etumnu, 2013). Animal agriculture is a source of livelihood for several rural populaces, 68% of households earn income from livestock. In practice, animal agriculture among rural dwellers is integrated with cultivation of crops (Davis *et al*., 2007).

Animal agriculture is constrained by inadequate deployment of innovative tech for its productivity and sustainability in developing countries. In Nigeria, animal agriculture is mostly handled by rural farmers who are less informed on the relevance of recent technologies in animal production. However, innovation is designed, driven and disseminated to the end-users by researchers. Hence, there is need for researchers to be abreast of information on recent tools that can drive animal production to adequately meet increasing demand for animal protein.

Internet of Things (IoT) is a recent technology that is gaining widespread awareness and acceptance in several fields due to its practical relevance in everyday life improvement. IoT has found its utility in transportation, environmental monitoring and forecasting, home and office appliances, agriculture, health, security and energy conservation (Bamigboye and Ademola 2016). In Nigeria, agriculture serves as one of the main resources for income generation for individuals, private and public organisations. However, agriculture in Nigeria as an enterprise and food security outlets for her populace is still backward in the use of IoT. Internet of Things has the potential to improve, enhance and absolutely change the face of Nigerian agriculture to a world class standard (Bamigboye and Ademola, 2019).

New innovative IoT applications can be deployed to increase the quality, quantity, sustainability and cost effectiveness of animal agriculture. Initially, technology started with the advent of tractors and other implements attached to it. However, the use of these farm machineries metamorphosized to less human driven machines powered and controlled by software. However, sustainability, efficiency and profitable of animal productivity in large quantities is hinged on improved practices, through the use of modern tools. Hence the present study considered the applications of Internet of Things for sustainable animal agricultural production.

Place of IoT in Feed and water management of farm animals

It is a known fact that administering of feed and water to farm animals is cumbersome and time consuming. Many times, these resources are also wasted due to human errors and animals' impatience while the feed or water is served. Also, due to some behavioural pattern exhibited by these animals, they sometimes scup out the feed from their feeder leading to economical losses. In the same vein, water is wasted in livestock management. Hence, there is need for technological intervention to tackle feed and water wastage in livestock production. NodeMCU-powered Pet feeder with Mobile App was developed to supply water and feed to animals at set time despite the absence of their owners. This system also offers the ability to feed pet, schedule a feed, save pet's name and monitor the amount of feed remaining in the feeder (Balamreddy *et al*., 2022).

Feeding of poultry birds is a major task that is time-consuming and labour-demanding. Its efficiency also can determine the profitability of a poultry farm. In Nigeria, feed dispensing methods working based on IoT were developed by researchers. In a mobile intelligent poultry feed dispensing system was developed (Arulogun *et al*. 2010). The system was able to move, detect and avoid obstructions and dispense solid feed to poultry birds. However, designed a mobile intelligent poultry feed and water dispensing system; using fuzzy logic control technique (Olaniyi *et al*. 2014).

This unit was responsible for dispensing solid feed to the poultry birds. It comprises of a solid feed trough, a 12 V DC motor connected to a conveyor and a feeder. The solid feed trough is expected to be filled with the appropriate solid feed to be administered to the birds. A feed sensing unit which comprises of a light dependent resistor checks the feed level and in turn determines if there is a need to dispense the feed or not. The microcontroller will then send a signal through the PID controller to the DC motor which will enable it to rotate. The rotation of the DC motor will in turn rotate the conveyor which will result in the dispensing of the solid feed to the feeder. The poultry birds feed from the feeder after feed is dispensed to the feeder for the pre-defined time determined by the microcontroller. A relay circuit is connected between the microcontroller and the DC motor so as to enable proper functionality of the system (Olaniyi *et al*. 2016). Farmers can also use movement tracking to monitor specific behaviors in their herds to determine how frequently they feed. They can correlate cows' movements with specific behaviors such as grazing, socializing or lying down chewing the cud. Knowing how often each of these behaviors occurs can allow farmers to fine-tune their herd's feed requirements so as to prevent wasting feed or overfeeding the livestock. Farmers can also use IoT devices to monitor feed levels so as to know when a trough needs to be refilled or purchase more feed (Dawsey, 2017).

Internet of Things in health management of farm animals

The spread of farm animal diseases is primarily due to traditional farming methods, lack of reliable information, and inadequate farming techniques. Farmers rely on experts to diagnose and detect diseases, but the limited number of extension and veterinary officers available to help is a huge obstacle. However, with the advent of IoT, diagnostics process for the most common diseases can be automated.

Internet of Things solutions allow farmers closely monitor the health of their livestock, which can be an effective way to prevent losses. Solutions generally employ livestock wearables connecting to a gateway using a low-cost, low-bandwidth technology to stream data to the cloud. Connected sensors in the wearable can monitor blood pressure, heart rate, respiratory rate, digestion, temperature and other vitals that allow a farmer to be alerted at the first sign of illness. Without IoT monitoring, problems like a feed issue or illness in a herd may go undetected until one or more animals require veterinary care. With sensors continuously measuring each individual animal's condition and behavior, farmers can avoid those costs by taking corrective action sooner (Dawsey, 2017).

In livestock farming animals can get several viruses due to variant conditions and checking all animals on a daily basis is an impossible and time-consuming task in large farms. It is a lengthy process to manually and individually check the health condition of animals. Hence, an automatic disease detection device was developed. For an animal suffering from a disease, the sensors detect modified changes in the animal body to make it easy for a farmer to find and treat the diseases promptly. A mounted sensor can extract the behavior of an animal and maintain data of it (Vijay *et al*., 2023).

A solution to predict poultry diseases using their faecal images through the use of Google's Teachable Machine with chicken was developed. The dataset could be obtained from an open-access Zenodo repository. The dataset was divided into training and testing, with each having 85% and 15% of the total 4880 faecal images, respectively. Pre-trained models were utilised, and the experimental results showed that the accuracy of the model created using Google Teachable Machine was 99%. It was integrated into a mobile application developed using Flutter and Python for easy use by end-users (Bamigboye *et al*., 2024, unpublished). Mishra *et al*. (2023) recently discussed on the advanced contribution in IoT in livestock farming, potential benefits of artificial intelligence, machine learning, and the Internet of Things for the cattle industry. Digital twin technology holds great promise for improved efficiency and lower costs. The results of using digital twin technology to improve precision livestock farming, reduce costs, and increase the efficiency of management processes are highly encouraging.

Taneja *et al*. (2019) developed a SmartHerd system using a fog computing based end-to-end IoT interface that analyzes animal activities and monitors health conditions in a dairy farming set-up. The proposed system outlines a microservices-oriented interface to support the distributed computing pattern and highlights the key challenges for constructive Internet connectivity in remote farm areas. The study was processed on 147 dairy cows from the herd consisting of 150 dairy cows.

Application of Internet of Things in dairying and dairy animal production

It is always considered as a challenging task to decide the correct time for milking the cow. Lack of technology can cause the milk to be perishable and fragile. In this matter, 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 affects the milk production. The farmer 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. These wearable sensors can spot cow's illness and diseases such as mastitis or any other disease that can reduce milk production (Heinrichs *et al*., 1997).

Monitoring Reproductive Cycles and Calving

IoT can also be useful during a cow's reproductive cycle to monitor when a cow goes into heat and when they are ready to birth. Because cows can be in heat for as little as eight hours, IoT devices can notify the farmer as soon as this happens, which increases productivity, efficiency and potential revenue. If the cows are in from the field, a more advanced system with IoT-controlled fencing can automate the process of corralling the cow in heat away from the rest of the herd and into a chute for artificial insemination. When the cow goes into labor, an IoT sensor can send an alert to the farmer, making the calving process safer while eliminating the need for the farmer to continually check on the cow to see if she has started calving.

Maximizing Milking

Manual milking in a dairy farm is very time consuming and slow procedure. The preserving process of milk is also not hygienic. Manual process can cause bacterial infection in milk. IoT has solved this problem more efficiently, reducing cost and manpower, by introducing automilking. If the temperature is not favorable, the chances of milk getting spoiled are very high, but automilking can automatically preserve the milk by using different smart cooling tanks. Common automilking systems rely on two components: computer and special herd management software. It carried out several tasks like collecting the animal, cleaning the animal before milking, attaching the milking equipment, extracting milk, removing the equipment, and routing the animal out of the special area (Heinrichs *et al*., 1997).

IoT devices are also useful to dairy farmers who have cows that need to be milked several times a day. Robots can increase a dairy operation's milk production by allowing cows to choose when they would like to be milked, which can result in increased milking sessions. Sensors around a cow's neck alert the robot to the identity of the cow about to be milked, individualizing the session for her. It can also track each animal's milking speed, the amount and quality of milk produced, how much the cow has eaten and the number of steps each cow has taken per day. From that data, the farmer can determine which cows are able to produce more milk and improve their diets to increase lactation (Dawsey, 2017).

The concept of robotic milking is not new, but reducing the overall labor cost and procedural cost is the most challenging task in large-scale dairy farming. In research (Wondatir, 2010), the authors

proposed a novel robotic milking technology that can grab the milking claws to cows. This system contains automated milking, cleaning, and feeding of cows. Robotic feeding is also a feature of this system; this system can calculate the effectiveness of feed for milk production and the nutritional requirement of a cow. Automated milking system can help to reduce labor cost.

In conclusion, implementing Internet of Things in farm animal production can lead to increased efficiency, improved animal welfare, and better overall management practices. It is evident that deployment of IoT in animal agriculture is the way to go for achieving sustainability, better revenue and increased productivity.

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