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Application of Sensor-based System for Animal Husbandry Mechanization

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Livestock and crop production are interdependence for energy being a distinguishing characteristic of the mixed crop-livestock systems. The Indian Council of Agricultural Research has been operating the All India Coordinated Research Project on "Increased Utilization of Animal Energy with Enhanced System Efficiency" with its Coordinating Cell at ICAR-Central Institute of Agricultural Engineering, Bhopal since July 1, 1987. The scheme has conducted lead research in the area of draughtabilty, harnessing system, work-rest cycles, use of animal in rotary mode, loading car, treadmill and instrument to measure the precise work output of animals under laboratory and field conditions in addition to various animal drawn improved implements/ technologies for different unit farm operations in the country through the cooperating centres located at various parts of the country. Presently name of this AICRP is *renamed to AICRP on Mechanization of Animal Husbandry (MAH)* with Mandate to mechanize feeding, watering, manure handling, milking *etc.* operations for dairy and livestock animals for better productivity and reduce cost and drudgery during their management. It also includes improved housing, sanitation and health control measures for better environment for livestock. The four pillars of management for farm animals can be managed properly and even remotely by integrating IoT solutions that assist in farm management, animal health, animal nutrition, and animal tracking. Research and development work of the cooperating centres related to sensor utilization are summarised and presented in the paper for mechanization of animal husbandry sector on the principals of animal husbandry.

INTRODUCTION

Animate power in Indian agriculture is a very crucial source of farm power since inception. Draught Animal power obtained through domestication of cattle, horses and other animals has existed for over 8,000 year (https://www.fao.org/4/x8054e/x8054e05.htm). Traditionally, animal power has been a decentralized practice, managed by small groups of individuals on a relatively modest scale. The growing demand for animal products due to rising populations and incomes has necessitated more efficient animal management systems (Neethirajan, 2020).

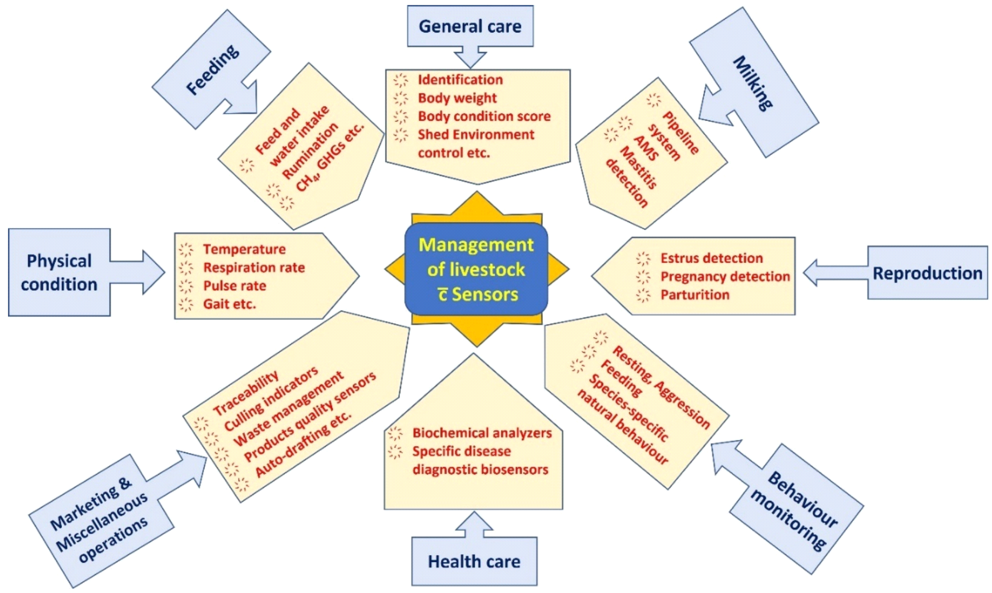
Animal husbandry stands at the forefront of evolving agricultural practices, playing a crucial role in promoting sustainability within modern farming systems. As the global demand for food continues to rise and environmental challenges intensify, innovative strategies are transforming the management and welfare of livestock (Rojas-Downing *et al.*, 2017). These emerging trends encompass a wide range of advancements, including sophisticated livestock health monitoring systems, cutting-edge animal breeding technologies, increased integration of farm automation, and the application of precision livestock farming (PLF) techniques (Koutouzidou *et al.*, 2022). Collectively, these innovations aim to optimize livestock productivity and welfare while supporting environmentally responsible and resource-efficient agricultural practices. Technology adoption in animal husbandry has been accelerated by the widespread availability of the internet, affordable smartphones, and increased computational power. Traditional manual methods may no longer be sufficient to meet growing demands, making it necessary to implement advanced systems that enhance productivity and efficiency. Technologies such as sensors, artificial intelligence (AI), and the Internet of Things (IoT) are revolutionizing industries, including animal farming, by enabling real-time monitoring and data-driven decision-making (Wolfert *et al.*, 2017).

Farm mechanization has been helpful to bring about a significant improvement in a task. Livestock and crop production are interdependence for energy being a distinguishing characteristic of the mixed crop-livestock systems. The Indian Council of Agricultural Research (ICAR) has been operating the All India Coordinated Research Project on "Increased Utilization of Animal Energy with Enhanced System Efficiency" with its Coordinating Cell at ICAR-Central Institute of Agricultural Engineering, Bhopal since July 1, 1987. The scheme has conducted lead research in the area of draughtablity, harnessing system, work-rest cycles, use of animal in rotary mode, loading car, treadmill and instrument to measure the precise work output of animals under laboratory and field conditions in addition to various animal drawn improved implements/ technologies for different unit farm operations in the country through the cooperating centres located at various parts of the country (Din *et al.*, 2024). Presently name of this AICRP is *renamed to AICRP on Mechanization of Animal Husbandry (MAH)* with Mandate to mechanize feeding, watering, manure handling, milking *etc.* operations for dairy and livestock animals for better productivity and reduce cost and drudgery during their management. It also includes improved housing, sanitation and health control measures for better environment for livestock. The four essential pillars of management for farm animals are feeding (study of proper food), breeding (obtaining animals with desired characters), weeding (elimination of uneconomic animals) and heeding (good livestock management and general supervision including housing, hygiene, sanitation and care of animals). These four pillars can be managed properly and even remotely by integrating IoT solutions that assist in farm management, animal health, animal nutrition, and animal tracking. Integrating sensors in animal farming enables continuous monitoring of key animal and environmental biomarkers, collecting data for analysis using advanced AI and machine learning (ML)/deep learning (DL) algorithms to detect deviations and inform decision-making (Neethirajan, 2023). In smart dairy farming, IoT devices with sensors play a crucial role in monitoring livestock health and productivity. Wearable sensors on cows collect real-time health data, while advancements in AI, computer vision (e.g., YOLO v9), and automated sensors enable barn environment analysis and behaviour assessment. These technologies facilitate early detection of health changes, offering non-contact, low-cost, and high-yield solutions (Siberski-Cooper *et al.*, 2023). Given IoT's transformative potential in agriculture, particularly dairy farming, a comprehensive review of existing technologies is essential. The cooperating centres are focussing the research work on utilization of sensors on the principals of these four pillars of animal husbandry management. The implementation of sensor-based solutions can lead to significant improvements in farm efficiency, animal health, and resource utilization, making them indispensable tools for the future of livestock management (Tangorra *et al.*, 2024). Depending on the kinds and quantity of sensors used, as is typically the case with bigger herds, sensors can assist livestock farmers and managers enhance their managerial abilities to varied degrees. It even aids in the standardization of different agricultural techniques that result in effective nutrition and energy use for thermoregulation and other production performance attributes. Precision Livestock Farming (PLF), also referred to as Smart Livestock Farming, is the result of the use of sensors based on contemporary artificial intelligence (AI) and other information technologies (IT), including internet of things (IoT). Physiology and health (body temperature, rumination, lameness, body condition score, feed intake, disease detection, etc.), production (milk, fiber yield), and reproduction (heat detection, insemination, pregnancy diagnosis) accounted for the majority of early developed sensors' that focus on characteristics that affected animals' economic performance. With the development of biosensors, the emphasis has recently switched to behaviour and welfare features in order to address the growing problems surrounding industrial livestock production through the assessment of animal welfare indicators (AWIs). The different areas of livestock management where sensors can be implemented are shown with the help of the diagram below in Figure 1.

Types of Sensor Technologies Used

Considering the barn setup, dairy farm automation typically focuses on two primary areas: (i) IoT sensors for animals and (ii) IoT sensors for the farm environment. Figure 2 illustrates how IoT and data-driven techniques offer new opportunities for dairy farmers to manage their farms more efficiently through the use of diverse sensor technologies in animal husbandry.

Figure 1. Sensor application potential in livestock management areas (Singh, 2023a)



(i) IoT sensors for animals

Sensors in animal identification

The most important prerequisite for farm management and record keeping is animal identification. Through the use of IoT and AI applications, sensors can generate the necessary vital information about the farm animals and exchange it with other devices or administration systems (Eradus and Jansen, 1999). This can help livestock farms manage animals more efficiently by reducing the amount of labor required for a variety of routine tasks, such as the detection of heat-related estrus in animals, growth monitoring, record keeping, routine culling, milking, feed formulation, and distribution. Using electronic identification tags, such as electronic ear tags, injectable transponders, or boluses with a transponder implanted into the rumen/reticulum (in ruminants) for animal identification is the most popular sensor use at livestock farms.

Sensors for body measurement

Body measurements, such as Body Condition Score (BCS) and Body Weight (BW), play a crucial role in informed livestock management. These metrics help refine breeding strategies, assess nutritional health, and monitor daily weight gain (Martins *et al.*, 2020). BCS serves as an early indicator of weight fluctuations, particularly during early lactation and pre-calving periods. In early lactation, it helps mitigate metabolic disorders, while in pre-calving stages, it aids in managing dry cows. Traditionally, BCS is assessed visually by experts, providing an estimate of an animal's energy reserves at various lactation stages (Wildman *et al.*, 1982). The Edmond scale (Edmonson *et al.*, 1989) assigns scores from 1 (underweight) to 5 (overweight), with a range of 3–3.5 indicating a healthy condition.

To automate BCS analysis, several experimental trials have explored image-based assessment models (Kojima *et al.*, 2022). (Peacock *et al.*, 2006) and (Bewley *et al.*, 2008) utilized 2D cameras for evaluation. (Halachmi *et al.*, 2013) introduced thermal imaging to isolate the cow's body shape and estimate BCS using specialized algorithms. Further advancements by (Spolianski *et al.*, 2016) and (Calcante *et al.*, 2017) leveraged low-cost 3D cameras for automated BCS estimation. Similarly, (Kuzuhara *et al.*, 2015) and (Gomes *et al.*, 2016) applied 3D imaging techniques to develop models for BW assessment. This approach allows the farmer to monitor the herd at the most suitable time with high precision and objectivity, and to adjust the feeding of individual cows by modifying the quantity and quality of their rations through the feeding system.

Sensors for assessing physical conditions of animals

Biophotonic and biopotential sensors are being used to monitor the physiological characteristics of dogs (heart rate, variability in heart rate, and rate of breathing), (Brugarola *et al.*, 2014) and (Neethirajan, 2017). Surface-mount light sources, such as glass capsules used for

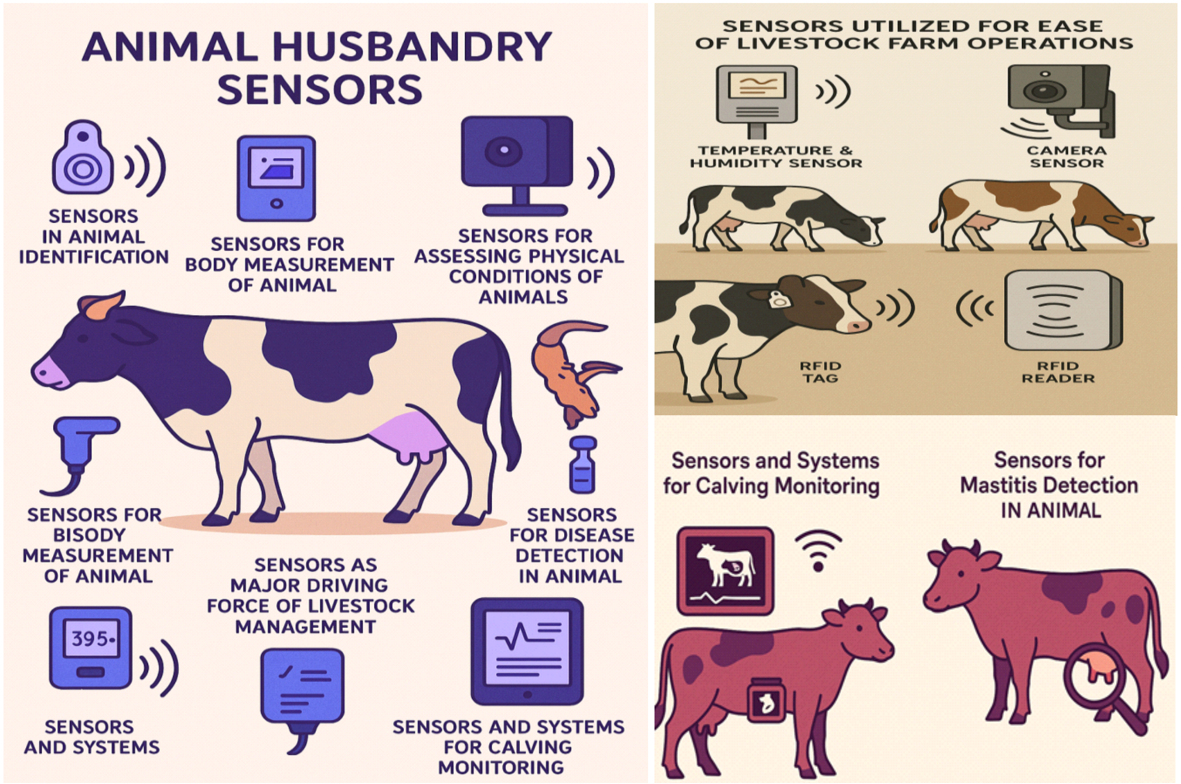


Figure 2. Different types of sensor technologies used in animal husbandry

microchip implantation, were employed as detectors. The sensor-equipped-milking robots for detection of mastitis based on measurements of milk parameters viz. milk acidity, pH, somatic cell count, milk conductivity etc., are considered as integral part of modern milking systems to assess parlor performances and milking efficiency. In order to detect mastitis and separate affected milk from the common pool, an electronic tongue may be used which is designed to detect potentiometric chemical sensors made of plasticized PVC membranes with cross-sensitivity to multiple chemicals (inorganic and organic cations and anions, chalcogenide glass sensors, glass pH electrode, chloride-, potassium-, and sodium- selective electrodes, etc.). Newly developed sensors, including as lactate dehydrogenase (LDH), somatic cell count (SCC), and near-infrared (NIR) spectroscopy, are being used (Dzermeikaitë *et al.*, 2023).

Sensors for improved reproductive performance

Accurate estrus identification, prompt insemination, early pregnancy diagnosis, and close monitoring throughout parturition are all essential components of an effective reproduction management program. For this purpose, different sensors have been explored in the last decade (Kaewbang *et al.*, 2024). For instance, pressure-sensitive radio telemetry equipment is fastened to the cow's sacral area, directly in front of its tail head. Estrus detection has made extensive use of motion sensors, which send radio signals in response to movement. Pedometers, which are typically mounted above the knee joint of the cow's foreleg, record the number of steps taken in a given amount of time to indicate walking activity. In contrast, an activity meter fastened to the cow's neck collar measures the horizontal accelerations associated with the upward movements of the cow's head and neck during walking and mounting. Apart from these, many other sensors such as radio telemetric thermal sensor, infrared thermography sensor, acoustic sensor and image sensors have been used for detection of estrus.

Sensors for disease detection

Numerous commercially accessible sensor technologies have been created to measure body temperature, track movement, monitor behavior, analyze sound and breath, and identify stress, sweat components, and infections (Rios *et al.*, 2024). In addition to collecting valuable data on animal health, the integration of these sensors with mobile phones and other devices is significantly improving farm monitoring compared to traditional approaches, resulting in significant development in the livestock health industry.

Sensors as major driving force of livestock management

The use of sensors in the livestock industry has remained limited to date due to a number of issues, including the need for additional infrastructure to support sensor use, the moderate to high skill level needed for use and interpretation of sensor results, budgetary restrictions, a lack of available sensors, and the challenge of reaching the breakeven point of sensor use in smaller herds (Table 1). The growth of biometric, chemical, process, proximity and location, touch, and image sensors is far quicker than that of other types of sensors.

Sensors for Activity Monitoring

Tracking key behaviours (eating, rumination, standing, lying, walking, drinking, and mounting) provides insights into a cow's health. Behavioural monitoring helps detect issues like lameness, thermal stress, oestrus, calving, and diseases. For example, podiatric issues correlate with changes in walking speed and leg swing patterns.

Lameness can be identified using pressure-sensor mats that detect footfall and weight distribution anomalies (Nuffel *et al.*, 2016). These sensors offer real-time data, enabling prompt intervention and improving herd management. Behaviour monitoring enhances animal welfare, performance, and decision-making (Liu *et al.*, 2023). Common sensors include pedometers and accelerometers, typically integrated into collars, leg bands, or ear tags.

Sensors and Systems for Calving Monitoring

Calving time is critical in dairy farms, particularly for primiparous cows, due to risks of complications affecting both cow and calf. Difficult births can reduce milk yield, lead to infections, increase veterinary costs, and result in infertility or early culling (Tangorra *et al.*, 2024). Accurate calving prediction helps mitigate health risks to calves. Various prediction methods–such as monitoring body temperature, ultrasound, hormone levels, pelvic relaxation, and milk electrolytes–have been explored, though many are costly and time-consuming. Intravaginal sensors offer a practical alternative, triggering alerts via temperature and light changes during parturition. These are especially useful in pasture or intensive systems. For extensive grazing areas, where timely intervention is challenging, (Calcante *et al.*, 2014) developed GPS-CAL, a GPS/GSM-based alarm system that notifies farmers of calving time, cow ID, and precise location via text message, easily viewable on Google Maps.

Sensors for Mastitis Detection

Mastitis significantly affects dairy cow health, milk yield, and quality, leading to economic losses from

Table 1. Impact of AI and sensor technology on supply chain management in livestock management (Neethirajan, 2023)

Aspect	AI and Sensor Technology Role	Specific Technology	Benefits
Automated Cattle Counting	Facilitates accurate, efficient cattle counting using AI-powered image processing.	Machine vision systems, image recognition algorithms	Minimizes human errors, accelerates counting, allows real-time livestock tracking
Supply Chain Traceability	Uses sensors for location and condition tracking throughout the supply chain, coupled with AI for real-time tracking and issue prediction.	GPS trackers, RFID tags, IoT connectivity, Big Data Analytics	Boosts traceability, promotes animal welfare through timely interventions, assists in regulatory compliance.
Market Development	Leverages AI for market trend analysis, demand-supply dynamics, and price fluctuations, offering predictive insights for production and exports.	Machine Learning algorithms, big data analytics	Promotes proactive decision making, optimizes market demand fulfilment, potentially increases profits.

treatment and potential culling (Kunes *et al.*, 2021). Electrical conductivity (EC) of milk is a key early indicator, with predictive models using time series analysis and inter-quarter comparisons. Integrating additional detection tools–such as somatic cell count, milk color sensors, and biosensors for enzymes like lactate dehydrogenase (LDH)–enhances diagnostic accuracy. (Friggens *et al.*, 2007) A dry-stick LDH biosensor with 82% sensitivity is already available. Advanced devices like NIRS analyzers offer real-time analysis of milk composition, enabling early detection of diseases and improving herd health and productivity.

Some of the important sensors used in different farm operations have been narrated in Table 2.

(ii) IoT sensors for the farm environment

IoT technologies offer an additional advantage: real-time monitoring, which ensures automatic, rapid, and efficient intervention in the event of machine failure. Moreover, the integration of robotic automation solutions can boost productivity and enhance competitiveness. These technologies encompass the use of sensors for herd management, milk production optimization, efficient feed distribution, and environmental control (Filho *et al.*, 2020).

Automatic Milking System (AMS)

Automatic milking systems (AMSs) offer significant improvements in both the milking process and overall cow management when compared to traditional milking systems. Rather than simply replacing conventional milking parlours, AMSs introduce a transformative approach to dairy farm operations. These systems incorporate advanced sensor technologies and machine-to-machine (M2M) communication to automate numerous aspects of farm management (Perov *et al.*, 2022). For instance, AMSs can measure and dispense concentrated feed based on each cow's lactation stage and milk production, while also continuously monitoring milk yield and quality-from individual udder quarters to the entire cow.

Additionally, sensors embedded in AMSs provide valuable data on physiological parameters related to animal health, such as somatic cell count, milk color and conductivity, milk composition, rumination activity, and fertility indicators like heat detection. Thousands of data points are collected daily through remote sensors integrated into milking robot arms and wearable devices such as collars and pedometers. These data are transmitted wirelessly-via the Internet or local servers-and are typically stored in the cloud for real-time analysis and decision-making.

The latest advancement in AMSs is the implementation of batch milking, a practice where cows are milked in groups at fixed times-typically two to three times per day (Calcante *et al.*, 2022). Robotic batch milking combines the benefits of automation with flexible labour and herd management, enabling producers to tailor operations to their specific farm needs.

Automatic Feeding Systems (AFS)

Feeding is a major expense for dairy farms, accounting for up to 50% of operating costs and ranking as the second most time-consuming task after milking (Tangorra *et al.*, 2020). Automation has focused on using automatic concentrate feeders for cows and self-feeders for calves to deliver precise nutrition. These technologies save time, reduce labor, and improve health monitoring.

NIR sensors allow instant, non-disruptive checks of ration composition, helping maintain consistency and reduce seasonal variation (Modrono *et al.*, 2017). They also improve feed efficiency by minimizing waste. Optical sensors, using cameras, assess fibre length and mix quality, reducing human error.

Automatic feed-pushing systems improve feed access and reduce manual labour. The latest advanced systems automate the entire feeding process-including preparation, distribution, and re-pushing. Over 1,250 such robots have been installed so far.

Recent work at Cooperating centres on utilization of sensors for development of device

Real-world applications include smart dairy farms and precision feeding and dispensing system or poultry farming, implemented across various regions by AICRP on MAH Cooperating centres.

A controller-based feed dispensing system for poultry was developed by ICAR-CIAE Bhopal centre (Figure 3). A computer vision-based bird identification system was developed to count birds and determine the amount of feed to dispense. The system used the YOLOv7 object

Table 2. Different types of sensors utilized for ease of livestock farm operations

Utility in livestock management	Available equipment/ sensor types	Features
Livestock Identification (RFID based) ● Passive type: LF, HF (short distance monitoring) ● Active type: UHF, microwaves (long distance monitoring) ● Commonly integrated with other sensor types for wider utilities	Ear tag	Easy application; Less secure (theft, replacement etc.);
	Neckband	Easy application; Less secure; Integrated sensors to monitor motion, rumination etc.
	Bolus (rumen/ reticulum)	More secure; Integrated sensors to measure temperature, pH etc.; For ruminants
	Sub-cutaneous Microchip	More secure; Integrated sensors to provide temperature, blood pressure etc.; Caution in food animals at slaughter
Assessment of physical condition of animals or environment	Electronic balances (load cells)	BW in static posture
	Image processing enabled digital platforms	BW and BCS even in dynamic situations
	Thermal imaging cameras	Body surface temperature; Ear tag (Cow Sense from Quantified Ag® CS) with accelerometer (activity) and an infrared beam (inner-ear temperature) (Siberski–Cooper *et al.*, 2022)
	Wearable heart monitoring devices	Heart rhythm via electricalor optical methods (Nie *et al.*, 2020)
	Combined video and thermal imaging cameras, microphones, and wearable TNO Holst 3-in-1 patches	Monitoring heart rate, respiration rate, and activity (Neethirajan, 2022)
	Behaviour monitoring sensors	Feeding, drinking, vocalizations (microphones) etc.; multimodal integrated approach is more common
	Facial grimace scales	Pain measurement in animals (Mogil *et al.*, 2020)
	Environment (microclimate) control system	Automatic discrete-analog-digital control system to regulate heating, air exchange based on temperature, humidity, CO_2 content etc. (Ivanov and Novikov, 2020; Arulmozhi *et al.*, 2021)
Automation of Weight Collection	Walk-over-weighing systems, IoT connectivity, cloud computing, machine learning algorithms	Sensor-based walk-over-weighing systems with AI interpretation for automatic weight collection. (Neethirajan, 2017)
Milking management	Conventional milking machines	Estimates milk yield, pH etc.
	AMS	Various models from GEA, DeLaval etc.; Inspection of milk and segregation (if required, from individual teat) and disinfection of teats; Estimation of milk yield, composition, conductivity, pH, SCC etc.
Monitoring of feeding	Feed monitoring system (Integrated sensors)	Rumi Watch (Zehner *et al.,* 2012), Calan Broadbent Feeding System (American Calan®, Northwood, NH) (Siberski–Cooper *et al.*, 2022)
	Automated Head-Chamber System (AHCS)	Estimates enteric methane, CO_2 etc. (Hristova *et al.*, 2015)
	Feed intake sensors, IoT (Internet of Things) connectivity, cloud computing, machine learning algorithms	Sensors track feeding metrics with AI identifying abnormal patterns in real time, offering actionable insights. (Knight *et al.*, 2015)

Table 2 contd...

Utility in livestock management	Available equipment/ sensor types	Features
Estrus detection and reproductive performance	Pressure sensors	Radio telemetry system get activated by weight of mounting animal
	Activity recording sensors (pedometer, accelerometers etc.)	Detection of Estrus, lameness or other diseases
	Radio-telemetric thermal sensors	Temperature sensing vaginal or rectal implant/probe, ruminal bolus etc (Alzahrani *et al.*, 2011; Cooper-Prado *et al.*, 2011, Han *et al.,* 2022).
	IR thermography sensors	Detects surface temperature; better results with thermal and behavioral biometrics (Marquez *et al.*, 2021)
	Acoustic sensors	Acoustic features analyzed with ML, DSS etc. (Yajuvendra *et al.*, 2013; Devi *et al.*, 2019)
	Chemical/ E-nose sensor	Estrus, pregnancy, parturition detection; hormonal/ chemical substances derived from perianal odor, urine etc. (Ali *et al.,* 2022; Sanderink *et al.*, 2017; Astuti *et al.*, 2018)
	Biosensors (electrochemical impedance spectroscopy, bacterial allosteric transcription factors, aptamer-based)	Detection of biomolecules such as progesterone; significant improvement in repeatability, sensitivity and specificity (Cui *et al.*, 2020; Lawal, 2023)
Healthcare and Disease diagnosis	Sweat/ saliva/ tear analysers	Electrolytes, biomolecules (enzymes, hormones) estimation as clue of stress, disease etc.
	Chemical sensors, blood biomarkers	Cortisol, lactate andoxytocin estimation; Early detection of metabolic disorders
	Functional near-infrared spectroscopy (fNIRS)	Assessing chemicals such as cortical activity (Chincarini *et al.*, 2018)
	Biosensors (aptamer-based, DNA based, electro-chemical, immunosensors etc.)	Detection of specific pathogens
Identification of 'Shy Feeders'	RFID tags, computer vision, machine learning algorithms	Uses AI and video analytics to spot 'shy feeder' behavior through RFID tag data analysis (Neethirajan, 2023) Aids early identification and intervention, improving herd health and productivity. Enables personalized nutrition plans.
Miscellaneous utilities	Waste handling integrated sensors	Composite AI, ML, robotics, computer vision, IoT based solutions; Automatic dung scrappers to disposal for treatment
	Auto-drafting sensors	RFID based device integrable with Herd-Man dairy herd management software
	Aerial or satellite-based monitoring system	Forage quantity & quality
	LoRaWAN communications technology	Wireless transmission of data from numerous types of sensors (300) at a time (Neethirajan, 2022)
	Biosensors (commonly aptamer-based)	Drug residues (especially antibiotic) in feed, products etc.

AI: artificial intelligence; AMS: automatic milking system; BCS: body condition score; BW: body weight; DMI: dry matter intake; DSS: decision support system; E-nose: electronic nose; FI: feed intake; fNIRS: functional near-infrared spectroscopy; GHGs: greenhouse gases; HF: high frequency; IP: image processing; IR: infra-red; LF: low frequency; LoRaWAN: Long-range wide area network; ML: machine learning; RFID: radio frequency identification; SCC: somatic cell count; UHF: ultra-high frequency.

Figure 3. Controller based feed dispensing system for broiler unit

detection algorithm, which offered fast detection, high precision, and ease of deployment. The model achieved an overall precision of 83.6%, recall of 82.5%, and a mean Average Precision (mAP) value of 84.4%. These results demonstrate that the computer vision approach is effective in detecting birds and can be successfully integrated into an automatic feed dispenser for poultry. The system resulted in a 65-70% saving in time and a 65% reduction in feeding costs as compared to manual circular feeding methods. It ensured timely operations with less man-power and also helping in preventing disease transmission between birds and human (Singh *et al.*, 2025).

OUAT Bhubaneswar centre developed the solar powered water sprinkling system (Figure 4) to control the temperature inside the poultry house through sensor. A temperature sensor system, integrated with a solar panel and a 0.5 hp DC motor-based water sprinkling system, operates four micro sprinklers on the poultry house roof. The sensor, set at 30°C, automatically activates the sprinkler system when the shed temperature reaches or exceeds 30°C, continuing until the temperature drops below the set threshold. Hourly ambient conditions, including temperature and humidity inside and outside the shed, were recorded from 8:00 AM to 5:00 PM using a wall thermometer and hygrometer. The Temperature Humidity Index (THI) was subsequently calculated. The experiment was performed during May, 2023, for the period of Two weeks. In summer season, the inside ambient temperature of the poultry shed during 8.00 AM to 5.00 PM varied from 25-32ºC with a humidity range of 38-60%. The temperature humidity index (THI) varied from 68-76. Whereas the out-side temperature during the corresponding period varied from 27-37ºC with a humidity range of 70-83%. Findings revealed that the inside ambient temperature of the shed was 5-6ºC lower than the outside temperature during the noon in summer season. The relative humidity of outside air varied from 33-58%. The THI of the poultry shed was found to be below the threshold limit of 74 throughout the day except from 1.00 PM to 3.00 PM during which it was 75–76 that comes under caution zone having mild heat stress indicating a better environment for the poultry birds due to continuous water sprinkling by the sensor based solar powered water sprinkling system. This technology can be adopted by poultry farmers which can improve comfort and performance of poultry birds (Singh, 2023b).

IGKV Raipur centre developed the sensor based non-invasive type respiration rate monitor for accurate, continuous and long-term respiration rate monitoring in cattle (Figure 5). The developed machine consists of

Figure 4. Outer and inner views of sensor based solar powered water sprinkling system in poultry

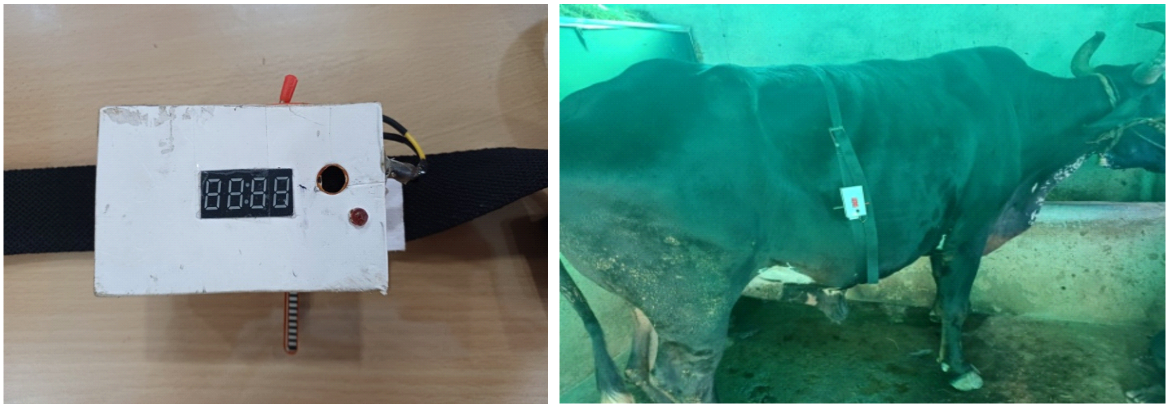


Figure 5. Respiration rate monitor for animals

sensor (flex type), amplifier, microcontroller and display. The collected data was validating with the help of reference methods i.e. counting of flank movement and counting of breathe in front of nostril with hand. A 4-digit 7-segment display is used in this study as counter. This counter or timer is connected to an Arduino as a display. TM1637 module display is used in this study which have only four connections in total – two for power and two for controlling the display. A nylon belt of size 3 m in length and 35 mm width with buckle is used to hold the device around cattle body. Developed device is fixed on the belt and belt is tightening around the animal body. This ensures that the device can be installed at a desired place while taking respiration rate. The cost of developing the respiration rate monitor was estimated as Rs. 7500/- (Singh *et al.*, 2025).

Figure 6. Sensors-based washing system for cattle before milking

A prototype of a sensor-based mechanized washing system for cattle has been developed by GBPUAT, Pantnagar centre (Figure 6) to facilitate the washing and cleaning of cattle when the atmospheric temperature exceeds 35°C. This sensor-based washing system has been developed for washing the animals before milking. The primary components of the system include the main frame, reflective-type photoelectric proximity sensor, controller box, nozzles, pipes and fittings, pressure regulator and gauge, and water pump. The sensor detects when an animal reaches the washing station's sensing area and sends an output signal to turn on the control box, which is the next component of the system and includes an SMPS, timer, relay, and contactor. The timer relay is triggered upon receiving the sensor's output signal. A 2.24 kW electric motor receives electricity from the contactor, which is activated by the relay. After that, the electric motor powers the two-stage plunger pump. Water is delivered by the pump to the washing station via 12.5 cm GI pipes. It has twenty-seven flat-fan-style nozzles. These nozzles atomize the water into fine droplets and distribute evenly over the cattle's body. After the set duration on the timer, the pump's power supply is automatically cut off. The developed sensor-based washing system for cattle is currently being evaluated for buffaloes (Singh *et al.*, 2025).

A batch type cattle washing unit has been developed by VNMKV, Parbhani centre (Figure 7). A cattle washing unit structure is fitted on an RCC platform measuring 4.25 x 1.25 x 0.15 meters. The rectangular boom moving and

Figure 7. Batch type sensor-based washing system for cattle

scrolling at top and fitted with seven hollow cone nozzles, one from top side of animal, two each from upper side, middle and lower side of animal respectively. The boom is moving horizontally on main frame by chain (12.7mm) and sprocket (72 teeth) arrangement with the help of small 300 watt electric motor which is fixed at top of the main frame. The drain is kept for drain out the water falling on the concrete ramp. The two gates are provided in frame for enter and exit the animal comfortably. The HTPE pump of 2.24 kW capacity is used for water supply. Animals require 50% less labor, 76-88% less time, and 2.15 times (50%) more effective in ectoparasite removal as compared to traditional practices during washing with the developed system. Additionally, water usage is reduced by 67-72% (Singh *et al.*, 2025).

CONCLUSION

This paper provides an overview of emerging technologies relevant to modern dairy farming, including automated milking systems (AMSs), cow monitoring sensors, automated feeding solutions, and environmental quality sensors. The integration of these tools within the Internet of Things (IoT) marks a significant shift from traditional practices, allowing farmers to proactively manage herd productivity, animal health, and production cycles.

The use of sensors and artificial intelligence in livestock farming offers great potential to enhance animal welfare. These technologies enable real-time, objective monitoring of health and well-being, supporting more personalized, humane, and proactive care. Precision Dairy Farming (PDF) is transforming farm management by allowing individual cow monitoring, improving feeding and health strategies, and reducing labor needs. However, the effectiveness of these systems relies on the quality of collected data, the seamless integration of different technologies, and their overall cost-efficiency.

WAY FORWARD

Mainstays of animal husbandry management components are being addressed under the revised mandate of AICRP on Mechanization of Animal Husbandry by the cooperating centres. The developed sensor –based devices on feeding and heeding of animal husbandry management. There is great scope of artificial intelligence (AI)/ internet of things (IOT), drone, sensors, cameras etc for mechanizing the animal husbandry sector in the country. Livestock farmers can detect the onset of health issues often before clinical symptoms appear through facial recognition and monitoring health status. Modern technologies have the potential to improve livestock productivity, enhance their traceability, assist in disease prevention etc. This will also help the farmers to go on digital animal farming.

Declarations

Conflict of interest: The authors have no conflict of interest.

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