Application of Artificial Intelligence in Animal Nutrition

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Abstract

Artificial Intelligence (AI) has emerged as a transformative tool in animal nutrition, integrating machine learning, artificial neural networks (ANN), deep learning, sensors and Internet of Things (IoT) technologies to enhance precision feeding and livestock management. Historical advancements—from Turing's foundational work to modern large language models—have enabled AI systems to perform complex analytical tasks once limited to humans. In animal nutrition, ANN and deep-learning models accurately predict rumen fermentation, methane emissions, gas production and metabolizable energy of feed ingredients, supporting data-driven ration formulation. Sensors and IoT devices, including rumen pH sensors, gas sensors, accelerometers and smart containers, provide continuous real-time monitoring of feeding behaviour, rumination, health indicators and feed intake. Machine-vision systems using convolutional neural networks (CNNs) and YOLO-based models further automate behaviour detection with high accuracy. AI is also widely applied for early disease prediction, with deep-learning and gradient-boosted models effectively identifying mastitis, lameness and physiological abnormalities. In India, AI adoption is rapidly expanding across agriculture and livestock sectors, supported by precision feeding companies and automated feeding systems. Overall, AI technologies significantly improve feed efficiency, health monitoring, welfare assessment and farm productivity, emphasizing the need for collaboration between nutritionists, data scientists and engineers to fully leverage AI-driven innovations in animal nutrition.

INTRODUCTION

Artificial intelligence (AI) refers to computer systems capable of performing complex tasks that historically only a human could do, such as reasoning, making decisions, or solving problems. Al is the intelligence exhibited by machine, rather than human or animals, its one of the most fascinating and incredible creations ever made in the history of mankind (Asif & Gouqing, 2024).

The history of Artificial Intelligence began in 1950 when Alan Turing posed the famous question, "Can machines think?" The term AI was officially introduced by John McCarthy in 1956 at Dartmouth College. Early developments included the first computer-based neural network by Frank Rosenblatt in 1967 and the use of AI in medicine at Stanford in 1973. A major breakthrough came in 1997, when IBM's Deep Blue defeated world chess champion Garry Kasparov. AI became more common in homes with devices like the Roomba robot vacuum in 2002 and later through digital assistants such as Siri (2011) and Alexa (2014). The year 2023 marked a major leap with the rise of powerful language models like ChatGPT, Gemini bringing a new era in AI performance.

Types and Sub types:

Artificial Intelligence has three main types: ANI (Artificial Narrow Intelligence), which performs a single task like Siri or Alexa; AGI (Artificial General Intelligence), which aims to think and work like a human; and ASI (Artificial super Intelligence), which could one day surpass human intelligence. AI is a synergy between humans and machines, where computers imitate intelligent behaviour. Its major subsets include Machine Learning, Deep Learning, Natural Language Processing, Expert Systems and Robotics, which together power applications from facial recognition to medical diagnosis and defence robots (Rawas, 2024).

How we can apply it into animal nutrition

Artificial Intelligence (AI) in livestock and agriculture works through several interconnected technologies. Machine Learning plays a major role by using tools like automated feeding machines, deep learning and artificial neural networks (ANN) to analyse data and improve decision-making. AI systems rely on algorithms and mathematical models to predict animal needs and optimize management. Along with these, electronic sensors such as rumen pH sensors, gas sensors and rumen sensors help monitor animal health in real time. The Internet of Things (IoT) further strengthens AI applications by connecting devices through wireless sensor networks, allowing continuous data collection and smart monitoring. Together, these technologies create an intelligent, data-driven system that improves efficiency, health and productivity on farms.

Use of Artificial Neural Networks (Ann) In Animal Nutrition

Artificial Neural Networks (ANN) are made of interconnected nodes called artificial neurons, designed to mimic the functioning of the human brain. These networks serve as foundational building blocks for many AI systems and models used in animal nutrition. Several studies have demonstrated their usefulness. Dong & Zhao (2014) used a back-propagation neural network (BPNN) to predict in-vitro rumen methane, CO_2 and total gas production based on CNCPS carbohydrate fractions. Using 55 rations for training and testing, the predicted and observed gas values were very similar, with low RMSPE values (3–4%) and high correlation (>0.90), indicating strong model accuracy. Craninx *et al.* (2008) developed ANN models to predict rumen fermentation patterns—acetate, propionate and butyrate—using milk fatty acid profiles. With 138 samples divided into training, validation and testing sets, the ANN's performance was comparable to statistical regression models, showing low RMSE values and good predictive ability. More recently, Wang *et al.* (2023) applied LSTM neural networks to predict metabolizable energy of feed ingredients using data from 10 raw materials. The model achieved high fitting accuracy (>95%) with the best performance at 10 hidden nodes, reinforcing the potential of deep learning for feed evaluation. Overall, ANN and advanced machine-learning models provide accurate, data-driven tools to predict rumen fermentation, gas production and energy values, supporting smarter nutrition management in animals.

A sensor is a device that detects physical signals—such as movement, pressure, temperature, or gas—and converts them into measurable data. In livestock farming, sensors are widely used to monitor animal behaviour and rumen function with high accuracy. They automatically track feeding behaviour, feeding time, feed intake, rumen pH, rumen gases and ruminating activity, which helps in early disease detection and better nutrition planning. Higuchi *et al*. (2020) developed a long-lasting rumen pH sensor that works for over two years with very high accuracy and fast response and is small enough to be swallowed easily. Similarly, Bishop *et al.* (2016) and CSIRO created an intra-rumen gas sensor that measures methane, CO_2, temperature and pressure using infrared technology, supported by data storage, radio communication and a special gas-permeable membrane.

Sensors are also used to detect rumination, a behaviour linked to milk yield, reproduction, stress and disease. Reiter *et al.* (2018) developed a video-based system using the Smart-Bow algorithm to measure chewing and rumination time. Wu *et al.* (2019) designed a neck-mounted wearable sensor that uses activity signals and logistic regression to identify rumination with more than 94% accuracy. Commercial systems like SensOor, CowManager, CowScout, Afimilk, RumiWatch and SmaXtec use accelerometers, temperature sensors and RF communication to continuously track feeding, rumination, activity and overall health (Himanshu *et al.*, 202). These technologies help farmers detect problems early, improve nutrition and enhance farm productivity through continuous, data-driven monitoring.

The Internet of Things (IoT) refers to devices equipped with sensors, software and communication technologies that collect and exchange data over the internet (Shafiq, 2022). In livestock farming, IoT-based systems such as the Wireless Sensor Network developed by Sarker *et al*. (2022) help monitor cattle health by measuring temperature, pulse rate, heart rate, body weight and feeding frequency, allowing farmers to manage animals remotely. Cameras are used to identify cattle by capturing images of logos on their backs and sending the data through Wi-Fi to a smartphone app, helping farmers know which animals have been fed. Smart containers further improve feed management by dispensing the correct amount of feed and sending alerts when the feed weight crosses a set threshold, such as 500 g. Together, these IoT components enable efficient, automated and real-time monitoring of cattle health and feeding status.

Machine learning (ML) is increasingly used in animal nutrition to improve feed quality, performance and manufacturing efficiency. You *et al*. (2022) applied ML regression models to predict the pellet durability index (PDI) of pelleted feeds, which is important because pelleting alters nutrient digestibility, palatability and physical characteristics, leading to better animal performance compared with mash feed (Jafarnejad *et al.*, 2010; Briggs *et al.*, 1999). Using 2,471 observations collected over eight months from a commercial feed mill in Canada, 16 input variables related to feed formulation, processing conditions and environmental factors were used to train 12 ML algorithms. After removing four models that showed overfitting or underfitting, eight algorithms were evaluated through 5-fold cross-validation. Support Vector Regression (SVR) and Stacking Regression (SR) showed the best performance, with the lowest MAE and MSPE and higher concordance correlation coefficients, indicating superior accuracy in predicting PDI. This demonstrates that ML can effectively model complex feed-manufacturing relationships and support precision formulation in animal nutrition.

Feeding behavior detection using Artificial Intelligence:

Artificial intelligence is widely used to automatically detect feeding behaviour in dairy cows, which is an important indicator of health, welfare and productivity. Changes in feeding time, frequency and feed intake are strongly associated with diseases such as mastitis and lameness, making early detection essential for intelligent livestock management. Two major approaches are used: wearable sensors, which record physiological and activity data and machine-vision systems, which analyse images and videos using AI. Yu *et al*. (2022) developed a deep-learning and edge-computing model using a ZED2 depth camera and NVIDIA Jetson TX2 to process feeding images in real time without relying on a central server. Feeding behaviour was classified into feeding and non-feeding categories using metrics such as precision, recall, mAP and F1-score. Among the tested models— YOLOv4, SSD, Faster R-CNN and DRN-YOLO—DRN-YOLO showed the best performance with the highest accuracy and fastest detection time. Machine learning is also applied through convolutional neural networks (CNN). Chen *et al.* (2020) used CNN to analyse activity data converted into two-dimensional matrices, enabling the system to detect feeding behaviour, estimate feed intake, judge health status and even predict milk production. When compared with threshold judgement, neural networks and RNNs, the CNN model achieved the highest accuracy (89.5%), making it the most effective method for precise feeding-behaviour recognition.

AI for disease prediction and prevention in livestock:

Artificial Intelligence is increasingly used in livestock farming to predict and prevent diseases before they cause major economic losses. Machine-learning models can analyse large datasets of animal behaviour, physiology and milk composition to detect early signs of health problems such as mastitis and lameness. For mastitis detection, Ebrahimi *et al*. (2019) applied seven algorithms—including Deep Learning, Gradient Boosted Trees (GBT), Logistic Regression, Random Forest and Naïve Bayes—using a dataset of 297,004 cleaned milking records containing parameters like milk volume, lactose, protein, electrical conductivity and milking time. Among these, Deep Learning achieved the highest AUC (0.826) and lowest error (15%), while GBT provided the highest accuracy (84.9%), making both strong predictors of sub-clinical mastitis. In contrast, Random Forest showed poor performance with the lowest accuracy and AUC. For lameness detection, methods such as fog computing, Classification and Regression Trees (CART) and the XGBoost algorithm analyse leg and neck movements or video-based gait patterns to identify abnormal locomotion, as demonstrated by Gertz *et al*. (2020) and Hidalgo *et al*. (2018). Overall, AI-based models allow farmers to monitor animals continuously, detect disease early, reduce unnecessary antibiotic use and improve herd welfare and productivity.

AI Scenario in India

Artificial Intelligence adoption in India is rapidly rising, with the country ranked 5th globally in AI-related research and reporting a 45% increase in AI usage according to PwC. Sectors such as telecommunications, finance, agriculture, healthcare, smart cities and education have seen the highest integration of AI technologies. In animal nutrition, companies like eFeed (India).

AI-driven precision feeding systems to generate personalized feed recommendations and have received ICAR validation, while global firms such as Precision Livestock Technologies (US) and Farmsee (Israel) apply machine vision and AI for behaviour monitoring, feed optimization and welfare assessment. Automated feeding robots like the Lely Vector, Trioliet Triomatic, DeLaval Optiwagon and smart systems like Rakr's NeatMeter improve ration precision, reduce labour, minimize feed waste and enhance productivity.

CONCLUSION

In conclusion, AI-though ANN, CNN, IoT, machine-learning models, wearable sensors and smart-video analytics—is transforming animal nutrition by enabling precision feeding, predicting rumen fermentation, estimating gas emissions, identifying sub-clinical mastitis and monitoring behaviour with high accuracy, highlighting the need for close collaboration among nutritionists, data scientists and AI developers to unlock its full potential.

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