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AI-based feeding management: Future for precision feeding of Livestock and Poultry

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Introduction

Feeding is one of the important aspects of livestock and poultry management. Balanced feeding ensures health and well-being of the animals and birds, and thereby optimum productivity and reproductive performances. Feeding cost accounts for nearly 2/3rd of the total production cost of any livestock and poultry enterprise. Therefore, well-planned feeding strategy is very important for remunerative and sustainable profit. Wastage of feed should always be minimal in farm. The digestibility of nutrients of feeds/rations provided is also equally important for better feed conversion efficiency. In the recent years, growing population, industrialization, globalization and urbanization have increased the demands for livestock and poultry products manifold than before. As predicted by Organization for Economic Co-operation and Development (OECD) and the Food and Agriculture Organization (FAO, 2024), the global meat consumption is expected to rise by 12% by 2033 relative to the 2021–2023 base period. The entrepreneurs or farmers associated with livestock and poultry farming are now adopting more and more intensive and -production oriented farming systems. Considering the feeding cost involved, farming communities are concentrating on finding out suitable cost-effective feeding strategies without compromising the productivity. Animal nutritionists are working on finding out alternative of conventional feed resources to curtail feeding cost. Exploring cost-effective feed additives and supplements are also other feeding strategies nutritionists are trying to explore to enhance growth and productivity of animals and birds. Besides, environment friendly livestock production system is also the need of the hours as nearly 14.5% global greenhouse gas emission is contributed by livestock (Gerber *et al*., 2013). Moreover, animal production system is also the major contributor to global nitrogen (N) excretion, nearly 102 to 138 TG (trillion tonnes) of manure nitrogen annually (Cellier *et al*., 2014).

The concept of precision feeding of animal and birds is getting popularity among the

farmers because of the advantages associated with this strategy compared to traditional feeding management. Precision feeding ensures optimum utilization of feed resources by reducing wastage, increasing digestibility and fulfilling the nutritional requirements of the animals avoiding both over and under feeding. Precision feeding is the feeding of animals and birds with the right feed at right amount and at right time. Right feed indicates balanced rations containing all the required nutrients exactly at the amounts required depending on physiological stage, which should also possess the characteristics of ideal balanced ration. Providing right amount at right time ensures optimum utilization of feed. Maintaining the same feeding time is important as it aligns with the body's **circadian rhythm**, and thus optimizing digestion process, absorption and metabolism of absorbed nutrients and body's energy regulation. Consistent feeding times help in managing appetite along with hormonal release for optimum digestion of feeds. However, precision feeding warrants efforts at various levels to fulfil its objectives. In this regard, AI-based feeding management will be able to fulfil the objectives of precision feeding of animal and birds. It will be able to address adequately the probable human errors at various levels and to standardise the processes efficiently and consistency. The utilization of the developments on AI-based technologies will be a reliable option for making the precision feeding of animals and birds consistent and successful.

Role of AI technologies in precision feeding management

Precision feeding is an integral part of precision livestock farming. AI technologies may be applied for designing and development of measuring devices, ration computational methods, and feeding systems capable of providing the required number of right feeds which will generate the desired production efficiency. The accurate estimation of available nutrients in feeds and feed ingredients, precise diet formulation considering nutrient requirements of individual animals or groups of animals are the main factors in the development of precision livestock feeding including the environmental and animal welfare issues.

AI technologies may be utilized for automatic collection of data, accurate processing of data, and efficient management of control systems. Accurate measurements of feed intake i.e. quantity, feeding behaviour of animals, body parameters like weight and composition, and the measurements of behavioural and health status in terms of physical activity, interactions among themselves should be dome on regular basis. Appropriate AI-based sensor technologies to monitor the animals, reliable cameras, real-time sound analysis and audio-visual observations can help in accurate assessment of feeding requirements. The HACCP principles have to be followed during automatic data collection include identifying the factors having major impacts on quantification and determination of the response of the animal to the nutrient

supply and farm or animal level measurements to ensure the application of precision livestock feeding.

Mathematical modelling is a methodology to understand and quantify the complex biological phenomena involved in animal production and can be the basis for data processing in precision feeding control systems. These have to be designed to operate in real-time using real-time system measurements. Data collection and monitoring devices provide information about health and performance of the animals and utilization pattern of farm resources. Data processing helps in surveillance of diseases and estimation of optimal production strategies. Automatic AI-based controller can utilize this information for decision making to maximize growth rate, minimize feeding cost and nutrient excretion.

The determination of nutrient requirements and the control of the nutrient intake through feed composition and intake are two essential elements of precision livestock feeding. Farm animals and birds always differ in feed intake and growth potential. Therefore, nutrient requirements will be different and different feeding strategy should be followed.

Requirements of precision feeding strategy

Precision feeding of animals is an integrated approach of feed delivery to match precise nutrient needs of the animals utilizing automated data collection sensors, RFID, real-time data processing models (Jiang *et al*., 2025). Key requirements include continuous monitoring of body weight and health of the animals, precise nutrient analysis of feed offered, dynamic modelling to adjust rations daily, and automated, individualized, or sub-group feeding equipment. Individual animal identification and monitoring involve tracking of daily feed consumption, behaviour of the animal and body weight measurement. This can be achieved by use of electronic ID (RFID) and sensors. Real time data processing includes calculation of the exact nutritional needs (energy, amino acids, minerals) based on physiological and performance status. Algorithms and AI-based models may be used for real time data processing. Single diet formulation for phase feeding and daily adjustments based on actual consumption and growth is another requirement for precision feeding. Automated feeding system capable of mixing and dispensing specific, customized rations to individual animals or small groups, and precise knowledge of nutrient content of feed ingredients along with monitoring environmental factors (temperature, humidity etc.) and animal health metrics to adjust rations for stress or illness are the important requirements of precision feeding strategy. Implementing these requirements also reduce nutrient excretion (nitrogen/phosphorus), improved feed efficiency, lower costs, and enhanced health of animals and birds.

AI-based precision feeding of livestock

AI-based feeding of animals and birds helps in precision feeding managent through combined application of Artificial Intelligence (AI), Internet of Things (IoT) sensors, and computer vision (CV) models. IoT sensors are wearable sensors which include ear tags, collars etc. fixed on animals/birds and which helps in monitoring activities of the animals along with various health indicators like body movement, temperature, heart rate, pulse rate etc. These sensors also help in assessing feed/nutritional consumption and stress level of the animals. AI-controlled cameras (CV) are installed for monitoring feeding and drinking behaviour of the animals/birds, individual growth pattern and to assess body condition score. AI-assist data analysis helps in predicting optimal nutrient requirements based on consumption patterns and to identify health issues of the animals and birds such as lameness etc. Thus, AI-based feeding management not only helps in precision feeding via automated feeding of the animals and birds, but also to assess feed consumption and health condition benefiting through increasing feed efficiency, animal welfare and decreasing impacts on the environment. However, biggest challenges associated with AI-based feeding management include higher initial cost for setting up infrastructures, data quality and connectivity and skill gaps. In the days to come, however, AI can be expected to revolutionize animal feeding from simple monitoring to automated self-optimizing farm operations.

How AI works on precision feeding management

AI integrates traditional knowledge-driven models with data-driven models (Pomer and Remus, 2023) to generate effective animal feeding regimes. With the help of input databases, AI models can generate and scale up high throughput datasets by techniques like on-site monitoring systems. Wearable and image-based sensors as well as ingestible sensors are used to collect animal data and to monitor physiological parameters of the animals, and thereby generate real-time and high-resolution data providing information on responses of animals to feed and nutrient supplies (Zhang *et al*., 2025). Wearable sensors (like accelerometers, GPS trackers, temperature sensors, heart rate monitors, and respiratory rate monitors) attached as ear tags, collars, jackets, or leg rings collect data on activity levels, location, body temperature, and physiological responses of animals and give information on behaviour, health, nutritional status, and even reproductive cycle. Environmental sensors are used to monitor parameters like environmental temperature, humidity and gas composition (e.g. Ammonia level). Ingestible sensors can accurately measure feed and water consumption, GIT pH and temperature (Curti *et al*., 2023). The radio-frequency identification (RFID) tags facilitate individual animal identification and tracking. Spectroscopic technology like Near-infrared (NIR) spectroscopy

can rapidly determine nutrient values in feed or feed ingredients. Mid infrared (MIR) spectroscopy like Fourier-transform MIR can accurately determine the fibrous components in plant biomass and for age feed, including cellulose, hemicellulose, and lignin (Kostryukov *et al*., 2023; Cleland *et al*., 2018). To overcome drawbacks associated with NIR and MIR, hyper spectral imaging (HSI) technology is utilized now-a-days for evaluation of feeds and feed ingredients.

Computer vision technologies can monitor the animals without direct contact. To monitor feed and water intakes, feeding and drinking behaviours, rumination behaviour in ruminant animals, and to measure the body weight, computer vision technologies can be applied and the data generated will help in establishing a practical model for implementing precision feeding regimes (Menezes *et al*., 2025; Meckbach *et al*., 2021; Bresolin *et al*., 2023). Computer vision can also be used for determining the body condition score, fat reserves, and muscle mass of animals needed for feed formulation optimization (Liu *et al*., 2020).

Digestive and fermentative kinetics of animals can be integrated into the modern feed evaluation system to optimize spatiotemporal nutrient synchronization. Combining *in vitro* analyses of digestion and fermentation kinetics with *in vivo* nutrient evaluation of feed ingredients can provide precise assessment framework. Omics studies in recent times have been assisting in understanding the complex biological processes associated with nutrient utilization in animals. Genomics, transcriptomics, proteomics, and metabolomics are the omics technologies which can provide information on biological processes for better understanding of the animals' physiology and requirements (Gupta *et al*., 2021**)**. Identifying molecular markers associated with nutrition-related traits have been helping in better understanding the nutritional responses at the gene regulation level. Interpretation of omics findings with suitable AI-based technologies can create suitable precision feeding model for animals.

Limitations of AI-based feeding system

Application of AI-based technologies in precision feeding management may be constrained by several technical, economic, and practical limitations. The key limitations include inaccurate, missing or incorrect data and inconsistency of data, involvement of high implementation and operational cost, technical and infrastructure constraints, socio-technical barriers like lack of technical knowledge on digital tools, lack of adequate surveillance, and constraints relating to animal monitoring (Bayer *et al*., 2025). Applying intelligent sensor and computer vision technology farm-based situation is challenging even with significant advancements. Involvement of high infrastructure cost limits the adaptation by the smaller-scale producers. Another challenge is the requirements of extensive computational resources

and efficient algorithms, and integration of data from various sensor sources. However, developments of cost-effective and user-friendly sensors, deep learning models, edge computing, and standardized data protocols and platforms can streamline the processes for easy implementation as potential solution provider for precision animal feeding in days to come (Tedeschi, 2022).

Conclusion

AI-based feeding management of livestock can transform traditional feeding system to precision and intelligent models with advantages of more control over feeding, and more precise individual prediction. It can optimise feed efficiency, reduce feeding cost, improve animal welfare and minimise environmental impacts for sustainable and profitable livestock enterprises.

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