



Precision Feeding Strategies for Ruminants and Monogastrics

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Abstract

Precision feeding is an advanced nutritional management strategy that aims to provide animals with nutrients according to their individual requirements, minimizing waste and maximizing performance. This article looks at how precision feeding is being used in both ruminants (such as cattle, sheep, and goats) and monogastrics (like pigs and poultry). With rising feed costs and environmental concerns, optimizing feeding strategies has become critical in modern livestock production. The article discusses key concepts, technologies involved, physiological differences between animal types, implementation challenges, and future prospects. Case studies and research findings are also presented to support various aspects. Ultimately, precision feeding not only improves animal productivity but also contributes to environmental sustainability and economic viability in livestock farming.

Key Words: Precision feeding, ruminants, monogastrics, nutrient, efficiency, sustainability

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Introduction

Feeding is one of the most crucial and cost-intensive components of animal production systems. It directly influences growth performance, reproductive success, health status and the overall profitability of livestock operations. Traditionally, feeding strategies have relied on group-based formulations that assume uniform nutritional needs across all animals within a production batch or herd. However, this generalized approach often leads to the over-supply or under-supply of specific nutrients, which can compromise animal performance, increase feed costs and contribute to environmental pollution through nutrient excretion. With the advent of new technologies and advances in animal nutrition science, there has been a paradigm shift toward more individualized approaches collectively referred to as precision feeding. Precision feeding involves the provision of feed that closely matches the specific nutritional requirements of individual animals or defined subgroups within a herd or flock. The core objective is to enhance nutrient utilization efficiency while simultaneously minimizing waste. This is

achieved through the integration of real-time data collection, predictive modelling and automated feeding technologies.

The importance of precision feeding has gained momentum in recent years especially in light of global challenges such as climate change, limited natural resources and increasing consumer demand for sustainable animal production. As feed resources become more expensive and environmental regulations grow stricter, the livestock industry is under pressure to improve its efficiency without compromising productivity or animal welfare. Precision feeding provides a scientifically sound and economically viable solution to address these challenges. The application of precision feeding varies significantly between ruminants and monogastrics due to their distinct digestive physiologies. Ruminants, with their complex stomach systems and microbial fermentation capacity, require a different approach to nutrient supply compared to monogastric species, which depend primarily on enzymatic digestion. Understanding these physiological differences is essential for designing feeding systems that are both effective and species-appropriate.

Moreover, precision feeding is not merely a technical intervention; it represents a systems-based strategy that integrates multiple disciplines, including animal physiology, nutrition, engineering and data science. Its implementation requires robust infrastructure, advanced tools such as sensors and software and informed decision-making by livestock managers.

Core Principles of Precision Feeding

Dynamic Nutrient Adjustment

One of the key pillars of precision feeding is the frequent and responsive adaptation of dietary formulations to meet the evolving nutrient requirements of animals. Nutrient needs vary considerably with factors such as age, body weight, production stage (e.g., lactation, growth, gestation), genetic potential, and environmental stressors (e.g., heat, humidity). Precision feeding systems incorporate nutrient requirement models, such as those developed by the National Research Council (NRC) or INRA and enhance them with real-time performance data to refine dietary formulations. For example, growing pigs may exhibit different rates of protein deposition depending on genetics and environmental temperature. Traditional feeding programs may over-estimate protein needs, leading to unnecessary nitrogen excretion and feed cost. Precision feeding, through daily updates of lysine and energy levels can achieve a 25–30% reduction in nitrogen excretion, without compromising growth performance (Pomar & Remus, 2019).

Individual Animal Tracking

Conventional feeding programmes are based on group averages which fail to account for intra-group variability in nutrient requirements. Precision feeding, however, uses individual animal identification systems such as Radio Frequency Identification (RFID) tags, electronic collars or biometric readers, to monitor individual feed intake and behaviour patterns. For instance, in dairy herds, RFID ear tags combined with automated feeders can detect how often a cow visits the feeder, how much it consumes and its time of feeding. This information is synchronized with physiological data (e.g., milk yield, rumination time) to infer nutrient requirements and modify the feeding plan accordingly. Individual tracking allows for early detection of health issues, such as subclinical ketosis or lameness, based on changes in feeding behaviour or intake patterns, enabling timely intervention and improved herd health management.

Feedback Loops

A distinguishing feature of precision feeding is the continuous collection and analysis of animal performance data to inform decision-making. This creates a feedback loop where the effects of dietary adjustments are monitored in real time and used to further fine-tune the feed delivery system. These feedback loops rely on integration between sensor data, animal responses and decision-support algorithms. For example, in broiler production, precision feeding systems can analyse weight gain patterns, feed conversion ratios (FCR) and environmental data (temperature, humidity) to automatically adjust nutrient density or feed particle size. If growth slows or FCR deteriorates, the system can recommend or implement changes in energy or amino acid concentrations. In essence, feedback loops ensure that the feeding strategy is adaptive, data-driven and outcome-oriented, leading to continuous improvement in efficiency and performance.

Physiological and Digestive Differences of Ruminants and Monogastrics

Ruminants and monogastrics exhibit fundamental differences in their digestive anatomy and physiology, which significantly influence how they utilize nutrients. These distinctions must be carefully considered when developing precision feeding protocols tailored to each species group. Understanding these contrasting digestive traits is key to maximize feed efficiency and health outcomes. A concise comparison is presented in Table 1.

Technologies Supporting Precision Feeding

The success and scalability of precision feeding depend heavily on the deployment of advanced technologies that enable accurate data collection, individualized nutrient delivery and continuous monitoring. These technologies work in an integrated manner to form a cohesive precision feeding system, where hardware (e.g., feeders, sensors) and software (e.g., models, analytics platforms) interact seamlessly. Each technological component plays a critical role in enabling dynamic, animal-specific feeding practices while ensuring that real-time adjustments can be made based on biological and environmental feedback. This section elaborates on the core technologies that underpin the precision feeding framework.

Table 1: Comparative Digestive Features of Ruminants and Monogastrics

| Feature | Ruminants | Monogastrics |
|----------------------------------|----------------------------------------------------------------|----------------------------------------------|
| Stomach structure | Multi-compartment stomach (rumen, reticulum, omasum, abomasum) | Single-chambered stomach |
| Primary digestive mechanism | Fermentation by rumen microbes | Enzymatic digestion |
| Fiber digestion | Highly efficient due to microbial fermentation | Less efficient with high-fiber diets |
| Protein utilization | Can utilize non-protein nitrogen and microbial protein | Require high-quality dietary protein sources |
| Vitamin synthesis | Microbial synthesis of B-vitamins and vitamin K | Depend largely on dietary vitamin intake |
| Adaptation to low-quality forage | Well-adapted | Poorly adapted |
| Examples | Cattle, sheep, goats | Pigs, poultry, humans |

Automated Feeders and Weighing Systems

Automated feeders are central to precision feeding systems. These devices are designed to dispense feed in measured quantities tailored to individual animals, based on predetermined nutritional requirements or real-time performance indicators. In modern systems, automated feeders are equipped with integrated weighing mechanisms, which assess both the quantity of feed delivered and the body weight of animals at the time of feeding. Such feeders are also paired with individual animal identification technologies, such as RFID (Radio Frequency Identification) ear tags, neck collars or boluses, allowing the system to recognize specific animals as they access the feeder. For example, in swine production, precision feeders can adjust feed composition and quantity for each pig several times per day based on growth rate data collected from in-pen weighing platforms. This enables daily fine-tuning of lysine, energy and phosphorus levels, preventing nutrient excess or deficiency. Similarly, in dairy operations, robotic milking stations can integrate with automated feeders, adjusting concentrate delivery based on milk yield, body condition score (BCS) or lactation stage. These systems greatly reduce labour requirements while improving feeding precision and consistency.

Sensors and Data Collection Tools

Precision feeding systems rely on a network of biometric, environmental and behavioural sensors to gather data that inform feeding decisions. These sensors continuously monitor variables such as feed intake, water

consumption, body temperature, live body weight, locomotion activity and behavioural patterns such as rumination, chewing and lying time. Some advanced systems incorporate image recognition and machine vision technologies to evaluate body condition or detect signs of illness or lameness through gait analysis. For example, load cells placed under feeders or drinking troughs measure the amount of feed and water consumed per animal, while temperature sensors embedded in rumen boluses or wearable devices monitor thermal stress, which affects feed intake and digestion. Accelerometers and gyroscopes in collars or leg bands detect behavioural anomalies, such as reduced movement or excessive lying time, which could signal discomfort or early stages of disease. The integration of these sensors allows for early intervention, proactive health management and continuous refinement of dietary strategies.

Software and Modelling Tools

At the core of data interpretation and diet optimization in precision feeding lies a suite of nutritional modelling tools and decision-support software. These tools process real-time or near-real-time data collected from sensors and feeding equipment and translate them into actionable insights for dietary formulation. Among the most widely used models are the Cornell Net Carbohydrate and Protein System (CNCPS) and the guidelines developed by the National Research Council (NRC) for various livestock species. These models simulate animal metabolism, predict nutrient requirements based on physiological and environmental inputs and recommend balanced rations that

optimize performance while minimizing nutrient waste. Modern software platforms are often cloud-based and use artificial intelligence (AI) and machine learning (ML) algorithms to enhance prediction accuracy over time. They can dynamically adjust nutrient levels, feeding frequencies and ration ingredients based on individual animal data trends. Some platforms also include economic modules to analyse feed cost-benefit ratios or environmental footprint estimators that calculate greenhouse gas emissions and nutrient excretion. Through user-friendly dashboards, producers can monitor herd or flock performance metrics, receive alerts and customize feeding programs from remote locations.

Near-Infrared Spectroscopy (NIRS)

Another critical component of precision feeding technology is Near-Infrared Spectroscopy (NIRS), a rapid, non-destructive technique used for the real-time analysis of feed composition. NIRS devices use the interaction of near-infrared light with organic compounds to estimate moisture, crude protein, fiber, starch, fat and other nutritional parameters of feed ingredients. This capability is essential for maintaining accurate feed formulations, especially when dealing with variable feedstocks such as silage, hay or by-products. In practical settings, NIRS scanners are installed either in feed mills, mixing wagons or directly on feeding equipment. These systems can detect deviations in nutrient content due to changes in ingredient quality, weather conditions or storage duration. For instance, if corn silage shows lower than expected starch levels, the feeding system can automatically increase concentrate supplementation to meet energy targets. This real-time nutrient profiling ensures that animals consistently receive diets that meet their current requirements, improving performance and reducing over-supplementation.

Precision Feeding in Ruminants

Implementation Challenges:

Although precision feeding offers promising benefits, putting it into practice can be quite challenging especially for smaller farms. One of the biggest hurdles is the cost of the technology. The equipment and systems needed, require a significant investment which many smallholders simply cannot afford. Then there is the issue of handling the large amounts of data these systems generate. Without proper infrastructure and technical support, managing and making

Dairy Cattle: Precision feeding in dairy cows helps optimize milk production and reproductive performance. Customized diets based on real-time milk yield improved milk fat content and reduced nitrogen excretion.

Beef Cattle: In feedlot systems, precision feeding allows better control over growth rate and carcass quality. According to Silva *et al.*, (2020), adjusting protein levels during finishing phases improved feed conversion by 8%.

Sheep and Goats: Smaller ruminants benefit from precise mineral and vitamin management. For instance, accurate selenium supplementation prevents white muscle disease.

Precision Feeding in Monogastrics

Swine (Pigs): Precision feeding in swine has seen substantial advancement. Systems like precision liquid feeding (PLF) allow blending of ingredients in real-time. Pomar & Remus, (2019) reported that such systems reduced nitrogen excretion by 30%.

Poultry: Precision nutrition in poultry focuses on phase feeding, amino acid balancing and enzyme supplementation. Broilers fed *via* individualized systems show improved feed efficiency and lower mortality rates.

Aquaculture: Although not strictly a monogastric group, precision feeding in fish has parallels. Automated feeders and water-quality sensors improve feed conversion and reduce eutrophication.

Environmental and Economic Implications

Precision feeding can drastically reduce nutrient emissions (**Table 2**). A study by Andretta *et al.*, (2018) showed a 15-35% reduction in greenhouse gases through precision diet formulations. Economically, feed constitutes up to 70% of livestock production costs. Reducing overfeeding and improving conversion efficiency translate to higher profitability. Sense of this data can be overwhelming. Farmer training is another key piece of the puzzle. Even the best technology will not be effective if farmers are not comfortable or confident using it. Lastly, animals do not always behave the same way, each animal can respond differently to the same feed, which means the system needs to be flexible and adaptable to individual needs. These real-world challenges must be addressed to ensure precision feeding can succeed on the ground.

Table 2: Environmental Impact of Precision Feeding Systems

| Aspect | Conventional Feeding | Precision Feeding |
|----------------------------|-----------------------------------------------------|-----------------------------------------------------|
| Greenhouse gas emissions | Higher due to overfeeding and inefficient digestion | Reduced by 15–35% through tailored nutrient supply |
| Nitrogen excretion | Excessive, leading to environmental pollution | Significantly lower due to optimized protein intake |
| Phosphorus runoff | Common in over-supplemented diets | Controlled through accurate mineral management |
| Feed conversion efficiency | Lower due to mismatch in nutrient needs | Improved through individualized diet formulations |
| Feed cost | Higher due to waste and inefficiencies | Reduced through precise nutrient targeting |
| Profit margin | Lower due to feed waste | Higher due to improved efficiency and performance |

Future Directions:

The road ahead for precision feeding is both exciting and full of potential to make a real difference especially for farmers and the environment. One big leap will be the use of AI and machine learning to create smarter feeding systems that can predict what each animal needs, helping farmers make better decisions without guessing. For smallholders, mobile-based advisory apps could be a game-changer, putting expert advice right in their hands, even in remote areas. There is also a growing push to connect feeding efficiency with sustainability labels, so farmers who use resources wisely can be recognized and rewarded in the market. Most importantly, bringing these innovations to developing countries could help improve food security and livelihoods for millions, making sure that the benefits of precision feeding are shared more widely and fairly.

Conclusion

Precision feeding is changing the way we care for animals. It is a move toward smarter and more thoughtful farming. Instead of giving every animal the same feed, this approach focuses on

giving each one exactly what it needs. That means healthier animals, better production and less waste harming our environment. It is a win-win for farmers and the planet. Yes, there are still challenges like high costs and complicated data, but with the right support, training and continued innovation, these obstacles can be overcome. As the livestock industry grows and evolves, precision feeding offers a practical and sustainable path forward for one that balances productivity with care for animals, people and the environment.

Conflict of Interest

The author declares no conflict of interest.

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