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Topic Insights

Animal Nutrition and Feed Science

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1. Introduction

The subject of animal nutrition and feed science is readily divided into the following two categories:

- Studies on the physiological needs of animals for amounts and balances of specific absorbed substances (i.e., nutritional requirements); and
- The abilities of naturally occurring plant and animal products or synthetic substances to supply all or some of these nutrients (i.e., feed composition and nutrient availability).

To balance the feed supply to meet animals' requirements, nutritional scientists develop a system of feeding standards or guidelines for the species in question. Over the past century, feeding standards have been developed for many species of farm livestock and fowls, working animals, pet animals, and other animals held in confinement.

Research in these fields may involve a species for which the requirements are as yet unknown, a potential feed material about which little is known, or a set of environmental conditions under which balancing the feed supply to meet animal requirements imposes additional constraints or limitations.

The engineering focus in this field may be on understanding enough about animal nutrition and feed science to envision the following factors:

- Critical control issues in feed production and processing chains;
- Methods of monitoring relevant processes; or
- Contributions to innovations in relevant processes, equipment, and infrastructure.

These factors support continuous improvements in animal health and appropriate productivity in the management and care of animals.

2. Nutritional requirements

Regarding nutritional requirements, animals can utilize an array of chemical substances (e.g., carbohydrates and fats) to provide the energy to drive all body processes, thus keeping the animals alive, healthy, and productive. Other substances (e.g., protein, some lipids, and some minerals) are required as building blocks for body tissue components—not just for the growth and production of, say, meat, eggs, or milk, but at a basic level, in the natural maintenance processes that involve the degradation and replacement of body components. This tissue "turnover" is a distinguishing feature of all living organisms. Still other nutrients (e.g., some minerals and a collection of unique organic molecules known as vitamins) are very specific substances that are required in small but regular amounts, and that cannot be synthesized in the body; these act as critical factors in the vast array of biochemical reactions that are involved in providing energy or building body tissue components. The general nature of these linked biochemical reactions, or metabolic pathways, is widely consistent among animal species. However, the evolutionary strategies that tie a species to a particular niche of food sources are reflected in some differences in the nature and relative amounts of the nutrients that are required in or derivable from the feed components for that particular species.

An animal's requirements depend on the species, age and stage of development, and nature of the product (e.g., eggs, fetal growth and development, milk, or growth for meat). Research has provided guidelines for calculating these requirements for most livestock species; these are primarily based on the live weight of the animal, on the additional demands of forming the desired products, which differ in composition, and on the efficiencies with which the nutrients are used for that class of product.

3. Feed science

Regarding feed supply, the chemical composition of most plant or animal materials commonly used as feed sources can be found in chemical composition tables, which can provide a broad indication of how that feed material can relate to an animal's requirements. Direct analysis of the available feed material allows better predictability.

When a new material or industrial byproduct attracts attention as a potential animal feed or human food source, chemical analysis comes first. Next, based on the analysis, a feeding trial is conducted in which the new material is incorporated into a formulated diet in order to investigate the empirical response of the animal. However, for feed materials of both known and unknown feeding value, the chemical composition alone does not define the degree to which the chemical components or their digestion products can be absorbed. This step calls for additional approaches that may rely on a knowledge of the physical attributes and chemical structure of the components in the feed material. In some cases, standard chemical, physicochemical, or biological test methods have been developed

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that provide useful indicators of the extent to which the derived nutrients will be made available to the animal. New approaches in this field are steadily being developed to make the way in which a given feed material can contribute to meeting an animal's requirements more predictable. The article by Yu and Prates (this special issue) titled "Molecular structure of feeds in relation to nutrient utilization and availability in animals: A novel approach" is one such effort to address this issue.

Potentially useful feed materials may also contain disadvantageous (or even toxic) components. Fiber is a relatively indigestible component in feed that can dilute the nutrients and limit the level of feed intake. To some degree, significant benefits in gut health are associated with lower fiber content. Investigations into this area of feed science are typified by the article titled "Nutritional and metabolic consequences of feeding high-fiber diets to swine: A review" (Agyekum and Nyachoti, this special issue)

Regarding animals that normally consume fibrous herbage-based diets, such as ruminant animals (e.g., sheep and cattle), it is important to understand the digestive physiology of the animal as well as the nature of the microbial fermentation process in the gut compartments that are affected by the diet. During fermentation, and particularly during the degradation of fibrous carbohydrates by the microbial population in the gut, methane is produced. Methane is a significant, potent, and undesirable greenhouse gas. Adding substances to feed to suppress methane production and, if possible, to drive the production of fermentation products that are directly useful to the animal, is another objective in this field. The article "Methane emissions from grazing Holstein-Friesian heifers at different ages estimated using the sulfur hexafluoride tracer technique" (Morrison et al., this special issue) addresses this aspect. The article also provides an example of the use of tracer methodology to estimate the rate of production of a metabolic end product that assists in the evaluation of digestive and metabolic processes in the animal in an open environment.

Research continues as new potential feedstuffs become available and as non-nutrient substances are added to feed to improve feed intake or feed conversion rates. For example, antibiotics have been widely used in the past in animal feed to improve animal performance. In the light of growing global concerns about human mortality and morbidity due to infection by antibiotic-resistant bacteria, this practice cannot continue. Therefore, alternative appetite stimulants, growth promotants, nutriceuticals, and herbal remedies are being tested for efficacy in both terrestrial and aquatic animal production systems. An aspect of this field is the focus of the article titled "Research progress in the application of Chinese herbal medicines in aquaculture: A review**"** **(**Pu et al., this special issue). Another view is presented in "The biofunctions of phytochemicals and their applications in farm animals: The Nrf2/Keap1 system as a target" (Qin and Hou, this special issue).

The presence of elevated levels of some chemical compounds, such as amino acids or antioxidants, may have direct metabolic effects that result in improved animal performance. Such possibilities can be tested in model animals to evaluate the empirical effect and identify the possible mechanisms, as in the study titled "Leucine supplementation in a chronically protein-restricted diet enhances muscle weight and postprandial protein synthesis of skeletal muscle by promoting the mTOR pathway in adult rats" (Zhang et al., this special issue).

The development of feeding standards and feed-delivery systems for marine and aquatic animals is gaining intense attention as both environmental health and feed-to-growth efficiency targets become more demanding. Measuring processes in animals within an open aquatic environment presents challenges, but is the basis on which improved feeding systems for such animals can be developed. Exacting methodology is required to make the necessary experimental measurements. One approach is through mathematical modeling based on data from experiments on the subject animal in a closed environment or a flow chamber where dilution rates for metabolic end products and excreta can be measured. Only then can the animal nutritionist address the challenges of developing feeding standards and practices that will deliver optimum nutrition consistent with the feeding behavior of the aquatic animal in question.

4. Evidence-based product warranting

At the highest level of organization in domestic and international trade, markets set specifications and demand quality assurance. This means that feed sources, all additives, the production system, and animal products (whether processed or not) must be safe for consumption and must follow ethical requirements. In turn, these requirements call for trace-backs to ensure that noncompliance can be quickly and effectively dealt with at the source of the problem.

5. Summary

Contemporary research into animal nutrition and feed science is primarily concerned with the following areas:

- Refining the existing databases of feeding standards for species and breeds of livestock, and of classes of feedstuffs that are already covered by guidelines but lack the desired precision;
- Defining the requirements of animals for which feeding standards do not already exist;
- Analyzing feeding materials that may offer sources of available nutrients but are as yet of unknown value;
- Establishing and applying better methods for the physical and chemical analysis of nutritionally important components in feed such as carbohydrates, fiber, proteins, and lipids, in order to correlate with the level of intake and the rate and extent of digestion;
- Establishing and applying analytical methods to determine the presence and potency of components in diets that may adversely affect the digestion or absorption of nutrients;
- Investigating feeding behavior, digestive processes, and metabolism;
- Developing feeding systems that will ensure animals receive the appropriate amounts of feed with as great a degree of uniformity or as close to the optimum quantity for their needs as possible, while avoiding waste;
- Exploring special circumstances, such as the supplementary feeding of pasture- or rangeland-based livestock or aquatic animals, in which some feed material is naturally available in the animals' environment but where supplementation will improve the productivity of the animal; and
- Providing evidence-based assurance of product safety and quality, as required by the market (also referred to as "honesty in labeling").