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Poultry feed availability and nutrition in developing countries

Advances in poultry nutrition

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Feed represents the greatest single expenditure associated with poultry production. Nutritional research in poultry has therefore centred on issues related to identifying barriers to effective digestion and utilization of nutrients, and on approaches for improving feed utilization. Poultry nutritionists have increasingly combined their expertise with that of specialists in other biological sciences, including immunology, microbiology, histology and molecular biology.

Although broilers and layers are highly efficient in converting feed to food products, they still excrete significant amounts of unutilized nutrients. For example, in their manure, broilers lose almost 30 percent of ingested dry matter, 25 percent of gross energy, 50 percent of nitrogen, and 55 percent of phosphorus intake. There is therefore considerable room for improving the efficiency of feed conversion to animal products. Much of the inefficiency results from the presence of undesirable components and the indigestibility of nutrients in the feed.

Recent advances in poultry nutrition have focussed on three main aspects: i) developing an understanding of nutrient metabolism and nutrient requirements; ii) determining the supply and availability of nutrients in feed ingredients; and iii) formulating least-cost diets that bring nutrient requirements and nutrient supply together effectively. The overall aim is *precision feeding* to lower costs and maximize economic efficiency. In the past, there was a tendency to overformulate diets when there was doubt about the availability of critical nutrients (especially amino acids and phosphorus) or when nutrient requirements were uncertain. This practice is no longer acceptable, not only because it is wasteful, but also because excess nutrients excreted in the manure are ultimately a source of pollution. Fine-tuning diets so that they more closely match the requirements of the birds, helps to optimize the efficiency of nutrient utilization. The major developments towards achieving the goal of precision feeding are discussed in the following sections.

DEFINING NUTRIENT REQUIREMENTS

Defining nutrient needs is challenging because they are influenced by several factors and are subject to constant change. The factors influencing nutrient requirements are of two main types: bird-related ones, such as genetics, sex, and type and stage of production; and external ones, such as thermal environment, stress and husbandry conditions. Precision in defining requirements requires accuracy in both areas. Great advances in the definition of nutrient requirements for various classes of poultry have been made possible largely by the increasing uniformity of genotypes, housing and husbandry practices throughout the poultry industry.

Defining requirements for the ten essential amino acids has been made easier by acceptance of the *ideal protein* concept. As for other nutrients, the requirements for amino acids are influenced by various factors, including genetics, sex, physiological status, environment and health status. However, most changes in amino acid requirements do not lead to changes in the relative proportion of the different amino acids. Thus actual changes in amino acid requirements can be expressed in relation to a balanced protein or ideal protein. The ideal protein concept uses lysine as the reference amino acid, and the requirements for other essential amino acids are set as percentages (or ratios) of the lysine requirement. Table 1 shows the ideal protein balances for meat chickens at different growth phases. The advantage of this system is that once the lysine requirements for a variety of conditions are determined, the needs for all other essential amino acids can be calculated. This approach has now become accepted practice for setting the amino acid specifications of feed formulations in the poultry industry.

DEFINING NUTRIENT COMPOSITION AND INGREDIENT QUALITY

Poultry producers are continually looking for opportunities that allow more flexibility in both the types and the levels of feed ingredients for use in feed formulations. Such opportunities are becoming increasingly frequent because of advances in nutrient analysis and feed evaluation techniques.

TABLE 1

Ideal amino acid ratios of meat chickens for three growth periods

Amino acid	1–21 days	22–42 days	43–56 days
Lysine[1]	100	100	100
Arginine	105	108	108
Histidine	35	35	35
Isoleucine	67	69	69
Leucine	109	109	109
Methionine + cysteine	72	72	72
Phenylalanine + tyrosine	105	105	105
Threonine	67	68.5	68.5
Tryptophan	16	17	17
Valine	77	80	80

[1] Recommended digestible lysine requirements for meat chickens of 1 to 21, 22 to 42 and 43 to 56 days are 1.070, 0.865 and 0.745 percent, respectively.

The principal role of feed ingredients is to provide the nutrients that the bird digests and utilizes for productive functions. Currently, considerable data are available on the ability of raw materials to supply these nutrients. However, a degree of variability is inherent to each raw material, and this places pressure on precise feed formulations. Data on variation (or matrices) are available for the main feed ingredients and are applied in feed formulation programmes to achieve better precision. A related development is the availability of *rapid tests*, such as near-infrared reflectance analysis, to predict gross nutrient composition and assess the variability in ingredient supplies on an ongoing basis.

It is recognized that not all the nutrients in ingredients are available for production purposes, and a portion of nutrients is excreted undigested or not utilized. As feed evaluation techniques develop, data have been accumulating on the availability of nutrients for poultry, especially of amino acids and phosphorus. For example, a recent development has been the wider use of *digestible amino acid* concentrations, rather than total amino acid concentrations, in feed formulations. The use of digestible amino acid content is particularly relevant in developing countries, where highly digestible conventional ingredients are not available and diet formulations may include ingredients of low digestibility. Formulating diets based on digestible amino acids makes it possible to increase the range of ingredients that can be used and the inclusion levels of alternative ingredients in poultry diets. This improves the precision of formulation, may lower feed costs, and ensures more predictable bird performance.

BETTER FEED FORMULATION

Once the nutritional needs are defined, the next step is to match these needs with combinations of ingredients and supplements. The object of formulation is to derive a balanced diet that provides appropriate quantities of biologically available nutrients. For commercial producers, a further object is to formulate a balanced diet at least cost. Given the range of possible feedstuffs and nutrients needed, a large number of arithmetical calculations are required to produce a least-cost diet. Over the years, feed formulation has evolved from a simple balancing of a few feedstuffs for a limited number of nutrients to a linear programming system that operates with the aid of computers. Systems using *stochastic non-linear programming* are now becoming popular, with commercially available formulation software. Variability in ingredient composition is non-linear, so stochastic programmes address this issue in the most cost-effective manner possible.

A related development is the use of *growth models* to simulate feed intake and production parameters under given husbandry conditions. Such models are effective tools for: i) comparing actual versus potential performance, which can indicate the extent of management or health problems in a flock; and ii) providing economic analysis of alternative feeding regimens. Several commercial growth models are available for predicting the production performance of both meat chickens and laying hens. However, because of the extreme complexity of biological responses, the models are only as good as the data used to establish them. There is a need for accurate and detailed information and data from a variety of production systems to enable the development of robust models that can provide accurate prediction of performance.

TABLE 2

Examples of biotechnological applications that are widely used in animal nutrition

Application	Aim(s) of the technology
1. New ingredients	To produce microbial proteins as new feed sources for animal feeding (e.g., single-cell protein, yeast protein)
2. Designer ingredients	To enhance nutrition (e.g., high-oil maize, high-methionine lupins) or reduce the level of anti-nutritive components in common feed ingredients (e.g., low-phytate maize)
3. Feed additives: a) Antimicrobials	To suppress the growth of harmful bacteria and promote the establishment of a desirable gut flora balance (e.g., antibiotics)
b) Crystalline amino acids	To increase the dietary supply of specific amino acids and improve the protein balance in diet formulations
c) Feed enzymes	To improve the availability of nutrients (energy, amino acids, phosphorus, etc.) in feed ingredients by reducing the negative effects of anti-nutritive components (e.g., microbial phytases acting on phytate, xylanases acting on arabinoxylans in wheat)
4. Gut ecosystem enhancers: a) Probiotics	To promote the establishment of a desirable gut ecosystem through the proliferation of beneficial species (e.g., direct-fed microbials)
b) Prebiotics	To exclude harmful organisms competitively, to promote the establishment of a desirable gut ecosystem (e.g., mannan oligosaccharides)

PRODUCTS OF BIOTECHNOLOGY IN POULTRY FEEDING

Progress in biotechnology during the past two decades has provided new opportunities for enhancing the productivity and efficiency of animals through improved nutrition. Biotechnologies have a vast range of applications in animal nutrition. Some of these are already in use (Table 2), while others are known to have potential but are not yet commercially applied because of technical limitations and public concerns (Table 3).

FEED PROCESSING

Today, after their ingredients have been mixed, most poultry feeds undergo some form of processing, which involves a wide range of thermal treatments including extrusion, expansion, conditioning and pelleting. Most of the feed used in the production of meat chickens is fed in pelleted or crumbled form, which enhances the economics of production by improving feed efficiency and growth performance. These improvements are attributed to decreased feed wastage, higher nutrient density, reduced selective feeding, decreased time and energy spent on eating, destruction of pathogenic organisms, and thermal modification of starch and protein. Introduction of pellet feeds is a notable feature in countries seeking to improve the production efficiency of the poultry sector.

PHASE FEEDING

The current recommendations for poultry list the nutrient requirements for only selected growth periods; the three periods of up to three weeks, three to six weeks, and six to eight weeks are con-

TABLE 3

Examples of biotechnological applications with future potential in animal nutrition

Application	Aim(s) of the technology
1. Modification of gut microbes	To modify genetically the microorganisms naturally present in the gut, to enhance their capacity for defined functions or to add new functions (e.g., rumen microbes to improve cellulose digestion)
2. Introduction of new gut microbes	To introduce new species or strains of micro-organisms into the gut
3. Bioactive peptides	Improved growth and efficiency (e.g., growth hormone-releasing peptides), improved gut function, immunomodulation, antibacterial properties
4. Antimicrobial replacers	Antimicrobial enzymes (e.g., lysozyme), to deliver specific antibodies via spray-dried plasma and egg products
5. Transgenesis	To modify nutrient metabolism and improve growth efficiency by transfer of genes

sidered for meat chickens. In practice, however, grow-out periods can range from four to ten weeks of age, depending on local market needs. Recognizing that changes in nutrient needs are more dynamic than these general recommendations, the commercial poultry industry is increasingly using phase-feeding systems to maximize performance and increase profit margins. Dietary protein and amino acid specifications are usually decreased in a progression of different feeds that satisfy changing requirements and economics. Typical feeding programmes over a five- to seven-week production cycle now include four to five feeds, such as pre-starter, starter, grower and finisher; or pre-starter, starter, grower, finisher and withdrawal. The withdrawal diets often fed during the last seven to ten days of growth involve removal of certain pharmaceutical additives and reduction of protein/amino acids. In recent years, they have also involved the reduction of certain vitamins and trace minerals, and energy.

WHOLE GRAIN FEEDING

Another recent development has been the feeding of whole grains (wheat or barley) along with a balanced concentrate feed. The benefits of whole grain feeding include better performance, reduced feed processing costs and improved flock health. These benefits appear to arise from a combination of two physiological actions: physical benefits of gizzard development and increased proventriculus secretions; and better matching of daily requirements through self-selection by the bird. The usual method of whole grain feeding is to blend 10 to 25 percent of the weight of the feed on top of the feed in delivery trucks or at the poultry house.

SUSTAINABLE POULTRY FEEDING

Not long ago, the main objective of formulating feeds was to supply nutrients (nutrient input). Today there is much public concern about what comes out of the bird (nutrient output). Animal agriculture, including the commercial poultry sector, is clearly releasing excess nutrients into the environment, and must assume responsibility for its impact on the environment, especially on water quality. Without question, the poultry industry must achieve the goal of sustainability, as environmental concerns have a major influence on its future growth and expansion. From a nutrition point of view, the most obvious strategy is to feed birds to match their requirements (precision feeding) and to improve the efficiency of birds' nutrient utilization, which will reduce the nutrient load in manure.

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