Poultry feed availability and nutrition in developing countries

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Worldwide, production of poultry meat and eggs has increased consistently over the years, and this trend is expected to continue. It is predicted that most increases in poultry production during the next two decades will occur in developing countries, where rapid economic growth, urbanization and higher household incomes will increase the demand for animal proteins. Several factors have contributed to the consistent growth in world poultry production, including: i) genetic progress in poultry strains for meat and egg production; ii) better understanding of the fundamentals of nutrition; and iii) disease control. For example, the age for a meat chicken to reach the market weight of 2 kg has steadily decreased from 63 days in 1976 to 35 days in 2009, and the efficiency of converting feed into poultry products also continues to improve. This growth in poultry production is having a profound effect on the demand for feed and raw materials. Feed is the most important input for poultry production in terms of cost, and the availability of low-priced, high-quality feeds is critical if poultry production is to remain competitive and continue to grow to meet the demand for animal protein.

PRODUCTION SYSTEMS AND FEEDING

Historically, the poultry sector has evolved through three phases: i) traditional systems, which include family poultry consisting of scavenging birds and backyard raising; ii) small-scale semi-commercial systems; and iii) large-scale commercial systems. Each of these systems is based on a unique set of technologies. They differ markedly in investment, type of birds used, husbandry level and inputs such as feeds. The feed resources, feeding and feed requirements required to raise poultry also vary widely, depending on the system used.

The traditional system is the most common type of poultry production in most developing countries. Possible feed resources for the local birds raised in this system include: i) household wastes; ii) materials from the environment (insects, worms, snails, greens, seeds, etc.); iii) crop residues, fodders and water plants; and iv) by-products from local small industrial units (cereal by-products, etc.). The survival and growth of extensive poultry systems are determined by the competition for feed resources in villages. This system works well where biomass is abundant, but in areas with scarce natural resources and low rainfall, the competition for natural resources with other animals can be extreme.

Between the two extremes of traditional and commercial production systems is the semi-commercial system, which is characterized by small to medium-sized flocks (50 to 500 birds) of local, crossbred or "improved" genotype stock, and the purchase of at least part of their feed from commercial compounders. Several feeding strategies may be used in this system: i) on-farm mixing of complete rations, using purchased and locally available feed ingredients; ii) dilution of purchased commercial feeds with local ingredients; and iii) blending of a purchased concentrate mixture with local ingredients or whole grains.

The large-scale commercial system is the dominant production system in developed countries, and this sector has also recently expanded in many developing countries. Commercial systems are characterized by large vertically integrated production units and use high-producing modern strains of birds. In these systems, feed is the most important variable cost component, accounting for 65 to 70 percent of production costs. High productivity and efficiency depend on feeding nutritionally balanced feeds that are formulated to meet the birds' nutritional requirements.

POULTRY NEED TO BE FED WELL-BALANCED DIETS

Most poultry species are omnivores, which in nutritional terms means that they have a simple digestive system with non-functional caeca. Exceptions to this general rule include geese and ostriches, which have well-developed functional caeca. The digestive tract of poultry has more organs but is shorter than that of other domestic animals. The unique features of this digestive tract include the crop, which is a storage organ, and the gizzard, which is a grinding organ. In fast-growing meat chickens, it takes less than three hours for feed to pass from mouth to cloaca and for nutrients to be digested and absorbed. To compensate for the relatively short digestive tract and rapid digesta transit time, high-performing birds need easily digested, nutrient-dense diets. Nutrient balance is critical.

The rates of genetic change in growth and feed efficiency over the years have also changed the physiology of the birds. Nutrient requirements and nutritional management have therefore changed to satisfy the genetic potential of the new strains. The high genetic potential of current poultry strains can only be achieved with properly formulated feeds that are protein- and energy-dense. Poultry, especially growing birds, are unique among domestic animals in that any change in nutrition is reflected in bird performance almost immediately. This phenomenon has been successfully exploited by the commercial poultry industry to improve growth, carcass yield and egg production.

The term "poultry" encompasses a range of domesticated species, including chickens, turkeys, ducks, geese, game birds (such as quails and pheasants) and ratites (emus and ostriches). This overview does not discuss the nutrition of all these species, but focuses on chickens, which constitute more than 90 percent of the poultry market. However, the principles of nutritional management for chickens are generally applicable to other poultry species grown for meat and eggs.

NUTRIENT REQUIREMENTS

For maximum growth and good health, intensively reared poultry need a balanced array of nutrients in their diet. The nutrients required by birds vary according to species, age and the purpose of production – whether the birds are kept for meat or egg production. Table 1 provides a summary of recommended minimum levels of selected nutrients for meat chickens of different ages and for layers. To meet these specific needs, different classes of poultry have to be fed different types of diets. These recommendations should only be considered as guidelines and used as the basis for setting dietary nutrient concentrations in practical diets. Historically, recommendations on nutrient requirements have been based on available literature and data from expert groups. Currently, however, because each specific genotype has its own requirements, most commercial feed formulations use minimum requirements recommended by the breeding companies that supply the chicks.

Poultry require nutrients to maintain their current state (maintenance) and to enable body growth (weight gain) or egg production. Birds need a steady supply of energy, protein, essential amino acids, essential fatty acids, minerals, vitamins and, most important, water. Poultry obtain energy and required nutrients through the digestion of natural feedstuffs, but minerals, vitamins and some key essential amino acids (lysine, methionine, threonine and tryptophan) are often offered as synthetic supplements.

Energy

Poultry can derive energy from simple carbohydrates, fat and protein. They cannot digest and utilize some complex carbohydrates, such as fibre, so feed formulation should use a system based on available energy. Metabolizable energy (ME) is the conventional measure of the available energy content of feed ingredients and the requirements of poultry. This takes account of energy losses in the faeces and urine.

TABLE 1

Recommended minimum nutrient requirements of meat chickens and laying hens, as percentages or units per kilogram of diet (90 percent dry matter)

		Meat chickens			Laying hens
Nutrient	**Unit**	**0–3 weeks**	**3–6 weeks**	**6–8 weeks**	
Metabolizable energy	kcal/kg	3 200	3 200	3 200	2 900
	MJ/kg	13.38	13.38	13.38	12.13
Crude protein	%	23	20	18	15
Amino acids					
Arginine	%	1.25	1.10	1.00	0.70
Glycine + Serine	%	1.25	1.14	0.97	-
Histidine	%	0.35	0.32	0.27	0.17
Isoleucine	%	0.80	0.73	0.62	0.65
Leucine	%	1.20	1.09	0.93	0.82
Lysine	%	1.10	1.00	0.85	0.69
Methionine	%	0.50	0.38	0.32	0.30
Methionine + Cysteine	%	0.90	0.72	0.60	0.58
Phenylalanine	%	0.72	0.65	0.56	0.47
Phenylalanine + Tyrosine	%	1.34	1.22	1.04	0.83
Threonine	%	0.80	0.74	0.68	0.47
Tryptophan	%	0.20	0.18	0.16	0.16
Valine	%	0.90	0.82	0.70	0.70
Fatty acid					
Linoleic acid	%	1.00	1.00	1.00	1.00
Major minerals					
Calcium	%	1.00	0.90	0.80	3.25
Chlorine	%	0.20	0.15	0.12	0.13
Non-phytate phosphorus	%	0.45	0.35	0.30	0.25
Potassium	%	0.30	0.30	0.30	0.15
Sodium	%	0.20	0.15	0.12	0.15
Trace minerals					
Copper	mg	8	8	8	-
Iodine	mg	0.35	0.35	0.35	0.04
Iron	mg	80	80	80	45
Manganese	mg	60	60	60	20
Selenium	mg	0.15	0.15	0.15	0.06
Zinc	mg	40	40	40	35

Source: Adapted from National Research Council, 1994.

Birds eat primarily to satisfy their energy needs, provided that the diet is adequate in all other essential nutrients. The energy level in the diet is therefore a major determinant of poultry's feed intake. When the dietary energy level changes, the feed intake will change, and the specifications for other nutrients must be modified to maintain the required intake. For this reason, the dietary energy level is often used as the starting point in the formulation of practical diets for poultry.

Different classes of poultry need different amounts of energy for metabolic purposes, and a deficiency will affect productive performance. To sustain high productivity, modern poultry strains are typically fed relatively high-energy diets. The dietary energy levels used in a given situation are largely dictated by the availability and cost of energy-rich feedstuffs. Because of the high cost of cereals, particularly maize, the use of low-energy diets for poultry feeding is not uncommon in many developing countries.

Protein and amino acids

The function of dietary protein is to supply amino acids for maintenance, muscle growth and synthesis of egg protein. The synthesis of muscle and egg proteins requires a supply of 20 amino acids, all of which are physiological requirements. Ten of these are either not synthesized at all or are synthesized too slowly to meet the metabolic requirements, and are designated as *essential* elements of the diet. These need to be supplied in the diet. The balance can be synthesised from other amino acids; these are referred to as *dietary non-essential* elements and need not be considered in feed formulations. From a physiological point of view, however, all 20 amino acids are essential for the synthesis of various proteins in the body. The essential amino acids for poultry are lysine, methionine, threonine, tryptophan, isoleucine, leucine, histidine, valine, phenylalanine and arginine. In addition, some consider glycine to be essential for young birds. Cysteine and tyrosine are considered semi-essential amino acids, because they can be synthesized from methionine and phenylalanine, respectively. Of the ten essential amino acids, lysine, methionine and threonine are the most limiting in most practical poultry diets.

Poultry do not have a requirement for protein *per se*. However, an adequate dietary supply of nitrogen from protein is essential to synthesize non-essential amino acids. This ensures that the essential amino acids are not used to supply the nitrogen for the synthesis of non-essential amino acids. Satisfying the recommended requirements for both protein and essential amino acids therefore ensures the provision of all amino acids to meet the birds' physiological needs. The amino acid requirements of poultry are influenced by several factors, including production level, genotype, sex, physiological status, environment and health status. For example, high levels of lean meat deposition require relatively high levels of lysine. High levels of egg output or feather growth require relatively high levels of methionine. However, most changes in amino acid requirements do not lead to changes in the relative proportions of the different amino acids. There is therefore an ideal balance of dietary amino acids for poultry, and changes in amino acid requirements are normally expressed in relation to a balanced protein or ideal protein.

Fats and fatty acids

Because of the greater energy density of fat compared with carbohydrates and protein, poultry diets usually include fats to achieve the needed dietary energy concentration. Fat accounts for about 3 to no more than 5 percent of most practical diets. Other benefits of using fats include better dust control in feed mills and poultry houses, and improved palatability of diets. Poultry do not have a specific requirement for fats as a source of energy, but a requirement for linoleic acid has been demonstrated. Linoleic acid is the only essential fatty acid needed by poultry, and its deficiency has rarely been observed in birds fed practical diets. Linoleic acid's main effect in laying birds is on egg size.

Minerals

Minerals are needed for formation of the skeletal system, for general health, as components of general metabolic activity, and for maintenance of the body's acid-base balance. Calcium and phosphorus are the most abundant mineral elements in the body, and are classified as macro-minerals, along with sodium, potassium, chloride, sulphur and magnesium. Macro-minerals are elements required in the diet at concentrations of more than 100 mg/kg.

Calcium and phosphorus are necessary for the formation and maintenance of the skeletal structure and for good egg-shell quality. In general, 60 to 80 percent of total phosphorus present in plant-derived ingredients is in the form of phytate-phosphorus. Under normal dietary conditions, phytate phosphorus is poorly utilized by poultry owing to the lack of endogenous phytase in their digestive enzymes. It is generally assumed that about one-third of the phosphorus in plant feedstuffs is non-phytate and is biologically available to poultry, so the phosphorus requirement for poultry is expressed as non-phytate phosphorus, rather than total phosphorus. A ratio of 2:1 must be maintained between calcium and non-phytate phosphorus in growing birds' diets, to optimize the absorption of these two minerals. The ratio in laying birds' diets is 13:1, because of the very high requirement for calcium for good shell quality.

Dietary proportions of sodium (Na), potassium (K) and chloride (Cl) largely determine the acid-base balance in the body for maintaining the physiological pH. If a shift occurs towards acid or base conditions, the metabolic processes are altered to maintain the pH, with the likely result of depressed performance. The dietary electrolyte balance is described by the simple formula ($Na^+ + K^+ - Cl^-$) and expressed as mEq/kg diet. Prevention of electrolyte imbalance needs careful consideration, especially in hot climates. Under most conditions, a balance of about 250 mEq/kg of diet appears satisfactory for optimum growth. The overall balance among these three minerals, and their individual concentrations are important. To be effective, their dietary levels must each be within acceptable ranges, not deficient and not excessive. Birds exposed to heat stress consume more water, and are better able to withstand heat when the water contains electrolytes. The replacement of part of the supplemental dietary sodium chloride with sodium bicarbonate has proved useful under these conditions.

Trace elements, including copper, iodine, iron, manganese, selenium, zinc and cobalt, function as components of larger molecules and as co-factors of enzymes in various metabolic reactions. These are required in the diet in only very small amounts (Table 1). Practical poultry diets should be supplemented with these major and trace minerals, because typical cereal-based diets are deficient in them. Organic forms of some trace minerals are currently available, and are generally considered to have higher biological availability than inorganic forms.

Vitamins

Vitamins are classified as fat-soluble (vitamins A, D, E and K) and water-soluble (vitamin B complex and vitamin C). All vitamins, except for vitamin C, must be provided in the diet. Vitamin C is not generally classified as a dietary essential as it can be synthesized by the bird. However, under adverse circumstances such as heat stress, dietary supplementation of vitamin C may be beneficial. The metabolic roles of the vitamins are more complex than those of other nutrients. Vitamins are not simple body building units or energy sources, but are mediators of or participants in all biochemical pathways in the body.

Water

Water is the most important, but most neglected nutrient in poultry nutrition. Water has an impact on virtually every physiological function of the bird. A constant supply of water is important to: i) the digestion of feed; ii) the absorption of nutrients; iii) the excretion of waste products; and iv) the regulation of body temperature. Water constitutes about 80 percent of the body. Unlike other animals, poultry eat and drink all the time. If they are deprived of water for even a short time, production and growth are irreversibly affected. Water must therefore be made available at all times. Both feed intake and growth rate are highly correlated with water intake. Precise requirements for water are difficult to state, and are influenced by several factors, including ambient conditions, and the age and physiological status of the birds. Under most conditions, water intake is assumed to be twice the amount of feed intake. Drinking-water temperatures should be between 10 and 25 °C. Temperatures over 30 °C will reduce consumption.

The quality of water is equally important. Quality is often taken for granted, but poor water quality can lead to poor productivity and extensive economic losses. Water is an ideal medium for the distribution of contaminants, such as chemicals and minerals, and the proliferation of harmful microorganisms. Water quality for poultry can be a major issue in arid and semi-arid regions where water is scarce. In particular, underground water in these areas can have high levels of salt. Saline drinking-water containing less than 0.25 percent salt is tolerated by birds, but can cause sodium toxicity if water intake is restricted.

REFERENCES

Daghir, N.J. 1995. *Poultry production in hot climates*. Wallingford, UK, CAB International.

Ensminger, M.E., Oldfield, J.E. & Heinemann, W.W. 1990. *Feeds & Nutrition*. Clovis, California, USA, Ensminger Publishing Company.

Hunton, P., ed. 1995. *Poultry production*. World Animal Science No. C9. Amsterdam, Netherlands, Elsevier.

Leeson, S. & Summers, J.D. 2001. *Scott's nutrition of the chicken*, 4th edition. Nottingham, UK, Nottingham University Press.

Leeson, S. & Summers, J.D. 2005. *Commercial poultry nutrition*, 3rd edition. Nottingham, UK, Nottingham University Press.

National Research Council. 1994. *Nutrient requirements of poultry*, 9th revised edition. Washington, DC, National Academy Press.

Ravindran, V. & Bryden, W.L. 1999 Amino acid availability in poultry – in vitro and *in vivo* measurements. *Australian Journal of Agricultural Research*, 50: 889–908.

Rose, S.P. 1997. *Principles of poultry science*. Wallingford, UK, CAB International.

Scanes, C.G., Brant, G. & Ensminger, M.E. 2004. *Poultry science.* Upper Saddle River, New Jersey, USA, Pearson Prentice Hall.

Scott, M.L. & Dean, W.F. 1991. *Nutrition and management of ducks*. Ithaca, New York, USA, M.L. Scott & Associates.