ENERGY AND PROTEIN NUTRITION OF COMPANION BIRDS

Energie en eiwit in de voeding van siervogels

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ABSTRACT

The general nutrient guidelines developed for companion birds are based on extrapolations of requirements determined for commercial poultry and game birds, the food habits of wild birds, and trial and error feeding experience. The maintenance energy requirements are derived from equations based on wild birds, without taking species-specific differences into account. The protein nutrition aspect is focused on the quantity rather than on the quality of the protein, as determined by the availability of protein and amino acids in different feed ingredients. Suggestions are given for determining the energy, protein and amino acid requirements of companion birds according to the Edinburgh model. Specific practical recommendations on bird diets, however, are not yet available.

SAMENVATTING

Nutriëntrichtlijnen voor siervogels zijn gebaseerd op extrapolaties van behoeften voor nutspluimvee en sport, voedingsgewoonten van wilde vogels en empirische bevindingen. Energiebehoeften voor onderhoud zijn afgeleid van vergelijkingen op basis van wilde vogels, zonder rekening te houden met specifieke soortverschillen. Eiwitvoorziening richt zich vooral tot de hoeveelheid en niet tot de kwaliteit van het eiwit, hetgeen bepaald wordt door de beschikbaarheid van eiwit en aminozuren in diverse voedermiddelen. Suggesties worden gegeven om de energie-, eiwit- en aminozurenbehoefte van siervogels te bepalen volgens het Edinburgh model. Aanbevelingen voor vogelrantsoenen in de praktijk kunnen echter nog niet gegeven worden.

INTRODUCTION

The lack of scientific research on the feeding and nutrition of companion birds in comparison to most other pet species could be attributed firstly to the perception that the diets available for companion birds are not nutrient-deficient, secondly to the financial constraints universities and industry experience with regard to employing nutritionists to study these species, and thirdly to the expense and difficulty of studying nutrient requirements in a great variety of different species and metabolic conditions (Brue, 1994). Current general nutrient guidelines for companion birds are derived firstly from extrapolations of the nutritional requirements for commercial poultry and game birds, which are expected to grow rapidly and die young, secondly from the food habits of wild birds, and thirdly from information on trial and error feeding that has been generated through the years (Brue, 1994; Nott and Taylor, 1994; Donoghue and Stahl, 1997; Koutsos *et al.*, 2001a). Although this approach has resulted in a general estimation of the nutrient needs of companion birds which could possibly be accurate, it does not quantify specific nutrient requirements. Furthermore, it attempts to compensate for species-specific problems rather than trying to solve them (Brue, 1994).

Companion birds often select individual elements of the feed mixes they are given, thus creating potential imbalance in a diet that otherwise appears nutritionally sound. Most research is done by private corporations and, with a few noteworthy exceptions, the information gathered remains proprietary (Donoghue and Stahl, 1997).

Despite the problems of species diversity, the variety of feeding behaviours and food preferences, and the lack of information from controlled trials, we nevertheless expect companion birds to live in restricted habitats and to consume limited diets of questionable nutritional value that create a high risk for the development of nutritional disorders (Kamphues, 1993; Donoghue and Stahl, 1997). To optimize the health, longevity and reproductive capacities of companion bird species, it will be necessary to go beyond the misinterpretation to judge the nutrient adequacy of a diet strictly on the basis of the total amounts of nutrients in the feed, and evaluate both the intake and bioavailability of the nutrients to the animal. There is a great need for the establishment of dietary guidelines to aid aviculturists and companion bird owners, to guide the commercial feed manufacturers in producing diets that can assure longevity and good health, and to help veterinarians assess the patient's diet and educate the client in proper feeding methods (Bruce, 1994).

ENERGY

In order to ensure adequate nutrient intake, dietary concentrations of nutrients must be balanced according to energy density (Harper, 2000). The amount of dietary metabolizable energy (ME) needed to support basal metabolism, expressed as basal metabolic rate (BMR), plus the additional energy needed to fuel activity and thermoregulation is called the maintenance energy requirement (Klasing, 1998). Growing birds need additional energy to support the accretion of new tissues, reproducing birds need additional energy for the accretion of gametes and egg production (Nott and Taylor, 1994), and molting birds need additional energy to support feather growth (Klasing, 1998).

The avian metabolic rate is higher than that of mammals, with body temperatures averaging 41 to 42 °C (Nott and Taylor, 1995). Moreover, birds excrete surplus nitrogen in the form of uric acid, a process that requires 3.25 times as much energy as the excretion of an equivalent amount of urea (Longland *et al.*, 1999). Allometric relationships, which are based on body weight (Table 1), are often used to predict the maintenance energy requirements of birds. However, the equation of McDonald *et al.* (1988) for the domestic fowl, and the *Galliformes* equation of Nagy *et al.* (1999), gave values of 21 and 16.5 kJ/day respectively for the maintenance energy requirements of a 22 g canary (*Serinus canaria*), in comparison to 62.11 kJ/day determined in an energy balance study (Harper *et al.*, 1998). Values derived using Bryant's small bird equation (1997) gave an overestimation (82 kJ/day). Equations derived under normal aviary conditions and based on the body weight range of the bird in question are considered to be the most accurate for companion birds (Harper, 2000). However, birds expend the level of energy estimated by BMR only when

Table 1. Constants for the allometric equation y (kJ/day) = a x body weight (g) ^{b} for determining the maintenance energy requirements of birds.

Type of bird	a	b	Reference
Domestic fowl[1]	360	0.75	Mc Donald *et al.* (1988)
Wild *Galliformes*	0.851	0.959	Nagy *et al.*(1999)
All wild birds	10.5	0.68	Nagy *et al.*(1999)
Small wild birds	15.94	0.53	Bryant (1997)
All birds1	451	0.668	Lasiewski and Dawson (1967)
Small adult passerines[2]			
(<100g)	2.59	1.1	Harper *et al.* (1998)
(100-1500 g)	18.95	0.55	Harper (2000)

[1] Bodyweight in kg.
[2] Corrected for uric acid production.

sleeping (Koutsos *et al.*, 2001a). Flight in budgerigars (*Melopsittacus undulatus*) requires 11 to 20 times more energy per minute than BMR (Tucker, 1969). In addition, the energy requirements of free-living birds are typically greater than those of captive birds because of the extra energy spent on foraging for food, thermoregulation and defenses (Koutsos *et al.*, 2001a; Harper and Turner, 2000). The rates of protein and lipid gain were found to be 177 and 160 mg/day, respectively, for budgerigars, and 153 and 153 mg/day for lovebirds (Kamphues and Wolf, 1997). Correcting these rates for the cost of deposition (52 kJ/g), gives the additional energy needed for growth to be 17.5 kJ/g for budgerigars and 15.9 kJ/g for lovebirds (Koutsos *et al.*, 2001a).

The amounts of food required to fulfil the energy requirements depends on the density of the metabolizable energy in the food, digestibility, environmental conditions, body size, physiological state and activity level (Koutsos *et al.*, 2001a; Harper, 2000; Harper and Turner, 2000). Granivorous and omnivorous species are comparatively efficient at obtaining energy from feed, whereas nectarivorous species are relatively inefficient (Koutsos *et al.* 2001a; Table 2). Using an equation based on the chemical composition of feed ingredients to determine the apparent metabolizable energy (AME) in diets established in poultry. (Hill and Dansky, 1954), overestimated most of the already determined AME values for budgerigars (Harper, 2000). As the dietary protein content of budgerigar feeds increases, the metabolizability of energy decreases (Drepper *et al.*, 1988), probably due to the increased energy expenditure associated with the higher excretion of uric acid (Nott and Taylor, 1994).

Birds will generally eat the amount that is required to satisfy their daily energy expenditure when food is available *ad libitum* and provided all other nutrients in the diet are balanced. Thus, when provided diets with lower than normal energy density, they increase the grams consumed each day, and vice versa (Koutsos *et al.* 2001a). However, this is not always true: with budgerigars, a diet containing 13 MJ ME/kg maintained

Table 2. Metabolizable energy in food, as determined with adult birds.

Species	Feed ingredients	GE1 (MJ/kg)	ME2 (MJ/kg)	Reference
Budgerigar	White millet	16.7	15.6	Earle and Clarke (1991)
	Red millet	15.5	14.3	Earle and Clarke (1991)
	Canary seed	14.0	12.3	Earle and Clarke (1991)
	Maize, soybean meal	17.5	14.0	Underwood *et al.* (1991)
Rainbow Lorikeet	Bread, honey, dried milk	18.3	16.3	Cannon (1979)
Kaka	Sunflower seeds, apple	28.8	22.7	Beggs and Wilson (1987)
	Insect larvae	33.9	30.6	Beggs and Wilson (1987)
Canary	Yellow millet, white millet, canary seed, black rapeseed niger[3]	18.6-20.6	15.8-17.5	Taylor *et al.* (1994b)
	Yellow millet, white millet, canary seed, black rapeseed niger[3]	20.6	17.7	Harper *et al.* (1998)
Zebra Finch	Yellow millet, white millet, canary seed, black rapeseed niger[3]	17.6	16.6	Harper *et al.* (1998)

[1] GE: Gross energy.
[2] ME: Metabolizable energy.
[3] Commercial diet, ingredients in varying proportions

Table 3. Level of protein shown to be adequate for companion birds at a given physiological state.

Species	Physiological status	ME (MJ/kg)	Protein (%)	Reference
Budgerigar	Maintenance	14.4	6.8	Kamphues and Wolf (1997)
	Maintenance	14.23	12	Underwood *et al.* (1991)
	Growth	13.39	13.2	Angel and Ballam (1995)
	Egg production	13.39	13.2	Angel and Ballam (1995)
African Grey Parrot	Maintenance	Not reported	10-15	Kamphues *et al.* (1997)
		16.65		
Rainbow Lorikeet	Maintenance		2.9	Frankel and Avram (2001)
		14.57		
Cockatiel	Maintenance	14.64	11	Koutsos *et al.* (2001b)
	Growth		20	Roudybush and Grau (1986)
		-		
Pesquet's Parrot	Maintenance		3.2	Pryor *et al.* (2001)
		-		
Canary	Growth		9.9-13.1[1]	Kamphues and Meyer (1991)

[1] g/MJ ME; derived factorially from carcass analysis.

body weight, but a diet containing 14 MJ ME/kg resulted in obesity (Drepper *et al.*, 1988). The provision of excess fruit and vegetables lowers the overall energy density of a diet and leads to a risk of insufficient energy intake (Donoghue and Stahl, 1997).

PROTEIN

An essential level of protein must be included in the diet to meet the nitrogen requirements of the bird (Koutsos *et al.*, 2001a). Very few scientific studies have been conducted to determine the protein requirements of companion and aviary birds (Table 3). Too much protein is linked to articular and visceral gout in birds, probably due to inadequate removal of excessive dietary nitrogen by uric acid (Donoghue and Stahl, 1997), while too little protein causes more body fat and greater mortality (Underwood *et al.*, 1991).

When seed protein sources are used without supplementation of the first limiting amino acid (the amino acid found in the lowest proportion compared to the dietary requirements), a higher level of protein intake is required (Koutsos *et al.*, 2001a). Across granivorous avian species, the protein requirement (expressed as a percentage of the diet) increases with increased body size (Klasing, 1998). The quantitative amino acid requirements, which depend on the physiological state of the bird, are lowest in adults at maintenance and highest in hatchlings and females that lay large clutches of eggs (Koutsos *et al.*, 2001a). A minimum glycine dietary requirement for meeting metabolic demand has been observed in the budgerigar. This has also been demonstrated in chickens (Taylor *et al.*, 1994a). Although the amino acid composition of the tissue of budgerigars is very similar to that of chickens (Massey and Sellwood, 1960), a fact which indicates that the balance of the required amino acids is probably similar to that which has been determined for growing chickens, the higher fractional growth rate of companion birds might be expected to increase the total amino acid requirements (Koutsos *et al.*, 2001a). In a study using a purified amino acid diet, which caused a low growth rate, the lysine required to support maximum growth of cockatiel (*Nymphicus hollandicus*) chicks was found to be 0.8 % of dietary dry matter (Roudybush and Grau, 1985). Requirements for amino acids are further increased during the period of feather development (Brue, 1994) and mol-

Table 4. Digestibility of protein in different food ingredients with different adult birds.

Species	Feed ingredients	Protein content (%, as is)	Protein digestibility (%)	Reference
Budgerigar	White millet	11.5	71.8[1]	Earle and Clarke (1991)
	Red millet	11.6	90.8[1]	Earle and Clarke (1991)
	Canary seed	15.6	89.5[1]	Earle and Clarke (1991)
	Red millet, white millet, canary seed[2]	Not reported	73.4[1]	Earle and Clarke (1991)
Canary	Yellow millet, white millet, canary seed, black rapeseed niger[2]	15.9-17.4	82.0[1]	Taylor *et al.* (1994b)
	Yellow millet, white millet, canary seed, black rapeseed niger[2]	17.9	80.9	Harper *et al.* (1998)
Zebra Finch	Yellow millet, white millet, canary seed, black rapeseed niger[2]	15.9	87.1	Harper *et al.* (1998)
African Grey Parrots	Not reported	22.2	54.2	Angel (1996)

[1] Corrected for the contribution of uric acid.
[2] Commercial diet, ingredients in varying proportions.

ting. Feathers contain 85 to 97 % protein in the form of keratin, and their amino acid composition is considerably different from other body proteins or egg proteins (Massey and Sellwood, 1960).

Kamphues *et al.* (1996) recommended 13.4 g protein containing 0.67 g lysine, 0.70 g arginine and 0.70 g of a combination of methionine and cystine per MJ of ME for canary chicks between two and 19 days of age with a daily growth rate of 1.2 g. Ullrey *et al.* (1991) recommended 24 % protein in the diet for all life stages of psittacine birds.

Nutritionists must be concerned with the quality of dietary protein sources. Quality varies on the basis of amino acid balance and digestibility (Koutsos *et al.*, 2001a). The digestibility of protein in different feed ingredients used with different adult companion birds is presented in Table 4. According to Vendramin-Gallo *et al.* (2001), there were no differences due to age (less than one year versus over three years) in the protein digestibility of sunflower seeds, maize or soy beans in parrots (*Amazona aestiva*).

Improving the overall amino acid profile and balance through the addition of high quality protein appears to be safer than attempting to supplement the feed with one or two amino acids (Donoghue and Stahl, 1997).

ENERGY, PROTEIN AND AMINO ACID REQUIREMENTS

From the above it is clear that, although several reviews have been written on companion bird nutrition, very little scientific evidence is available on the energy, protein and amino acid requirements of companion birds. Furthermore, the available research has concentrated on birds in the smaller size class, namely the budgerigar, canary and cockatiel, and provides only scanty information on parrots.

To determine the energy, protein and amino acid requirements for every breed under every condition will be an enormous task. In what follows we present a proposal for how to address the problems of the protein requirements and protein nutrition of companion birds.

According to Emmans and Fisher (1986), it is better to approach the problem of determining the requirements by considering the bird's characteristics that lead to predictions of the rates at which certain functions

The Gompertz equation.

$C = C_m \times \exp(-\exp(-B \times (t-t^*)))$
where C_m is the final mature weight (g),
B is the growth constant (g/d), and
t^* is the time from hatching (days).
The growth rate of protein in the empty body weight is calculated by:
dP/dt (g/day) $= B^* \times P_m \times u \times \ln(1/u)$
where B^* (the growth coefficient) is $B.P_m^{0.27}$,
P_m is the mature protein weight of the empty body weight (g) and
u is the degree of maturing (P_t/P_m).
While the growth rate of feather protein (FP) is determined by:
dFP/dt (g/day) $= B \times FP_t \times \ln(FP_m/FP_t)$
where FP_t is the protein weight (g) of feathers at any given time,
FP_m is the final mature feather protein weight (g), and
B is the growth constant for feather protein (g/d).
The maintenance protein requirements (g/d) for empty body weight are calculated by:
$0.008 \times P_m^{-0.27} \times P_t$
where 0.008 is the ideal amount of protein needed (g/unit),
while the maintenance protein requirements for feathers (g/d) is determined as 1% of feather protein weight per day.
Protein requirements needed for the growth of either empty body weight or feathers (g/day) is determined by multiplying the protein growth by 1.25, where 1.25 is the reciprocal of the presumed net efficiency of 0.80.
From the above, the total protein requirements (g/day) can be calculated.
Maintenance heat is determined by:
MH (MJ/day) $= 1.63 \times P_m^{0.73} \times u$
where 1.63 is the energy (MJ/unit) needed.
The growth rate of lipid in the empty body weight can be calculated by:
dL/dt (g/day) $= (dP/dt) \times z_{lipid} \times (uc_{lipid})$
where z_{lipid} is $(L_m/P_m) \times (c_{lipid} + 1)$, and
c_{lipid} is $\{(\ln(L_m)-\ln(L_0))/(\ln(P_m)-\ln(P_0))\} - 1$.
The effective energy requirements (EERQ) are calculated by (Emmans, 1994):
EERQ (MJ/day) = MH + 50dP/dt + 56dL/dt
where the effective energy requirements for protein and lipid retention have been estimated as 50 and 56 MJ/kg respectively.
The energy or protein concentration of the diet (%) can be calculated by EERQ (MJ/day) or Total Protein Requirements (g/day)/Feed intake (g/day).

take place, by defining resource scales carefully, and by considering the quantities of each resource needed per unit of function. This approach has a greater chance of success than an attempt to measure requirements by direct experimentation.

The Edinburgh model (Emmans and Fischer, 1986; Emmans, 1989) for determining the protein requirements for maintenance and growth, as well as for determining the effective energy requirements, is based on the description of growth. The growth of the live mass, as well as that of body protein and feather protein, are described by means of the Gompertz equation (see box).

This model can also be used to determine individual amino acid requirements. It was successfully applied to determine the EERQ and protein requirements of turkeys (Emmans, 1989), guinea fowls (Sales and Du Preez, 1997) and poultry (Gous *et al.* 1999).

The model specifies that chemical analyses must be performed on the carcasses and feathers of birds of different succeeding ages, which is not possible with companion birds, due to animal welfare considerations and costs. However, all birds that die due to natural circumstances could be analyzed, and certain assumptions will have to be made, particularly in the beginning.

The next step should be to determine the availability of energy, protein and amino acids in the different feed ingredients for companion birds so that feeds can be designed to meet the requirements of the different species. There has been only one study with budgerigars to determine the nutrient digestibility of individual feed ingredients. And any attempt to extrapolate the digestibility values of the feed ingredients for poultry and game birds will fail because these species do not consume ingredients similar to those used in companion bird feed.

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