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RAPTOR NUTRITION

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"It is the careful feeding of your Hawke that makes her serviceable: for there is no Hawke but will flie according as she is ordered and governed, as if her stomake be right, she will flie with spirit, courage and attention to the man…"

Lathams's Faulconry. Or The Faulcons Lure, and Cure

Symon Latham 1615

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RAPTOR NUTRITION

"I have flown a Hawke all one season, and never fed but upon the best meat I could, she never tasted Beefe, neither was her feathered meate (but very very feldome) cold; and to helpe her metter, a night did hardly efcape me but I thrust out the marrow of the wings of either Ducke, Pheasant, Partridge, Dove, Rooke or such like…."

An Approved Treatise of Hawkes and Hawking
Edmund Bert
1619

INTRODUCTION

Modern falconers can only sit back in wonder at Bert's dedication to his sport. Whilst we may not be inclined to push the marrow out of the bones of prey species to add to our hawks daily diet, we would all agree that the correct nutritional state of our birds is fundamental for both good health and efficient aviary management.

The argument, that In the absence of detailed nutritional data the dietary needs of any individual species are most likely to be met by feeding a diet closely approximating to that which would be taken in the wild under ideal conditions (Kirkwood 1981), can be contested. Firstly, without detailed nutritional data, how can 'ideal' conditions be identified? Even a relatively accurate analysis of 90% of a wild birds intake may not be truly reflective of the nutrient profile of the diet (Brue 1994). In the wild most raptors are opportunistic eaters i.e. they eat anything which is available e.g. feathered and furred quarry also insects, reptiles and carrion. Whilst some species have adapted over many thousands of years to a certain food intake, in many others the environment in which they live and hence the food availability will have altered, often at a rate faster than the birds metabolism has been able to adapt to (Brue 1994). A totally natural diet is impossible to replicate in captivity regimes (Dierenfeld *et al.* 1994), particularly because a wild bird has the option of choice (even if availability determines this) whilst a captive bird does not. In addition, feeding regimes based on replicating feeding patterns observed in wild raptors may not conform to optimal nutrition for captive birds who may have different inherent nutritional requirements on account of their unnatural life style (Brue 1994; Gill 1999).

Wild birds often live short lives and death due to malnutrition is the most common cause of mortality in wild populations (Keymer *et al.* 1980; Southern 1970; Hirons *et al.* 1979; Brue 1994).. Indeed "In all raptor species so far studied in the wild, more than half the birds that fledged died in their first year" (Newton 1979:203), although one accepts that competition for food, variable availability and concurrent disease or injury are significant factors (Brue 1994). Furthermore, unusual patterns of incubation have been observed in Finnish wild Eurasian kestrels, *Falco tinnunculus*, where the females were in poor body condition (Wiebe *et al.* 1998). In essence, the modern falconer needs to develop feeding regimes based on the requirements of captive bred, raised and maintained birds as opposed to trying to replicate the, less than perfect, feeding patterns of wild raptors.

Experienced falconers have bemoaned the lack of scientific research into raptor nutrition for domesticated raptors (Turner & Haslen 1991, Gill 1999). Even those falconers with a scientific background (Fox 1995), as well as the scientific community generally, have commented on the lack of research into the nutritional requirements of raptors (Bird & Ho 1976, Dierenfeld *et al*. 1986, Clum *et al.* 1997, Heidenreich 1997, Forbes & Rees Davies 2000). Indeed the majority of scientific information on avian nutrition has been adapted from extensive research into commercial feeding regimes for poultry (Angel & Plasse 1997, Brue 1994, Cooper 1985, Duke 1987, Gallagher 1999). Poultry nutritional data is clearly not relevant in view of the contrast in food requirements and life style when compared with raptors.

With a dearth of readily available information on nutritional practices, which correctly promote longevity, fitness, hunting ability and sustained reproductive success, feeding has become an art form, with practices adopted and modified because of perceived benefits, hearsay and anecdotal evidence (Brue 1994, Heidenreich 1997).

Whilst such a situation may be justified when conducted by experienced falconers and breeders, starvation is not an uncommon cause of death in inexperienced falconers' birds (Kenward 1980, Cooper 1985).

Even if one discounts the extreme of starvation in captivity, neglect of correct feeding regimes can lead to inappropriate, unnecessary or at times, detrimental vitamin and mineral supplementation regimes (Angel & Plasse 1997, Cooper 1985, Dierenfeld *et al.* 1994), often with disastrous results (Bruning *et al.* 1980). The majority of non-specific illnesses in captive birds of prey can be traced back to poor feeding regimes (Forbes & Rees Davies 2000) with sub-optimal diets being responsible for poor flight performance, premature deaths, infertility, low hatchability and weak chicks (Angel & Plasse 1997, Dierenfeld *et al.* 1989, Heidenreich 1997, Gill 1999, Forbes & Rees Davies 2000).

WHY IS SCIENTIFIC INFORMATION SO SCANT?

Historically, the study of raptor nutrition was confined to observing what wild birds of prey ate in order to assess their impact on game animals and livestock (Fisher 1893, Errington 1930). This trend has continued to the modern day with studies, for example, on Hen Harrier predation of grouse chicks on Scottish moors (Anon 1999). Whilst this can be seen as reflecting the economic importance of country sports, the resultant information has little relevance to falconer's birds or captive breeding projects.

Modern research, however, whilst accelerating and increasing in scope ($2.5 million on 265 projects in the US during 1982) has continued to concentrate on the study of wild populations. This could be considered somewhat short-sighted given the positive impact that captive breeding can have on endangered populations through correctly managed release projects. The truth is, however, that a lack of financial incentives - most aviculturists aren't set up as commercial operations – limits funding availability for captive nutritional research projects.

The majority of scientific research on avian nutrition has been conducted on poultry giving us a baseline with which to start, however, we are still learning about poultry nutrition after about 100 years of research (Laing 1999). Indeed some areas of poultry research will never be applicable to raptors. The greatest difference between Galliformes (chickens) and raptors is the fact that Galliformes are precocial (the neonate is mobile and generally self-sufficient at only a few hours of age), therefore, nutritional research into the growth requirement for young chickens will hardly apply to eyasses.

Indeed with approx. 8500 avian species, all with quite different metabolic requirements, we must take care not to extrapolate between species (Brue 1994). Research, for example into parrots or quail cannot be assumed to relate to raptors (Tell et.al. 1998). Given the current low levels of research in to non-commercial avian nutrition, we may never understand raptor nutrition as well as we understand the nutritional requirements of commercially produced poultry.

In raptor specific terms, although the importance and significance of the nutritional composition of food is understood, the health benefits of the various vitamins and minerals and the optimum level of each component and the ratios and inter-action between them is not. Attached at annex B is an outline of the general benefits to health of the major vitamins and minerals.

AIM

The aim of this paper is to review the available scientific and practical falconry text on raptor nutrition in order that falconers can base their feeding regimes on proven scientific research, on the experiences of the foremost falconers of today and where possible on proven raptor specific nutritional information.

WHY STUDY NUTRITION?

The primary reason to study nutrition, for the falconer, should be to improve the wellbeing of the raptors in our care. It is important to be aware of potentially incorrect advice that may be offered by more or less experienced falconers, anecdotal information, or product literature from the vendors of certain food supplements[1] which can on occasions be inaccurate or misleading.

There are many factors that can influence both the quantity of food required by a raptor and its' requirements for specific vitamins. Life style, husbandry, geographical area, different stages of the life cycle, for example the stage of development, growth rate, health status and production level of our birds can all affect their nutritional requirements (Laing 1999).

Nutritional knowledge, therefore, can be used to:

1. Achieve / maintain optimal health

Greater longevity (achieving the full potential [flight and breeding] life span of your bird) may be possible by optimising the diet as some dietary components may have protective effects, for example, antioxidants are known to help reduce cholesterol levels.

2. Promote disease avoidance

Nutritionally related disease can occur, which with knowledge can usually be avoided, for example:

I. *DIRECT*, because of inappropriate diet content or quantity:

- Starvation;
- Malnutrition / sub optimal nutrition;
- Metabolic Bone Disease ($Ca:P:D_3$ in balance) (i.e. rickets);
- Obesity (leading most commonly to cardiovascular or liver disease);
- Toxicities (e.g. excessive fat soluble vitamin supplementation, or mineral poisoning);
- Competition for food between birds in the same aviary.

II. *INDIRECT, a*s a consequence of altered requirements due to other conditions:

- Management techniques and housing;
- Rapid levels of neonatal growth;
- Fledging;
- Moulting;
- Reduced or ineffective plumage leading to increased heat loss;
- Breeding, egg laying and rearing;
- Old age;

[1] 'Falconry Fact Sheet' from a 'well known' vitamin supply company, which incorrectly states the calcium levels in day-old chicks.

- Increased or decreased exercise;
- Following medical treatment e.g. antibiotics altering the gut flora;
- During recovery after illness or treatment;
- Altered ambient temperatures;
- During periods of high stress e.g.:
    - (a) Adverse weather reaction;
    - (b) Weight reduction prior to entering;
    - (c) Injury, change of aviary / husbandry or other conditions leading to sudden increases in metabolic rate.

III. *DISEASE*, leading to:

- Reduction in appetite;
- Reduction in availability of food (e.g. parasitism);
- Diarrhoea – decreased absorption of nutrients and electrolytes in view of increased transit rates;
- Reduced ability to store or mobilise nutrients, especially in liver disease.

IV. *GENERAL ILL-HEALTH*, for example:

- Metabolic disorders, e.g. liver disease, thyroid disorders, diabetes;
- Neoplasia (i.e. cancers);
- Senility

V. *FOOD QUALITY*, for example:

- Excessive storage times reducing nutritional value;
- Excessive storage times reducing water content;
- Restricted food source / type, leading to limiting factors e.g. Essential Amino Acids;
- Poor hygiene precautions resulting in bacterial contamination;
- Reduced quality food e.g. rancidity (caused by excessive storage) which reduces vitamin E levels;
- Usage of incorrectly balanced food supplements;
- Excessive or inappropriate usage of food supplements.

HOW ARE NUTRIENT REQUIREMENTS QUANTIFIED?

In establishing dietary requirements the goal is to determine what amount of food or particular nutrient is sufficient, if ingested routinely, to prevent impairment of health even if intake becomes inadequate for a short period, for the life stage and life style intended. Below are some of the criteria that have been used to determine dietary requirements plus an outline of the advantages and disadvantages of the various methodologies. It becomes clear that no single method can give an absolute indication of the optimum levels of either the total amount of food an individual falcon requires, or indeed the requirement for each individual nutrient. Falconers should guard against advice that lays down absolute levels of nutrients or rigid feeding regimes, without regard to how the advice was arrived at. Even if the advice is sound, the exact nutrient requirement varies significantly not only between species, but also between individuals of the same species. Furthermore, the total amount of information and/or number of subjects in many studies have not been sufficient to assure total reliability of the results obtained.

Common methods for determining feeding regimes:

1. **Maximum growth in the young**

This is a common criterion used for commercial animals. However: whilst maximum growth is advantageous in birds destined for meat production, very rapid growth rates are often contra indicated in raptors (Forbes and Rees Davies 2000)

2. **Prevention/cure of deficiency diseases**

This depends on the observational endpoint chosen. (*E.g.,* 5-10 mg of vitamin A per day prevents growth defects, but skin tissue becomes discoloured at this intake level). Seemingly this criterion could on occasion, therefore, be considered inappropriate in the light of the current concern for levels that promote optimal health as opposed to disease prevention.

3. **Saturation of tissue**

Determines the amount that will not cause any further increases in concentration of the nutrient in the tissues.

Problem: some nutrients (*e.g.,* fat-soluble vitamins) dissolve in adipose tissue, and will accumulate to toxic levels, leading to potentially life threatening diseases.

4. **Balance studies**

Method -- measure input and output; when they are equal, assume the body is saturated.

Assumes that the size of the body pool of the nutrient is appropriate and is *not changed* by the experiment.

Assumes that higher levels of intake would do no good (clearly not true of water -- *hardly anyone* would recommend *just enough* water to maintain balance). Such results are only relevant to the bird in that controlled environment, at that life stage.

5. **Changes in a secondary variable**

Changes in some secondary variable in response to the nutrient may be measured, *e.g.,* changes in copulation frequency in tiercels in response to Vitamin E supplementation.

6. **Amounts in typical diets**

Sometimes it is difficult or impossible to determine the amount of a nutrient that is required. In such cases the amounts that seemingly healthy raptors in a wild population take in may be accepted as the norm. These levels, however, may be limited by population levels, prey availability, seasonal factors, lifestyle or geography (raptors in the wild may not need vitamin D in their diets, however, those kept in poorly designed, dark aviaries may).

WHAT IS AN ESSENTIAL NUTRIENT?

The classical definitions (Baggott 1999) are:

1. **Nutrient**

   Substance in food that provides structural or functional components or energy to the body.

2. **Essential nutrient**

   Substance that must be obtained from the diet because an animal cannot make it in sufficient quantities to meet its needs.

   - Biotin is necessary in metabolism, but raptors normally produce sufficient quantities within their bodies.

   - In contrast, Pantothenic acid is equally necessary, but it is not produced internally. Hence, Pantothenic acid is an essential nutrient.

Research, however, is incomplete and the question remains 'Are substances like dietary fibre, which are not nutrients, any less essential?'. For example, low fibre levels may be of importance in terms of pellet casting, although the requirement for this function has yet to be proven physiologically (Bird & Ho 1976). Nevertheless, the observations of falconers over the years as to the indication that casting acts to clear out accumulated mucous in the digestive system and crop, suggests that the provision of some casting material may have a beneficial effect. Mendelssohn & Marder (1970) observed that those birds fed on lean meat ingested other materials (e.g. rangle) to form a pellet and clear their stomach lining.

The question: ' What role, for example, does casting material, bone, blood or even rangle play in the nutritional well being of raptors?' remains unanswered. Some of these substances are demonstrably desirable in the diet, but do not meet the classical definitions given above. Still other elements, like lead, tin and boron, are yet to be investigated, although there is some evidence to warrant further study of their essentiality.

The final problem relates to quantity. The dramatic difference in the required amounts of certain nutrients gives rise to the following differentiation's (Baggott 1999):

1. **Macronutrient**

   Nutrient needed in large amounts (many grams daily).

2. **Micronutrient**

   Nutrient needed in small amounts (typically milligrams daily).

3. **Conditional requirements**

   Some substances are *not* generally considered essential to life, but might become so under specific circumstances (that is, conditional deficiencies are possible).

The existence of conditional deficiency states may give rise to exaggerated claims of the importance of certain substances in normal diets, leading to the recommendation of unnecessary routine supplementation. For example the supplementation of a raptors diet with thiamine may be recommended for fish eating birds. These may improve in condition and cease fitting if the supplement is given. The additional thiamine, however, is only required, because of the naturally occurring 'thiaminase' (an enzyme which digests thiamine) in the fish, which is destroying the normally available levels of thiamine.

OUTLINING THE BASICS OF A FEEDING REGIME

As a basic principle, it is important to remember that each raptor species has evolved over millennia to fill a very specific ecological niche (Brue 1994). The consumption of a prey animal by a raptor involves the bird eating casting (fur & feather), muscle, bone, viscera and the prey's gut content. In supplying food to captive birds, all these elements should be considered. Any alteration to the birds diet, even from one prey species to another, in either captive or free living individuals can result in a change in the relative proportions of these materials consumed.

It has been established that a raptors food requirement varies with body size. Buzzards, kites and eagles require approximately <10% wet weight, in food, of their body-mass per day, large falcons and *Accipiter* species 10-15%, whilst small falcons and *Accipiters* 20-25% (Craighead & Craighead 1969, Brown 1978, Kirkwood 1980 & 1985).

Total food requirement, therefore, can be seen as a correlation between an individual birds digestive efficiency and its metabolic rate.

Barton & Houston (1993) calculated the digestive efficiency of several individual raptors in summer (>20^{o}C) and winter (0^{o}C) fed on a diet of day old cockerels, in Table 1, as follows:

	% Efficiency	
Species	Summer	Winter
Red Kite	82.44	78.66
Red Kite	81.50	79.47
Hobby	80.36	78.45
Buzzard	80.79	77.16
Buzzard	82.14	76.66
Buzzard	82.92	80.22
Buzzard	80.80	76.90
Peregrine	78.85	75.83
Kestrel	79.83	77.17

As part of the same study, Barton & Houston discovered that digestive efficiency effected body-mass when fed on a variety of foods. When fed on rabbit for 8 days, the peregrine lost an average of 5.01% of their initial body mass, the Buzzards gained 2.78%. When fed the same mass of pigeon, Peregrines gained an average of 1.81% of initial body-mass, and the Buzzards gained 7.17%. In other words Buzzards gained significantly more body-mass than Peregrines when fed on either rabbit or pigeon. It should be noted that the food samples fed during this study were lean meat only, all casting material and fat was removed. Results may, therefore, vary if repeated with casting material, surface fat and bone structure intact.

Whilst Barton & Houston studied digestive efficiency, other authors have considered metabolic rate. Metabolic rate affects a bird of preys' ability to maintain a positive energy balance in that it influences morphological, physiological and behavioural adaptations. Metabolic rate is influenced by several factors including climate and latitude (Weathers 1979). *Basal metabolic rate (BMR)* = The number of kilocalories of energy a resting animal requires to 'tick over' i.e. to maintain respiration, circulation, metabolism, digestion of food, the immune system and maintenance of body temperature.

Birds have some of the highest BMR levels of vertebrates since they are endothermic: body temperature is maintained by food conversion into energy. There is also an inverse relationship between body size and metabolic rate, the smaller the raptor, the higher the BMR. Although larger birds eat more food they require a significantly smaller percentage of their body mass as food daily.

Unfortunately, it is not a simple matter of calculating the BMR of our birds and matching the kilocalorie content of the food we feed to it. Not all the kilocalories of the food we feed to our raptors are available to the bird.

Some is lost as indigestible parts are cast up as pellets or passed out as faeces. The usable proportion of the food we feed generates the metabolisable energy (ME) of that food, and can be considered as the gross energy (GE) of the food, less the kilocalories contained in both pellets/castings and in the excreta.

Again, we can not simply match the ME of the food we feed to the BMR as the ME of food item varies with:

- The type of food;
- The method of preparation i.e. de-yoking of chicks, removal of feet, legs etc.;
- The amount of casting material left on the food.

The percentage of the gross energy of the food that is available as metabolisable energy varies, for example, from day old chicks at 85% (Duke *et al.* 1973) to lab mouse at 75% (Kirkwood 1979). Any excess metabolisable energy that is fed to a resting raptor above the BMR is converted and stored as fat for use later when the falcon or hawk has less food or is more active such that energy requirements are greater, for example, during cold weather, moulting or breeding.

Experienced falconers have learned the above through observations of their birds weight when fed differing foods in differing conditions. In other words at a constant temperature different foods will add more or less weight when fed to a specific raptor. This basis enables 'falconry training' through weight control.

Kirkwood (1980) has calculated the ME requirements of some raptors as shown in Table 2:

	Weight (g)	**Kcal ME/day for maintenance**
Ferruginious Buzzard (M)	1,237	127
Ferruginious Buzzard (F)	1938	172
Red-tailed Hawk	1000	110
Kestrel	225	40
Barn owl	400	59

The temptation, however, is to consider the dietary requirements of our hawks only in terms of the energy ME required to maintain BMR, or in other words how much food to feed in order to maintain our hawks at flying (hunting) weight. This focus on food quantity can lead, unfortunately, to a disregard for food quality and variety.

In the drive to maintain constant weights, falconers can be tempted to stick to one staple food throughout the hunting season (and often the breeding season as well) as weight calculation and control is easier when only one type of food is used.

Food, however, consists of more than just its' ME/kilocalorie content (see annex B), and just as the ME of food varies with type, so does the nutritional content in terms of the nutritional availability, composition and proportions of vitamins and minerals it contains. A modern falconer must be aware of the nutritional value of a range of foods in order to develop a diet that is both adequate in terms of energy content but also in vitamin and mineral content. It is not acceptable to use one food type and add a proprietary food supplement (see later section on 'problem areas').

Bearing in mind the above as well as the methods by which nutritional requirements are established, the following parameters used by Houston Zoo in establishing its new feeding regimes (Angel & Plasse, 1997), provides a working start point:

Breeding and maintenance recommendations were developed based upon:

- Feeding habits in the wild;
- Behavioural differences between species;
- Where available, nutrient content of diets that have been successfully used;
- Where available, general nutrition information available in the scientific literature;
- The baseline used was National Research Council. 1994. Nutrient requirements of poultry. Ninth revised edition. National Academy Press, Washington, D.C.[2].

Whilst, it may be argued, that this system may not achieve optimal nutrition initially, with built in reviews on a 18 month cycle, feeding regimes, for individual collections, may be established over time. As Angel & Plasse state themselves, the "… true test of the new diet will not be complete until the birds experience the seasonal challenges of breeding, laying eggs, raising chicks and also growing older".

AN OUTLINE OF READILY AVAILABLE RAPTOR FOOD

Day-old chicks

Day-old chicks are often, mistakenly, considered to have the equivalent nutritional value of a single hen's egg. This is not the case. The formation of an embryo within an egg and the development and subsequent hatching of a chick dramatically changes the chemical and nutritional value of yolk and albumen (Table 3). Day-olds are used as the basis of a staple diet for the majority of species of birds of prey. Offering a high protein, low fat diet with good levels of vitamins and calcium.

In a recent study, the body composition of young American kestrels (*Falco sparverius*) fed on a diet of either day-old cockerels or mice were compared. This comprehensive study (Lavigne *et al.* 1994a & 1994b) provides ample evidence as to the nutritional adequacy of day-old cockerels as a food source for American kestrels. Indeed those kestrels fed on a diet of mice showed evidence of protein deficiency with lower growth rates and slower fledging. It should be noted, however, that the lipid (fat)/protein ratios of the mice in Levignes' study vary considerably from the mice analysed by other authors (Gessaman 1987), (Table 3). It may be that the mice used by Levigne were considerably older i.e. having higher fat reserves than those examined by other authors. It is essential in studying the results of analysis of any food item, that the analysis results does relate specifically to the food which was tested, and both day olds and rodents do vary in nutritional values dependent on age, type and source.

Cooper (1978) has discussed possible low levels of calcium in day-old chicks, yet the figures outlined in Table 3, based on current and extensive study, give little credence to the possibilities of deficiency. The calcium levels, which are required by growing birds of prey, would be met by any of the whole prey outlined in Table 3 (Dierenfeld *et al.* 1994, Robbins 1983).

Calcium levels, however, also need to be evaluated in relation to both dietary phosphorus (P) and vitamin D_3. Ca:P ratios of 1:1 – 2:1 have been reported for indeterminate egg layers (poultry) with determinate egg layers i.e. those birds which lay eggs during a specific breeding season e.g. raptors, requiring lower levels (Bird & Ho 1976; Dierenfeld *et al.* 1994). Day-old chicks have the correct Ca: P ratio (the most important single factor) as well as good overall levels of calcium.

The conclusion, therefore, is that day-old chicks are the ideal staple diet for most species of birds of prey, being nutritionally sound, with high ME/GE ratios, as well as being economically priced, readily available and convenient to use. As previously discussed, however, it would be most unwise to feed exclusively one type of food, therefore, consideration should be given to the other types of hawk food that are readily available.

[2] Given that no nutrient recommendations exist for the avian species being reviewed at the zoo, recommended nutrient levels for commercial poultry were used as base line, with regular reviews being undertaken.

Quail

At 6-wks old there appear to be no nutritional differences between male and female quail, however, at 16-wks of age marked differences appear: the nutritional quality of males remains unchanged yet the fat levels in female quail have almost doubled (Clum *et al.* 1997).

Age and sex differences in quail leads us to classify the main types that are available as follows:

- 5 week old male culls;
- 6 – 8 week old prime birds;
- 8 month old ex-layer birds;
- Vitamin E enhanced quail.

Quail become sexually mature at 6 weeks of age, therefore, the most readily available quail are surplus males that are culled at 5 weeks old, i.e. those birds not required for breeding programmes. These are small birds, typically, 3-5ozs (85 – 142g) in weight, and due to their low fat deposits and immaturity are low in (fat soluble) vitamins. Often sold as prime birds, these are not ideal for falconry purposes but are plentiful and hence relatively cheap.

6 – 8 week old birds, on the other hand, have been specifically raised for raptor food and have been allowed to mature, gain weight and are a good source of most vitamins and minerals. They are generally considered to be the best quail readily available and are suitable for most raptors.

8 month old layer birds are larger still, typically 8-10ozs (225 – 280g), and are almost exclusively female with a correspondingly high vitamin content. They are, however, the by-product of egg production, frequently yolk and fat filled and often carrying significant levels of pathogens and disease. These birds can represent a bio-security risk to captive raptors if not carefully sourced with this fact in mind. These birds should not be fed to eyasses or breeding birds (especially females).

Quail, therefore, are not as perfect as many falconers believe. Low hatchability rates in falcons at the Peregrine Fund facility at Boise Idaho was traced back to poor vitamin E levels in quail (Dierenfeld *et al.* 1989). Vitamin supplementation of the quail at the time of feeding to the falcons had no effect. When additional vitamin E was fed to the quail prior to killing, on feeding of the enhanced quail to the falcons, the results were significantly improved.

Vitamin E enhancement of quail fed to falcons, at the Peregrine Fund facility Boise Idaho has seen:

- Improved libido effects in adults (increased copulation frequency);
- Increased hatchability of eggs (59% to 83%);
- Increased activity in chicks with, for example, food begging occurring between 4 & 10 hours earlier than in previous years (although one accepts this was not a controlled trial).

Clearly the coming on to the market of vitamin E enhanced quail will offer breeders of falcons real improvements over previously fed quail.

It should be remembered that in the same way as our birds are as good as what we feed them, so in turn the food we feed our birds is only as good as what they, in turn, were fed.

Rats

Notwithstanding the above comments regarding vitamin E enhanced quail, rats are naturally high in vitamin E, therefore, a strong argument exists for using both rat and quail as part of a feeding regime.

Rats appear to be almost opposite to the quail in that the younger the rat the higher the vitamin content (Dierenfeld 1994). Their larger size and thick skin and fur, however, means that greater preparation time is required in terms of evisceration, portioning and skinning particularly when feeding rats to smaller hawks and falcons. It should be remembered that whilst many falconers do not wish to handle rats, their nutritional value is excellent.

Larger rats represent excellent value in terms of value for money, however, as with ex-layer quail, their high fat content renders them less suitable than small – medium sized rats for eyasses and breeding programmes.

In terms of bio-security, it should be remembered that the feeding of rodents to birds of prey also reduces the risk of the transmission of avian specific diseases from prey species to consumer.

Hamsters

Nutritionally equivalent to rats, hamsters may be a good substitute for those falconers who do not wish to prepare rats. The thin skin and fur combined with their smaller size, means that hamsters do not require evisceration and can be fed whole. Unfortunately, their popularity as pets and their scarcity as a food item makes them more expensive than rats of an equivalent size.

Guinea pigs

Guinea pigs are herbivores and as such have long digestive tracts in order to extract the nourishment they require from their food. The result is that guinea pigs should be eviscerated prior to feeding to raptors as uneaten intestines left within an aviary can quickly present a health risk and encourage vermin.

Guinea pigs have very loose fur, which is readily removed by a raptor. This fur can quickly fill a falcon's crop resulting in the excessive uptake of casting material at the expense of flesh content. Guinea pigs should therefore be totally or predominantly skinned prior to feeding. Clearly guinea pigs, because of their low price and large size at an early age represent excellent value for those falconers prepared to take the time and trouble to eviscerate and skin them correctly.

Mice

Mice are typically the most expensive food available to smaller hawks and owls in terms of their cost to weight ratio. Clum *et al.* 1997 expressed concern over their particularly high levels of vitamin A. Additionally, their high fat content and low protein levels (Lavigne *et al.* 1994a & 1994b) suggests they are less suited to feeding to birds of prey than is generally accepted. This is particularly true of the larger older mice that are most frequently available to falconers and owl keepers.

As young rats have very high nutritional value with high protein and low fat contents consideration should be given to using smaller rats of the 'weaner' category in preference to mice. These also tend to be cheaper and so represent better value for money.

Wild prey species

Any wild source of food (e.g. pigeon, game, road traffic kills) must be considered potentially contaminated.

That animal failed the 'fitness for life test' and we do not know why. Such birds may be carrying organisms such as *Mycobacteria*, *Salmonella*, *Campylobacter*, *E. coli*, *Trichomonas*, Paramyxovirus, Adenovirus, Falcon herpesvirus, Rotavirus or alternatively may have been poisoned (e.g. alphachloralose, mercury, lead, mevinphos).

Any wild sourced food should be in good body condition, have been caught and killed by physical means, and on examination the carcass should look, in all respects, to be thoroughly wholesome and free of disease. The abdomen should be opened and the surface of the liver examined. If lesions are detected the whole carcass must be rejected. Many infectious diseases (e.g. avian tuberculosis or viral disease) cause gross hepatic lesions.

Wild sourced foods may also be infested with internal (*Caryospora*, *Capillaria*, *Syngamus* etc.) or external parasites. Ectoparasites may act as vectors for haematozoa and other blood born infections. Viral diseases have been encountered (e.g. Adenovirus, Rotavirus) where healthy commercially sourced poultry (DOCs, turkey poults, quail), had been fed to healthy raptors which have then succumbed to disease (Forbes & Simpson 1997, Forbes *et al.* 1997). Apathogenic poultry viruses (of no commercial importance) may be pathogenic to raptors. Adenoviruses are commonly pathogenic to only one species e.g. Mauritius kestrels *Falco punctatus* (Forbes & Simpson 1997, Forbes *et al.* 1997). Viruses that are apathogenic in a food species, especially those that may only be pathogenic to one target species (e.g. Adenovirus), cannot be predicted. The only precaution is to avoid feeding avian derived food. Cost and availability, however, may render this in practical.

Columbiformes (pigeon) form a particular risk to raptors due to their high sub clinical incidence of *Trichomonas* spp. Discarding the head, crop and oesophagus is insufficient as breast muscle and liver are often contaminated. Stressed, senile, juvenile or diseased raptors are most susceptible. Pigeon to be fed to raptors should be frozen completely and thawed prior to feeding in order to destroy any Trichomonas organisms. Other diseases commonly carried by pigeons include Falcon Herpes Virus, Owl Herpes Virus, Newcastle Disease Virus, Pigeon Paramyxovirus, Salmonellosis, Avian Tuberculosis and Chlamydiosis, many of which are not controlled by freezing.

Raptors may consume parasite intermediate hosts. In free living and captivity the consumption of Earthworms (e.g. *Eisenia foetidus* and *Allolobophora caliginosus*) and Arthropods (slugs, snails) which can act as intermediate, paratenic or transport hosts for helminth parasites such as *Syngamus* spp and *Capillaria* spp. Aviary design can assist in preventing disease by avoid access to aviaries by these parasite intermediate hosts.

Many falconers' feed ferreted, rifled or shotgun shot foods (especially rabbit and pigeon). Shotgun killed quarry should never be fed. Rifle bullets frequently fragment on impact, so even head rifle shot food should be discarded. Ferreted rabbits may contain lead pellets from a previous non-fatal shooting incident. Lead ingestion from the consumption of fallen shooters quarry is a major cause of mortality especially in free living eagles (Saito *et al.*, 2000) Road traffic casualties may have been shot prior to vehicular collision.

Keepers should be aware of the clinical signs of lead poisoning (weakness of legs and wings, inability to stand, often grasping the feet each in the other, inco-ordination, poor appetite, green faeces, and weight loss). It only takes one lead pellet to kill a raptor; any suggestive signs should result in immediate presentation to an avian vet for examination and appropriate life saving therapy.

Other foods

The feeding of muscle (e.g. shin of beef) as a major part of the diet is unsatisfactory without supplementation. Birds flying on public display, are often fed beef as the public may object to seeing fluffy chicks or mice fed. This can lead to calcium deficiency even in adult birds presenting with central nervous signs or muscle cramps.

Dietary composition is more critical in neonates than that of adults. The diet for chicks and growing eyasses must comprise of whole carcasses, and not simply muscle (i.e. meat). When considering eyass diet it is important to study the food that is being consumed by the chick rather than the food which is being offered to the parents, the two may be very different.

General

In conclusion, a balance needs to be made between cost and food quality. The ideal diet for birds of prey seems to be one based on day-old chicks supplemented with feeding of other prey species. This would appear to be the case for both hunting and breeding birds. Falconers should not neglect the vitamin requirements of their birds in an effort to maintain weight control or feed excessive quantities of quail and rats during the breeding season.

As a general guide for breeding birds, daily feeding of day-old chicks should be the norm with supplementary feeding of, for example, quail and rat. For flying birds, the choice would be day-old chicks with, again, supplementary feeding of quail and rat with amounts tailored to maintaining flying weight. Larger portions being fed during the moult (although obesity should be avoided) then a gradual weight reduction programme undertaken prior to the start of the hunting season. The loss of a few days hunting whilst the bird is gradually weight conditioned is a small price to pay for maintaining the nutritional well being of a hunting hawk. Table 3, outlines the nutritional content of some common foods fed to raptors.

The specific requirements of individual species should also be taken into consideration as well as any additional dietary needs particular to the stage of an individual raptors life cycle, life style and general activity level.

Nutritional Composition of Raptor Foods – Notes on Tables 3a & 3B.

General

All units except moisture content and those marked with an asterix (*), are expressed on a dry matter (DM) basis. Care should be exercised when comparing wet weights (as fed) figures with dry matter figures.

Preparation Methods

- Quail

  The quail in both studies were rough plucked and had legs and wings removed, in order to simulate those portions of the carcass a falcon may consume. Quail were not eviscerated.

- Rats

  Rats were generally sampled whole, except for the column marked ‘eviscerated’. These rats were eviscerated and de-tailed.

- Guinea Pigs

  The guinea pigs in the Clum *et al.* 1997 study had the head removed as these are rarely eaten by birds of prey.

- Day Old Chicks

  Day old chicks were tested using three preparation methods:

  Whole

  De-Yolked – Abdominal skin, yolk sac and intestines removed

  Skinned – As above but with all skin and down removed

- Beef

  Two preparation methods are cited by Heidenreich 1997:

  Lean – All skin, bone and visible fat removed (see also Barton & Houston 1993 study)

  Washed – Soaked for 24 hours with three changes of water.

FOOD TYPE	Chicken Egg	Day Old Chick	Day Old Chick	Day Old Chick	Day Old Chick	Day Old Chick	Day Old Chick	Quail (Male)	Quail (Female)	Quail	Quail Vit E+	Rat Weaner	Rat	Rat	Rat
CATEGORY		Strain 1	Strain 2												
AGE		1 Day	1 Day	1 Day	1 Day	1 Day	1 Day	6 Weeks	6 Weeks	6 Weeks	7 Weeks	5 Weeks	11 Weeks		11 Weeks
SEX		Male	Male	Male	Male	Male	Male	Male	Femal	Mixed	Mixed	Mixed	Male		Mixed
SAMPLE SIZE					200		200	3	3	18	100	200	3		75
PREP METHOD	No Shell				Whole	Skinned	De-Yolked	Plucked	Plucked		Plucked				Eviscerated
NUTRIENT TYPE															
Moisture (%)	75.3	72.4	73.6	75	76.1	77.8	78.5	65.1	65.6	67	66.6	72.5	64.3	65.6	68.3
Gross Energy (Kcal/kg DM)	14700	6020	6000	6100	6162	6000	6042				5565	5756		5780	6305
Crude Fibre (%DM)	trace	0.8	1.1		0.4		2.8				3.3	2.9		2.4	1.3
Protein (%DM)		62.2	62.5	60	72.4	59.2	69.3	64.9	71.6	47.4	58.7	59.6	63.4	62.8	62.1
Lipid (%DM)		24.2	23.4	28.1	22.6	26.9	20	33.2	26.3	25.8	27.8	25.5	34.9	22.1	31.5
Ash (%DM)		7.4	7.1	7.1	7.5	8.1	8.8	9.6	12	10.3	13.5	10.5	7.5	10	6.6
Calcium (%DM)		1.36	1.24	1.2		1.4				3.8				2.06	
Phosphorus (%DM)		1	0.94	0.9		0.9								1.48	
Protein (g/100g)	12.5*				17.3*		14.9*				19.6*	16.4*			19.7*
Nitrogen (g/100g)															
Lipid (g/100g)	10.02*				5.4*		4.3*				9.3*	7*			11.3*
Ash (g/100g)					1.8*		1.9*				4.5*	2.9*			2.1*
Vitamin A- Retinol (IU/100g)	634*				496.7		363.3	3299	6644	9010	3633.3	816.7	6824		4000
Vitamin B1- Thiamine (mg/100g)	0.06*	1.6	1.06		0.06		0.07				0.18	0.31		1.33	0.21
Vitamin E- Alpha-tocopherol (IU/100g)	14*				40.7		21.4	4.16	7.93	4.5	10.1	9.6	21.05		15.6
Ca:P Ratio	0:28:1	1:36:1	1:32:1	1:3:1	1:49:1	1:5:1	1:17:1				1:54:1	1:21:1		1:39:1	1:33:1
Calcium (mg/100g)	50*				775		680	3268	4361		2140	1010	2286		5930
Phosphorus (mg/100g)	178*				521		581				1390	838			4470
Copper (mg/100g)	0.014*	0.33	0.34		0.264		0.268	0.266	0.302	0.29	0.48	0.847	0.13	0.45	0.18
Iron (mg/100g)	1.44*	3.4	3.19		5.23		5.57	8.5	11.24	7.14	11.1	6.74	4.3	5.89	4.79
Magnesium (mg/100g)	10*				36		33.1	57.9	75.3	66	74.8	59.5	24.7		30.2
Manganese (mg/100g)	0.024*	0.08	0.06		<0.1		<0.01	0.66	0.85		0.417	0.92	0.29	0.25	<0.1
Zinc (mg/100g)	1.1*	2.99	3.63		2.96		2.89	5.5	5.43	5.7	3.88	3.73	3.5	4.33	2.14
Sodium (mg/100g)	126*				370		371				204	254			114
Sources	(5)	(1)	(1)	(2)	HBF	(2)	HBF	(3)	(3)	(8)	HBF	HBF	(3)	(1)	HBF

FOOD TYPE	Mouse	Mouse	Mouse	Mouse	Mouse	Chicken	Chicken	Guinea Pig	Sparrow	Pigeon	Pheasant	Crow	Rabbit	Hare	Beef	Beef
CATEGORY																
AGE	12 Weeks		12 Weeks				6 Weeks	10 Weeks								
SEX	Male		Mixed				Male	Male								
SAMPLE SIZE	3		200				3	3	11							
PREP METHOD					Skinned		Plucked	Decapitated	Plucked	Lean	Lean	Lean	Lean	Lean		Washed
NUTRIENT TYPE																
Moisture (%)	66.9	64.9	66.9	64.4	67.7	66.5	67.7	69.3	68.38	72.2	72.4	69.6	74.2	74.8		
Gross Energy (Kcal/kg DM)		5840	5923	6500	6900	5930			5393	6100	5520	5780	5890	5990	1149	819
Crude Fibre (%DM)		1.7	1.5			2			0.43							
Protein (%DM)	64.4	56.1	58.9	42.7	44.8	56.7	64	58.9	64.58							
Lipid (%DM)	23.7	24.9	29.9	46.5	41	26.9	47.2	45.4	15.93	20.7*	0*	8.6*	5*	11.7*		
Ash (%DM)	9.2	10.4	9.7	7.6	10.3	9.5	10.4	8.9	10.62							
Calcium (%DM)		2.38		1.7	2.3	1.94			2.94							
Phosphorus (%DM)		1.72		1.2	1.5	1.4			2.35							
Protein (g/100g)			19.5*												20.7	14.4
Nitrogen (g/100g)										13*	14.8*	11.3*	14.4	13.8		
Lipid (g/100g)			9.9*												5.7	4.2
Ash (g/100g)			3.2*													
Vitamin A- Retinol (IU/100g)	65734		13533				3559	1999								
Vitamin B1- Thiamine (mg/100g)			0.02			0.85										
Vitamin E- Alpha-tocopherol (IU/100g)	7.44		5.9				6.14	2.98								
Ca:P Ratio		1:38:1	1:51:1	1:2:1	1:5:1	1:39:1			1:25:1						0:05:1	0:08:1
Calcium (mg/100g)	3208		2110				2455	2946							30	40
Phosphorus (mg/100g)			1400												660	490
Copper (mg/100g)	0.38	0.8	0.549			0.45	0.27	0.6	1.26							
Iron (mg/100g)	7.64	8.46	13.3			4.91	9.76	5.19	59.2							
Magnesium (mg/100g)	43.2		72.2				53.6	63.7	30							
Manganese (mg/100g)	0.53	0.41	0.709			0.3	1.1	0.66	1.14							
Zinc (mg/100g)	4.4	4.77	4.87			5.28	7.41	6.44								
Sodium (mg/100g)			273													
Sources	(3)	(1)	HBF	(2)	(2)	(1)	(3)	(3)	(6)	(4)	(4)	(4)	(4)	(4)	(7)	(7)

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(1) Gessaman 1987
(2) Lavigne et al. 1994
(3) Clum et al. 1997
(4) Barton and Houston 1993
(5) McCance and Widdowson 1991
(6) Bird et al. 1982
(7) Heidrenreich 1997
(8) Dierenfeld et al. 1994

PROBLEM AREAS TO BE AVOIDED IN FEEDING

1. Anthropomorphism

As a general principle, Brue (1994) warns us against the dangers of the enthusiast's anthropomorphic views. The tendency to 'humanize' an animal and perceiving all its needs through the eyes of the owner can lead to nutritional problems as a result of earnest attempts to do the best in terms of dietary provision. There is often a belief that nothing can be too good for a bird, and it is provided with an incredible variety of often not so nutritious foods. Similarly, the inexperienced can fall victim to the advice of self-proclaimed experts trying to achieve personal recognition through the emphatic and frequent unsupported recommendations of certain feeding programmes. The authors have encountered the following problems that can be directly linked to an attempt by the falconer to do the best for his bird:

- Overfeeding;
- Feeding exclusively one type of expensive food e.g. quail or rat;
- Feeding a varied diet but using the wrong items e.g. lean beef, turkey necks & super-market chicken;
- Additions of non-standard foodstuffs to the diet e.g honey, cod liver oil and even 'vegetarian' sausage;
- Using the feeding regime of one type of hawk for another e.g. high fat diets for Merlins;
- Over usage of vitamin supplements;
- Using live-trapped wild mice for owls, risking poisoning.

2. Ignoring differences between species

Where keepers have a varied collection of hawks, or where the novice has based his dietary regime on the advice, for example, of another falconer, who may own a different type of hawk, the temptation is to use the same feeding regime for all birds of prey. The nutritional requirements of hawks, however, vary with age, reproductive cycle and whether the bird is being flown, moulted out or free lofted.

Wide variances exist between species, for example, European Kestrels (*Falco tinnunculus*) can breed successfully for several generations on an exclusive day old chick diet (Forbes & Cooper 1993). In contrast merlins (*Falco columbarius*) fed on the same diet will not thrive. Free living merlins consume a predominantly insect-based diet and a high fat diet may be a contributory factor in Fatty Liver Kidney Syndrome of Merlins (Forbes & Cooper 1993). The diet of free living Secretary birds *(Sagittarius serpentarius*) is predominantly snakes, which are lower in energy and higher in Ca:P ratio than most commercial raptor diets. Young fast growing Secretary birds fed on standard raptor diets may suffer a Ca:P:D_3 in balance with resultant metabolic bone disease (rickets).

3. Unnecessary or excessive vitamin supplementation

Vitamin supplementation, without quantitative analysis, is not a good substitute for good basic nutrition (Sandfort *et al.* 1991, Forbes & Rees Davies 2000). Furthermore, if raptors are being fed a good diet, supplements will only be required at times of additional stress, if at all (Forbes & Rees Davies 2000).

The problem is two-fold:

a. Incorrectly balanced supplements, for raptors i.e. a vitamin/mineral supplement based on the nutritional requirements of one species is unlikely to be suitable for another (Angel & Plasse 1997, Forbes & Rees Davies 2000). All fat-soluble vitamins compete with each other for absorption. Hence if any one of the fat-soluble vitamins is available in excess there can be competitive exclusion in the fat micelle – (it simply gets super saturated with whichever fat-soluble vitamin there is in greatest abundance and the others get left out). This leads to an antagonistic interaction among the vitamins. An incorrectly formulated and unbalanced vitamin supplement preparation can be harmful if any one vitamin is out of balance and present in excessive amounts. A vitamin supplement formulated for one species may well be incorrect for another. Any supplement used should be one prepared professionally specifically for raptors.

b. Inaccurate portion control, either in an attempt to 'do good' i.e. in the mistaken idea that if one pinch is good, two pinches are better. Or simply through lack of accurate manufacturers guidelines or portion control.

In a study undertaken at Houston Zoo (Angel & Plasse 1997), wide variations were found amongst individual keepers' interpretation of the quantities of supplements that should be added to avian diets. "A pinch" was found to weigh between 0.1 and 1.9 g, with differences existing within the same feed preparation area and between separate feed preparation areas. This led to large nutrient variations with instances of, in some cases, excesses and, in others, deficiencies. Houston Zoo has discontinued the use of additional vitamin and mineral supplements preferring to feed a balanced diet.

Vitamin supplementation added directly to the food has also not shown any detectable differences in health (Crawford 1987) although food supplementation when provided in the food to prey species, has shown benefits to the secondary consumer (Crawford 1987, Dierenfeld *et al.* 1989). Furthermore, a recent study of antibiotic dosage rates (ceftiofur sodium) shows that different avian species have widely varying pharmacokinetic rates and that such differences must be considered when establishing nutrient levels for different avian species (Tell *et al.* 1998). Consequently, nutritional levels for raptors will vary significantly and the usage of non-raptor specific, commercial, supplementation compounds may well be ill advised.

In conclusion, varied, whole animal diets are desirable as they require little or no supplementation (Carpenter *et al.* 1987, Burnham *et al.* 1987, Cooper 1985, Dierenfeld *et al.* 1994, Bruning *et al.* 1980, Lavigne *et al.* 1994a & 1994b, Forbes and Rees Davies 2000). The Macdonald Raptor Research Centre has, for example, reviewed its requirements for vitamin supplementation (Bird 1987) and now feeds its large colony, 250+, of American kestrels (*Falco sparverius*) a diet of exclusively day-old cockerels (Bird *pers. comm.*)

4. Monotypic diets – (being provided with only of one kind of food)

Despite the adequacy of day-old cockerels as a staple food for many species of raptors, monotypic diets are unlikely to be advisable. Manganese deficiency, for example, has been documented in captive raptors fed a diet containing exclusively rat (Clum *et al.* 1997).

5. Monophagism – (habitual eating of only one kind of food)

Comparative work on digestive efficiency of birds of prey has shown that the Common Buzzard (*Buteo buteo*), a generalist species, has a greater digestive efficiency on a wider range of prey than the Peregrine Falcon (*Falco peregrinus*), a specialist species (Barton & Houston 1993). Such variation in the ability of different species to extract nutrients from their food requires the falconer to consider the dietary suitability for his own species and to ensure that the birds of prey in his care do not become locked into eating a narrow selection of foods.

Allowing a bird to eat in this manner invites nutritional problems. Unfortunately, monophagism often goes unrecognised when birds are allowed to eat free choice from a small variety of foods placed in front of them. The problem is most noticeable when changing from one type of food to another. In such cases a falcon may not eat for several days prior to trying the new food offered. A wide and varied diet throughout the year will accustom raptors to the range of food that they are expected to eat. Whilst offering a wide range of food throughout the year, birds of prey should only receive a single type of food at each feed. The temptation to offer both chicks and quail or rat at a feed should be avoided, as it will tend to favour selective feeding. Monophagism means that the hawk will only eat the type of food it wishes to, or only that part of the animal it happens to prefer.

It should be remembered that birds of prey do not have any innate nutritional knowledge. They are like children who would eat burgers and sweets daily if allowed. Only enough food of a single type per day should be fed, with diet variation taking place over a period of time, in order to ensure that large enough portions of each food type are eaten thereby maximising the nutritional advantages of each food consumed.

6. Excessive food provision

Birds eat to satisfy energy demands, so on a diet high in energy e.g. a high fat diet; they will eat less and therefore may not obtain the required micronutrients or trace elements from the food they consume. Likewise, the energy requirements of captive birds of prey are less than their wild counterparts, if fed as much as a wild bird obesity will ensue. However although their energy requirement is less, their micro nutrient and trace element requirements will be the same. In order for captive birds to consume sufficient micronutrients and trace elements whilst consuming a smaller food volume the levels of these elements in their food must be greater.

Many falconers over feed their falcons in the misplaced concept that they will regulate their own consumption. This situation, whether through a lack of care in measuring and portioning food or through a misplaced attempt to do the best for our raptors, should be avoided. The result of over feeding is even more dangerous than monophagism, mentioned earlier, as it encourages or permits a bird to be selective in which part of the portion they consume. This often leads to poor nutrition and nutritional deficiency related diseases.

Great care needs to be taken to match the amount of food being fed to the energy requirements of the bird of prey. Whilst less of a problem in flying/hunting birds, it is relatively common in aviary birds, particularly those which form part of a breeding programme. Much care needs to be taken in matching the levels of food offered to the food intake levels and the actual energy requirement of the bird. The ultimate aim should be to feed sufficient food daily to ensure that a small amount of waste is left and that as much of the carcass is consumed as possible, with the excess being frequently removed from the aviary. Excessive feeding leads to selectivity, obesity and the potential for food decay, ingestion of spoiled food and the attraction of vermin.

7. Incomplete diets

Whole diets comprising flesh, bone, skin and casting materials are preferable to partial diets comprising just lean meat.

Bones, for example, found in pellets cast by the gyrfalcon, *Falco rusticolus*, were heavily modified by digestion, with traces of digestion observed on more than 80% of articular ends, nearly 100% of broken surfaces and on some shafts (Bochenski *et al.* 1998). It would appear, therefore, that the digestive tract of falcons are adapted to cope with bone structure and that the high levels of digestion found suggest that bones form an important part of the diet of birds of prey.

8. Over enthusiastic evisceration

The liver of an animal stores over 90% of the vitamin A content of a carcass as well as many other vitamins (Annex B). The evisceration of animals, therefore, beyond the removal of the intestines (where necessary) should be avoided. The routine de-yolking of day-old chicks will also dramatically reduce their vitamin A content and is not recommended except in specific situations, for example when feeding merlins, when yolk once a week is the maximum recommended frequency (Forbes and Cooper 1993).

When eviscerating supplementary food animals, every effort should be made to leave the internal organs in place particularly when they are being fed to flying birds which have received a diet of skinned and de-yolked chicks to maintain flying/hunting weights.

9. Poor preparation, storage and handling

Manner and length of storage can dramatically affect food quality and nutrient levels. Blast feeding of day-old chicks, for example, produces a significantly higher nutritional quality end product when compared to slow freezing in a domestic chest freezer. Home freezing, in a chest freezer, is a health hazard to birds of prey as the slow freezing process can allow bacteria to reach dangerous levels. Modern blast freezing equipment produces high quality food economically.

Linked to the method of freezing is the length of storage time. Food kept for protracted periods in domestic and commercial freezers deteriorates in nutritional quality, particularly in terms of water-soluble vitamins and vitamin E. Freezing is a drying process and long-term storage (unless sealed) can reduce the water content of food. As birds of prey obtain the majority of their water intake from their food, moisture depletion caused by long-term storage can cause potential problems during warm weather.

Food should be sourced from suppliers with modern large-scale freezing plant and with sufficient turnover of stock to ensure that the food supplied has been frozen immediately after culling and is supplied as soon afterwards as possible. The temptation of bulk buying to obtain quantity discounts, with subsequent long-term storage in domestic freezers should be avoided. Some falconry clubs have purchase deals with food suppliers to ensure that each member need only buy sufficient food for their immediate requirements at competitive rates, rather than splitting a larger order.

The method of killing should be ascertained and it should be certain that no toxic or noxious substances could be in the food. Barbiturate poisoning has occurred in both wild and captive raptors after birds have been fed the carcasses of animals euthenased with pentobarbitone. Other possible toxic contaminants include alphachloralose, mercury, mevinphos and other pesticides.

Animals or birds fed to raptors must not have been on any form of medication, or medicated food prior to their death. Withdrawal times will depend on agents involved. The feeding of day old poults hatched from antibiotic treated turkey eggs has led to infertility (Forbes & Rees Davies 2000).

Food should not be kept stored (frozen) for more than 3 months.

The potential risks of zoonotic (diseases transferable to man from animals) infections should always be considered when handling raptors or their food.

10. Husbandry techniques

- Poor aviary design

Low calcium levels in food offered have often been accused of causing bone defects in raptors and thin-shelled eggs. Although some researchers have accepted such claims the authors believe that this is now an uncommon cause. It is more likely the Ca:P:D_3 ratios are abnormal (which gives rise to bone or egg defects) as a consequence of selective feeding of lack of vitamin D_3. Activated vitamin D_3 is not normally obtained from food sources, but is manufactured on the bird, when ultra violet light (in unfiltered sun light) reacts with vitamin D_3 which is secreted from the preen gland and spread across the plumage by the bird during preening. During preening sufficient levels of activated D_3 are consumed by the bird.

The body for the correct absorption, mobilisation and control of both phosphorus and calcium requires Vitamin D3. As a consequence a vitamin D_3 deficiency leads to a calcium deficient bird, despite the ingestion of a diet with an adequate Ca content. A bird requires a minimum of 45 minutes un-filtered (i.e. no glass or PVC etc) daylight daily to activate sufficient vitamin D_3, to meet its' requirements.

Poor aviary design or sighting can have a dramatic effect on the nutritional well being of our birds. Those raptors, which are not be routinely pegged out on the weathering lawn, should be housed in light, airy aviaries that ensure they are exposed to good daily levels of natural light.

- Poor hygiene standards

The cleanliness of the food preparation that we use for our birds should match those that we use for ourselves. Whilst wild birds of prey may be forced to eat carrion, there is no requirement to inflict this on our birds. After all we expect our captive birds to enjoy a considerably greater life expectancy than wild birds, and the provision of quality wholesome food has an integral role in achieving this. For example vitamin E acts as an anti-oxidant in our food and as such high levels act as a preservative. Rancidity, arising due to excessive storage, therefore, rapidly depletes the vitamin E content of the food fed to our raptors. Food sourced from a reputable supplier, correctly stored, defrosted and prepared should cause little problems when fed to our birds of prey.

- Poor quality food

Taylor *et al.* (1991) found that American Kestrels *Falco sparverius*, when feeding on prey species which were close to starvation and therefore in poor condition due to low fat reserves, increased their food consumption by more than 120% but were still unable to satisfy their energetic demands. The moral for the falconer is that a larger quantity of poor quality food does not compensate for feeding a high quality diet initially.

The temptation to use ‘road-kills’, spent racing pigeons and domestically raised rodents fed on poor quality diets (as opposed to lab raised animals) should be avoided. The extra cost of top quality raised food when compared to the high investment, both financial and in terms of training and upkeep, in our raptors is negligible when compared to the potential risks involved in feeding cheap, poor quality food.

The influence of diets upon the ultimate nutrient composition of prey items should not be underestimated in managed feeding programs. We are, after all, what we eat. Clearly by managing the diets of prey species, optimal diets could be developed for its secondary consumers: birds of prey. At the very least the feeding regimes of the prey items must be considered when evaluating the nutritional adequacy and choice of supplier for food items to be fed to raptors, let alone the potential benefits of feeding food such as the vitamin E enhanced quail mentioned previously.

CONCLUSIONS

The lack of complete scientific evidence and research does not allow anyone to set down formal rules for the feeding of domestic birds of prey. This guide can only be an introduction to what is currently known.

Given the analytical data in Table 3, it is clear that day-old chicks are a cost effective and nutritious staple diet for raptors particularly when supplemented by a variety other whole prey items. Furthermore the alternative to the provision of a varied diet: routine vitamin supplementation under taken by many falconers is either unnecessary or indeed may be detrimental to the health of their birds.

Allied to the correct feeding of whole prey items is the question of its quality. The use of poorly raised and prepared foodstuffs whilst, perhaps, being low in price are expensive when considered against the potential harm they can cause.

In essence, an individual raptors requirement for food, in terms of both quantity and type is affected by the interaction between:

1. Food specific factors:

    Quality;

    Method of preparation;

    Nutritional content and make-up of non-food items (castings etc.).

2. Individual bird specific factors:

    Size;

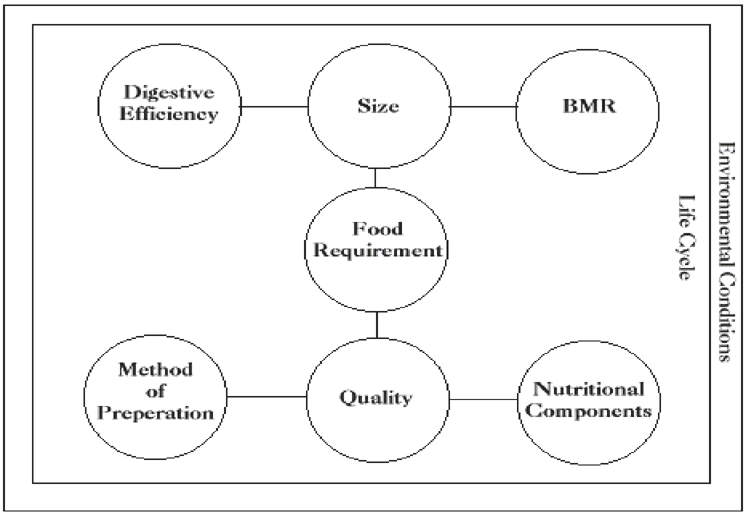
    Digestive efficiency;

    Basal Metabolic Rate (BMR).

3. For a given stage in its life cycle (moult, growth, breeding, hunting and illness etc.).

4. And for a particular set of environmental conditions (climate, geographical location etc.).

A change in any one variable will impact on what should be fed and in what quantity, see Figure 1, below.



Annex A

VETERINARY ASPECT OF RAPTOR NUTRITION

Common deficiencies and excesses

Although this is already covered, since this subject is so important the practical aspects of Ca:P:vitamin D_3 are also considered, in greater depth, here.

Ca:P:D_3 in balance, metabolic bone disease (MBD), also commonly known as rickets is the most important nutritional deficiency of raptors. Birds may present with signs ranging from slight bowing of the legs, longitudinal rotation of the lower legs to major multiple folding fractures of the skeleton and even fits. MBD is most likely to occur in fast growing larger species. Breeders should be advised not to feed such species ad libitum, but rather to restrain the potential growth rate. 'Angel wing' or 'slipped wing' (an outward rotation of the section of the wing from which the primary feathers originate) has been experienced one of the authors (NF) in several fast growing larger raptors. This is readily controlled if diagnosed early by bandaging the primaries against the body, together with Ca, vitamin D_3 supplementation and restriction of the growth rate. The diet must comprise of whole carcasses, i.e. not simply muscle (i.e. meat). The author (NF) has investigated calcium deficiencies in free living Golden eagle (*Aquila chrysaetos*) and European buzzard (*Buteo buteo*). In the former case the young were parent reared in an area with limited ground game. The birds were feeding predominantly on fallen sheep carcasses. However, they were only consuming meat from the carcasses (as sheep bones were too large for young chicks to consume). The buzzards were rearing young in an area with a significant rabbit die off due to myxomatosis. Food was plentiful and rabbit bones were too large for young buzzard chicks, moreover in view of excessive food availability selectivity of ingestion was encouraged. A similar situation can arise when a breeder feeds a whole carcass diet of rabbit and pigeon for the parent rearing of young Harris' *hawks (Parabuteo unicintus*). Either the young are unable to consume the larger bones or the parents feed what is easiest. The result is severe MBD**. It is a question of what food is consumed by the birds rather than what is offered**. Although day old chicks have often historically been considered a marginal diet, the bones are small, analytical data shows that they contain a sufficient Ca level, moreover all the bones can and typically are consumed. Day olds are therefore considered a suitable diet for young chicks, although supplementation with other foods (whole carcass ground up completely) is advisable. Calcium deficiency may also be encountered in neonates produced by a hen with significant renal pathology, or from one which has laid an excessive number of eggs (usually due to egg pulling or multiple clutching). Any multiple clutching hen should have her diet supplemented with Ca, D_3 as soon as the first clutch has been completed. Calcium deficiency due to inadequate D_3 levels is less common in raptors in comparison with psittacines in view of the contrast in typical husbandry.

Obstructions

Casting: is the indigestible parts of the carcass, which are consumed and then regurgitated as a pellet by raptor. This includes hair, feathers and in some cases (e.g. Owls) skeletal elements. Casting should not be given to any chicks under 12 days of age, and for some species (e.g. Merlin) not until 20 days of age. This applies in particular to 'hard' casting such as rodent fur, whilst chick down is considerably easier to deal with. Young chicks are often unable to cast such material; leading to a proventricular obstruction and death. Clinically a firm swelling may be palpable caudal to the edge of the sternum. Treatment using prokinetics (metoclopramide, cisapride), oral and parenteral fluid therapy, antibiosis and cautious use of oral liquid paraffin is often effective. If this is unsuccessful, surgery could be attempted, but success rates of proventriculotomy on neonates are often poor. Breeding females with developing ovarian follicles and a swollen active oviduct may have difficulties with excessive casting due to lack of abdominal space. A normal raptor will produce a casting 8 – 16 hours after a meal. Birds cannot be fed again until they have cast. If this does occur, a small intestine obstruction can arise.

Inadvertent ingestion of indigestible matter: On occasions organic material may be consumed with food (e.g. peat or vegetable material from nest ledges, wood shavings, which the bird is unable to cast. In such cases an ingluviolith or proventricular impaction will occur. Harris' hawks are the most intelligent of the common captive raptor species. They will at times 'play' with materials in their surroundings and can ingest various foreign bodies. One example is that they can learn to untie the knot tethering their leash to the perch. The leash can be pulled free of the swivel and the bird can then swallow the leash necessitating an ingluviotomy. Large foreign bodies may be safely left 24 hours, in the expectation that the bird will naturally cast them. Owls, both in captivity and in the wild, occasionally eat very long twigs (on occasions 6 - 8 inches long). The bird may appear inappetant, uncomfortable and miserable. Sometimes the twig is 'cast', but on other occasions, it may perforate the crop or proventriculus with a grave prognosis. Endoscopic or surgical removal may be necessary. Another form of obstruction seen especially in the larger owls is the ingestion of pea gravel. The bird is presented with a history of having a good weight but marked loss of body condition. Gastric distension by the gravel reduces the bird's appetite and little or no food is ingested. The condition is often advanced by the time of presentation.

Ingestion of over size food items: the feeding of rabbit or hare carcasses with intact femurs can cause problems. The bone may pass directly into the proventriculus and be digested. However, in larger raptors the bone may rotate into a transverse position in the crop or proventriculus. The bone may form an obstruction in the crop or perforate the gut leading to a terminal peritonitis. If the bone is broken (preferably without sharp ends) before feeding the problem does not arise. A similar situation can develop when pheasant necks are fed whole. The neck usually passes down straight, but occasionally will double over in the crop or distal oesophagus becoming. On occasions, birds will eat uncommon prey items. The most unusual obstruction encountered by the author (NF) was a female Red Tailed Hawk (*Buteo jamaicensis*) which had caught and eaten a hedgehog (*Erinaceous europaeus*). Initially the bird was fine, but after 18 hours with no casting, she was presented for examination. Barium contrast radiography confirmed the presence of multiple spines and fur lodged in the proventriculus. The obstruction was successfully removed via abdominal surgery.

Decreased motility: Decreased gastrointestinal motility can occur due to gastrointestinal obstructions and infections but also many other diseases. It may occur following over-eating, especially if the bird is in low condition or suffering from any illness. This occurs most commonly when a bird has made it's first kill. The bird may have been reduced in weight to encourage it to 'enter'; having killed it is rewarded by being allowed to eat a large part of the kill. 'Sour Crop' is a common and rapidly serious manifestation of this decreased motility. Ingested meat is held within the crop being maintained at 38 - 40^{o}C, with no gastric acid or enzymes present to prevent bacterial multiplication. Initial treatment by the falconer for a slow emptying crop is administration of 5 - 10ml/kg of saline by crop tube. The additional lubrication will often speed the passage of the food from the crop. If this is not effective and the crop is still unmoved after 6 - 8 hours, the bird will require urgent veterinary intervention. Intravenous fluids, antibiotics and non-steroidal anti-inflammatory drugs and are given. The most urgent action required is to empty the crop. With the bird anaesthetised and entubated crop contents may be 'milked back' to the mouth from the crop and removed. However this may be time consuming and traumatic to the patient. It is considered that an ingluviotomy is a more rapid, complete, and lower risk procedure, which also facilitates lavage of the crop with warm saline to remove all unabsorbed toxins. In a critical patient, it may be prudent to close the ingluviotomy on a subsequent day. Every effort should be made to identify possible underlying conditions. Following surgery the bird is given iv and oral fluid replacement therapy, gradually moving over to liquid foods once the crop is emptying normally, and finally solid food without casting once the bird is begging for it.

Feeding in abnormal circumstances

Neonates: chicks are "immune incompetent" for the initial days of their lives. Hygienic food preparation is imperative. In our experience, the best preventive action is to feed a probiotic, for the first ten to fourteen days of life. The probiotic will colonise the gut with helpful organisms thereby reducing the chance of an over growth with pathogenic organisms.

Feeding the bird which is low in condition: casting is not required on a daily basis. If a bird is low in condition, withhold casting, feed half crop of food this may be repeated as soon as the crop is empty, rather than waiting hours for the bird to cast.

Feeding the Vomiting Bird: vomiting may arise in raptors because of a whole range of different conditions, all of which require veterinary attention. A bird, which is vomiting, should not be immediately offered more food, even if it is loosing weight fast. The bird should be anaesthetised, diagnostic test performed, an indwelling iv catheter placed, and antibiotics, prokinetics and fluid therapy administered. If vomiting ceases, an hour later 5ml/kg warm oral electrolytes may be administered. If the fluid is kept down, it should be repeated once more two hours later. If that is retained then a further two hours later, a feed with the same volume of a liquidised food (e.g. Hills A/d. Hills UK. Hatfield) should be given by crop tube. This liquidised food is repeated every 2 hours, increasing to 10ml/kg on at least 3-4 occasions. Meat is only offered when the bird recognises it from a distance and demonstrates it is keen to eat it. The first solid food offered should be easy to 'put over' and digest e.g. skinned DOC.

Feeding the inappetant bird: often one is presented with a bird, which is low in condition, but is inappetant. There are many causes for this scenario. Any mouth (e.g. trichomoniasis, capillariasis, candidiasis), oesophagus/crop (e.g. local irritant, bacterial infection, sour crop, pox virus), stomach (e.g. impaction, infection), air sac (e.g. aspergillosis, air sacculitis, egg peritonitis), major organ failure or septicaemia is likely to lead to a depressed appetite. Some birds do not want to eat on other occasions the bird attempts to eat, but then head flicks and brings the food back. A specific diagnosis must be made and the condition treated. In the authors opinion appropriate fluid therapy and nutritional support save more birds than any other medical or surgical therapy. In cases of oral or cervical trauma in ingluviostomy tube may be used, i.e. a plastic feeding tube which may be surgically inserted direct into the crop. Care should be taken in maintaining hygiene of the tube.

The bird who is not maintaining weight on it's normal food intake or not gaining weight on an increased food intake: this is common reason for presentation of a bird by a falconer. As the falconer is weighing his bird daily, minor changes in metabolic efficiency are readily apparent. Frequent cast free meals should be given to increase the bird's weight, whilst a diagnostic work up is performed.

Feeding birds and travelling: birds should not be fed directly before travelling, in particular if they are not used to travelling. If considering an experienced flying bird, which is used to travelling, known not to suffer from travel sickness, then feeding up after a kill travelling home is acceptable. In other situations, a bird should not be travelled with food in the crop or proventriculus. The bird should have cast prior to travelling. If a bird casts whilst hooded or closely confined in a travelling box it may choke on the casting, if it were to attempt to cast during transit.

Annex B

NUTRIENTS ESSENTIAL FOR LIFE[3]

The following are the known categories of essential nutrients:

- Water
- Protein, 8-10 essential amino acids (all 20 are necessary for protein synthesis, but some are made from other amino acids or from carbohydrate and ammonium ions).
- Calories (energy) from protein, carbohydrate or fat.
- Essential fatty acids
- 13 vitamins (organic compounds required in "small" amounts).
- 16-20 minerals (inorganic compounds required in "small" amounts).

1. WATER

Whole prey provides an excellent source of water for raptors (Dierenfeld *et al.* 1994). Additionally, the younger the animal the more water it contains (Robbins 1983). Nevertheless, incorrect handling i.e. long-term freezer storage can deplete the water content of food necessitating re-hydration, particularly, during warm weather.

Additional fresh, clean water in the form of a hawk bath, both for bathing and drinking should also be readily available to birds of prey in captivity on a daily basis.

It is essential for keepers to appreciate that although a raptor may receive the vast majority of its daily water intake from its food, if it is not eating, it may well have no water intake. Whilst a bird may survive for a day or two without eating, it cannot survive this long without taking in water.

2. PROTEIN

Amino Acids are the building blocks of proteins. These make the DNA and RNA inside the cells.

Proteins are made up of a combination of 22 Amino Acids, 10 of which can't be manufactured by the body and are deemed essential Amino Acids.

The usefulness of protein in the diet depends on its quality.

Factors affecting quality are:

(a) Balance of Amino Acids

(b) Availability of these AA's in the foodstuff

Proteins are broken down by digestive enzymes in the stomach and pancreas and then absorbed into the small intestine. Stomach and pancreas disease can result in low protein digestion.

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[3] The assistance of the University of Oxford Chemistry Department in preparing this section is gratefully acknowledged.

In raptors, growth studies to determine optimum protein levels found the optimal growth and earliest fledging was achieved with a high protein diet (day-old cockerels) as opposed to a high fat (mouse) based diet (Lavigne 1994a & 1994b)

3. ENERGY

Energy is necessary for all bodily functions and is derived from the metabolism of Protein, Fat and Carbohydrates. The energy content of food is measured in kilocalories: the oxidation of a gram of fat liberates 9.5 kcal, twice that of a gram of carbohydrate or protein. Animals and birds have no specific requirements for fats, but they do require essential fatty acids (lipids) that make up the fat.

The theoretical energy content of protein is 22.59 kJ/g, but only 17.99 kJ/g are available. Therefore, meat with a high proportion of fat is energetically more valuable than a diet, such as rabbit, which is virtually all protein (Barton & Houston 1993).

Fats are the most efficient source of energy, they are very easily absorbed and fat deposits are the method of storing energy in the body.

Carbohydrates are very important because this is the only energy source the brain can use. These include starches and sugars.

More strenuous activities consume more calories. The liver and muscles store excess energy (calories) in the form of glycogen, whilst further excess is stored in adipose tissue in the form of fat. Monomers from any of the complex organic molecules can be used to produce energy, although those from carbohydrates and fats are used first. In inactive birds, however, protein is used before fat if muscle usage is not required, for example, in body temperature maintenance in cold weather. Protein levels, therefore, need to be maintained during the winter as well as increasing the fat content of food.

Lipid content of foods are unlikely to be a limiting factor in the energetics or reproduction of captive birds that experience lower energy demands and more regular access to food (Clum *et al.* 1997). A greater potential problem in captivity is likely to be egg and chick viability, which can be severely affected by vitamin and mineral content of food (Dierenfeld *et al.* 1989).

4. VITAMINS

These are nutrients essential for proper health and are generally only required in small amounts. There are two main groups of Vitamins:

a) Fat soluble - A, D, and E.

b) Water soluble - all others

Vitamin A

Vitamin A is required for:

Vision;
Integrity of skin and mucus membranes;
Disease resistance (especially oral, gut and respiratory infections);
Reproduction;
Growth, especially of bones.

Its absence from diet leads to a loss in weight and failure of growth in young animals, to the eye diseases; xerophthalmia, and night blindness, kidney disease and to a general susceptibility to infections. It is thought to help prevent the development of cancer.

Vitamin A levels in prey items meet or exceed all known requirements for this vitamin (Robbins 1983), yet many commercial supplements fed to carnivores contain unwarranted high levels of this vitamin (Dierenfeld *et al.* 1994). Indeed excess vitamin A has been cited as a relatively common cause of death in captive wildlife (Robbins 1983).

The liver stores Vitamin A and contains approx. 90% of the body's Vitamin A, therefore, when eviscerating prey items it is suggested that the liver as well as the other organs: heart, lungs, kidneys etc are left in place.

Vitamin A is structurally related to carotene. Carotene is converted into vitamin A in the liver, two molecules of vitamin A are formed from one molecule of beta carotene. Excess carotenoids in the diet do not cause toxicity, as they are not converted to Vitamin A unless more is required, however, too much may cause the skin and fat to turn yellow. Vitamin A - there are several forms of this vitamin all with different activities in the body. Birds don't obtain Vitamin A from plants, but obtain its precursors, the Carotenoids. These are generally yellow/orange pigments of which Beta-Carotene is the most important.

Vitamin D_3

Vitamin D_3 is needed for the absorption of calcium and phosphorus from the gut and the regulation of calcium levels in the blood.

Sunlight activates vitamin D_3 on the plumage, which is then ingested. The absence of vitamin D_3 in the food of young birds may lead to the development of rickets ($Ca:P:D_3$ in balance, metabolic bone disease) unless the animal is exposed to unfiltered sunlight for at least 45 minutes per day or UV irradiation.

There are two main forms of this vitamin:

- Vitamin D_2 manufactured by plants and, therefore, available from prey species;
- Vitamin D_3 manufactured in the body.

Activated Vitamin D_3, however, is 30 to 40 times more potent than Vitamin D_2 and as vitamin D_3 is activated in the body by exposure to UV light, juvenile birds in covered flights may be predisposed to hypovitaminosis D and ultimately rickets. Birds that do not preen for any reason (and may be identified as those with poor plumage) may also be at risk, as in failing to preen they will not spread Vit D_3 or ingest activated D_3.

Vitamin D_3 deficiency causes calcium deficiency, hence a keeper must appreciate that when such signs arise the whole picture ($Ca:P:VitD_3$ ratio) must be considered rather than assuming that the bird or the diet offered is calcium deficient.

Production of thin or soft shelled eggs;
Egg binding;
Low clutch size;
Low hatchability;
Leg weakness;
Paralysis;
Tremors in young growing birds:
Rickets ;
Bent or broken bones.

It is clear that exposure to sunlight, either through correct aviary design or the frequent use of the weathering lawn, can have real and positive benefits on the health of raptors.

Vitamin E

Vitamin E is essential for fertility, reproduction and red blood cell formation.

Vitamin E enhancement of quail fed to falcons, at the Peregrine Fund facility Boise Idaho, (Dierenfeld *et al.* 1989) has seen:

Improved libido effects in adults;
Increased hatchability of eggs (59% to 83%);
Increased activity in chicks with, for example, food begging occurring between 4 & 10 hours earlier than in previous years.

Vitamin E is widely distributed in the body fat of animals, though animals cannot synthesise it, however, rancidity of fats will use up vitamin E from the prey carcass and create a deficiency. Vitamin E is absorbed freely in the bowel but requires proper liver and pancreas function for digestion. It is stored in the liver and in plasma in blood. As with vitamin A, prey should be freshly killed or correctly frozen and thawed and if eviscerated the body organs should be left in as a valuable source of this vitamin.

Deficiencies produce:

White muscle disease - a muscular dystrophy;
Low hatchability due to a weakness in the pipping muscle of the chick;
Splayed legs;
Brain dysfunction – incoordination;
Infertility;
Odema - swelling around the neck, wings or breast.

Vitamin K

This is the first of the water-soluble vitamins. Vitamin K is needed for effective blood clotting.

A deficiency is rare due to bacterial synthesis within the body and deficient diets are almost impossible to produce (Dierenfeld *pers. comm.*).

Deficiencies occur with coccidiostats and long term antibiotic treatment that kill off the bacteria in the bowel and is characterised by haemorrhages due to a failure of the blood to clot properly.

A good source of Vitamin K is the liver of prey species and the earlier comments regarding partial evisceration of food items apply to this vitamin. The use of a pro-biotic to encourage beneficial gut bacteria after antibiotic treatment should prove beneficial.

THIAMINE (B1) –

Vitamin B1, thiamine, releases the energy from carbohydrates and fat.

It is an anti-neuritic factor, the absence of which from the diet of birds to polyneuritics, the most fundamental symptoms of which is general nervous atrophy.

Thiamine is available in most foods but requires constant uptake as is not stored in the body and, consequently, may be in short supply within the carcass of prey species. Deficiencies can also occur where there is competition for uptake - e.g. Amprolium in coccidiostats and are characterised by:

Decreased appetite;
Incoordination;
Seizures and death.

Concerns have been expressed as to the levels of thiamine found in day-old chicks (Cooper 1975), however; other research can not substantiate these concerns (Bird & Ho 1976). Clearly the feeding regimes undertaken during the production of prey items will have a marked effect on thiamine levels contained in the food. Raptor food should, therefore be sourced from reputable suppliers where the nutritional requirements of the prey species have been adequately addressed.

RIBOFLAVIN (B2)

Vitamin B2, riboflavin is involved in the release of energy from protein, fat and carbohydrate. A good source of Vitamin B2 is the liver of prey species, though it occurs widely in most animal tissue.

Excesses don't occur as this vitamin is readily excreted.

NIACIN (B3)

Vitamin B3, nicotinic acid, niacin, or 3-pyridine carboxylic is involved in the oxidative release of energy from food, protects the skin and helps improve circulation.

Although no specific storage of this vitamin occurs within organs in the body it is very high in animal products due to its distribution throughout most body tissues and deficiencies are unlikely in raptors fed on correctly raised prey species.

PYRIDOXINE (B6)

Vitamin B6, pyridoxine, is essential for protein metabolism, and for the formation of haemoglobin - the pigment in the blood that carries oxygen round the body. Its absence from a diet is, therefore, most commonly associated with anaemia.

Freshly killed prey species will contain sufficient levels of vitamin B6; however, excessive freezer storage will deplete levels of this vitamin. In a diet consisting of freshly killed or freshly frozen and thawed food, deficiencies are unlikely.

CYANOCOBALAMINE (B12)

Vitamin B12, cyanocobalamine, helps protect nerves and is involved in the formation of red blood cells in the bone marrow. Vitamin B12 is also concerned in the biosynthesis of methyl groups of choline and methionine.

Vitamin B12 is produced by the growth of certain microorganisms in the gut and is also produced in the liver. This vitamin is stored very efficiently in the liver and muscle tissue.

A deficiency of vitamin B12 is often due to failure to absorb B12 from the stomach and, as with vitamin K, deficiencies occur with coccidiostats and long term antibiotic treatment that kill off the bacteria in the bowel.

A good source of vitamin B12 is, once again, the liver of prey species and the earlier comments regarding partial evisceration of food items applies also to this vitamin. The use of a pro-biotic to encourage beneficial gut bacteria after antibiotic treatment should prove beneficial.

Deficiencies produce:

Decreased growth rate;
Decreased food intake;
Poor feathering;
Anaemia;
Fat accumulation in heart, liver and kidneys.

FOLIC ACID (Bc)

Folic acid, pteroyl-L-glutamic acid, or vitamin Bc is involved in the formation of new cells and therefore essential for the normal growth and development of the chick within the egg.

Folic acid is only required in small quantities and is produced by bacteria in the large bowel.

Deficiencies may occur with long-term antibiotic therapy and the use of a pro-biotic to encourage beneficial gut bacteria after antibiotic treatment should prove beneficial.

PANTOTHENIC ACID

Pantothenic Acid is an oil that is required by higher animals and some microorganisms. This is considered a member of the vitamin B group and is present in most body tissues of prey species.

BIOTIN

Biotin is widely distributed in foods in low concentrations. It is absorbed from the large intestine following production by bacteria in the gut. Biotin is stored in the liver but is slow to be mobilised if needed.

CHOLINE

This vitamin is found in all tissues of the body and deficiencies are rare.

VITAMIN C

Vitamin C or Ascorbic acid is essential for the formation of collagen and intercellular material, bone and teeth and for the healing of wounds. It helps maintain elasticity of the skin, aids the absorption of iron and improves resistance to infection. Most birds do not require it, only highly evolved fruit eating birds such as the Willow Ptarmigan and Red Vented Bulbul. The liver usually manufactures the levels of vitamin C required by raptors and absorption occurs in the small intestine.

5. MINERALS

Minerals are inorganic nutrients required in the diet. They are needed in small quantities ranging from 1 mcg to 2500 mcg per day depending on the mineral.

Some minerals serve structural and maintenance roles in the body (calcium, phosphorous) while others serve as part of enzymes (copper) or other molecules (iron).

Little is known about the mineral requirements of raptors other than potential low levels of calcium in day-old cockerels have been discussed by Cooper (1975). Modern research (Dierenfeld *et al.* 1994; Robbins 1983), however, shows that the calcium levels required by growing birds of prey would normally be met by both day-old chicks and any of the whole prey items outlined in the main text.

Calcium (Ca) levels need to be evaluated in relation to both dietary phosphorus (P) and vitamin D.

Optimum Ca:P ratios of between 1:1 & 2:1 have been reported for indeterminate egg layers (poultry) with determinate egg layers i.e. those who lay eggs during a breeding season e.g. raptors, requiring lower levels (Bird & Ho 1976; Dierenfeld *et al.* 1994). Furthermore, calcium deficiency can easily be confused with that of vitamin D_3 and given that most diets are sufficient in calcium, falconers need to look at Ca levels ingested, the Ca:P:D_3 ratio and to their husbandry techniques to ensure that lack of access to daylight may not be the problem.

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