

Nutritional Requirements of Australian Psittacine Birds from an Anatomical, Physiological and Practical Perspective.

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The Order Psittaciformes contains a great variety of birds, including the bird groups parrots, lorikeets, cockatoos and parakeets. There is a remarkable degree of differentiation between members of this order, ranging from the tiny New Guinean Pygmy Parrots to the huge Macaws of South America. There are over 330 species of Psittaciformes globally, with 55 of these species found in Australia. Parrots are usually nomadic animals, and are often gregarious, living in flocks. Some Psittaciformes have highly specialised nutritional requirements and are well adapted to niche ecological positions, but many are adapted in a more general fashion for survival by opportunism.

Australia has the greatest range and number of species of parrots of any country throughout the world. A sixth of the total number of parrot species in the world are native to Australia, and Australia has the greatest diversity of genera and subfamilies. Australian parrots are found in a variety of different biotypes, including arid deserts, woodlands, coastal plains and tropical rainforests. A number of species of Australian parrot have adapted well to an urban lifestyle, and some parrots (such as Twenty-eights, *Barnardius zonarius semitorquatus*) are commonly seen in suburban areas. The 55 species of Australian Psittacines are distributed between families such as Family *Cacatuidae* (Cockatoos), Family *Psittacidae* (True Parrots) and Family *Loridae* (Lorikeets) (Shephard, 1989).

This essay will discuss the nutritional requirements of members of the Family *Psittacidae*. It will examine the rationale behind diet formulation and the dietary requirements of both adult and juvenile animals. It will attempt to promote an understanding of psittacine nutrition and the logic behind ration formulation for Australian parrots via examination of psittacine digestive anatomy, nutritional physiology and practical dietary options. The value of this examination is three-fold. Firstly, an improved understanding of psittacine nutrition will aid conservation of natural stocks of Australian parrots, which are in jeopardy for some species. Secondly, Australian parrots are highly sought after and often kept by aviculturalists. The expansion of the knowledge of aviculturalists regarding psittacine nutrition would result in increased health and increased success in breeding and raising with decreased mortality. Thirdly, as Australian parrots are widely kept by aviculturalists worldwide, there is a large market for potential producers of psittacine diets. These manufacturers would require nutritional knowledge in the avian field. This essay will only consider the scientific and practical basis of ration formulation. It will not discuss the formulation of specific rations and diets, which is deemed too lengthy in light of the number of species of Australian parrots and their varied nutritional requirements.

The Digestive Anatomy of Australian Psittacine Birds.

Before considering specific nutritional requirements of any species, some consideration of digestive anatomy and physiology are required. The digestive tract of parrots serves the same function as other animals, and is, to some degree, similar to that of other animals. There are, however, unique digestive structures possessed by birds which are absent in mammals and other animals. These include the crop, the proventriculus, the ventriculus, and the cloaca.

Parrots are generally characterised by their large skull and strong curved beaks. As opposed to a number of other groups of birds, the upper mandible of the beak of parrots is moveable against the head. This allows a special mechanism of mastication, allowing greater force to be exerted and facilitating ingestion of larger nuts and seeds. The tongue is broad and fleshy. Some members of

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the parrot group show specialisation of the beak and tongue. For example, members of the Family *Loridae* (lorikeets) have a brush-like tongue specialised for eating nectar and soft fruits.

The oesophagus passes from the oral cavity, down the right side of the neck and into the crop. The crop is basically an expandable portion of the oesophagus located at the thoracic inlet. It serves to store and moisten food. The food then passes into the stomach. The avian stomach is significantly different to that of the typical monogastric mammal, and is divided into two portions: the proventriculus and ventriculus. The proventriculus is the glandular division of the stomach, secreting digestive enzymes, acid and mucus. Birds produce more gastric acid and pepsin per kilogram bodyweight than most other animals. The proventriculus is separated from the ventriculus by the pyloric sphincter, which regulates the passage of food. The ventriculus (or gizzard) is the muscular portion of the stomach involved in mechanical breakdown of ingesta. Mechanical breakdown of ingesta is aided by the use of grit and the extremely low luminal pH (about pH 1-2). The ventriculus is highly effective in the breakdown of seeds and nuts, producing digesta with a paste-like consistency suitable for rapid nutrient absorption in the small intestine (Dyce *et al.*, 1987).

Both the small and large intestines are relatively short in the psittacine. The avian small intestine is not specifically divided into three sections, as is its mammalian counterpart. Specific digestive enzymes are secreted and the small intestine is the primary site of nutrient absorption. It also receives secretions from the bile and pancreatic ducts. Parrots lack a caecum and have a short large intestine. Hence fibre is not digested and cannot be used as a source of carbohydrate (or energy). The large intestine joins the small, short rectum, which has some role in water reabsorption but does not take part in any digestive processes. The rectum terminates at the cloaca - the common opening for the gastrointestinal and urogenital tracts. Droppings usually contain both urine and faeces (Dyce *et al.*, 1987).

Hence the digestive tract of birds, especially parrots, is short and designed to digest concentrated high calorie feeds. The passage of ingesta through the gut is relatively short for parrots, with an average time of 4 - 5 hours for complete passage time. Hence the time for absorption of nutrients is limited and fermentation is not commonly used for digestion. Careful consideration of the anatomy and physiology of the digestive tract is hence of paramount importance when determining ration formulation and feeding. There are functional limitations of avian digestion which vary from those experienced by monogastric or ruminant animals, and hence there are restrictions on the types of feeds suitable for parrots, and for birds in general. Food must be readily digestible, and must be primarily carbohydrate based. It must not contain excessive levels of indigestible fibre, and nutrients must be easily 'unlocked' or released from the food sources (Gestier, 1991).

The Digestive Physiology of Australian Psittacine Birds.

The relative energy requirements of birds (including parrots) are higher than those of most other animals. This is mostly due to higher levels of usage from activities such as flight. In the wild, much of a parrot's daily activity involves food gathering. The natural diet of Australian parrots varies widely between species, location and season. Some common foods recovered from the crops of Australian parrots include products from *Banksia sp.*, *Hakea sp.*, *Casurina sp.*, *Acacia sp.*, *Eucalyptus sp.* and *Melaluca sp.* trees; seeds such as corn and clover seed; and insects such as weevils, moths, insect larvae, termites and jassids. Parrots are generally social feeders (Gestier, 1991). Vision seems to be the most important sense for identification of food. Taste is a fairly limited sense in parrots due to low numbers of taste buds and a dry mouth, and as such it only has a minor role in food selection. Optimally, the diet provided to captive parrots should reflect the natural Psittacine diet in nutritional content, supplying adequate energy, protein, fat, carbohydrate and vitamin and mineral requirements. This will be discussed further below.

The daily food intake of a normal parrot ranges from 10% - 30% of body weight, with smaller birds consuming a higher proportion of food in relation to their body weight. Centres in the hypothalamus regulate food intake. Water consumption is 0% - 30% of body weight per day, varying with the species, size and age of the bird, ambient temperature and diet type. The diet of any animal, including that of a parrot, must contain components derived from 6 nutritional groups: carbohydrates, proteins, fats, vitamins, minerals and water. Each of these nutritional groups will now be considered in detail.

Carbohydrates

Generally, carbohydrates form the energy source of the avian diet. Carbohydrates contribute up to fifty-five percent of the total solid component of the psittacine diet. Carbohydrates in the diet vary from simple sugar molecules such as fructose and glucose (found in fruits and nectars) to large, complex long-chained polysaccharides such as cellulose and starch (found in seeds). Carbohydrate digestion begins with amylase-based breakdown of starches and other long-chained polysaccharides into more simple mono- and di-saccharide units. This digestive process occurs along much of the intestinal tract, including within the crop, where three different species of *Lactobacillus* bacteria produce amylolytic enzymes involved in carbohydrate breakdown. These enzymes, together with other amylases present in the saliva, begin the hydrolysis of complex carbohydrates (Hagen, 1997).

Pancreatic amylase is also involved with carbohydrate breakdown, and is produced by the pancreas and secreted into the small intestine. Pancreatic amylase is an amylase that catalyses the hydrolysis of 1-4 glycosidic bonds in starch and glycogen to form maltoses and residual glucose. It is a metalloenzyme and has an absolute requirement for Ca^{2+} . Intestinal brush border enzymes also play a role in carbohydrate breakdown (Bolton and Howell, 1997). In contrast, Psittacine birds lack the enzymes required to digest cellulose. This undigested cellulose is commonly referred to as fibre, and is essential for normal intestinal function, maintaining enteric tone and bacterial flora population balance.

Hence carbohydrates are split to release monosaccharides. These monosaccharides cross the enterocyte membrane via specific transmembrane transport proteins and then pass into the bloodstream. Once in the bloodstream, monosaccharides are transported via the portal circulation to the liver. From here, they can be used to synthesise glycogen (via glycogenesis) for storage, or can be passed to the peripheral tissue for catabolism and energy synthesis (generally via glycolysis and the TCA cycle) (Costa and Pethick, 1996). Refer to Appendix 1 for a specific method of calculation of energy requirements.

Protein

Proteins are large organic compounds composed of carbon, hydrogen, oxygen, nitrogen, usually sulphur and occasionally phosphorus. Structurally, proteins consist of a number of amino acids bound by peptide linkages (Blood *et al*, 1988). Proteins are an essential component of the psittacine diet, and have important structural, physiological and catabolic roles in the animal. For example, proteins have a vital structural role in the skin (including feathers) and the musculoskeletal system. Physiologically, proteins (or enzymes) are required as mediators of almost every chemical reaction occurring within the body. They are also important as hormones, and in some cases as neurotransmitters (Bolton and Howell, 1997). An intake of protein in the diet is required as body proteins are in a dynamic state, with synthesis and degradation occurring continuously. Long term inadequate protein intake will result in poor growth and productivity, weight loss, physical changes (such as reduced feather quality) and possibly death.

Ingested proteins are broken down in the proventriculus and small intestine to yield amino acids, which are primarily absorbed by the small intestine. These amino acids are either used in the synthesis of new proteins (for structural or physiological processes), or they are catabolised in the liver via the urea cycle, providing energy in the form of ATP. Catabolism of dietary protein to provide energy is considered a secondary use for dietary protein and will only occur after other protein requirements have been satisfied.

Acceptable protein nutrition is an essential component in the successful aviculture of Australian Parrots. It is a subject that is often overlooked or considered unimportant. For this reason, protein nutrition will be considered in detail. The dietary requirement of protein is really a dietary requirement for amino acids. There are twenty-two different types of amino acids in total, and all of these are present in the living animal. Nutritionally, amino acids can be divided into two categories: those that can be synthesised from other amino acids (non-essential) and those that must be provided in the diet (essential). The essential amino acids include arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine and glycine. Note that glycine is not an essential amino acid in mammals (Sell *et al*, 1994).

Protein and amino acid requirements vary considerably with species, age and productive state of the animal (such as growth, maturity or egg-laying). For example, parrots which are nesting and egg-laying have higher amino acid and protein requirements than mature resting birds. Birds with a high level of feather growth (such as those

that are moulting) will have a much higher requirement for cystine than birds at a quiescent stage of life. Cystine also serves as the precursor of taurine, which in is conjugated with cholic acid during the formation of bile. Bile formation is induced by feed fat content, which is high in oilseed kernels and approximately twice as high in most psittacine hand-feeding formulas than in standard poultry starter diets. Hence these high fat diets require increased levels of cystine (Hagen, 1997). Young growing animals also have higher requirements than mature birds.

There are two important components of satisfactory protein nutrition for Australian Parrots: the quality of dietary protein and the quantity of dietary protein.

Protein Quantity

Protein quantity refers to the amount of in-feed protein required by the bird each day. As discussed above, the exact amount varies significantly depending on age, activity and physiological status. Estimates of crude protein requirements are given in Table 1.

Table 1. Estimated Protein Requirements for Psittacines.

Physiological Status	Crude Protein Requirement
Immature	18 - 20 %
Mature Maintenance	6 - 14 %
Mature Breeding	20 - 24 %

Adapted from Gestier, 1991.

Protein Quality

The essential amino acid content of different protein sources varies, allowing the concept of biological value or protein quality. High biological value protein is defined as protein that contains adequate levels of essential amino acids. On the other hand, low biological value protein is that which is deficient in one or more essential amino acids.

Animal protein (such as meat, fish, insects, milk and eggs) generally has a high biological value. Vegetable protein (such as seeds, leaves and roots) often has a low biological value, but there are exceptions, including sunflower and safflower seeds, soyabeans, peanuts, oats and pollen. (Shephard, 1989)

Hence the Psittacine diet must contain protein of adequate quality. It must provide sufficient quantities of each essential amino acid, and also must provide sufficient quantities of protein for synthesis of non-essential amino-acids. There is no one feed which provides total and complete protein nutrition for any animal. Instead, combinations of different feedstuffs must be used which together will satisfy protein and amino acid requirements. Animal protein sources, even though an excellent source of high quality protein, are not highly palatable for parrots and as such are not a suitable general protein source in psittacine diets. Seed rations are usually the primary source of protein in psittacine diets, with most diets relying on a combination of seed types to provide all essential amino acids. In these diets, the deficiency of any essential amino acids in one seed is complemented by the presence of these amino acids in other seeds. Some manufacturers may also add protein supplements to seed mixtures in order to increase protein quality. Unfortunately, in practice many birds will develop a preference for one or two seed types, and hence they will not receive a diet with balanced protein. Refer to Appendix 2 for examples of seed protein quality as compared with average psittacine requirements.

Supplementation is one method of increasing the quality of the protein in a diet. Limiting amino acids can be added individually to the dietary mixture, or a source of high quality protein (animal protein) can be added. The addition of high quality animal protein on a day-to-day basis is not commonly used for psittacine diets due to the lack of palatability and the risk of bacterial contamination. The addition of amino acids (in the chemical form) is possible, but is usually limited to use by manufacturers or large aviaries due to expense and difficulty.

Fats

Fats, or lipids, are another essential component of the psittacine diet, comprising 15% of the total solid intake. They have vital roles in both the growing and mature bird, and can be used for both catabolic and anabolic processes. Fats have vital structural anabolic roles, being a necessary component of all cell membranes and also having a role in insulation and minimisation of heat loss. Fats are very important for catabolism and energy synthesis, providing much energy (ATP) via a combination of β -oxidation and the TCA cycle. Fats are the most concentrated source of dietary energy, producing more than twice as much energy per gram as carbohydrates or proteins. (Shephard, 1989)

There are four different forms in which fats can exist: free fatty acids (FFAs), triacylglycerides (TAGs), phospholipids and cholesterol. Many fats can be synthesised by the psittacine body on requirement, but there are also some essential FFAs which must be provided in the diet. The fatty acid constitution of three commonly used feeds is given in Table 2.

Table 2. Fatty Acid Composition of Sunflower, Safflower and Peanut Oils.

Fatty Acid	Sunflower Seed	Safflower Seed	Peanut
Palmitic acid (16:0)	5 - 7	5 - 7	8 - 12
Stearic acid (18:0)	2 - 6	1 - 3	2 - 5
Arachidonic acid (20:0)	trace - 0.5 0.7 - 1.0	trace	1 - 2 2 - 3
Behenic acid (22:0)	16 - 35	9 - 20	42 - 54
Oleic acid (18:1)	57 - 71	66 - 80	20 - 37
Linoleic acid (18:2)	trace - 2	trace - 3	trace
Linolenic acid (18:3)			

Adapted from Hagen, 1997.

Fats are assimilated in the small intestine. Digestion of dietary triacylglycerides requires pancreatic lipase from the pancreas and bile salts from the liver. The hydrophobic end of the bile salts attaches to the surface of the TAGs, causing them to accumulate and form a micelle. The polar surface of the micelle faces outwards and allows the actions of pancreatic lipase, which requires an oil-water interface to be active. Co-lipase binds the pancreatic lipase to the micelle, and digestion begins with the release of FFAs in a much smaller micelle that can be absorbed through the small intestine wall. The bile salts are generally reabsorbed and recycled (Bolton and Howell, 1997). Some dietary fats are more digestible than others. Fatty acid chain length, the extent of saturation and the nature of esterification all influence intestinal absorption. Fat digestion and utilization may also improve with age (Sell *et al*, 1994).

There are two possible sources of dietary TAGs in the psittacine diet: those inherently contained within constituent feeds and those added directly to the feeds. Most diets designed for caged aviary birds rely on fats inherently present within dietary constituents such as seeds.

Vitamins

Vitamins are organic substances whose distribution varies among foodstuffs. Even though they are only required in small quantities, they are an essential component of a balanced psittacine diet (Blood *et al*, 1988). The only exceptions to this are Vitamin D, which can be produced in the skin following exposure to sunlight; and Vitamin C, which can be manufactured by many species of birds. There are two categories of vitamins: those that are fat soluble (Vitamins A, D, E and K) and those that are water-soluble (Vitamin C and the B group). Vitamins are essential for a variety of biochemical and physiological processes. The absence of one or more vitamins from the diet, or poor absorption of vitamins, can cause deficiency diseases such as enzootic muscular dystrophy, poor feather growth and polyencephalomalacia (See Appendix 3) (Shephard, 1989).

The increasing usage of multi-vitamin supplements by aviculturalists has rendered gross vitamin deficiencies are

fairly uncommon in aviary-kept psittacines. Specific vitamin preparations available in Australia include Pentavite, Vetemul and Ornithon. Deficiencies syndromes may occasionally be seen in birds with specific malabsorption syndromes or during periods of increased vitamin requirements (Shephard, 1989). Over-supplementation of vitamins is possible, and hence multi-vitamin supplementation should only be used when indicated.

Minerals

There are nineteen or more minerals forming the mineral composition of the animal body. At least thirteen of these minerals are essential and must be supplied in the diet. (Blood *et al*, 1988). Minerals are only required in small amounts in the diet, and are required for a variety of functions, including bone synthesis and modelling, enzyme activity and body water homeostasis.

Minerals are often divided into two categories: macro-minerals, which are required in relatively large quantities and trace minerals, which are only required in small quantities. A brief description of essential minerals and their functions is given in Table 3.

Table 3. Essential Minerals and Their Role.

Mineral	Category	Major Functions / Roles.
Calcium	Macro	Bone and egg formation, blood clotting, second messenger roles
Phosphorus	Macro	Bone and egg formation, energy formation as ATP, structural phospholipid roles
Sodium	Macro	Acid-base and osmotic gradient maintenance
Potassium	Macro	Acid-base and osmotic gradient maintenance
Bicarbonate	Macro	Acid-base and osmotic gradient maintenance
Chloride	Macro	Acid-base and osmotic gradient maintenance
Magnesium	Trace	Essential co-factor for enzymes
Manganese	Trace	Essential co-factor for enzymes
Zinc	Trace	DNA structural motifs (zinc fingers), essential co-factor for enzymes
Copper	Trace	Essential co-factor for enzymes
Iodine	Trace	Thyroid gland function and thyroxine production
Molybdenum	Trace	Essential co-factor for enzymes
Selenium	Trace	Anti-oxidant
Iron	Trace	Haemoglobin and cytochrome function
Cobalt	Trace	Supplied with Vit B ₁₂

Hence both macro- and trace minerals are a vital component of the psittacine diet. The mineral content of conventional feed components often satisfies the requirements for trace minerals. The specific mineral requirements vary significantly according to the physiological status of the bird. For example, birds that are rapidly growing or are egg-laying have greatly increased mineral requirements, especially for phosphorus and calcium.

Mineral absorption is affected by the presence of other minerals within the digestive tract, with excessive concentrations of one mineral strongly diminishing the absorption of other minerals.

Specifically, excessive concentrations of calcium can interfere with the availability of phosphorus, manganese, magnesium and zinc. There are also interactions between the absorption of copper and molybdenum; and selenium and mercury. These interactions can result in effective mineral deficiencies (Sell *et al*, 1994). For example, the optimal ratio of calcium:phosphorus in the diet of an average bird is 1.5:1. However, the ratio present in most commercially available seed mixes ranges from roughly 1:6 to 1:10. For this reason, calcium deficiency is one of the most common mineral imbalance syndromes occurring in aviary birds fed a basic seed diet. This problem becomes even worse when the bird has higher calcium requirements due to growth or egg-laying (Shephard, 1989).

Water

Water is an essential requirement for all animals. Water is responsible for more than half a bird's body weight, and even small fluxes in total body water have significant effects on health and vitality. Some water is produced via the oxidation and catabolism of carbohydrates and fats to produce energy, but this is not sufficient to satisfy the bird's daily requirements. Water must be taken in from external sources to replace that lost by evaporation and excretion. Some water supplies contain considerable concentrations of certain minerals such as sodium, chloride, phosphorus and various trace minerals. These can form an important supplementary source if dietary intake is inadequate.

Precise requirements for water varies with species, activity, diet, physiological status and environmental climate. In general birds drink approximately twice as much water as the amount of feed consumed daily on a weight basis. Water must be provided at all times, with water deprivation for more than 12 hours causing adverse effects, and water deprivation for more than 36 hours often resulting in mortality. Water restoration after a prolonged period of deprivation can also result in death following 'water intoxication'. Water is nearly always provided to birds in large containers and intake is self-regulated.

Practical Dietary Options for Australian Psittacine Birds

As stated above, the psittacine diet should roughly reflect that which the animal would receive in nature. The diet of Australian birds is highly varied according to family, species, time of year and geographic location. However, for most Australian parrots, a number of generalisations can be made regarding diet. There are essentially four different sources of feed for a psittacine diet: seed and seed derived feeds, fruit and vegetable matter, live food and manufactured feeds. Each of these three sources of feeds will now be discussed with respect to provision of a balanced diet for Australian parrots.

Seed and seed-related feeds make up the primary food source for most Australian Parrots, both in the wild and those in captivity. Seed-related feeds include dry seed, soaked seed, sprouted seed and seeding grass. Dry seed is probably the most commonly used diet for all captive birds, especially parrots. It is commonly purchased pre-mixed by suppliers and with brands including "Trill" and "Anchor Bird Seed". Different seed types can also be purchased individually and mixed by the aviculturalist. The advantage of buying pre-mixed seed is that it often contains protein and mineral supplementation and is nutritionally balanced (see Table 4).

Table 4. Proximate Analysis of "Trill".

Nutrient	Content (%)
Moisture	9.04 ± 0.04
Protein	17.88 ± 0.20
Fat	18.76 ± 0.20
Nitrogen-free Extract	51.71 ± 1.6
Ash	2.61 ± 0.05

Adapted From Taylor, 1996.

Different seed varieties may also be fed using separate containers to determine feed preferences. This should be avoided, however, if one seed type (such as sunflower seeds) is excessively eaten at the expense of other varieties, resulting in an unbalanced diet. Some aviculturalists have also reported deaths of aviary parrots following excessive feeding of sunflower seed due to perforation of the proventriculus.

Seed types can be classified as carbohydrate rich, such as the millets and panicum; or oil rich, such as sunflower seed and canola. All seeds are an excellent source of energy. The basic seed diet for parrots varies slightly according to the size of the species and to some degree the bird's personal preferences, but should comprise a mixture of the following seeds: sunflower, safflower, hulled oats, panicum, canary, French millet and Japanese millet. Other seeds, such as linseed, canola, maw and niger can also be added. Larger parrots will often prefer increased quantities of sunflower seeds (up to 30-40% of the total seed mixture); whereas smaller parrots will prefer a higher proportion of smaller seed types (Shephard, 1989). Seed mixtures should be clean, non-dusty and free from pests such as weevils. Preferably, seed should be fed daily. If this is not possible, twice weekly or at least weekly feedings are necessary.

Even though they are an excellent source of energy, unsupplemented dry seed mixtures are inadequate as a total diet for Australian parrots, especially those in the growing or breeding phases. They are relatively low in protein and have a gross imbalance in the Ca:P ratio. A diet consisting only of dry seed would also be deficient in a number of other essential minerals, especially the trace elements (Stunkard, 1984).

Soaked seed is also commonly used by aviculturalists, especially during the breeding season. Soaked seed is prepared by soaking dry seed overnight immediately before feeding. It has the advantages of being more readily digestible by younger birds following regurgitation from the parents. The soaking process leaches out any possible contaminants such as insecticides and pesticides. Weevils may also float to the surface, allowing removal. Soaked seeds have identical nutritive qualities to dry seed, except that the water component of the seed is increased. Hence an appropriate diet can be formulated using a similar mixture of seeds as described above for dry seed.

Sprouted seed is another feed component derived from dry seed. It is produced by soaking dry seed in water for 24 hours, then spreading the soaked seed over a surface in a warm, sunny position. The seed is allowed to sprout (which usually takes about 2 days), and is then fed to the birds. Sprouted seed shares the benefits of soaked seed and has also been demonstrated to have increased levels of nutrients, including increased levels of some vitamins. This is a major advantage over soaked and dry seed. Sprouted seed also has an increased water content. However, one disadvantage of both sprouted and soaked seed is the promotion of fungal growth during the soaking process.

Seeding grass may also be used as a feed supplement for Australian parrots. The seed heads of the grass are the most nutritionally valuable component, and can be collected from natural sources or cultivated by the aviculturalist. Seeding grasses commonly fed to aviary birds include chickweed,

dandelion, dock, milk thistle and rye grass. Advantages of using seeding grass include its elevated fibre, mineral and vitamin content. Seeding grass heads are especially high in some vitamins not present in seed such as vitamins A, E, B₂, folate and C (Shephard, 1989). Disadvantages include possible toxicity due to herbicide or pesticide spraying and possible contamination by fungus (such as *Acremonium rigidum* or *Claviceps purpurea* infected Rye grass). Overfeeding of seeding grass can also cause diarrhoea.

Green feeds (fruit and vegetable matter) make up the second category of feed sources for Australian parrots. This plant material is high in a number of essential vitamins (such as A, E, B₂, folate and C), minerals and fibre; all of which are lacking in dry seed mixtures. For this reason, green feeds are high quality supplements, and are vital for the provision of a varied and balanced diet. Green feeds also provide variety in the diet, and to some extent provide a stimulus and exercise to otherwise 'bored' caged birds. Research has also shown that green feeds help birds to develop sound eating habits, and help prevent caged birds from only eating one feed type (Shephard, 1989). The fibre provided by green feeds is important in the maintenance of a healthy gastrointestinal tract (see p 3:Carbohydrate). On the other hand, green feeds have a high water content and are low in protein and energy. Hence they are unsuitable as a sole or even staple diet for Australian parrots.

Nearly any vegetable or fruit (providing it does not contain toxic components) are suitable for feeding Australian parrots. Common green feeds include spinach, silverbeet, peas, beans, tomato, oranges, bananas, peaches, grapes and sultanas. The most nutritious green feeds include parsley, kale, broccoli, brussel sprouts and spinach. The least nutritious green feeds include lettuce, celery and apple. An excellent but often overlooked source of green feeds for Australian parrots is the native plants that the bird would eat in its natural habitat. Branches from native plants such as *Eucalyptus*, *Hakea*, *Grevillea*, *Leptospermum*, *Banksia*, *Acacia*, *Melaleuca* and *Callistemon* are all excellent sources of 'natural' feeds for Australian parrots, especially if the tree is flowering or seeding at the time of collection (Shephard, 1989).

Other green feeds enjoyed by parrots include blackberry, privet berries, hawthorn berries; and pinecones, peanuts, almonds and hazelnuts for the large Psittacine. It must be remembered, however, that these feeds are all merely supplementary feeds, and must not be overfed.

Live food is the third source of dietary components to be considered for Australian parrots. Live food is less important in the diet of parrots than for some avian species (such as finches, pigeons, raptors and magpies), but still has an important role as an occasional dietary addition. Live foods fed to parrots are mainly insects, such as meal worms and beetles, but can also include earthworms and other invertebrates. They provide an excellent source of high quality protein, and are useful to as an sporadic boost to dietary protein levels, especially during the breeding season when protein requirements are elevated. They are not, however, suitable as a regular diet for Australian parrots.

One other dietary component used by some aviculturalists is the manufactured feeds. These include preparations specifically designed for birds, such as the "Wombaroo" mixes and "Lafeber's Premium Daily Diets" pelleted seed mixtures. Specific formulations of both of these diets are available for Australian parrots, representing a high quality and nutritionally balanced feed source if used as directed. A nutritional analysis of "Wombaroo Granivore Rearing Mix" is given in Table 5. Other food, such as biscuits, cakes and baby food can also be added to the psittacine diet. These are not a balanced dietary source for birds, and cannot be used as a sole diet or as the base for a diet.

Table 5. A Nutritional Analysis of “Wombaroo Granivore Rearing Mix”.

Nutrient	Quantity	Nutrient	Quality
Crude Protein	22%	Vitamin A	6 mg/kg
Crude Fat	8%	Vitamin D ₃	100 ug/kg
Crude Fibre	5%	Vitamin B ₂	8 mg/kg
Calcium	1.1 - 1.8%	Magnesium	800 mg/kg
Phosphorus	0.9 - 1.4%	Ferrous Iron	80 mg/kg
Salt	0.5 - 0.8 %	Zinc	20 mg/kg
Fluorine	1 mg/kg	Manganese	30 mg/kg
		Copper	2 mg/kg
		Iodine	500 ug/kg
		Selenium	100 ug/kg

Ingredients : Whey and soy protein isolates, corn starch, maltodextrins, rice bran, lecithins, fish and vegetable oils, dehydrated vegetables, vitamins, minerals.

Finally, provision of a balanced mineral component of the psittacine diet is essential. Calcium requirements are often supplemented using grit. Grits can either be insoluble (such as river sand) or soluble (such as cuttlebones, eggshells, calcium powders and oyster shell). Insoluble grits are thought to aid the mechanical crushing function of the gizzard, enhancing digestion. Soluble grits are used to supplement mineral requirements, especially calcium and phosphorus (see Table 6).

Table 6. Mineral Analysis of Oyster Shell (a Typical Soluble Grit).

Mineral	Content (%)
Calcium	28.38
Magnesium	0.24
Phosphorus	0.02
Sodium	0.27
Potassium	0.03
Manganese	0.02
Copper	0.01
Zinc	0.01
Iron	0.06

(Adapted from Taylor, 1996)

Recent studies have shown that soluble grit is a more vital component of the diet than insoluble grits (Taylor, 1996). Supplementation of minerals (especially calcium) can become especially important during the breeding and egg-laying season. On the other hand, calcium oversupplementation can have negative effects such as the interference with absorption of other minerals. Mineral blocks are another commonly used source of mineral supplementation. These can be purchased from most pet shops or avicultural suppliers, or prepared by the aviculturalist. Mineral requirements can also be supplemented using mineral mixture powders that are sprinkled on seed or green feeds.

The only other addition to the diet that must be mentioned is water. Water should be provided in the aviary at all times and preferably should be changed at least bi-weekly. Mineral mixtures and some medications can be added to water supplies and has the advantage of ease of administration, but intake cannot be precisely controlled.

In summary, the nutritional requirement of Australian parrots has been discussed from an anatomical viewpoint, a 'natural intake' viewpoint, a physiological requirement viewpoint and an 'aviary-based' viewpoint. A complete and unequivocal ration formulation has not been given. This was considered beyond the scope of this essay, especially in light of the number of Australian psittacine species and their quite varied nutritional requirements. Instead, a general theoretical and practical approach to Australian Psittacine nutrition has been taken, allowing the reader or aviculturist to adapt this knowledge to his or her own area of interest, and allowing the formulation of a Psittacine diet from a scientific perspective.

Appendix 1***Determination of Energy Requirements by Considering Calorific Needs.***

To determine energy (carbohydrate and lipid) requirements, the aviculturist must consider the calorific needs of the bird. The basal metabolic rate (BMR) is rate of energy consumption by the animal when it is completely at rest (Blood *et al*, 1988). It is equal to the heat produced by the resting animal when it is in post-absorptive and thermo-neutral conditions. The general parrot BMR is equal to:

$$\text{BMR} = 78x(W^{0.75})$$

The maintenance energy (ME) is an approximation of the energy required by an animal during normal activity. In a normal situation, it is equal to:

$$\text{ME} = 1.5 \times \text{BMR}$$

This formula should be used by the aviculturist to determine calorific energy requirements for his or her birds when formulating a ration. For example, the theoretic energy requirement for Princess Parrot (*Polytelis sp.*) weighing 150g would be:

$$\text{ME} = 1.5 \times 78 \times (0.150)^{0.75} = 28.2 \text{ KCal/day} = 118 \text{ Kj/day}$$

This figure can then be used by the aviculturist to estimate an appropriate quantity of feed required, assuming the rough energy content of the feed source is also known. The ME will vary according to varying environmental conditions and other factors (see Table 7) (Gestier, 1991)

Table 7. Adjustment Factors for ME During Various Physiological States.

Physiological State	Adjustment Factor
Physical Inactivity	0.7 - 0.9
Starvation	0.5 - 0.7
Hypometabolism	0.5 - 0.9
Elective Surgery	1 - 1.2
Mild Trauma	1 - 1.2
Severe Trauma	1.1 - 2
Sepsis	1.2 - 1.5
Burns	1.2 - 2
Head Injuries	1 - 2

Adapted from Gestier, 1991.

Appendix 2

Estimated Essential Amino Acid Requirements of Parrots and Composition of Two High Protein Quality Seed Kernels.

Essential Amino Acids	Estimated Requirements	Sunflower Seeds	Safflower Seeds	Psittacine Carcass
% Crude Protein	6 - 14	33.0	27.0	
Arginine	6.0	10.0	9.4	5.9
Glycine & Serine	5.0	9.3	9.3	10.8
Histidine	1.5	2.8	2.6	2.2
Isoleucine	3.5	4.5	3.7	3.9
Leucine	6	7	6	6.2
Lysine	5	≈ 3.9	≈ 3.2	7.1
Methionine & Cystine	3.6	3.7	3.2	--
Methionine	1.9	≈ 1.8	≈ 1.5	2.2
Phenylalanine & Tyrosine	5.9	7.4	7.2	6.8
Phenylalanine	3.2	4.7	4.3	3.9
Threonine	3.7	3.8	≈ 3.2	4.0
Tryptophan	0.9	1.3	1.4	0.8
Valine	3.6	5.2	5.3	4.8
Number of Limiting Amino Acids	--	2	3	--

Note:

- Measurements are grams of amino acid per 16 g of nitrogen.
- * Essential for growing poultry.
- § Based on NRC requirement for broiler chickens receiving a diet of 20% protein and 3.200 Kcal ME/kg.
- ≈ Limiting amino acids and percentage of requirement supplied when compared with estimated requirements.
- Adapted from Hagen, 1997.

Hence, from the above table, a combination of Sunflower seeds and Safflower seeds will not satisfy protein requirements due to inadequate levels of lysine, methionine and possibly threonine (depending on specific ration combination). These amino acids must be supplied by another component of the diet or they may be supplemented (see page 4:protein).

Appendix 3
Essential Vitamins, Sources, Functions and Deficiency Syndromes.

Vitamin	Major Sources	Function	Deficiency Syndromes
A (Retinol)	Green vegetables, carrots, dairy products, liver	Vision, mucus secretion	Poor growth and fertility, blindness, skin lesions
D (Calciferol)	Sunlight, dairy products, liver	Mediates Ca ²⁺ homeostasis	Rickets in young birds, osteomalacia in mature birds, soft shelled eggs
E (Tocopherol)	Eggs, green vegetables, liver	Antioxidant and metabolic regulator	Coagulopathies and anaemia
K	Intestinal bacterial flora	Blood clotting	Muscle and heart disease, poor growth and fertility, neurological lesions
B ₁ (Thiamin)	Wheatgerm, oatmeal, yeast	Decarboxylation enzyme co-factor	Stargazing, loss of appetite, weakness, seizures, polioencephalomalacia
B ₂ (Riboflavin)	Green vegetables, dairy products, liver	Electron carrier in biological oxidation systems	Paralysis in juveniles, poor fertility in adults
Nicotinamide	Wheatgerm, yeast, dairy products, meat, liver	Electron carrier in biological oxidation systems	Poor growth and feathering
B ₆ (Pyridoxine)	Vegetable matter	Enzyme cofactor for decarboxylation and deamination reactions	Poor growth and egg hatchability
Biotin and Pantothenate	Yeast, eggs, dairy products	Enzyme cofactor	Dermatitis
Folate	Green vegetables, meat	Purine and pyrimidine metabolism	Anaemia
B ₁₂ Complex (Cobalamins)	Dairy products, liver	Cofactor in nucleic acid synthesis	Anaemia
C (Ascorbate)	Fruit, tomatoes, vegetables	Hydrogen carrier in oxidation reactions	Ill health, low disease resistance

Adapted from Shepard, 1989; Costa and Pethick, 1996.

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