Mineral and protein composition of seeds important to the Orange-bellied Parrot (*Neophema chrysogaster*) in the wild.

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Abstract

Mineral, fatty acid and protein content of a number of indigenous and introduced seeds important to the Orange-bellied Parrot (*Neophema chrysogaster*) were evaluated. Crude protein ranged between 5-43 %, with winter species 13-27%. Calcium content was variable ranging from 0.05% in a commercial seed mix to more than 0.7% in the smallest seed, with Ca:P ratio as high as 6.7:1. Copper content of mainland indigenous seeds exceeded prescriptions for avians ranging from 11-24 mg/kg. Iron concentrations generally exceeded reported requirements for granivorous birds ranging from 37.5-200.4mg/kg, while zinc concentrations ranged from 17.6 mg/kg in a nonfavoured food plant to 74 mg/kg in a favoured winter species. Selenium was variable ranging from less than 40 µg/kg-280 µg/kg. Fatty acid composition varied significantly between indigenous and nonindigenous species. There was a distinct absence of *n*-6 fatty acid from indigenous seeds, with the exception of *Suaeda australis,* which contained the highest concentration (0.23%). High concentrations of *n*-3 fatty acids in introduced species (22.6%) may impact antioxidant system and alter detoxification response to environmental toxins.

Introduction

A thorough understanding of avian nutrition is central to the management of captive and free-ranging birds, including knowledge of digestive physiology, feeding ecology and nutrient composition of wild foods. While wild birds are responsible for securing their own nutrition in the wild, it is rare that this process is not influenced by activities and interests of humans and adequate nutrition is critical for successful husbandry and reproduction of birds in captivity.

With an increased awareness of the plight of critically endangered species, responsibilities lie with modern zoos and private institutions to adopt the propagation and conservation of rare species as part of their mission. A lack of data on wild food resources and their nutrient composition results in problems with health and productivity of birds maintained in captivity. Proper nutrition comes at a substantial cost of time and energy to individual birds in the wild and food procurement is often the predominant activity in which a bird engages. Therefore, any changes in habitat quality, including taxonomic diversity of food resources, may have an impact on an individual's ability to procure sufficient nutritionally adequate food resources.

The orange-bellied parrot (*Neophema chrysogaster*) is an endangered Australian migratory species, which breeds in the button grass plains of southwest Tasmania, Australia, feeding predominantly on the seeds of summer grasses, sedges and herbaceous plants. It disperses to the southeast mainland of Australia, where it over-winters in the salt marsh communities, concentrating on the coastal areas of western Port Phillip Bay. While once more abundant, the population has steadily declined since 1920 and now numbers fewer than 200 individuals in the wild within a restricted range.

There has been no discernible increase in the wild population in the past 20 years, with comparatively short life spans (approximately 5 years). There is general agreement that mismanagement of winter habitat may be implicated in recovery efforts of the wild population, with midwinter food shortages possibly limiting population growth. The winter salt marsh communities consist of a number of native and introduced species, with the sequential flowering and seeding of plants from the Chenopodiaceae family primarily dictating the parrot's feeding habitats. Changes in temporal availability of key winter food species are correlated with concentrated feeding on introduced species but it is unclear whether taxonomic differences in nutrient composition are important.

With the prospect of securing additional salt marsh habitat through revegetation schemes, there is an imperative to better understand the relationship of the orange-bellied parrot with its winter environment to guide rehabilitation of degraded sites. This study evaluates the mineral and protein content of some of the major food plants of the orange-bellied parrot. It explores suggestions that nutrient composition of wild food plants has implications for the distribution of the orange-bellied parrot in the wild and whether increased feeding on introduced species may impact on the species' survival. Data also provides guidelines for the formulation of nutritionally balanced diets for birds maintained in captivity.

Methodology

Seeds were collected from plants from the summer breeding site at Melaleuca on the west coast of Tasmania, Australia, with winter sites around Port Phillip Bay, Victoria. Ten species were evaluated including four indigenous and three introduced species from Victoria and three indigenous species from Tasmania (Table 1). A commercial mix of birdseed of unknown botanical composition fed to wild birds at Melaleuca was also evaluated.

Protein content was estimated from Kjeldahl nitrogen (N% x 6.25). Six macrominerals (calcium, potassium, magnesium, sodium, phosphorus, sulphur) and six microminerals (boron, copper, iron, manganese, selenium, zinc) were evaluated. Fatty acid composition is expressed as percent total fatty acids.

Results

Protein content, Figure 1, ranged from 5% in *Gahnia grandis,* a nonfavoured food plant at the main breeding site, to 43% in *Restio complanatus*, a favoured summer food plant. Most values ranged between 13-27%.

Calcium content, Table 2, was variable, ranging from 0.05% in the seed mix fed as a supplementary food at the summer breeding site, to 0.74% in *Samolus repens* a favoured winter food plant. Phosphorous content was variable, with on *S. repens* showing a favourable Ca:P ratio. Copper content exceeded 20% in three winter species, with iron concentrations of winter seed species ranging from 66-197 mg/kg. Zinc concentrations were higher in winter species.

Principal components analysis, Figure 2, highlighted a separation of introduced winter species from indigenous species on the basis of fatty acid composition. Long chain fatty acids of 18 carbons dominated most species (80%), with saturated (15%) and monounsaturated fatty acids (20%) less common. Less than 3% of fatty acids of Victorian indigenous species consisted of essential fatty acids, Table 3, with *n*-9 fatty acids dominant.

Species	Common Name	Seed Availability	Seed Weight
Exotic Species			
Atriplex prostrata	Hastat Orache	April-August	1-3 mg
Cakile maritima	Beach Rocket	late s-w	7.4-9.6 mg
Chenopodium glaucum	Glaucus Goosefoot	April-August	0.4 mg
Tasmanian Indigenous Species			
Baumea tetragona	Square-Twig Rush	December	0.3 mg
Gahnia grandis	Brickmaker's Sedge	December	7.7 mg
Restio complanatus	Flat Cord Rush	December	0.5 mg
Victorian Indigenous Species			
Halosarcia pergranulata	Black-seed Glasswort	May-August	0.3 mg
Samolus repens	Creeping Brookweed	mid s-mid w	0.017 mg
Sarcocornia quinqueflora	Beaded Glasswort	March-August	0.3 mg
Suaeda australis	Austral Seablite	March-June	0.4 mg

Table 1. Species composition of seeds evaluated.

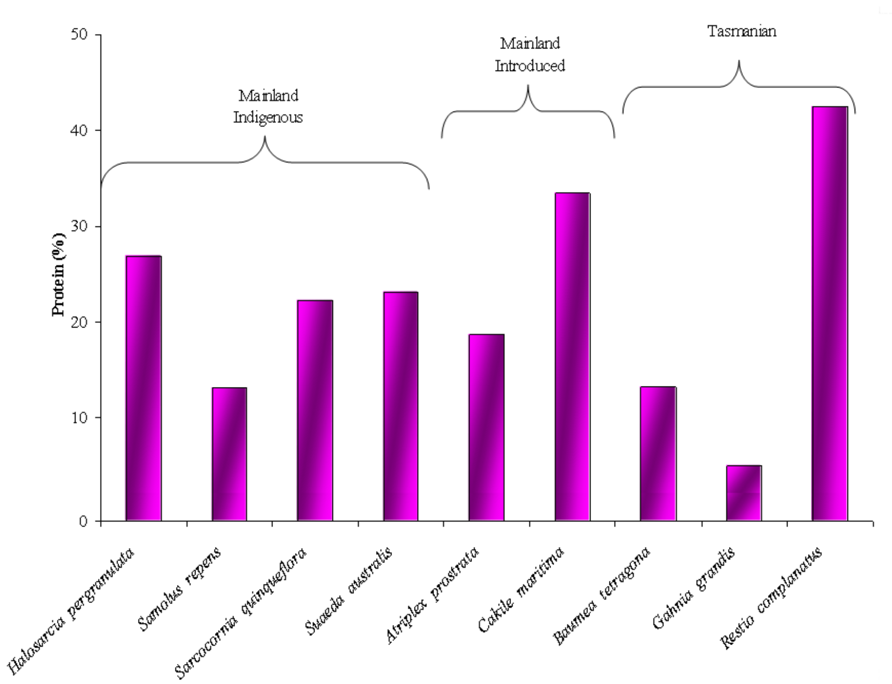

Figure 1. Protein content of seeds (dry matter basis).

		Winter Indigenous				Winter Introduced			Summer			
Nutrient	Unit	*Halosarcia pergranulata*	*Samolus repens*	*Sarcocornia quinqueflora*	*Suaeda australis*	*Atriplex prostrata*	*Cakile maritima*	*Chenopodium glaucum*	*Gahnia grandis*	*Baumea tetragona*	*Restio complanatus*	Commercial Mix
Ca	%	0.12	0.74	0.40	0.07	0.10	0.21	0.27	0.09	0.30	0.20	0.05
K	%	0.80	0.35	0.76	0.95	0.78	0.74	1.28	0.14	1.56	0.40	0.37
Mg	%	0.30	0.34	0.43	0.42	0.30	0.44	0.54	0.12	0.32	0.09	0.14
Na	%	0.52	0.54	0.48	0.61	0.30	0.05	1.46	0.13	0.85	0.62	0.02
P	%	0.58	0.11	0.55	0.63	0.54	1.04	0.27	0.08			0.36
S	%	0.27	0.16	0.27	0.24	0.23	1.55	0.23	0.09			0.19
Ca:P	ratio	0.20	6.59	0.82	0.11	0.18	0.20	0.99	1.13			0.13
Bo	mg/kg	15.50	45.30	36.60	31.80	17.20	6.78	29.70	4.87			2.72
Cu	mg/kg	24.01	25.73	14.25	11.51	9.09	3.88	30.41	7.47			5.96
Fe	mg/kg	148.00	196.60	178.90	66.20	119.75	89.45	137.18	37.50			54.20
Mn	mg/kg	65.20	15.10	69.85	18.70	50.70	16.85	167.90	40.10			45.40
Se	ug/kg	200.00	< 40	40.00	< 40	<40	40.00	280.00	< 40			40.00
Zn	mg/kg	73.49	39.79	61.44	49.34	57.41	67.39	69.43	17.62			26.76

Table 2. Mineral content of seeds (dry matter basis).

Species	α-linolenic acid C18:3n-3	linoleic acid C18:2n-6	AA C20:4n-6	EPA C20:5n-3	DHA C22:6n-3
Atriplex prostrata (French Island)	0.13	0.04	0.27	0	0.3
Atriplex prostrata (Lake Conneware)	0.12	0.05	0.28	0	0.31
Baumea tetragona	6.48	0	0	0	0
Cakile maritima (French Island)	21.49	0.07	0	0	0.71
Cakile maritima (Sand Island)	23.8	0.06	0	0	1.23
Chenopodium glaucum (1987)	5.28	0.06	0.14	0.02	0.06
Chenopodium glaucum (1992)	5.82	0.12	0.16	0.56	0.14
Gahnia grandis	0.37	0	0	0	0
Halosarcia pergranulata	1.6	0	0	0	0
Restio complanatus	3.55	0	0	0	0
Samolus repens	1.53	0	0	0	0
Sarcocornia quinqueflora (Lake Connewarre)	1.77	0	0	0	0
Sarcocornia quinqueflora (French Island)	2	0	0	0	0
Suaeda australis	2.39	0.23	0	0	0.04
Commercial Seed Mix	1.42	0	0	0	0.08

Table 3. Essential fatty acids composition of seed species, expressed as a percent of total fatty acids.

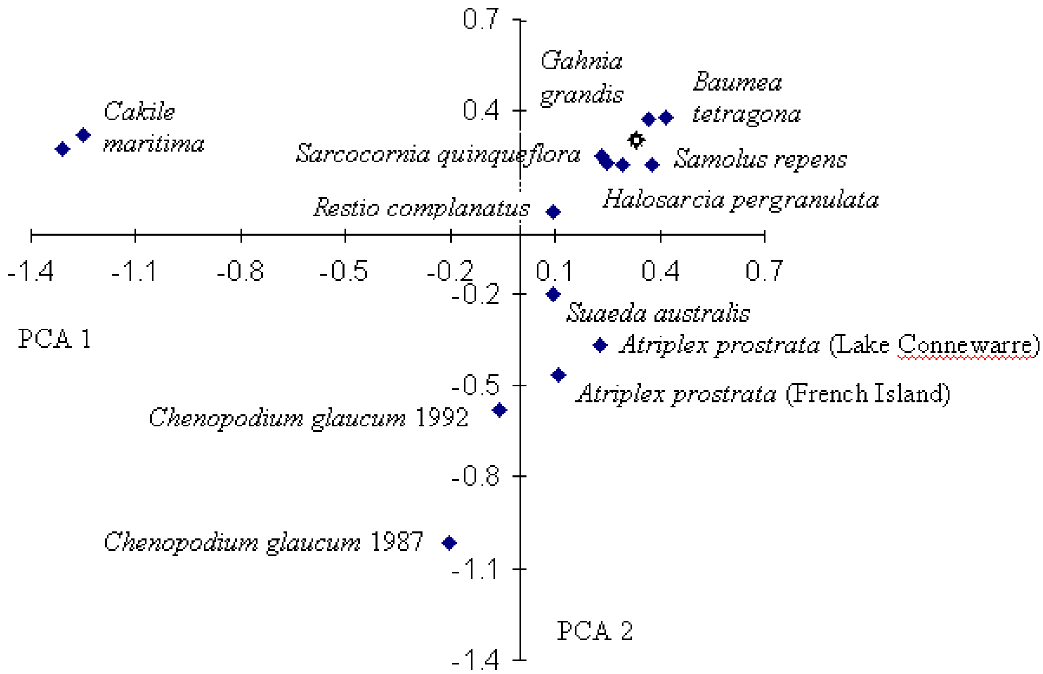

Figure 2. **Principal components analysis of percentage of total fatty acids.** Principal components 1 and 2. 86% variation is observed in principal component 1 and a further 8% in principal component 2. Commercial mix is represented by ✲.

Discussion

Wide annual variation in availability of seeds from indigenous species forces the orange-bellied parrot to supplement their diet with a range of introduced species. The parrot's selection of exotic species during times when native food resources are scarce, has led to consideration of incorporating these exotic species in revegetation schemes for degraded sites. However, while introduced species such as *Cakile maritima* and *Chenopodium glaucum* are important food plants supporting the migration of the population from the southwest of Tasmania to King Island, birds preferentially feed on native salt marsh on King Island and the nutritional adequacy of introduced species has not been evaluated.

Protein values of favoured seeds in this study mostly exceed dietary requirements of poultry (18%) and are sufficient for maintenance (12%) and egg production (13.2%) for budgerigars (Underwood et al 1991; Angel and Ballam 1995). Birds feed almost exclusively on *Restio complanatus* (42%) soon after arrival at the summer breeding grounds from October to November, a time when there is a higher dietary demand for nitrogenous compounds. These values far exceed those reported for cockatiels (8.8-14%: Jones, 1987) or budgerigars (10-13.2%: Drepper et al, 1988, Underwood et al 1991) and support views by Koutsos *et al* (2001) that psittacines can be maintained on higher protein diets without developing overt signs of protein toxicity. As there are a number of different plant species comprising both the breeding and maintenance diets of the orange-bellied parrot, an overall dietary protein requirement cannot be evaluated but *Gahnia grandis* (5% crude protein) is not a preferred dietary source. The higher protein levels of seeds in this study may be beneficial for periods of moult as the Orange-bellied Parrot moults from the second half of August to the end of September, a period when exotic species are generally unavailable.

Trace mineral requirements of poultry and game birds are generally applied to other bird species, but some psittacines have unique nutrient requirements and responses to nutritional deficiencies (Roudybush and Grau, 1991). Of all of the minerals, the requirement for calcium is the most variable, both between species and within a species, depending on the physiological state of the bird in question. Recommendations for budgerigars range from 0.3-0.7% (Roset et al, 2000), with low levels of phosphorous reducing calcium requirements to as little as 0.02% in some species (Klasing, 1998).

Calcium values in this study ranged from 0.05-0.74%. Introduced species such as *Atriplex prostrata* and *Chenopodium glaucum* and the less favoured indigenous *Gahnia grandis* all contained low levels of calcium, with only two species containing levels equal to or above 0.4% (*Samolus repens*: 0.7% and *Sarcocornia quinqueflora,* 0.4%). The high calcium concentration of *Samolus repens* (0.69%) is not indicative of overall dietary intake as seed size averages only 0.017mg and studies of feeding ecology of the orange-bellied parrot indicate that the bird would not be able to consume sufficient seeds solely of this species to maintain adequate energy intake. This highlights how critical it is to account for feeding rates when evaluating nutritional requirements of birds. While it is plausible that the orange-bellied parrot supplements its calcium intake with calcium-rich foods such as mollusc shells, it is plausible that this species' calcium requirements are similar to the budgerigar (0.3-0.7%). Many commercial foods (0.9-1.0%) are based on dietary requirements of poultry broilers and may be excessive.

Copper content of a number of winter species exceeded 24 mg/kg and may benefit the antioxidant system. In comparison, the introduced *Cakile maritima* and the commercial seed mix were low. Iron content of indigenous seeds was surprisingly high, while comparatively low in the commercial seed mix fed to birds at the breeding site. Zinc was higher in winter species compared to summer species, reflecting recommendations for poultry. Many commercial foods provide in excess of 100 mg/kg zinc and may be excessive for the orange-bellied parrot.

Fatty Acids

The fatty acid profiles of indigenous and introduced species varied in chain length, degree of unsaturation and proportions of essential fatty acids. While it is unclear whether these differences are important, remodelling the fatty acid composition within cellular membrane phospholipids could alter a variety of physiological processes. These may include influences on ovulation as prostaglandins are important mediators of cell activity in oviposition as well as contraction of the smooth muscle of the avian uterus.

Assimilation efficiency (AE) of fatty acids decreases with chain length and the degree of saturation, with unsaturated fats absorbed more efficiently than saturated fats. High levels of saturated fatty acids were only detected in the summer *Baumea tetragona* where more than 40% of the lipid content consisted of saturated fats. *Baumea tetragona* also exhibited a unique profile with roughly equal proportions of the C16 and C18 fatty acids, while most other indigenous species had more than 80% C18 fatty acids, with longer chain fatty acids confined mainly to introduced species.

While birds can adopt digestive strategies to deal with insufficient levels of fat in their diet from an energetics perspective, they are unable to synthesise essential fatty acids and require a dietary source of these nutrients, including those of the *n*-3 and *n*-6 families. Linoleic acid (*n*-6) is considered to be an essential fatty acid for poultry but the limited conversion efficiency of α-linolenic acid to the *n*-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) may result in a dietary requirement of the latter two forms. Linoleic acid was absent in all indigenous species with the exception of *Suaeda australis*, which contained the highest concentration of all seeds analysed. The absence of *n*-6 fatty acids in the majority of indigenous species may be problematic if birds focus on the introduced species, which contain comparatively high levels of α-linolenic acid (*n*-3) . While it is not clear whether α-linolenic acid is a dietary essential, high levels of this fatty acid will suppress metabolism of other fatty acid families and may result in an essential fatty acid imbalance. A deficiency of linoleic acid can result in enlarged fatty livers in chicks, influencing their ability to detoxify xenobiotics that may be present at the water treatment plant in winter. Dietary deficiencies in hens markedly increase early embryonic mortality. Dietary *n*-3 polyunsaturated fatty acids, especially DHA, can also decrease levels of vitamin E and increase susceptibility to peroxidation. Higher levels of *n*-3 fatty acids were detected in the introduced *Cakile maritima* and *Chenopodium glaucum,* possibly influencing levels of vitamin E and detoxification systems.

Docosahexaenoic acid (DHA) is responsible for maintaining physiological characteristics of membranes such as fluidity and flexibility which is critical in cold climates. Preformed DHA is required by brain and retina tissues even though tissues in the developing chick embryo contain enzymes to convert α-linolenic acid to *n*-3 PUFA. DHA was detected only in introduced species with a small amount in the indigenous *Suaeda australis.* The general absence of this fatty acid in the indigenous species suggests that it is unlikely that the orange-bellied parrot has a dietary requirement for DHA and is able to convert sufficient quantities from the dietary precursor α-linolenic acid, which was present in varying amounts in all species. An assessment of the ratio of linoleic acid:DHA shows a much higher ratio in the indigenous *Suaeda australis* (5.75:1) than in any of the exotic species (0.05-0.86:1) suggesting that higher proportions of linoleic acid may be required in the diet of the orange-bellied parrot than provided by introduced species. While there was a distinct lack of linoleic acid in most of the indigenous species, Austenfield (1988) found levels in *Salicornia europsaea* exceeded 70% and it is possible that seeds of native species not examined in this study contain high levels of this fatty acid.

Eicosapentaenoic acid (EPA) was only detected in the exotic *Cakile maritima* and arachidonic acid (AA) only in the exotic *Atriplex prostrata* and *Chenopodium glaucum*. Despite the limited efficiency in the conversion of linoleic acid to EPA in birds (Aymond and Van Elzwyk, 1995), it is possible that sufficient α-linolenic acid is provided to enable the conversion to EPA in the orange-bellied parrot.

Conclusions

While the three exotic species show some nutritional dissimilarities to the native species, without intensive physiological investigations, it is not possible to establish conclusively whether these species provide a nutritional profile that would sustain the parrots. However, some inferences may be drawn from other avian nutritional studies. Even if a diet is biochemically adequate, nutritional deficiencies may occur if the bird's nutritional requirements are altered by the stresses of reproduction, extremes of heat, cold, disease, environmental toxins or overcrowding resulting from habitat destruction. No obvious outward signs of nutritional stress have been identified in the birds in either their summer or their winter habitat, suggesting that if nutritional limitations exist, they may be expressed more subtly as changes in reactions to stress, injury, temperature tolerance or environmental toxins. Indeed, the short longevity of the species in the wild (approximately five years) indicates that the habitat is not sustaining a viable population and that sublethal environmental stresses may be contributing factors.

There are some clear recommendations about food supplied to captive birds and as a supplemental food in the winter habitat. The exotic species vary dramatically in their calcium content but this may not be problematic for adult, nonbreeding birds if they only feed briefly on these species. However, seeds such as *Sarcocornia repens* that are comparatively high in calcium are extremely tiny and would require high energy expenditure to harvest sufficient seed to meet their calcium demands. Preliminary energetic studies by W. Porter (pers. comm.) suggest that this species is living at its energetic limit so any shift in species diversity of food plants should not only take into account nutritional composition but also seed size and harvestability.

Deficiencies in essential fatty acids (Balnave, 1970) or changes in dietary protein levels (Koutsos et al 2001) may impact on the metabolic production of water and increase the need for free water. The orange-bellied parrot overwinters at Point Wilson, a site for treatment of Melbourne's sewerage and it is possible that the species is exposed to toxic chemicals that are not being sufficiently degraded nor detected by normal monitoring of water quality (Raloff 1999; Raloff 2000). Any significant changes in protein levels or dietary fatty acids and therefore tissue fatty acids may influence the uptake and absorption of any environmental toxins with unknown impact on its health. Additionally, changes in ratios of essential fatty acids may influence detoxification systems and susceptibility of phospholipid membranes to lipid peroxidation.

In the absence of intensive physiological studies of psittacines, results from this study do not indicate which species are more nutritionally adequate for the Orange-bellied Parrot. However, the differences in fatty acid chemistry between indigenous and exotic species have the potential to change reproductive output, immunocompetence and survivability of chicks. There are also concerns regarding the nutritional adequacy of the commercial seed mix fed to birds at the summer breeding site. This may compromise health of birds with subtle expression when exposed to toxins at the water treatment plant.

Results from this study also provide preliminary guidelines for nutritional maintenance of this species in captivity:

1) protein requirements may exceed those of the budgerigar and even poultry with more than 20% protein required during the winter moult. However, this is dependant on amino acid compositions and warrants further investigation.
2) calcium requirements may be lower than normally provided through commercial formulations and dietary supplementation may exceed dietary requirements of this mineral. However, agricultural grains fed to captive birds may be inadequate.
3) saturated fats should be limited in the diet of captive birds, and
4) ratios of essential fatty acids should be carefully evaluated
5) nutrient composition of supplementary foods fed to wild birds should approximate nutrient composition of wild foods

References

Angel, R. and G. Ballam (1995) "Dietary effect on parakeet plasma uric acid, reproduction and growth." *Proc. Annu. Conf. Assoc. Avian. Vet.* 27-32.

Austenfield, F. A. (1988). "Seed dimorphism in *Salicornia eupeae*: nutrient reserves." *Physiologia Plantarium* **73**: 502-504.

Aymond, W. M. and M. E. Van Elswyck (1995). "Yolk thiobarbituric acid reactive substances and n-3 fatty acids in response to whole and ground flaxseed." *Poultry Science* **74**: 1388-1394.
Balnave, D. (1970). "Essential fatty acids in poultry nutrition." *World's Poultry Science Journal* **26**: 442.

Drepper, K., K. Menke et al (1988). "Unteruschunen zum protein- und energiebedarf adulter welesittche (*Melopsittacus undulatus*). *Kleinteierpraxis*. 33.

Jones, D. (1987) "Feeding ecology of the cockatiel, *Nymphiacus hollandicus*, in a grain-growing area. *Aust. Wildl Res.* **14:**105-115.

Klasing, K. C. (1998). Comparative Avian Nutrition. UK, CAB International.

Koutsos, E. A., J. S. Smith, et al. (2001). "Adult cockatiels (*Nyphicus hollandicus*) metabolically adapt to high protein diets." *Journal of Nutrition* **131**: 2014-2020.

Raloff, J. (1999). "Medicinal waters: where ibuprofen goes." *Science News* **156**: 126.

Raloff, J. (2000). "More waters test positive for drugs." *Science News* **157**: 212.

Roset, K. et al (2000) "Determination of safe and adequate dietary calcium and vitamin D3 concentrations in a companion bird." Proc AAV.

Roudybush, T. E. and C. R. Grau (1991). "Cockatiel (*Nymphicus hollandicus*) nutrition." *Journal of Nutrition* **121**: S206.

Underwood, M.S., D. Polin et al (1991). "Short term energy and protein utilization by budgerigars fed isocaloric diets of varying protein concentrations. *Proc. Annu. Conf. Avian. Vet.* 227-237.