# FEEDING OF THE CAPTIVE KIWI

**J. Sales**

PO Box 51, Williston, 8920, South Africa
Email: James_Sales_1@hotmail.com

ABSTRACT

*The severe risk that kiwis could become extinct necessitates utmost care of birds that are in captivity. Furthermore, captive rearing and release into the wild is a management technique for kiwi conservation on the three major islands of New Zealand. Special attention has to be given to nutrition of these birds in captivity. The ultimate goal is release into a different ecosystem, where birds have to cope with completely different kinds of foods than those commonly fed in the captive setting. According to limited available literature on the digestive system and natural diet, the kiwi could be classified as an obligate insectivore. The protein and amino acid requirements of the kiwi could be determined experimentally from growth data available for kiwis, and assumptions derived with other closely related species. However, to fulfil these requirements with feed ingredients available in captive institutions, knowledge on the digestive capacity and flexibility of the kiwi's digestive tract is needed.*

KEYWORDS

*Captivity, feeding, kiwi, nutrition, protein requirements*

Kiwis are threatened birds found on the three major islands of New Zealand. The following five species of kiwi are recognized according to genetic and biological differences (Kiwi Management Advisory Committee, 2004) North Island Brown Kiwi (*Apteryx mantelli*), Okarito Brown Kiwi (*A. rowi*), Tokoeka (*A. australis*), Great Spotted Kiwi (*A. haastii*) and Little Spotted Kiwi (*A. owenii*). The North Island Brown Kiwi is the best known species, especially in holdings outside New Zealand. Kiwis are a biological oddity, with characteristics such as a relative low body temperature ($38^{0}$C), burrowing, a highly developed sense of smell, paired ovaries in females, and a low growth rate separating them from other avian species (Baker *et al.*, 1995). Literature available on taxonomy, conservation, anatomy, metabolism, behaviour, reproduction, nutrition, and diseases of kiwis has been reviewed by Sales (2005).

Due to their conservation status ultimate care of captive kept kiwis is vital. Conservation management to prevent kiwis from becoming extinct includes the raising of juvenile kiwis in captivity to a body weight of 800 to 1200g, whereafter they are return to the wild. It is believed that they are capable of resisting stoats, the main predators of young kiwis, upon reaching the latter size (Kiwi Captive Management Advisory Committee, 2004; McLennan *et al.*, 2004). Nutrition of kiwis in captivity is of utmost importance in that these birds will eventually be released into an environment entirely different from the rearing environment. The present study has been conducted to give insight on digestive physiology and nutrient requirements of kiwis. The digestive system of the kiwi has been described according to available literature, and an empirical approach has been used to determine the protein and amino acid requirements.

## Anatomy

The relationship between structure of the vertebrate digestive tract and diet is clearly illustrated by measurements of the overall size of the tract and detailed anatomy of the walls of the stomach and intestines (Ricklefs, 1996). A description of the digestive system of the kiwi by Owen (1841) was based on two incomplete specimen in the possession of the Zoological Society of London. According to this study the digestive system of the kiwi, as partly illustrated in Fig. 1, followed the anatomy of the general avian digestive system.

The kiwi is distinguished by a long and slender bill to seize and transmit objects of small size to the oesophagus. The latter is not modified to serve as reservoir, illustrating that food is swallowed in small qualities with successive intervals. No clearly identified circular strip of epithelium separates the proventriculus from the stomach as in the cassowary and emu. The oval-rounded stomach, which is small when contracted in relation to the bird's size, resembles the membranous stomach of carnivorous birds, and not the sub-compressed shape of a gizzard (Owen, 1841). In a more recent study (Reid *et al.*, 1982), the stomach of adult North Island Brown Kiwis measured approximately 75 x 55mm, and has an estimated maximum capacity of 40 to 45cc. Muscular fibres are not arranged in *digastrici* and *laterals* as in a true gizzard, but radiate from two tendinous centres of an oval form. No distinct sphincter has been found between the muscular stomach and the pylorus as in the emu or ostrich (Owen, 1841). Long and simple loops of intestine are found between the stomach and cloaca, which arrangement was described by Beddard (1899) as closely related to that of the cassowary and emu. Contradictory to Owen (1841), Beddard (1899) reported a zigzag pattern of villi throughout the duodenum.

The caeca, attached to the last folds of the ileum, is longer (Table 1) than in the cassowary and emu, in which it did not exceed 12.7cm in length (Pycraft, 1901). The avian caeca are related to bacterial fermentation, nitrogen recycling, osmoregulation, nutrient absorption, bacterial synthesis of vitamins, and immunological response (Clench & Mathias, 1995; DeGolier *et al.*, 1999). The longest caeca occur in herbivorous species, with a poorly-developed or non-existant caeca in nectarivorous, insectivorous, and piscivorous avian species. Caeca length (Table 1) and the proportion of caeca to total intestinal length, correspond to values derived for omnivorous and insectivorous avian species (DeGolier *et al.*, 1999).

As in cassowary and emu, and opposite to the ostrich and rhea, there are no transverse or spiral v*alvulae conniventes* in


*Manuscript 1574b; Received 06 June 2006; Finally accepted 01 September 2006; Date of publication 21 October 2006*

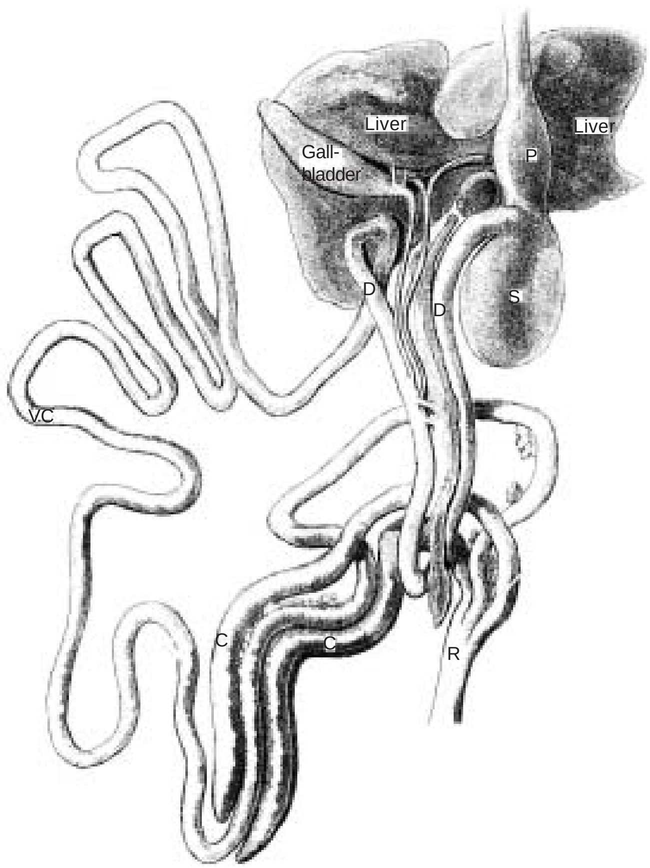


***Figure 1. Digestive system of the kiwi (Owen, 1841)***
***C - caeca; D - duodenum; P - proventriculus; R - rectum; S - stomach; VC - vitelline caecum***

the caeca and rectrum of the kiwi (Owen, 1841). Mitchell (1901) reported a 'supra-duodenal loop' at the posterior section of the intestinal tract, where the caeca are attached, in a Brown Kiwi from South Island, New Zealand. However, Beddard (1911) found no definite ileic loop in a kiwi from North Island, New Zealand, but only an attachment at the mesentery of the latter part of the ileum to the duodenum.

**Current diets**

According to Reid *et al.* (1982) North Island Brown Kiwis may be random feeders and numbers of prey ingested reflect supply rather than choice. Little Spotted Kiwis are selective feeders, choosing large slow-moving invertebrates from the upper layers of soil (Colbourne *et al.*, 1990). Kiwis use smell to locate food, with no evidence that sight is important (Reid *et al.*, 1982).

Due to the nocturnal and secretive behaviour of the kiwi knowledge of kiwi diets in the wild has depended largely on examination of stomach contents from accidentally killed kiwis (Reid *et al.*, 1982) and faeces examination (Colbourne & Powlesland, 1988). In all wild species investigated annelids have been found in most stomach and faeces samples, contributing to popular belief that New Zealand's rich earthworm fauna provides the kiwi's staple diet (Reid *et al.*, 1982; Colbourne & Powlesland, 1988). According to Reid *et al.* (1982), due to diverse feeding habits, a 'typical' diet probably does not exist for kiwis in the wild. He assumed an 'average' diet composed of 40-45% earthworms, 40-45% other invertebrates, and 10-15% plant material.

***Table 1. Length measurements (cm) of the digestive tract (DT) and caeca in different species of kiwi (Beddard, 1899).***

| Species | Scientific name | DT | Caeca |
|---|---|---|---|
| North Island Brown | *Apteryx mantelli* | 170.2 | 20.3 |
| Little Spotted | *Apteryx owenii* | 104.1 | 15.2 |
| Great Spotted | *Apteryx haastii* | 81.3 | 11.4 |

Organic matter of the stomach contents of wild kiwis ranged from 49.9-93.0% and protein content from 18.4-51.0%. Seven institutions holding kiwis in captivity in New Zealand used a total of 19 different ingredients in feed formulation, with ox heart, cat biscuits and roll oats as the main ingredients. Organic matter in diets varied from 89.6 to 96.9%, crude protein from 23.0 to 42.7% and crude fat from 5.4 to 24.4% of the dry matter (Hendriks *et al.*, 2005).

**Empirical approach to determine protein and amino acid requirements**

Due to metabolic factors high priority is given to protein and of amino acid requirements in animal nutrition. Birds are unable to synthesize nine of the 20 amino acids in proteins because of a lack of specific enzymes. The protein in the diet must supply sufficient levels of essential amino acids to meet requirements. Furthermore, enough excess amino acids have to be available to supply nitrogen needed to synthesize the nonessential amino acids (Klasing, 1998).

According to Emmans and Fisher (1986) a greater chance of success than through direct measurement of requirements is to approach the problem of describing protein and amino acids requirements by considering the bird's characteristics that lead to predictions of the rates at which functions take place. Further considerations are to define resource scales carefully, and to consider the quantities of each resource needed per unit of function. The Edinburgh model (Emmans & Fischer, 1986; Emmans, 1989) to determine protein requirements is based on the description of growth. Calculations used in this model have been described in detail by Sales and Du Preez (1997) and Sales and Janssens (2003a,b) as follows:

Growth of the body, feather and protein weight is described by means of the Gompertz equation:

$$C = C_m \times \exp(-\exp(-B \times (t-t^*)))$$

where $C_m$ is the final mature weight (g),
$B$ is the maturing rate constant (/d), and
$t^*$ is the time from hatching (days).

Growth rate of protein in the empty body (without feathers and gut contents) weight is calculated by:

$$dP/dt\ (g/day) = B^* \times P_m \times u \times \ln(1/u)$$

where $B^*$ (growth coefficient) is $B.P_m^{0.27}$,
$P_m$ is the mature protein weight of the empty body weight (g), and $u$ is the degree of maturing ($P_t/P_m$).

whereas growth rate of feather protein (FP) is determined by:

$$dFP/dt\ (g/day) = B \times FP_t \times \ln(FP_m/FP_t)$$

where $FP_t$ is the protein weight (g) of feathers at any given time, $FP_m$ is the final mature feather protein weight (g), and B is the maturing rate constant for feather protein (/d).

Maintenance protein requirements (g/d) for empty body weight is calculated by:

$$0.008 \times P_m^{-0.27} \times P_t$$

where 0.008 is the ideal protein needed (g/unit),

whereas maintenance protein for feathers (g/d) is determined as 1% of feather protein weight per day.

Protein requirements needed for growth of either empty body weight or feathers (g/day) are calculated by multiplying the protein growth by 1.25, where 1.25 is the reciprocal of the presumed net efficiency of 0.80. From the above the total protein requirements (g/day), and subsequently individual amino acid requirements, can be calculated.

With extremely limited information available on characteristics of kiwis the above model will rely on several assumptions to determine the protein and amino acid requirements. The growth of wild North Island Brown Kiwis until 1500 days after hatching were described with second-order polynomial regressions by McLennan *et al.* (2004):

Male (n = 34) - $y = 339 + 3.872x - 0.002x^2$
Female (n = 22) - $y = 294 + 4.613x - 0.002x^2$

where $y$ = weight (g) and $x$ = age (days).

By converting the above into absolute values until 1000 days after hatch, and keeping $C_m$ (final mature weight) constant at 2038 and 2662g for males and females, respectively, (McLennan *et al.*, 2004), Gompertz equations for body growth as presented in Table 2 could be produced. The rate of maturing of kiwis, derived from the Gompertz equation, in comparison to other avian species (Table 3), is extremely low. Growth of several avian species in the wild has been described by Ricklefs (1968, 1976); Oniki and Ricklefs (1981). However, previous studies on the growth of wild birds have concentrated on growth rate, with data sets often truncated before the bird approach asymptote (maturity). Further considerations that are rendering results unsuitable for comparison with B-values used in this manuscript are method of curve fitting, total number of points, and their spacing throughout the growing period (Brisbin *et al.*, 1987).

***Table 2. Parameters derived from the Gompertz equation for body growth in North Island Brown kiwis***

| Gender | Final mature weight (B, /d) | Maturing rate constant ($t^*$, days) | Time from hatching ($C_m$, g) |
|---|---|---|---|
| Male | 2038 | 0.0055 | 122.3 |
| Female | 2662 | 0.0048 | 168.7 |

***Table 3. Rate of maturing (B, /d) derived from the Gompertz equation for different domesticated avian species***

| Species | Rate of maturing Male | Female | Source |
|---|---|---|---|
| Broiler | 0.0382 | 0.0355 | Gous *et al.* (1999) |
| Quail | 0.0970 | 0.0770 | Du Preez and Sales (1997) |
| Guinea-fowl | 0.0360 | 0.0290 | Sales *et al.* (1997) |
| Ostrich | 0.0097 | 0.0090 | Du Preez *et al.* (1992) |

***Table 4. Essential amino acid composition (g/kg protein) of feather-free empty body and feather protein determined in 1.4 year old (41 kg body weight) emus (O'Malley 1996).***

| *Amino acid* | *Feather-free empty body* | *Feathers* |
|---|---|---|
| Arginine | 68.9 | 68.0 |
| Cystine | 11.2 | 62.9 |
| Histidine | 27.1 | 5.1 |
| Leucine | 71.4 | 100.3 |
| Isoleucine | 34.4 | 43.2 |
| Lysine | 73.3 | 14.3 |
| Methionine | 18.3 | 2.4 |
| Phenylalanine | 48.4 | 46.1 |
| Threonine | 40.4 | 52.4 |
| Tyrosine | 30.1 | 61.8 |
| Valine | 40.6 | 67.0 |

It has been assumed that feathers are 5.8% of live weight for all ages and sexes (Reid, 1972), whereas protein content is 19 and 85% for empty body and feather, respectively, for all ages and sexes. Assumptions on protein and amino acid contents (Table 4) are based on data derived with 70-week old (41kg body weight) emus (O'Malley, 1996). These values are in agreement with results obtained with seven-month old (70kg body weight) ostriches (Cilliers *et al.*, 1998). As no values were available for tryptophan this essential amino acid has been omitted.

From the above the maintenance and growth requirements for protein could be calculated as illustrated in Figure 2. Total absolute protein requirements are presented in Table 5. Subsequently, this could result in determination of amino acid requirements, as illustrated in Table 6. Differences in body weight between genders caused a considerable difference in requirements. To convert absolute requirements to dietary concentrations, information on feed intake is needed, that is unavailable for kiwis, as for most wild birds.

**Fulfillment of requirements**

Although the above model presents acceptable levels for protein and amino acid requirements of the kiwi, the achievement of these with the use of feed ingredients would be much more complicated. The potential of feed to supply a particular nutrient can be determined by chemical analysis. However, the actual

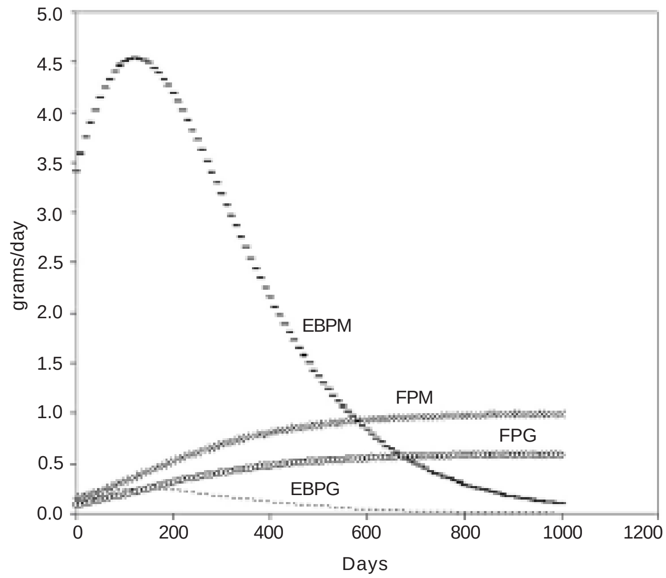


***Figure 2. Protein requirements for empty body growth (EBPG - ); empty body maintenance (EBPM -----); feather growth (FPG ∞) and feather maintenance (FPM ×) of a male North Island Brown Kiwi.***

***Table 5. Absolute total protein requirements needed by North Island Brown Kiwis.***

| Age | Body weight (g) | | Protein requirements (g/d) | |
|---|---|---|---|---|
| (days) | Male | Female | Male | Female |
| 10 | 319 | 313 | 4.0 | 4.2 |
| 50 | 460 | 454 | 4.6 | 5.1 |
| 100 | 658 | 663 | 5.3 | 6.0 |
| 200 | 1062 | 1126 | 5.3 | 6.6 |
| 300 | 1399 | 1563 | 4.5 | 6.2 |
| 500 | 1798 | 2171 | 2.9 | 4.3 |
| 750 | 1975 | 2503 | 2.0 | 2.8 |
| 1000 | 2022 | 2613 | 1.7 | 2.3 |

***Table 6. Daily amounts (mg/day) of essential amino acids needed by a 500-day old North Island Brown Kiwi.***

| Amino acid | Male | Female |
|---|---|---|
| Arginine | 196 | 295 |
| Cystine | 78 | 103 |
| Histidine | 58 | 93 |
| Leucine | 229 | 338 |
| Isoleucine | 106 | 157 |
| Lysine | 157 | 252 |
| Methionine | 38 | 62 |
| Phenylalanine | 137 | 207 |
| Threonine | 126 | 187 |
| Tyrosine | 114 | 163 |
| Valine | 139 | 203 |

availability of nutrients within the feed to the animal needs allowances for unavoidable losses occurring during digestion, absorption and metabolism (McDonald *et al*., 2002).

Furthermore, the ability of the gastrointestinal system to modulate its structure and function is an important response to shifting nutritional regimes (Karasov, 1994). Domesticated omnivorous species such as chickens, quail, rats, pigs and humans are capable of up-or-down regulating enzymes for amino acid catabolism (Koutsos *et al.*, 2001). However, information on wild species is limited. Commercial diets, while producing rapid and efficient body growth, may not prepare the digestive system to the less digestible foods birds will encounter after release (Thomas, 1997).

## Conclusions

This study illustrated that, according to information available on the digestive system and natural diet, the kiwi can be categorized as an obligate insectivore. Application of an empirical model developed with domesticated avian species, and based on growth, presents realistic results regarding protein and amino acid requirements of kiwis. However, to satisfy in these determined requirements with feed ingredients available at institutions that kept kiwis will need much more research into the digestive characteristics of the kiwi. Intake levels, to determined diet nutrient concentrations, and nutrient digestibility in different feed ingredients need to be addressed. This could be possible without disturbance to the birds with the use of markers. The plasticity and flexibility of the digestive tract to change of diet needs attention. Seen the high mortality reported for kiwis in captivity and the wild, most often healthy birds killed by predators, there has to be material available for this purpose. Domestic species, such as poultry, should be avoided as models to established digestive adaptations and digestibility of feed ingredients for kiwis, seen that the former has been adapted for many years on artificial diets, and thus have lost most of their digestive features as found in the wild.

## References

**Baker, A.J., C.H. Daugherty, R. Colbourne and J.L. McLennan (1995).** Flightless brown kiwi of New Zealand possess extremely subdivided population structure and cryptic species like small mammals. *Proceedings of the National Academy of Sciences* 92: 8254–8258.

**Beddard, F.E. (1899).** Notes on the anatomy of the genus Apteryx. *Novitates Zoologicae* 6: 386-402.

**Beddard, F.E. (1911).** On the alimentary tract of certain birds and on the mesenteric relations of the intestinal loops. *Proceedings of the Zoological Society of London* 1911: 47-93.

**Brisbin, I.L., C.T. Collins, G.C. White and D.A. McCallum (1987).** A new paradigm for the analysis and interpretation of growth data: the shape of things to come. *Auk* 104: 552-554.

**Cilliers, S.C., J.P. Hayes, A. Chwalibog, J. Sales and J.J. Du Preez (1998).** Determination of energy, protein and amino acid requirements for maintenance and growth in ostriches. *Animal Feed Science and Technology* 72: 283-293.

**Clench, M. and J.R. Mathias (1995).** The avian cecum: a review. *Wilson Bulletin* 107: 93-121.

**Colbourne, R., K. Baird and J. Jolly (1990).** Relationship between invertebrates eaten by Little Spotted Kiwi, *Apteryx owenii*, and their availability on Kapati Island, New Zealand. *New Zealand Journal of Zoology* 17: 533-542.

**Colbourne, R. and R.G. Powlesland (1988).** Diet of the Stewart Island Brown Kiwi (*Apteryx australis lawryi*) at Scollay's Flat, southern Stewart Island. *New Zealand Journal of Ecology* 11: 99-104.

**DeGolier, T.F., S.A. Mahoney and G.E. Duke (1999).** Relation-ships of avian cecal lengths to food habits, taxonomic position, and intestinal lengths. *Condor* 101: 622-634.

**Du Preez, J.J. and J. Sales (1997).** Growth rate of different sexes of the European Quail (*Coturnix coturnix*). *British Poultry Science* 38: 314-315.

**Du Preez, J.J., M.J.F. Jarvis, D. Capatos and J. De Kock (1992).** A note on growth curves of ostriches (*Struthio camelus*). *Animal Production* 54: 150-152.

**Emmans, G.C. (1989).** The growth of turkeys, pp.135-166. In: Nixey, C. and T.C. Grey (eds.) *Recent Advances in Turkey Science*. Butterworths, London (UK).

**Emmans, G.C. and C. Fischer (1986).** Problems in nutritional theory, pp.9-39. In: Fisher, C. and K.N. Boorman (eds.) *Nutrient Requirements of Poultry and Nutritional Research*. Butterworths, London (UK).

**Gous, R.M., E.T. Moran, H.R. Stilborn, G.D. Bradford and G. Emmans (1999).** Evaluation of the parameters needed to describe the overall growth, the chemical growth, and the growth of feathers and breast muscles of broilers. *Poultry Science* 78: 812-821.

**Hendriks, W., M. Potter and N. Pindur (2005).** *Nutrient composition of the diet of captive and wild kiwi (Apteryx mantelli) in New Zealand.* Proceedings of the fourth European Zoo Nutrition Conference, Leipzig Zoo, Danmark, 20-23 January 2005.

**Karasov, W.H. (1994).** Adaptive adaptations in avian omnivores, pp. 494-497. In: Wahlqvist, M. (ed.) *Nutrition in a sustainable environment.* Proceedings of the XV$^{th}$ International Congress of Nutrition, Livingstone, Edinburgh (UK).

**Kiwi Captive Management Advisory Committee (2004).** *Captive management plan for kiwi: Apteryx mantelli, Apteryx rowi, Apteryx australis, Apteryx australis 'Haast', Apteryx haastii, Apteryx owenii.* Threatened Species Occasional Publication 24. Department of Conservation, Wellington, New Zealand.

**Klasing, K.C. (1998).** Comparative Avian Nutrition. CAB International, Wallingford (UK), 350pp.

**Koutsos, E.A., J. Smith, L. Woods and K.C. Klasing (2001).** Adult cockatiels (*Nymphicus hollandicus*) undergo metabolic adaptation to high protein diets. *Journal of Nutrition* 131: 2014-2020.

**McDonald, P., R.A. Edwards, J.F.D. Greenhalgh and C.A. Morgan (2002).** *Animal Nutrition*, sixth edition: Pearson Education Ltd., Essex (UK), 672pp.

**McLennan, J.A., L. Dew, J. Miles, N. Gillingham and R. Waiwai (2004).** Size matters: predation risk and juvenile growth in North Island Brown Kiwi (*Apteryx mantelli*). *New Zealand Journal of Ecology* 28: 241-250.

**Mitchell, P.C. (1901).** On the intestinal tract of birds; with remarks on the valuation and nomenclature of zoological characters. *Transactions of the Linnean Society of London, Zoology* 8: 173–275.

**O'Malley, P.J. (1996).** An estimate of the nutritional requirements of emus, pp. 92-108. In: Deeming, D.C. (ed.) *Improving our Understanding of Ratites in a Farming Environment.* Ratite Conference, Oxfordshire (UK).

**Oniki, Y. and R.E. Ricklefs (1981).** More growth rates of birds in the humid New World tropics. *Ibis* 123: 349-354.

**Owen, R. (1841).** On the anatomy of the Southern Apteryx (*Apteryx australis*, Shaw). *Transactions of the Zoological Society of London* 2: 257-301.

**Pycraft, W.P. (1901).** Part II. On the morphology and phylogeny of the Palaeognathae (Ratitae and Crypturi) and Neognathae (Carinatae). *Transactions of the Zoological Society of London* 15: 149-290.

**Reid, B. (1972).** North Island Brown Kiwi: *Apteryx autralis mantelli*. Measurements and weight of a young chick. *Notornis* 19: 261-266.

**Reid, B., R.G. Ordish and M. Harrison (1982).** An analysis of the gizzard contents of 50 North Island Brown Kiwis, *Apteryx australis mantelli*, and notes on feeding observations. *New Zealand Journal of Ecology* 5: 76-85.

**Ricklefs, R.E. (1968).** Patterns of growth in birds. *Ibis* 110: 419-451.

Ricklefs, R.E. (1973). Patterns of growth in birds. II. Growth rate and mode of development. *Ibis* 115: 177-201.

**Ricklefs, R.E. (1976).** Growth rates of birds in the humid New World tropics. *Ibis* 118: 179-207.

**Ricklefs, R.E. (1996).** Morphometry of the digestive tracts of some passerine birds. *Condor* 98: 279-292.

**Sales, J. (2005).** The endangered kiwi: a review. *Folia Zoologica* 54: 1-20.

**Sales, J. and J.J. Du Preez (1997).** Protein and energy requirements of the Pearl Grey guinea fowl. *World's Poultry Science Journal* 53: 381-385.

**Sales, J., J.J. Du Preez and S.A. Van Niekerk (1997).** The chemical composition of the Pearl Grey Guinea Fowl. *British Poultry Science* 38: 223-224.

**Sales, J. and G.P.J. Janssens (2003a).** Energy and protein nutrition of companion birds. *Flemish Veterinary Journal* 72: 51-58.

**Sales, J. and G.P.J. Janssens (2003b).** Nutrition of the domestic pigeon (*Columba livia domestica*). *World's Poultry Science Journal* 59: 221-232.

**Thomas, V.G. (1997).** Nutritional, morphological, and behavioural considerations for rearing birds for release. *Journal für Ornithologie* 128: 423-430.