



CHAPTER 1

GENERAL INTRODUCTION



Members of the *ratidae* (flightless birds with no keel on the sternum) have assumed an ever increasing commercial importance and the ostrich, rhea and emu are farmed extensively throughout the world for their skins, meat, feathers and fat (Gillespie and Schupp, 1998; Sales, 2007). Emu farming in South Africa is a relatively new enterprise and efforts to place this emerging industry on a sound financial basis are hamstrung by a lack of basic knowledge on the biology of this bird. Although a number of studies have been carried out on the digestive tract of ratites, these have concentrated mainly on the gastro-intestinal tract (Owen, 1841, 1879; Gadow, 1879; Pycraft, 1900; Mitchell, 1901; Cho *et al.*, 1984; Herd, 1985; Bezuidenhout, 1999; Potter *et al.*, 2006), with little detailed information being provided on the structure of the upper digestive tract (oropharynx and oesophagus). This region is of considerable importance considering that it is the first area for food selection and intake which is vital to the nutrition and growth of the animal and therefore its commercial viability.

The gross morphology of the upper digestive tract of many species of birds has been extensively studied (for a review of the earlier literature see McLelland, 1979). More recent studies on this region have concentrated on relating structure to function and in providing more detailed morphological descriptions using a wider variety of techniques including immuno-cytochemistry and scanning and transmission electron microscopy (Gargiulo *et al.*, 1991; Kobayashi *et al.*, 1998; Samar *et al.*, 1999; Liman *et al.*, 2001; Jackowiak and Godynicki, 2005). However, most of this work has focused on specific areas or structures of the upper digestive tract, such as the tongue (Lucas, 1896; 1897; Gardner, 1926, 1927; Kobayashi *et al.*, 1998; Jackowiak and Godynicki, 2005; Rossi *et al.*, 2005). This organ has been studied in respect of its function (McLelland, 1979; Bonga Tomlinson, 2000; Gussekloo and Bout, 2005) and classification (Lucas, 1896, 1897; Gardner, 1926, 1927; Harrison, 1964; Iwasaki, 2002), whereas the structure and secretion of the lingual salivary glands (Samar *et al.*, 1999; Liman *et al.*, 2001; Al-Mansour and Jarrar, 2004) have also been investigated.



Other studies have concentrated on the distribution and classification of the glands within the oropharynx (Tucker, 1958; Warner *et al.*, 1967; Bailey *et al.*, 1997; Samar *et al.*, 1999; Liman *et al.*, 2001) as well as of the taste end-organs of birds (Bath, 1906; Botezat, 1910; Moore and Elliott, 1946; Lindenmaier and Kare, 1959; Gentle, 1971a, b). The avian oesophagus has also been described for many species, generally as part of studies dealing with the digestive tract as a whole (Calhoun, 1954; Ziswiler and Farner, 1972; Hodges, 1974; Nickel *et al.*, 1977; McLelland, 1979; Bailey *et al.*, 1997; Bacha and Bacha, 2000; Gussekloo, 2006).

In contrast to the wealth of information available on this region in birds in general, studies on the upper digestive tract of ratites are superficial, brief, fragmented and often difficult to interpret (Sales, 2006). This situation is further compounded by the fact that only single specimens were sometimes described, particularly in the earlier studies (see Faraggiana, 1933).

Much of the available information has centred on gross morphological descriptions of the ratite tongue, the most extensive report being that of Faraggiana (1933) who compared the tongue and laryngeal mound of the ostrich, rhea and emu. Descriptions of the ratite tongue have appeared in numerous publications over the years (Meckel, 1829; Cuvier, 1836; MacAlister, 1864; Gadow, 1879; Owen, 1879; Pycraft, 1900; Göppert, 1903; Duerden, 1912; Faraggiana, 1933; Roach, 1952; Feder, 1972; McCann, 1973; Cho *et al.*, 1984; Fowler, 1991; Bonga Tomlinson, 2000; Gussekloo and Bout, 2005; Porchescu, 2007; Crole and Soley, 2008; Jackowiak and Ludwig, 2008; Tivane, 2008), the majority of which, however, are brief and superficial.

The shape of the tonsils, as with the tongue, is also reported to vary between the ratites. A brief comparison is provided by Cho *et al.* (1984), which is vague and open to interpretation, giving little information on the specific location or structure of the tonsils. The authors simply note that “The ostrich tonsils and tongue are smooth, blunt and U-shaped. In the Darwin’s rhea both tongue and tonsils have simple, pointed V-shaped tips. The tonsils in the emu are similar to the rhea but have a small flap laterally” (Cho *et al.*, 1984).

Brief descriptions, as well as illustrations, of the ratite oropharynx or parts thereof have been supplied for the ostrich (Göppert, 1903; Faraggiana, 1933; Bonga Tomlinson, 2000), greater rhea (Pycraft, 1900; Faraggiana, 1933; Bonga Tomlinson, 2000; Gussekloo and Bout, 2005), kiwi (Owen, 1879; McCann, 1973) and emu (Faraggiana, 1933; Bonga Tomlinson, 2000). More recent studies incorporating gross morphological descriptions, light microscopy (Porchescu,





2007; Jackowiak and Ludwig, 2008; Tivane, 2008) and scanning electron microscopy (Jackowiak and Ludwig, 2008; Tivane, 2008) have supplied more comprehensive data of this region in the ostrich. Functional studies on the eating behaviour of ratites, involving structures of the upper digestive tract, have been documented using the ostrich, emu and greater rhea (Bonga Tomlinson, 2000) or greater rhea only (Gusseklou and Bout, 2005) as models.

Histological studies of the upper digestive tract of ratites include those of Feder (1972) on the tongue and oesophagus of the greater rhea, Herd (1985) on the oesophagus of the emu, Crole and Soley (2008) on the tongue of the emu, Jackowiak and Ludwig (2008) on the tongue of the ostrich, and Porchescu (2007) and Tivane (2008) on the oropharynx and oesophagus of the ostrich.

In respect of the emu, the tongue, and a description of its margins, surfaces and papillae have been reported, based on a single specimen (Faraggiana, 1933). Cho *et al.* (1984) describe the tongue as having a serrated edge and Bonga Tomlinson (2000) illustrates the tongue's outline in relation to surrounding structures and notes the presence of papillae. A brief histological description of this organ is supplied by Crole and Soley (2008). As part of a study on the anatomy and histology of the gut of the emu, Herd (1985) measured and briefly described the histology of the oesophagus based on two specimens.

As is evident from the above review, very little information is currently available on the morphology of the upper digestive tract of the emu, with only the tongue and oesophagus briefly being described. In view of the lack of any detailed information on the morphology and topographical relationships of the structures forming the upper digestive tract of the emu, this study aims to provide essential baseline data on a previously neglected segment of the digestive tract of this commercially important bird. The work will also provide additional data of academic significance enabling more accurate comparisons to be made between members of this important avian family.



The aims of the study are the following:

- To provide a comprehensive gross morphological description of the upper digestive tract (oropharynx and proximal oesophagus) of the emu,
- To describe the histological and surface morphological features of selected areas of the oropharynx and proximal oesophagus,
- To link microscopic findings to the gross morphology and formulate postulations for function,
- To critically appraise the existing literature on the topic and
- To gather base-line data for future studies.

The envisaged benefits arising from this study are the following:

- As morphology is so intimately linked to function, accurate, detailed morphological descriptions of the areas studied will lead to postulation of function.
- A sound knowledge of normal gross anatomical and histological features, including possible individual variations, will greatly assist in recognising pathology thus providing more accurate diagnostics and will aid in accurate tissue sampling.
- The collection of base-line data on the emu will provide a greater platform for an improved understanding of comparative ratite biology, will add to the data base of avian biology in general, may lead to the discovery of novel structures and will be of taxonomic value.
- A more accurate appreciation of the structure of the upper digestive tract will provide a greater insight into food selection and feeding behaviour of this bird and may possibly impact on feed formulation.



REFERENCES

- AL-MANSOUR, M.I. & JARRAR, B.M. 2004. Structure and secretions of the lingual salivary glands of the white-cheeked bulbul, *Pycnonotus leucogenys* (Pycnonotidae). *Saudi Journal of Biological Sciences*, 11:119-126.
- BACHA, W.J. & BACHA, L.M. 2000. Digestive system, in *Color Atlas of Veterinary Histology*, edited by D. Balado. Philadelphia: Lippincott Williams & Wilkins: 121-157.
- BAILEY, T.A., MENSAH-BROWN, E.P., SAMOUR, J.H., NALDO, J., LAWRENCE, P. & GARNER, A. 1997. Comparative morphology of the alimentary tract and its glandular derivatives of captive bustards. *Journal of Anatomy*, 191:387-398.
- BATH, W. 1906. *Die Geschmacksorgane der Vögel und Krokodile*. Berlin: In Kommission bei R. Friedländer & Sohn.
- BEZUIDENHOUT, A.J. 1999. Anatomy, in *The Ostrich, Biology, Production and Health*, edited by D. C. Deeming. Wallingford, UK: CABI Publishing: 13-49.
- BONGA TOMLINSON, C.A. 2000. Feeding in paleognathous birds, in *Feeding: Form, Function, and Evolution in Tetrapod Vertebrates*, edited by K. Schwenk. San Diego: Academic Press: 359-394.
- BOTEZAT, E. 1910. Morphologie, Physiologie und phylogenetische Bedeutung der Geschmacksorgane der Vögel. *Anatomischer Anzeiger*, 36:428-461.
- CALHOUN, M.L. 1954. *Microscopic Anatomy of the Digestive System of the Chicken*. Ames, Iowa: Iowa State College Press.
- CHO, P., BROWN, B. & ANDERSON, M. 1984. Comparative gross anatomy of ratites. *Zoo Biology*, 3:133-144.
- CROLE, M.R. & SOLEY, J.T. 2008. Histological structure of the tongue of the emu (*Dromaius novaehollandiae*). *Proceedings of the Microscopy Society of Southern Africa*, 38:63.





- CUVIER, G. 1836. *Leçons d'anatomie comparée*, Third edition. Volumes 1 & 2, edited by M. Duméril. Bruxelles: Dumont.
- DUERDEN, J.E. 1912. Experiments with ostriches XVIII. The anatomy and physiology of the ostrich. A. The external characters. *Agricultural Journal of the Union of South Africa*, 3:1-27.
- FARAGGIANA, R. 1933. Sulla morfologia della lingua e del rialzo laringeo di alcune specie di uccelli Ratiti e Carenati non comuni. *Bollettino dei Musei di Zoologia e Anatomia comparata*, 43:313-323.
- FEDER, F-H. 1972. Zur mikroskopischen Anatomie des Verdauungsapparates beim Nandu (*Rhea americana*). *Anatomischer Anzeiger*, 132:250-265.
- FOWLER, M.E. 1991. Comparative clinical anatomy of ratites. *Journal of Zoo and Wildlife Medicine*, 22:204-227.
- GADOW, H. 1879. Versuch einer vergleichenden Anatomie des Verdauungssystemes der Vögel. *Jenaische Zeitschrift für Medizin und Naturwissenschaft*, 13:92-171.
- GARDNER, L.L. 1926. The adaptive modifications and the taxonomic value of the tongue in birds. *Proceedings of the United States National Museum*, 67:Article 19.
- GARDNER, L.L. 1927. On the tongue in birds. *The Ibis*, 3:185-196.
- GARGIULO, A.M., LORVIK, S., CECCARELLI, P. & PEDINI, V. 1991. Histological and histochemical studies on the chicken lingual glands. *British Poultry Science*, 32:693-702.
- GENTLE, M.J. 1971a. Taste and its importance to the domestic chicken. *British Poultry Science*, 12:77-86.
- GENTLE, M.J. 1971b. The lingual taste buds of *Gallus domesticus*. *British Poultry Science*, 12:245-248.
- GILLESPIE, J.M. & SCHUPP, A.R. 1998. Ratite production as an agricultural enterprise. *The Veterinary Clinics of North America. Food Animal Practice*, 14:373-386.
- GÖPPERT, E. 1903. Die Bedeutung der Zunge für den sekundären Gaumen und den Ductus nasopharyngeus. *Morphologisches Jahrbuch*, 31:311-359.





- GUSSEKLOO, S.W.S. 2006. Feeding structures in birds, in *Feeding in Domestic Vertebrates: From Structure to Behaviour*, edited by V. Bels. Wallingford, UK: CABI Publishing: 14-19.
- GUSSEKLOO, S.W.S. & BOUT, G.R. 2005. The kinematics of feeding and drinking in palaeognathous birds in relation to cranial morphology. *Journal of Experimental Biology*, 208:3395-3407.
- HARRISON, J.G. 1964. Tongue, in *A New Dictionary of Birds*, edited by A.L. Thomson. London: Nelson: 825-827.
- HERD, R.M. 1985. Anatomy and histology of the gut of the emu *Dromaius novaehollandiae*. *Emu*, 85:43-46.
- HODGES, R.D. 1974. The digestive system, in *The Histology of the Fowl*. London: Academic Press: 35-47.
- IWASAKI, S. 2002. Evolution of the structure and function of the vertebrate tongue. *Journal of Anatomy*, 201:1-13.
- JACKOWIAK, H. & GODYNICKI, S. 2005. Light and scanning electron microscopic study of the tongue in the white tailed eagle (*Haliaeetus albicilla*, *Accipitridae*, *Aves*). *Annals of Anatomy*, 187:251-259.
- JACKOWIAK, H. & LUDWIG, M. 2008. Light and scanning electron microscopic study of the structure of the ostrich (*Strutio camelus*) tongue. *Zoological Science*, 25:188-194.
- KOBAYASHI, K., KUMAKURA, M., YOSHIMURA, K., INATOMI, M. & ASAMI, T. 1998. Fine structure of the tongue and lingual papillae of the penguin. *Archivum Histologicum Cytologicum*, 61:37-46.
- LIMAN, N., BAYRAM, G. & KOÇAK, M. 2001. Histological and histochemical studies on the lingual, preglottal and laryngeal salivary glands of the Japanese quail (*Coturnix coturnix japonica*) at the post-hatching period. *Anatomia*, 30:367-373.
- LINDENMAIER, P. & KARE, M.R. 1959. The taste end-organs of the chicken. *Poultry Science*, 38:545-549.
- LUCAS, F.A. 1896. The taxonomic value of the tongue in birds. *Auk*, 13:109-115.





- LUCAS, F.A. 1897. The tongues of birds. *Report of the United States National Museum*, 1895:1003-1020.
- MACALISTER, A. 1864. On the anatomy of the ostrich (*Struthio camelus*). *Proceedings of the Royal Irish Academy*, 9:1-24.
- MCCANN, C. 1973. The tongues of kiwis. *Notornis*, 20:123-127.
- MCLELLAND, J. 1979. Digestive system, in *Form and Function in Birds*, edited by A.S. King & J. McLelland. San Diego, California: Academic Press: 69-92.
- MECKEL, J.F. 1829. *System der vergleichenden Anatomie*. Halle: Der Rehgerschen Buchhandlung.
- 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.
- MOORE, D.A. & ELLIOTT, R. 1946. Numerical and regional distribution of taste buds on the tongue of the bird. *Journal of Comparative Neurology*, 84:119-131.
- NICKEL, R., SCHUMMER, A. & SEIFERLE, E. 1977. Digestive system, in *Anatomy of the Domestic Birds*. Berlin: Verlag Paul Parey: 40-50.
- OWEN, R. 1841. On the anatomy of the southern apteryx (*Apteryx australis*, Shaw). *Transactions of the Zoological Society of London*, 2:257-301.
- OWEN, R. 1879. *Memoirs on the extinct and wingless birds of New Zealand; with an appendix of those of England, Australia, Newfoundland, Mauritius and Rodriguez*. Volume 1. London: John van Voorst.
- PORCHESCU, G. 2007. Comparative morphology of the digestive tract of the Black African ostrich, hen and turkey. PhD thesis (in Russian), Agrarian State University of Moldova.
- POTTER, M.A., LENTLE, R.G., MINSON, C.J., BIRTLES, M.J., THOMAS, D. & HENDRIKS, W.H. 2006. Gastrointestinal tract of the brown kiwi (*Apteryx mantelli*). *Journal of Zoology*, 270:429-436.





- PYCRAFT, W.P. 1900. On the morphology and phylogeny of the palaeognathae (*Ratitae and Crypturi*) and neognathae (*Carinatae*). *Transactions of the Zoological Society of London*, 15:149-290.
- ROACH, R.W. 1952. Notes on the New Zealand kiwis (1). *The New Zealand Veterinary Journal*, 1:38-39.
- ROSSI, J.G., BARALDI-ARTONI, S.M., OLIVEIRA, D., FRANZO, C.V.S. & SAGULA, A. 2005. Morfologia do bico e da língua de perdizes *Rhynchotus rufescens*. *Ciência Rural*, 35:1098-1102.
- SALES, J. 2006. Digestive physiology and nutrition of ratites. *Avian and Poultry Biology Reviews*, 17:41-55.
- SALES, J. 2007. The emu (*Dromaius novaehollandiae*): A review of its biology and commercial products. *Avian and Poultry Biology Reviews*, 18:1-20.
- SAMAR, M.E., AVILA, R.E., DE FABRO, S.P., PORFIRIO, V., ESTEBAN, F.J., PEDROSA, J.A. & PEINADO, M.A. 1999. Histochemical study of Magellanic penguin (*Spheniscus magellanicus*) minor salivary glands during postnatal growth. *Anatomical Record*, 254:298-306.
- TIVANE, C. 2008. A Morphological Study of the Oropharynx and Oesophagus of the Ostrich (*Struthio camelus*). MSc dissertation, University of Pretoria, South Africa.
- TUCKER, R. 1958. Taxonomy of the salivary glands of vertebrates. *Systematic Zoology*, 7:74-83.
- WARNER, R.L., MCFARLAND, L.Z. & WILSON, W.O. 1967. Microanatomy of the upper digestive tract of the Japanese quail. *American Journal of Veterinary Research*, 28:1537-1548.
- ZISWILER, V. & FARNER, D.S. 1972. Digestion and the digestive system, in *Avian Biology*, edited by D.S. Farner, J.R. King & K.C. Parkes. New York: Academic Press: 344-354.

