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RENAL CONCENTRATING ABILITY IN SELECTED WEST AUSTRALIAN BIRDS

By ERIK SKADHAUGE

Institute of Medical Physiology, Dept. A, University of Copenhagen, and Department of Zoology, University of Western Australia

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SUMMARY

1. The osmotic ratio between 'urine' (the supernatant of the ureteral part of the droppings) and plasma has been determined in a number of dehydrated West Australian birds.

2. The U/P ratio was 1·4 in the Emu, 1·7 in two Columbidae (Senegal Turtle Dove and Crested Pigeon), 2·4 in two Meliphagidae (Singing Honey-eater and Red Wattle Bird), 2·6 in three Psittacidae (Bourke Parrot, 28-Parrot, and Galah), 2·7 in the Laughing Kookaburra, and 2·8 in the Zebra Finch.

3. The Na^+ and Cl^- concentrations in the 'urine' ranged from 5 to 71 m-equiv./l, the K^+ concentration from 92 to 201 m-equiv./l.

4. There seems to be a rather narrow range for the concentrating ability within each family, but the concentrating ability of xerophilic birds differs considerably.

INTRODUCTION

In the present study the cloacal excretion of salt and water has been studied in selected West Australian birds in the normally hydrated and the dehydrated state: the osmotic 'urine' to plasma ratio being measured in the latter state. The purpose of the study was threefold. First, to elucidate renal and cloacal salt and water conservation so as to understand the adaptation of birds to their habitat, particularly the degree of xerophilia. Secondly, to correlate the structure and function of excretory organs. Thirdly, to find a bird of suitable size with a good renal concentrating ability. This bird was sought in order to study the cloacal salt and water transport by perfusion experiments. The Galah (*Cacatua roseicapilla*) was chosen for this purpose. The cloacal transport studies are reported elsewhere (Skadhauge, 1974).

MATERIAL AND METHODS

Birds

The species studied are listed in Table 1. Further investigations on the Zebra Finch will be reported elsewhere (Skadhauge & Bradshaw, 1974).

Specimens of the Emu, Little Corella, Crested Pigeon and Zebra Finch were caught at Mileura station 800 km north-east of Perth. The climate and flora of this semi-arid location are described by Davies (1970). Singing Honeyeaters, Red Wattle Birds, Senegal Turtledoves, 28-Parrots, and Kookaburras were caught at the premises of the Zoology Department at the University of Western Australia in Perth. The Galahs were obtained commercially after trapping near Perth, the Bourke Parrots being loaned by the Zoological Gardens, Perth.

Food and maintenance

Except during experimental periods the birds were kept in large open aviaries. They had free access to water (supplemented with vitamins) and fresh lettuce. The seed-eating birds were fed commercial mixtures of seeds. The Emus received a mixture of wheat and turkey starter (50–50 %), the Honeyeaters a mixture of honey and wheat germs (50–50 %) and the Kookaburras received Kangaroo meat supplemented with live mice.

Experimental procedure

All experiments were carried out in an air-conditioned building maintained at 22–23 °C and relative humidity of 70–90 %. Natural daylight and artificial light was maintained from approximately 08.00 to 18.00 h. Droppings were collected, under a light mineral oil, food and water intake being also recorded. The birds were weighed daily. They were pre-adapted to the cages for a few days until stable food intake was achieved. The birds were dehydrated for 2–3 days with food available (except for the Kookaburras which were subjected to total inanition). A blood sample was drawn from the leg vein (Emus: neck vein) into a heparinized syringe before the birds were dehydrated and at the termination of the experiment. The droppings were collected for 4–6 h before dehydration and on the 2nd or 3rd day of dehydration respectively.

The droppings were separated into anal and oral fractions immediately after the experiments, placed in tubes on ice (still under oil) and centrifuged at 26000 g for 10 min within 24 h. All analyses were carried out on the supernatants. This collection and storage procedure does not cause a measurable increase in osmolality after 'voiding' (Skadhauge, 1968).

The anal fraction of the droppings contains some precipitated uric acid and urates and has been demonstrated to have almost the same osmotic and ionic composition as ureteral urine in the domestic fowl (Skadhauge, 1968) and in the Budgerigar (Krag & Skadhauge, 1972). The supernatant of the anal fraction was therefore used to estimate the composition of ureteral urine. Collection of ureteral urine in the Galah (Skadhauge, 1974) showed this assumption to be justified. The osmolality and ionic composition of the oral end of the droppings was, as in the domestic fowl (Skadhauge, 1972) and Zebra Finch (Skadhauge & Bradshaw, 1974), only slightly lower than that of the anal end.

Analyses

Osmolality was measured with a Knauer Osmometer (using NaCl standards), Na^+ and K^+ by Flame photometry and Cl^- with a Buchler–Cotlove chloridometer. Measurements were made on plasma and on supernatants of the anal end of the droppings (denoted henceforth as 'urine').

Field observations

A few blood and cloacal samples were secured from Emus, at Mileura Station, and from Galahs, from Manmanning (200 km east of Perth). The Emus were studied when narcotized after drinking water from sheep troughs dosed with α-chloralose (0·44 g/l). The Galahs were shot and blood and cloacal contents taken immediately.

Composition of the oral end of the droppings

Although most droppings in this study showed a gradual change from anal to oral end, pure 'ureteral' droppings (consisting of precipitated uric acid without faecal contamination) were occasionally encountered. In some of these the supernatants and faecal samples were analysed separately for osmolality and ionic concentrations (Table 2). In the majority of the cases the osmolality was only slightly lower in the faecal (oral) end of the samples, whereas the ionic concentrations were most often 70–90 % of the concentrations in the ureteral end. The same pattern was seen in five ureteral and faecal samples from the Kookaburra. In this species fluid ureteral urine often fell in droppings clearly separated from the brown coloured faecal material. The faecal samples had the following average fractional concentrations, as a function of those of the ureteral urine: osmolality: 0·95; Na^+, 0·75; Cl^-, 0·47; and K^+, 0·86.

RESULTS

The majority of the observations were made on Galahs, Red Wattle Birds, Zebra Finches, Senegal Doves, Crested Pigeons, Emus, and Kookaburras, only a few measurements being made on Little Corellas, Bourke Parrots, and 28-Parrots. The average food intake and body weight for the birds while receiving water *ad libitum* is given in Table 1.

Renal concentrating ability

The osmolality and electrolyte concentrations of plasma and 'urine' are reported in Tables 3 and 4. The osmotic 'urine' to plasma ratios have been calculated on the basis of these measurements and are given in Table 1, together with the average increase in plasma osmolality and average fall in body weight from the normally hydrated to the dehydrated state. In Fig. 1 the birds are listed according to the osmotic 'urine' to plasma (U/P) ratios which ranged from 1·36 in the Emu to 2·78 in the Zebra Finch.

The two members of the family *Columbidae* concentrated rather poorly. For the Senegal Dove this accords with its origin in a more humid habitat. The Crested Pigeon is, however, common (Fischer, Lindgren & Dawson, 1972) in the arid interior. The Little Corella originates in tropical rain forests and had also limited concentrating ability. The Meliphagidae concentrated rather well. They are observed to be active during the hot summer months. Of the parrots which live in mesic to xeric habitats, Bourke Parrot, Galah, and 28-Parrot were all good concentrators. The Kookaburra, the only bird of prey in the study, concentrated as well as the Zebra Finch. Birds of prey are not observed to drink in the desert (Fischer *et al.* 1972). This may partly

Table 1

(The species studied are listed according to order and family. Numbers in parentheses indicate that only few measurements were made. Body weight and food intake have been recorded when water was freely available. The increase in plasma osmolality, the fall in body weight and the ratio between 'urine' and plasma osmolality was measured after 2 or 3 days of dehydration.)

	Body weight (g)	Food intake (g/24 h)	Increase in plasma osmolality (%)	Fall in body weight (%)	Osmotic urine to plasma ratio
Order: Psittaciformes, family: Psittacidae					
Galah (*Cacatua roseicapilla*)	267	24	13	12	2·58
Little Corella (*Cacatua sanguinea*)	(600)	—	—	—	(1·9)
28-Parrot (*Barnardius zonarius*)	(150)	—	—	—	(2·6)
Bourke Parrot (*Neophema bourkii*)	39	3·3	—	11	(2·5)
Order: Passeriformes, family: Meliphagidae					
Singing Honeyeater (*Meliphaga virescens*)	25	6·8	11	15	2·41
Red Wattle Bird (*Anthochaera carunculata*)	103	7·2	13	13	2·36
Family: Estrildidae					
Zebra Finch (*Taeniopygia castanotis*)	13	4·2	7	3	2·78
Order: Columbiformes, family: Columbidae					
Senegal Turtledove (*Streptopelia senegalensis*)	91	5·3	16	15	1·74
Crested Pigeon (*Ocyphaps lophotes*)	159	6·4	12	10	1·77
Order: Casuariformes, family: Dromaiidae					
Emu (*Dromaius novae-hollandiae*)	17500	430	13	11	1·36
Order: Coraciiformes, family: Alcedinidae					
Laughing Kookaburra (*Dacelo gigas*)	382	—	10	10	2·71

Table 2. *Ureteral versus faecal samples of individual birds*

	Osmolality (m-osmoles)		Na (m-equiv/l)		Cl (m-equiv/l)		K (m-equiv/l)	
	Ureteral	Faecal	Ureteral	Faecal	Ureteral	Faecal	Ureteral	Faecal
Senegal Dove	662	648	10·5	7·5	5·7	11·0	122	115
Galah	968	901	5·0	3·7	12·8	5·5	158	156
Galah	968	939	32·6	22·3	24·2	17·2	176	153
Emu	485	466	12·6	10·0	—	—	116	86

result from physiological adaptation but also from the water content, of approximately 75 %, of the prey.

Electrolyte concentrations of plasma and 'urine'

The plasma osmolality and electrolyte concentrations were slightly higher than generally observed in mammals, but were in the range of domestic birds (see Skadhauge 1973, p. 19). In the dehydrated state increases of plasma osmolality of 10–15 % were tolerated well. The 'urine' always had lower concentrations of Na^+ and Cl^- than of K^+, reflecting the composition of the food of the seed-eating birds. The K^+ co

Table 3. *Osmolality and electrolyte concentrations of plasma*

(Mean ± S.E.)

		Osmolality	Na	K	Cl	*n*
Galah	Normal hyd.	336 ± 2	142 ± 2	4·9 ± 0·4	117 ± 5	4
	Dehyd.	400 ± 13	158 ± 4	6·6 ± 0·9	136 ± 4	6
Singing Honeyeater	Normal hyd.	343 ± 1	158 ± 3	3·9 ± 0·4	127 ± 2	7
	Dehyd.	384 ± 9	174 ± 3	4·3 ± 0·4	140 ± 2	7
Red Wattle Bird	Normal hyd.	346 ± 3	157 ± 3	4·0 ± 0·4	125 ± 2	7
	Dehyd.	388 ± 9	175 ± 7	6·2 ± 1·2	145 ± 6	3
Zebra Finch	Normal hyd.	336 ± 5	149 ± 1	4·7 ± 0·4	123 ± 2	5
	Dehyd.	361 ± 3	160 ± 2	5·2 ± 0·2	134 ± 3	4
Senegal Dove	Normal hyd.	333 ± 2	148 ± 1	3·6 ± 0·3	125 ± 1	10
	Dehyd.	379 ± 5	174 ± 3	4·4 ± 0·7	147 ± 3	6
Crested Pigeon	Normal hyd.	336 ± 2	149 ± 2	4·2 ± 0·4	123 ± 1	11
	Dehyd.	370 ± 5	169 ± 2	4·5 ± 0·7	140 ± 1	6
Emu	Normal hyd.	309 ± 4	138 ± 2	4·8 ± 0·4	108 ± 3	8
	Dehyd.	337 ± 5	156 ± 2	4·2 ± 0·2	126 ± 4	7
Kookaburra	Normal hyd.	322 ± 6	148 ± 2	4·8 ± 0·7	112 ± 4	3
	Dehyd.	348	159	4·7	129	2

Table 4. *Osmolality and electrolyte concentrations of urine*

(Mean ± S.E.)

		Osmolality	Na^+	K^+	Cl^-	*n*
Galah	Normal hyd.	708 ± 10	16·0 ± 7·8	109 ± 13	16·8 ± 5·1	4
	Dehyd.	982 ± 37	24·3 ± 5·7	125 ± 16	18·9 ± 3·1	7
Singing Honeyeater	Normal hyd.	795 ± 20	23·4 ± 6·4	130 ± 11	24·1 ± 3·1	4
	Dehyd.	925 ± 37	11·8 ± 1·0	114 ± 8	24·3 ± 1·0	5
Red Wattle Bird	Normal hyd.	705	72	196	51	2
	Dehyd.	917 ± 44	25·1 ± 8·0	201 ± 24	71·3 ± 23·6	4
Zebra Finch	Normal hyd.	381 ± 25	7·5 ± 0·7	42 ± 4·6	19·3 ± 1·2	14
	Dehyd.	1005 ± 26	7·6 ± 0·6	135 ± 5	39·8 ± 3·6	16
Senegal Dove	Normal hyd.	—	—	—	—	—
	Dehyd.	661 ± 12	8·0 ± 1·2	121 ± 14	8·4 ± 2·6	6
Crested Pigeon	Normal hyd.	568 ± 22	8·8 ± 1·5	151 ± 19	17·4 ± 2·6	4
	Dehyd.	655 ± 29	14·0 ± 1·5	162 ± 13	23·0 ± 6·5	6
Emu	Normal hyd.	348 ± 49	6·0 ± 1·4	77 ± 16	16·2 ± 3·3	4
	Dehyd.	459 ± 20	6·1 ± 1·2	120 ± 11	4·7 ± 0·6	4
Kookaburra	Normal hyd.	740 ± 40	38·3 ± 4·6	58·4 ± 15·2	33·2 ± 1·4	3
	Dehyd.	944	28·0	92·5	9·9	2

centrations were generally in the range of 150–200 m-equiv./l, thus contributing significantly to the total urine osmolality, of 15–20 %, both in the normally hydrated and dehydrated states.

Field observations of Emus and Galahs

The plasma osmolality, and the osmolality and electrolyte concentrations of cloacal contents are reported in Table 5. Both plasma and urine osmolality reflect the recent water intake of the Emus. The Galahs had an average urine to plasma osmotic ratio

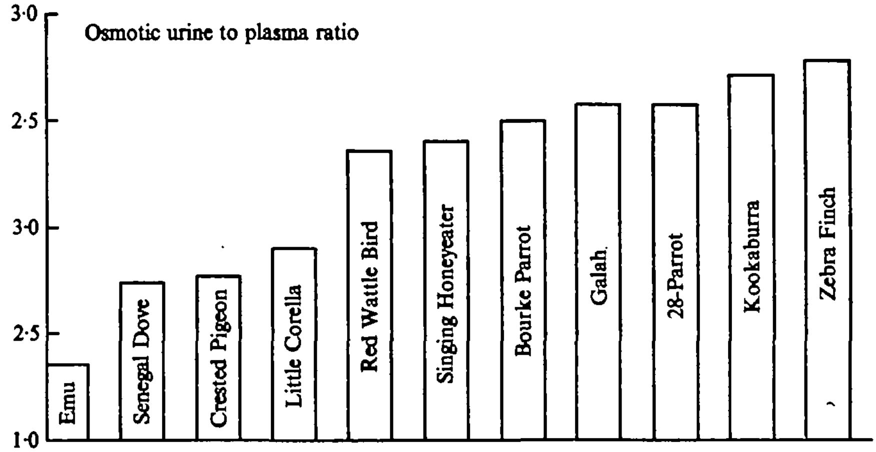

Fig. 1. Osmotic urine to plasma ratio in dehydrated West Australian birds. The birds are grouped according to their concentrating ability: the Psittacidae concentrating effectively, being only surpassed by the Zebra Finch and the only bird of prey in the study (the Kookaburra). The Meliphagidae are also good concentrators and contrast with the Colombidae and particularly the Emu which concentrate poorly.

Table 5. *Field observations*

(Mean ± S.E.)

	Plasma osmolality (m-osmoles)	Cloacal samples				No. of observations
		Osmolality (m-osmoles)	Na^+ (m-equiv./l)	Cl^- (m-equiv./l)	K^+ (m-equiv./l)	
Emu	286 ± 3	199 ± 9	35 ± 7	57 ± 10	24 ± 1	5
Galah	362 ± 5	761 ± 47	44 ± 10	40 ± 14	77 ± 11	5

of 2·1, and were thus in a state of moderate water conservation. The cloacal concentrations of strong electrolytes demonstrate that the diet, in nature, contains fairly large amounts of NaCl, relative to K^+, compared to the seeds offered in captivity(see Table 4). This puts the birds in a more favourable condition for cloacal solute-linked water absorption.

Food intake, 'sip' volume and panting in the dehydrated Emu

Because of the value of being able to judge the water intake in Emus (observed from a distance in nature by the number of 'sips' taken) the 'sip' volume was determined in 4 Emu chicks, about 6 months of age, kept in captivity for this study. The birds were dehydrated for 3 days at the ambient weather conditions in Perth in January with a resulting 10 % (1·75 kg) water loss. The food intake declined on the first day of dehydration to 37 % of the value when water was available, to 9 and 4 % on the second and third day respectively. They drank on average 1·69 l within the first half hour after water was made available. Thus within ½ h the weight loss was replaced. The 'sip' volume was determined by weighing the water and counting the number of 'sips'. Only the first 15 min intake was used. After that time the birds started eating, and wetting of the beak with little water intake was observed frequently. The average 'sip' volume was determined to 31·3 ± 2·6 ml (S.E.).

It was further noted that the dehydrated Emus did not pant (even at a 38 °C day time temperature), whereas panting regularly started approximately 15 min after water was made available.

Total water excretion in the Galah

In 2 Galahs the total 24 h production of droppings was collected under oil between 48 and 72 h of dehydration, and the water excretion determined after drying to constant weight at 105 °C. The excretion of water was determined to 101 μl/kg h and 124 μl/kg h respectively, based on the body weight before dehydration.

DISCUSSION

The present study showed little correlation between the renal concentrating ability and the expected degree of xerophilia for a number of birds studied.

Water conservation in hot arid lands involves many parameters, such as: evaporative water loss in relation to oxygen consumption, tolerance to increase in plasma osmolality, upper critical temperature, renal concentrating ability and post-renal modification of ureteral urine. It is, therefore, not surprising that of the species which are commonly found in the arid interior of Australia, the Zebra Finch, the Budgerigar and the Galah are good concentrators, while the Crested Pigeon and the Emu are poor ones (Davies, 1969; Davies, 1972; Fisher *et al.* 1972; Serventy, 1971; Serventy & Whittell, 1967). With the poor concentrators it is well to remember that the total cloacal water loss may, due to cloacal resorption of ureteral urine, be smaller if a bird does not concentrate well (Skadhauge & Kristensen, 1972; Skadhauge, 1973). Therefor, only when the cloacal transport parameters have been studied together with renal concentrating ability is it possible to judge just how xerophilic a bird is in this respect. It is entirely possible that the Emu (which has a well-developed coprodeum, large intestine and caeca) can conserve a significant fraction of the ureteral urine. The low concentrating ability may thus not be a disadvantage.

A correlation between concentrating ability and degree of xerophilia might be expected in more closely related species. Diversity was, however, sought in this study to enable a better correlation between renal function and subsequent studies of renal structure to be made (O. W. Johnson and E. Skadhauge, in preparation). Some generalizations concerning families can, however, be made. The parrots in this study and the Budgerigar (Krag & Skadhauge, 1972) are good concentrators, the Columbidae as with the European pigeon (Scothorne, 1959), being limited concentrators. The Zebra Finch like the North American Finches (Poulson & Batholomew, 1962) has, however an effective kidney function.

The only bird of prey in the study, the Kookaburra, had a high K^+ concentration in the urine, but was not much different from the seed-eating species and, particularly, the Honeyeaters. The fact that the ureteral droppings of the Kookaburra were fluid and had a high osmolality demonstrates that little attention should be paid to the water content of the droppings, except within the same species fed on a constant diet. As judged from the cloacal perfusion studies in the Galah (Skadhauge, 1974) the high K^+ concentration does not prevent the NaCl absorption which is necessary for a solute-linked water absorption in the cloaca. Therefore, the osmotic (water conserving) work of the kidney, which results in a high urine osmolality, is not lost in the period during which ureteral materials are retained in the cloaca (Skadhauge, 197[illegible]

A 10–15 % fall in body weight and an equivalent increase in plasma osmolality and electrolyte concentration were recorded in most of the birds used in this study. The poor concentrators reached this level within two days; the good ones within 3 days. The change in these parameters was small in the Zebra Finch, the only bird in this study which can live for longer periods without water under the experimental conditions employed.

A steep increase in plasma osmolality (10–20 %) can be tolerated, without apparent side effects. The fact that flying birds (Davies, 1969) are observed far from sources of water may possibly be due to this tolerance. Krag & Skadhauge (1972) and Tucker (1968) have calculated that the Budgerigar has both water and energy for 400 km flight (at neutral humidity and temperature).

The suppression of panting in the dehydrated Emu suggests that this bird is adapted to allow the body temperature to rise.

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