RENAL FUNCTION, RESPIRATION, HEART RATE AND THERMOREGULATION IN THE OSTRICH *(STRUTHIO CAMELUS)*

by
GIDEON N. LOUW, PETER C. BELONJE and HENDRIK J. COETZEE
Zoological Institute
and Department of Animal Physiology,
University of Stellenbosch, Stellenbosch.

(With 11 figures)

INTRODUCTION

As the ostrich is the largest bird in existence it is of considerable physiological interest. Moreover, in spite of being flightless and of too large a size to escape to a protective micro-climate, it is a successful inhabitant of many desert regions of Africa. This is particularly true of the Namib Desert in South West Africa where they are found in large numbers under very arid conditions. The ostrich has, however, received very little attention from physiologists. Crawford and Schmidt-Nielsen (1967) were the first to undertake serious physiological studies related to possible desert adaption. They studied the hot-room reaction of an ostrich in terms of temperature regulation and evaporative cooling. This study was followed by a refined investigation of respiration in the ostrich by Schmidt-Nielsen, Kanwisher, Lasiewski and Cohn (1967), again under artificial conditions. More recently Cloudsley-Thompson and Mohamed (1967) have examined the effect of water deprivation on body weight and feed intake of the ostrich.

No attempt has, as yet, been made to examine the nature or efficiency of renal function in the ostrich, which is central to the problem of assessing adaptation to desert survival. Moreover, apart from the body temperature study by Bligh and Hartley (1965), no effort has been made to make a composite study of the main physiological systems involved in water metabolism and thermoregulation under natural conditions, where the animals are exposed to cycling effects of wind, solar load, light and diurnal variation in ambient temperature. For these reasons, then, the present investigation was initiated to assess the physiology of adaptation of the ostrich to a desert environment under as near natural conditions as possible.

PROCEDURE

The birds used in the investigation were semi-domesticated adult females obtained from the Oudtshoorn District. In all, three ostriches were employed with body weights of 90 kg, 93 kg and 114 kg respectively. Throughout the experimental period they were housed in loose boxes. These were constructed of wood and were specially designed to allow free circulation of air around the animals. The birds were able to move several feet forwards and backwards. They were able to lie down and get up in comfort, but were not able to turn around. The crates provided no shade for the animals and they were exposed to natural climatic conditions at all times. The following treatments and methods were applied.

Water provision

For the first three days of the experimental period the birds were drenched daily by means of a stomach tube. Each bird receiving a total amount

DISCUSSION AND CONCLUSIONS

Renal function

A feature of renal function was the marked decline in urine volume and concomitant increase in osmoconcentration during dehydration, indicating efficient antidiuretic hormone control in the ostrich. Moreover, the pattern of electrolyte excretion points to increased release of aldosterone during the same period. The maximum osmoconcentration exhibited by the urine (2.7 times that of the plasma) is, however, not excessively high, particularly when compared with various desert mammals (Chew, 1965). Of greater interest was the disappearance of free water from the fluid fraction of the urine which was replaced by viscous mucus during dehydration. Moreover, the abundance of PAS-positive goblet cells found in the epithelial lining of the ureter would seem to indicate that this mucus originates, at least in part, from this source. It appears, then, that under conditions of dehydration the obligatory nitrogen excretion, in the form of undissolved uric acid, is facilitated by the lubricating effect of this mucus. The fact that nitrogen is excreted as uric acid represents a significant saving of water *per se,* and the use of mucus and not free water as lubricant for the expulsion of the uric acid may represent a further important water saving mechanism. It is not known whether this copious mucus secretion occurs in other birds.

It has been suggested (Crawford and Schmidt-Nielsen, 1967; Cloudsley-Thompson and Mohamed, 1967) that the nasal glands of the ostrich may contribute to the water economy of the bird during water deprivation. No experimental evidence has, as yet, been advanced in support of this hypothesis. Moreover, in spite of efficient renal function, outlined above, it appears that the ostrich cannot exist indefinitely on dry feed without additional water. In the present investigation feed intake declined sharply during the latter part of the dehydration period and on day 11 two of the three birds refused to feed. Cloudsley-Thompson and Mohamed (1967) came to a similar conclusion when studying the effect of water deprivation on feed intake and body weight. Under natural conditions, however, the ostrich can frequently find sufficient succulent plant material to be independant of free water. Alternatively, under dry feeding conditions the speed and mobility of the bird ensures that it can travel long distances between grazing areas and a suitable water supply. Moreover, as shown by Cloudsley-Thompson and Mohamed (1967), the ostrich is able to maintain its body weight while drinking saline water (20 per cent sea water or 0.2M NaCl) and can easily withstand a loss of 25 per cent of its body weight during dehydration, which is remarkably high.

Heart rate

The most interesting feature of the heart rate data was the relatively slow heart rate exhibited by the ostrich, particularly during the night. As heart rate is closely associated with metabolic rate, it would appear, then, that metabolic rate at night proceeds at a relatively slow rate. The insulating effect of the tightly folded wings and huddled posture of the ostrich during the night facilitates thermoregulation and makes it unnecessary for the metabolic rate to be raised to meet the demands of low ambient temperatures, which are typical of the desert night. A low metabolic rate, in turn, would be of considerable advantage to any desert animal for purposes of nutrient conservation on the highly variable nutritional plane encountered in the desert. It was therefore not surprising to find that ostriches, which had been on a high nutritional plan for a relatively short period, deposited large amounts of subcutaneous fat over the sternum. The importance of the above argument in terms of desert survival is, however, still highly speculative.

Thermoregulation

Under the conditions of this experiment, during which the maximum ambient temperature did not exceed 40° C and the relative humidity cycled daily between ± 40 per cent at noon and ± 90 per cent at 05.00 hr., the ostrich was found to be an excellent thermoregulator. The range of body temperatures in which most values fell (38.2 — 39.8° C) is in agreement with the mean body temperature (39° C) established by Crawford and Schmidt-Nielsen (1967) and the diurnal cycle which was established is very similar to that found by Blight and Hartley (1965) when using radiotelemetric methods on an unrestrained wild ostrich. The range in body temperature which was recorded is, however, considerably lower than in most other birds. The ostrich therefore does not enjoy the advantage of a high temperature which would minimise the temperature gradient between the body and the atmosphere when the latter exceeds the former.

Of greater significance, however, is the fact that the birds made maximum use of convective and radiant cooling through feather erection and wing drooping. Feather erection for cooling purposes may be unique for the species. Only as a last resort, when the ambient temperature approaches 34° C (screen temperature 31° C) and when there is no wind will the birds resort to evaporative cooling by increasing the respiration rate abruptly from a normally slow rate to a rapid oscillating type of respiration. Crawford and Schmidt-Nielsen (1967) estimated that the critical threshold for the above change in respiration rate was 25° C. Their investigation was, however, carried out in an artificially heated room where apparently opportunity for convective cooling was minimal. The threshold of ± 31° C established in the present investigation seems more realistic as temperatures of 25° C are very frequently encountered under desert conditions. Moreover, as the results indicated, the threshold of 31° C may well be increased considerably under windy conditions. It should also be noted that Schmidt-Nielsen *et al.* (1967) have shown that high respiratory rates in the ostrich, even if sustained for 8 hours, did not induce respiratory alkalosis in the birds. They concluded that under these conditions "a functional shunt system permits a regulated by-pass of the lungs" while increasing air circulation through the air sacs.

In final summary, then, the ostrich appears to be physiologically well adapted to desert survival. Moreover, certain behavioral reflexes are important in enhancing this physiological adaptation.

ACKNOWLEDGEMENTS

The generous financial assistance of the South African Council for Scientific and Industrial Research made this investigation possible. We wish also to thank the Director, Winter Rainfall Region, Dept. of Agricultural Technical Services for providing the ostriches and allowing us to carry out the experiment on the Oudtshoorn Experimental Station.

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