Water balance and osmotic regulation of the East African scorpion *Lychas burdoi* (Simon)

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The water balance and osmotic regulation of the scorpion *Lychas burdoi* from dry areas in Kenya were investigated. The scorpion had rates of water loss which were higher than those reported for desert scorpions from Soutwest United States. Metabolic production of water gave only a very moderate contribution to the water balance (less than 1% of the transpiratory water loss). During experimental dehydration the scorpions displayed no osmotic regulation. Sodium was the dominating extracellular cation. The concentration of free amino acids was low (below 10 mm) compared to values reported from insects.

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INTRODUCTION

Dry tropical areas support numerous species of scorpions. The adaptations making scorpions able to survive in these areas have been the object of a number of investigations (Edney 1977). Scorpions are reported to have a relatively restrictive water balance (Hadley 1970), about as restrictive as that of dry habitat tenebrionids, which are notorious for their success in arid areas (Zachariassen *et al.* 1988). Most scorpions lack the ability to osmoregulate when undergoing dehydration (Riddle *et al.* 1976, Warburg *et al.* 1980). Only one scorpion species is reported to osmoregulate (Robertson *et al.* 1982).

MATERIALS AND METHODS

Scorpions of the species *Lychas burdoi* (Simon) were collected from their natural habitats under stones in a semi arid area in the vicinity of Thika, Kenya in January 1987. They were kept inside plastic boxes and transported directly to the laboratory in Nairobi, where they were kept at 20°C for two days before the experiments started. During this period the specimens were not fed, but given water.

The dehydration experiments were carried out with the scorpions kept at 20°C inside a desiccator, in which the relative air humidity was kept low (5—10%) by means of silica gel. The scorpions were taken out and weighed each day, and the rate of weight loss was used as a measure of rate of water loss. Each day groups of scorpions were removed from the dehydration experiment for determination of metabolic rates, haemolymph solute concentrations and relative water content.

The metabolic rates of the scorpions were determined as rates of oxygen consumption, which were measured by the use of Engelmann constant pressure respirometers (Engelmann 1963) as described by Røskaft *et al.* (1986). The measurements were made at 20°C, and the values were recalculated to dry air and STP.

Samples of haemolymph were obtained by making a hole on the ventral side in the animals, the exuding haemolymph being drawn in to a capillary tube by means of capillary forces. To prevent evaporation the samples were treated as described by Zachariassen *et al.* (1982). The haemolymph was stored inside the capillary tubes at -20°C, and transported inside an ice-filled thermo box to the laboratory in Trondheim, where the samples were analysed after about 3 weeks.

The haemolymph osmolality was determi-

ned by measuring the melting point of 20 nl samples on a Clifton nanoliter osmomenter. The temperature at which the last tiny ice crystal disappeared during slow heating of frozen samples was taken as the melting point. The osmolality was calculated from the melting points by means of the osmolal melting point depression (1.86°C/Osm).

The sodium concentration of the haemolymph was measured on a Perkin Elmer atomic absorption spectrophotometer in relation to standard solutions with known sodium concentration.

The free amino acids in the haemolymph were measured as free ninhydrin positive substances (NPS) according to a method described by Moore & Stein (1948). The measurements were made on 1 μl samples of haemolymph, which were transferred to 50 μl 70% ethanol inside a thin glass tube. The protein precipitate was removed by centrifugation in a Compur M-1000 micro centrifuge, washed twice and recentrifuged, and the combined supernatants transferred to a plastic tube where the samples were stored for up to 3 weeks before they were analyzed. The content of NPS was determined as taurine equilvalents at 570 nm on a Bausch & Lomb micro spectrophotometer. The relative water content of the scorpions was determined by weighing them before and after drying to constant weight at 105°C.

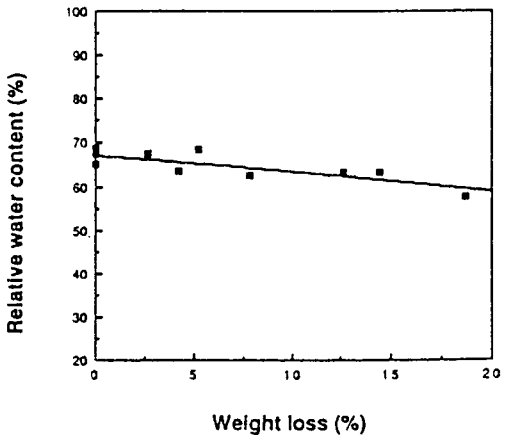

Fig. 1. Relative water content of *Lychas burdoi* scorpions plotted as a function of evaporative weight loss. Solid line: Estimated change assuming that all weight loss is water loss and that the dry weight remains contant.

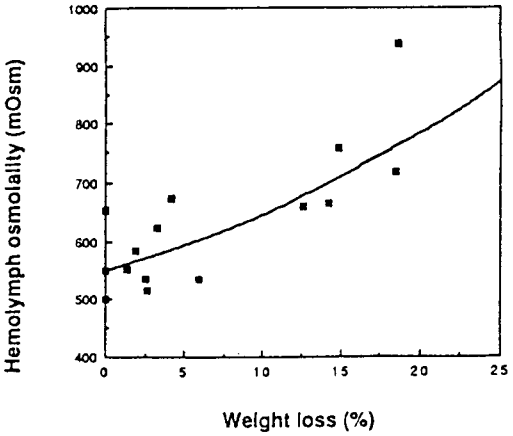

Fig. 2. Haemolymph osmolality of *Lychas burdoi* scorpions plotted as a function of evaporative weight loss. Solid line: Change assuming no osmotic regulation as the dehydration proceeds.

RESULTS

A group of six scorpions having an average body weight of 0,1216±0,047 g (M.V.±S.D.) had a rate of water loss of 0,25±0,05% of body weight per hour. The metabolic rate was 5,5±2,5 μl oxygen/(hour x g body weight).

The relative water content of the scorpions at different degrees of dehydration is shown in Fig. 1. The figure also shows the estimated change assuming that the entire weight loss is water loss, and that there is no change in dry weight, estimated as described by Zachariassen *et al.* (1987 b). The results reveal that the relative water content drops in agreement with the estimated curve.

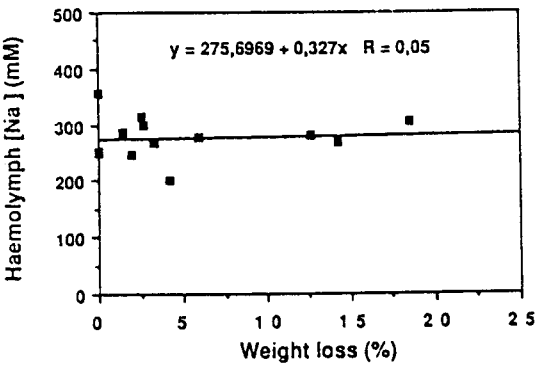

Fig. 3. Haemolymph sodium concentration of *Lychas burdoi* scorpions plotted as a function of evaporative weight loss.

Fig. 2 shows the haemolymph osmolality of the scorpions at different degrees of dehydration. The data show that the haemolymph osmolality of hydrated scorpions was about 550 mOsm, and that dehydration is accompanied by a substantial increase in osmolality. At the end of the dehydration period the osmolality had increased to about 900 mOsm. Fig. 2 also shows a curve describing the expected change in osmolality assuming that the solutes simply become concentrated in a gradually smaller volume of solvent water as the dehydration proceeds, estimated as described by Zachariassen *et al.* (1987 b). The data show that during dehydration the haemolymph osmolality increases in agreement with the estimated curve.

The haemolymph concentration of sodium at different degrees of dehydration is plotted in Fig. 3. The data show that the sodium concentration was about 270 mm, and that it remained constant throughout the observation period.

The concentration of free amino acids in the haemolymph was 8,34±3,7 mm. Due to the wide dispersion of the data it is not possible to say whether this parameter changed as the scorpions became dehydrated.

Due to shortage of haemolymph, no values of extracellular free amino acids from the most dehydrated scorpions were obtained, and the role of free amino acids as osmolytes therefore remains unclear.

DISCUSSION

Fig. 4 shows the rate of water loss — body weight relationship of the *L. burdoi* scorpions of the present study plotted together with corresponding data for other scorpions and for different families of beetles. The data in Fig. 4 reveal that when body weight is taken into consideration, the African *L. burdoi* scorpions of the present study have high rates of water loss compared to other scorpions. *L. burdoi* scorpions have rates comparable to those of dry habitat carabid beetles of the same body size, and considerably higher than the rates of dry habitat tenebrionids and curculionids.

The high rate of water loss of *L. burdoi* scorpions is also reflected in the fact that the relative water content changes as expected, assuming that all weight loss is water loss and that the dry weight does not change during the dehydration period. Apparently, the dehydration proceeds so rapidly that the metabolic oxidation of dry substance does not cause a significant reduction in dry weight, and no substantial production of metabolic water.

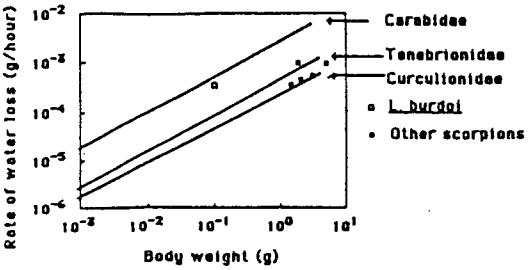

Fig. 4. Double logarithmic plot of rates of water loss of dry habitat scorpions and beetles as a function of body weight. Data for *L. burdoi* scorpions are taken from the present study and data for other scorpions are taken from Hadley (1970) and from Warburg *et al.* (1980). Data for carabid, tenebrionid and curculionid beetles are from Zachariassen *et al.* (1988).

The metabolic rate of the scorpions was approximately 5,5 µl oxygen /(hour x g body weight) which is considerably lower than the metabolic rates of desert beetles (Zachariassen *et al.* 1987 a). The low production of metabolic water is not only due to the high rate of water loss and the subsequent short time to reach lethal degree of dehydration, but also to the relatively low metabolic rate. Low metabolic rates in scorpions are also reported by Robertson *et al.* (1982). The low metabolic rate in combination with comparatively high rates of water loss leads to a very moderate contribution from metabolic water to the general pool of body water. Assuming that scorpions, like tenebrionid beetles (Zachariassen *et al.* 1987 b) metabolize fat as they undergo dehydration, the metabolic production of water can be estimated from the oxygen consumption by using the constant applying to fat metabolism, i e. 1,89 l of oxygen per g water produced. By using this constant in combination with the rate of oxygen consumption of the scorpions, the rate of metabolic water production will be about 0,0000029 g water/(hour x g body weight), i.e. below 1% of the rate of transpiratory water loss.

The relatively high rate of water loss is also reflected in the fact that the *L. burdoi* scorpions became lethally dehydrated in about

one week. Dry habitat tenebrionid beetles of the same body size survive for more than two months (unpubl.data)

The osmolality of hydrated scorpions was slightly higher than the values obtained from previous studies of other scorpions (Burton 1984). The agreement between the increase in haemolymph osmolality during dehydration and the curve representing passive concentration of the solutes indicates that the scorpions have no osmotic regulation as they undergo evaporative dehydration. This is in agreement with most previous studies of scorpion osmoregulation (Hadley 1974; Riddle *et al.* 1976; Yokota 1978; Warburg 1980; Robertson *et al.* 1982). Lack of ability to osmoregulate during dehydration has also been demonstrated in two species of dry habitat curculionid beetles from Kenya (Zachariassen, unpubl. data).

The results show that in *L. burdoi* scorpions sodium is the dominating extracellular cation. This appears to be common for all scorpion species, see Burton (1984) for review. In this respect the scorpions are more similar to crustaceans and non arthropod animals, which, in contrast to insects, always have sodium as the dominating extracellular cation.

The sodium concentration remains contant during the dehydration period, indicating that although they do not regulate their total concentration of extracellular solutes, the scorpions regulate their extracellular sodium concentration. This implies that the contribution of sodium to the total solute concentration is diminishing as the dehydration proceeds. This discrepancy must be made up for by some other solutes, but the identity of these solutes is not known.

The concentration of extracellular free amino acids in the scorpions of the present study (8,7 mm) is low compared to values reported for insects. Most insects may have extracellular concentrations of free amino acids in the range fro 30 to 80 mm, whereas vertebrates and non- arthropod invertebrates have values below 1 mm. Thus, the scorpions seem to have values in the range between insects and other animals.

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