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Effect of drinking saline water on food and water intake, food digestibility, and nitrogen and mineral balances of rusa deer stags (*Cervus timorensis russa)*

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Abstract

*The salinity tolerance of Javan rusa deer (*Cervus timorensis russa*) was investigated with seven stags, aged 4·5 years. Animals were offered a medium-quality chaffed lucerne hay and given five different levels of water salinity: (a) control (570 mg/kg of total dissolved salts (TDS)) and (b) 'saline' water with TDS contents of 1000, 3500, 6000 and 8500 mg/kg. Food intake, food digestibility and nitrogen balance were not affected by increasing salt concentration in drinking water, however the drinking water (DW) intake, the total (food plus drinking) water intake and the DW:dry-matter ratio increased with increasing salt concentration. Some deer given water containing 8500 mg TDS per kg showed signs of stress which included large between-day fluctuations in water intake, opening of the orbital gland, head shaking, and rapid breathing. Rusa deer can tolerate drinking water containing 6000 mg TDS per kg for at least 9 days without harmful effect but may be unable to tolerate water with 8500 mg TDS per kg.*

Keywords: Cervus timorensis, *food intake, saline water, water intake.*

Introduction

Water is an essential nutrient so it is important for animals to have an adequate supply of good quality water to maintain satisfactory production. The amount and quality of water needed varies between species of animals and classes in the same species (Schoeman and Visser, 1995) and is affected by the animals' environment which includes factors such as seasonal changes in pasture types and availability, food water content and ambient temperature (Birrell, 1992; Ismail *et al*., 1995; Karim and Rawat, 1996).

One of the principal factors affecting water quality is salinity, i.e. the amount of total dissolved salts (TDS) in the water. The presence in animals' drinking water of high concentrations of some inorganic ions such as Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, SO_4^{2-} and HCO_3^{-} may cause harmful effects resulting in poor performance, illness or even death (Kellems and Church, 2002).

Ru *et al*. (2004) have recently published data on the effect of saline water on food intake and health of red and fallow deer but there are no data for any other deer species. The data obtained in this study may help to answer questions about the risks faced by farmers who have to use underground water for farmed rusa deer, especially in semi-arid areas, and during droughts.

Material and methods

Animals, housing and basal food

Seven Javan rusa deer (*Cervus timorensis russa*) stags, 4·5 years old with mean weight 105·2 (s.d. 8·54) kg were confined in individual metabolism pens. These animals were introduced into the pens 3 weeks before the experiment started. They were accustomed to handling and were familiar with the metabolism pens. The deer were given *ad libitum* a chopped medium-quality lucerne (*Medicago sativa*) hay (Table 1). The amount of food offered at each feeding was adjusted on the basis of the intake on the previous day by giving proportionately 0·2 extra food, thus lucerne was offered in excess of animal intake at all times.

The study continued for 63 days in the southern hemisphere summer (28 November 2001 to 30 January 2002). The experiment was conducted at the Deer Research Unit, University of Queensland, Gatton. The unit is situated at 27° 36'S at an elevation of 90 m above sea level and has a subtropical climate.

Treatments

Five different water salinity treatments were used: control (570 mg TDS per kg), and saline water prepared daily by adding NaCl to the control water, to give TDS contents of 1000, 3500, 6000 and 8500 mg/kg. Deer had continuous access to water.

Table 1 *Chemical composition of lucerne hay offered to the rusa deer during this study*

	Period		
	1	2	3
Dry matter (DM; g/kg)	859	869	890
Constituents of dry matter (g/kg DM)			
Crude protein	245	248	248
Neutral-detergent fibre	409	409	417
Organic matter	907	903	901
Sodium	5·0	4·9	4·4
Magnesium	5·4	5·5	5·2
Calcium	11·7	11·8	11·7
Potassium	12·9	10·9	11·9

This was achieved by providing 15 kg of water at 09:00 h, and if necessary an additional 15 kg in the afternoon.

Experimental design

The treatments were imposed in a randomized incomplete block design (partially balanced), in which each deer (block) received three of the five treatments (Cochran and Cox, 1992). There were four deer in each of the treatments, except that five deer received water containing 3500 mg TDS per kg. The numbers of deer used, and the design adopted, were chosen to minimize the impact of the experiment on individual animals while retaining statistical validity. Each period of the experiment was 21 days. The deer were allowed to adapt to saline water during the adjustment period (days 1 to 7) of each experimental period by gradually increasing the salt concentration of the drinking water, until it reached the required concentration. This was achieved by day 5 of the adjustment period.

Animal health

The general health of the animals was monitored twice daily. Treatments were discontinued, and the animal returned to the control water treatment, if and when water intakes fell to less than 0·50 of the control intake on any one day, or fell to less than 0·75 of the control intake on any three consecutive days. The salinity treatments were also terminated if a deer showed significant adverse effects on general health, including diarrhoea, anorexia, vomiting, abnormal urine excretion (the possible formation of urinary calculi), or general weakness (possible, or reported, symptoms of salt poisoning in sheep given saline water; Pierce, 1957). The deer were also monitored for opening of their orbital glands as these are open in rusa deer if the animal is stressed (Van Mourik, 1983).

Measurements

Water and food intakes were measured between days 8 and 14. Urine and faeces from each deer were collected between days 9 and 14. The deer were rested on days 15 to 21, and given the control water.

Daily water and food intakes were measured during the collection period by recording the amount offered and the amount refused before the next feeding. Daily water loss by evaporation was measured by exposing water in a similar container in an area adjoining the metabolism pens. About 60 g each of food given and refusals were taken daily from each deer and oven dried at 103ºC for 24 h to measure the food water consumption.

A second set of approximately 100-g samples of food given and refusals was collected each day. At the end of each collection period, these daily food and refusals subsamples were pooled separately for each animal, ground (1-mm screen) for chemical analysis, and stored at 4ºC.

Urine was collected into a container with 50 ml of 50% sulphuric acid. Total urine voided was measured daily from each animal during the collection period. Urine samples were taken, and at the end of the data collection, they were pooled within animals over the collection period, and stored at –20ºC prior to nitrogen (N) analysis. Faeces from each animal were weighed daily. Faeces subsamples were taken and stored at 4ºC. At the end of each collection period, the daily subsamples were pooled and a representative sample was taken for each animal and stored at –20ºC. Total water loss was determined by summing the amounts of total urine water excreted and water contained in faeces.

Deer live weights were measured at the start and the end of each experimental period. The maximum and minimum ambient (shade) temperatures and humidity were recorded continuously at a weather station 10 km distant, and in the same locality as the Deer Research Unit.

Laboratory methods

At the end of the trial, faecal samples were thawed, mixed thoroughly, dried in a forced-draught oven at 60ºC for 48 h, then ground through a 1-mm screen and stored for chemical analysis. Faeces samples of approximately 120 g were taken daily from each animal to determine the faecal water by drying in a forced draught oven at 103ºC for 24 h.

Food, refusals and faeces were analysed for dry matter (DM) at 103ºC for 24 h, for organic matter (OM) by igniting at 500ºC for 8 h (Association of Official Analytical Chemists, 1996), and neutral-detergent fibre (NDF) by the method of Goering and Van Soest (1970) using a Fibretec System M1021 Hot Extractor (Tecator AB, Hoganas, Sweden). N in food, refusals, faeces and urine was determined by the semi-micro Kjeldahl technique using a Cu catalyst. Urine DM content was determined by drying in a forced-draught oven at 50ºC for 24 h. Drinking water, food, refusals, faeces and urine samples were analysed for Ca, Mg, Na, and K using inductively coupled plasma optical emission spectroscopy.

Statistical analysis

Treatment effects were compared by analysis of variance using the general linear model procedure (Statistical Analysis Systems Institute, 1989) and using least significant differences. The SAS model statement used was: response variable = deer period treatment/ss1. Significance was declared at $P < 0{\cdot}05$. Each comparison was done with the appropriate s.e.d. The s.e.d. shown in the tables are pooled values calculated using no. = 4. Regressions of dependent variables on water total dissolved salts content (TDS), and TDS^2 to test for curvilinearity, were fitted using the stepwise method of the SAS regression procedure.

Results

Ambient temperature and relative humidity

The mean maximum and minimum temperatures during this study were 29·8 and 17·3ºC in period 1, 35·9 and 21·2ºC in period 2, and 34·0 and 19·5ºC in period 3, and the mean relative humidities were 0·65, 0·56, and 0·58 for periods 1, 2, and 3 respectively.

Animal health and live-weight change

The stags did not show any signs of diarrhoea, anorexia, vomiting, urinary calculi, general weakness, or loss of body weight when given saline water. However, the four deer given water with 8500 mg TDS per kg showed signs of stress including the prolonged opening of the orbital gland, increased faecal moisture content and faecal texture changes, head shaking, and high between-day variability in water intake. These signs were observed in different deer at different times (Table 2).

The mean live weight increased during the experiment by 3·3 (s.d. 2·66) kg.

Table 2 *General responses showed by each rusa deer (A, B, C and D) given water containing 8500 mg/kg of total dissolved salts.*

Deer	Responses
A	High variability in water intake (3·5 kg on day 1, 7·3 kg on day 3, 1·4 kg on day 4 of the collection period).
B	Variability in water intake (10·3 kg on day 1, 14·7 kg on day 3, 11·5 kg on day 7 of the collection period), orbital gland open, soft faeces with higher moisture content and head shaking.
C	High variability in water intake (13·2 kg on day 1, 24·5 kg on day 3, 9·1 kg on day 6 of the collection period), orbital gland open, soft faeces, head shaking, and rapid breathing.
D	Orbital gland open.

Water intake and loss

Drinking water (DW) and total water (TW; DW plus food water) intakes were significantly different between deer given different levels of water salinity (Table 3). Deer given 8500 mg TDS per kg drank significantly more water than when they received the low-salinity water (570 to 3500 mg TDS per kg). The DW intake: DM intake ratios were significantly affected by TDS content. Deer given 8500 mg TDS per kg had higher ratios than those offered water containing 570, 1000, or 3500 mg TDS per kg (Table 3). Both these relationships were linear throughout the range of TDS contents tested: DW intake (kg/day) = 6·46±0·807 + 0·00047±0·000165 TDS (mg/kg) (value±s.e.; P=0·0101); DW intake:DM intake (kg/kg) = 3·62±0·290 + 0·00022±0·000059 TDS (mg/kg) (P=0·0015).

The amount of water excreted in the urine of those deer receiving water containing 8500 mg TDS per kg was similar to those given water containing 6000 mg TDS per kg but was significantly higher than for those given the other salinity levels. The linear relationship between urine water excretion and TDS content was: urine water excretion (kg/day) = 3·52±0·497 + 0·00037±0·000102 TDS (mg/kg) (P=0·0018). The total water loss increased with increasing water salinity, with significant ($P < 0·05$) differences between the deer drinking water with 8500 mg TDS per kg and those given water with 1000 mg or less TDS per kg. The linear relationship was: total water loss (kg/day) = 4·47±0·613 + 0·00041±0·000126 TDS (mg/kg) (P=0·0039). Between 0·53 (control) and 0·66 (8500 mg TDS per kg) of the DW intake was excreted in urine; with significant increases in this proportion with increasing water salinity: urine water excretion (g/g DW intake) = 0·55±0·021 + 0·000011±0·0000044 TDS (mg/kg) (P=0·0204). There were no significant differences in faecal water excretion between deer given the five different levels of water salinity (Table 3). Trends in DW intake and total water loss were similar, giving similar daily water balances (2·85 (s.d. 1·57) kg/day).

Food DM intake and digestibility, and N balances

There were no significant effects of water salinity on DM intake (Table 3), apparent digestibilities of DM, NDF or N, or N retention (Table 4). The deer were all in negative N balance; excretion in urine accounted for approximately 0·8 of total N losses.

Na, K, Mg and Ca balance

The Na intakes were significantly higher (Table 5) when the deer were given high-salinity water (6000 and 8500 mg TDS per kg), compared with those receiving low-salinity water

Table 3 *Dry matter intakes and water balances of rusa deer stags receiving different levels of water salinity (least-squares means)*

	Treatments (water salinity, mg total dissolved salts per kg)					
	570	1000	3500	6000	8500	s.e.d.
Adjustment period						
Dry matter (DM) intake (kg/day)	1·7	1·9	1·8	1·8	1·8	0·102
Drinking water intake (kg/day)	5·9^{a}	7·1^{b}	7·1^{b}	8·0^{c}	8·8^{c}	0·357
Collection period						
DM intake (kg/day)	2·03	1·98	1·97	1·96	1·84	0·118
DM intake (g/kg $M^{0·75}$ per day)	60·3	59·0	59·0	59·0	54·7	3·76
Drinking water (DW) intake (kg/day)	7·4^{a}	7·7^{a}	7·9^{a}	8·8^{ab}	9·8^{b}	0·83
DW intake (g/ kg $M^{0·75}$ per day)	222^{a}	228^{a}	236^{ab}	265^{ab}	292^{b}	24·6
Food water intake (kg/day)	0·28	0·28	0·27	0·28	0·25	0·061
Total water intake (kg/day)	7·7^{a}	8·0^{a}	8·1^{a}	9·1^{ab}	10·0^{b}	0·84
DW : DM (kg/kg)	3·9^{a}	4·1^{a}	4·4^{a}	4·7^{ab}	5·3^{b}	0·36
Urine water excretion (kg/day)	4·0^{a}	4·3^{ab}	4·7^{ab}	5·6^{bc}	6·3^{c}	0·58
Urine water excretion (g/g DW intake)	0·53^{a}	0·56^{ab}	0·59^{ab}	0·63^{bc}	0·66^{c}	0·028
Faecal water excretion (kg/day)	1·3	1·1	1·3	1·2	1·2	0·13
Total water loss (kg/day)	5·4^{ab}	5·3^{a}	5·5^{ab}	6·9^{ab}	7·5^{b}	0·84
Apparent water balance (kg/day)	2·6	2·9	3·3	2·5	2·9	0·97

$^{a, b, c}$ Means, in the same row, followed by the same superscript letter are not significantly different ($P < 0·05$).

Table 4 *Dry matter, organic matter, neutral-detergent fibre and nitrogen (N) digestibilities, and N balances, of rusa deer stags receiving different levels of water salinity (least-squares means)*

	Treatments (water salinity, mg total dissolved salts per kg)					
	570	1000	3500	6000	8500	s.e.d.
Digestibilities						
Dry matter	0·66	0·68	0·67	0·68	0·68	0·010
Organic matter	0·66	0·68	0·67	0·68	0·69	0·011
Neutral-detergent fibre	0·49	0·53	0·51	0·53	0·53	0·021
Nitrogen	0·79	0·80	0·80	0·80	0·79	0·007
N balance (g/day)						
Intake	72·3	69·7	71·0	70·0	65·7	4·13
Urinary losses	60·1[a]	71·0[b]	66·4[a,b]	62·9[a,b]	60·7[a]	3·29
Faecal losses	15·0	13·7	14·5	13·8	14·1	0·89
Retention	-3·7	-13·5	-4·4	-8·0	-7·9	6·56

[a, b] Means, in the same row, followed by the same superscript letter are not significantly different ($P < 0·05$).

(570, 1000 and 3500 mg TDS per kg). Deer receiving the highest levels of salinity excreted more Na in their urine than those receiving the lower levels (6000 and 8500 mg TDS per kg *v.* 570, 1000 and 3500 mg TDS per kg, respectively). There was no significant difference in Na loss between deer offered 6000 and 8500 mg TDS per kg. Almost all (0·95) of the ingested Na was excreted via urine. The amount of Na excreted in the faeces was not increased by the addition of salt in the drinking water.

Deer receiving the highest water salinity consumed significantly more Mg and Ca from drinking water than those offered control water (Table 5). The Mg and Ca intakes were mostly from food, and most of these minerals were excreted in the faeces. There were significant differences between treatments in the K and Mg balances.

Discussion

Water balance

In our experiment, water consumption increased with increasing salt content, and the deer offered 8500 mg TDS per kg drank significantly more water than those that received the control water (570 mg TDS per kg). This is interpreted as an attempt to maintain the Na contents of their body fluid compartments within physiological limits by increasing their water intake.

Similar results were reported by Ru *et al.* (2004) with fallow and red deer. These authors reported significantly increased water intakes for fallow deer up to salinities of 15800 mg salt per kg, and higher water intakes by red deer at all the salinity levels tested (i.e. up to 13000 mg salt per kg). There was a trend for decreasing water consumption (compared with deer given control water) when they gave fallow deer water

Table 5 *Mineral balances of rusa deer stags receiving different levels of water salinity (least-squares means)*

	Treatments (water salinity, mg total dissolved salts per kg)					
	570	1000	3500	6000	8500	s.e.d.
Sodium (g/day)						
Intake from food	9·7	9·6	9·4	9·4	8·8	1·55
Intake from water	2·7[a]	2·6[a]	9·8[a]	18·9[b]	30·0[c]	9·15
Urinary excretion	11·9[a]	10·8[a]	17·2[a]	26·8[b]	33·9[b]	7·59
Faecal excretion	0·5	0·6	0·8	0·8	0·8	0·50
Balance	0·1	1·0	1·8	1·8	4·6	4·61
Potassium (g/day)						
Intake from food	24·2	23·8	23·5	23·7	22·2	3·45
Intake from water	0·007[a]	0·007[ab]	0·008[ab]	0·008[ab]	0·009[b]	0·0018
Urinary excretion	23·8	22·5	25·7	26·5	24·3	5·03
Faecal excretion	1·6	1·5	1·6	1·5	1·5	0·60
Balance	–0·9[ab]	0·01[a]	–1·4[a,b]	–4·0[b]	–3·2[ab]	3·24
Magnesium (g/day)						
Intake from food	10·9	10·6	10·5	10·5	9·8	1·78
Intake from water	0·17[a]	0·18[ab]	0·19[ab]	0·21[ab]	0·22[b]	0·045
Urinary excretion	2·3	2·1	2·5	2·5	2·6	0·66
Faecal excretion	8·5	7·6	7·9	7·7	7·6	0·90
Balance	0·4[ab]	1·1[b]	0·5[ab]	0·7[ab]	0·02[a]	0·85
Calcium (g/day)						
Intake from food	22·9	22·2	22·0	22·2	20·4	3·94
Intake from water	0·21[a]	0·23[ab]	0·24[ab]	0·26[ab]	0·28[b]	0·056
Urinary excretion	2·2	2·4	2·4	2·7	2·4	0·52
Faecal excretion	21·4	20·2	20·3	19·9	18·2	3·01
Balance	-0·1	0·1	0·2	0·01	0·5	1·27

[a, b, c] Means, in the same row, followed by the same superscript letter are not significantly different ($P < 0·05$).

with more than 15800 mg salt per kg. These results, and our own, are consistent with the previous work of Pierce (1957, 1959 and 1968a), Wilson and Dudzinski (1973), Gihad *et al.* (1993), El Sherif and El Hassanein (1996) with sheep, and El Gawad (1997) with goats, and with the general conclusions made in National Research Council (1974). However, there are several reports with cattle in which water intakes were not increased by water salinity levels of up to 11000 mg TDS per kg (Saul and Flinn, 1985; Ray, 1989; Kattnig *et al.*, 1992; Bahman *et al.*, 1993), although non-significant increasing trends were reported by some of these authors.

Water excretion by our rusa deer increased as the drinking water salt content increased and the urine excretion:water intake ratio also increased significantly. Similar responses were reported by Ghosh *et al.* (1997) in goats. Increasing Na intakes from drinking water lead to osmotic diuresis, with increased Na excretion in urine and greater urinary volumes (Laredo *et al.*, 1996; Ganong, 1997; Stricker *et al.*, 2001). Ganong (1997) notes that animals have a maximal urinary Na concentration, and Stricker *et al.* (2001) reported that rats challenged with drinking water containing 29250 mg salt per kg could not increase their urinary Na concentration sufficiently to restore plasma tonicity. We suggest that our deer were similarly unable to concentrate their urine sufficiently to excrete the Na load imposed by the highest salinity level, leading to an increasing excretion of water in urine, and to an increasingly positive Na balance, as water salinities increased.

There was no difference in water excretion through faeces when rusa deer were given water of different salinities, although the faeces were sometimes soft when they were given high-saline water. Wilson and Dudzinski (1973) also found that the faecal water content of Merino sheep was not affected by water salinity. Pierce (1957), however, reported a condition resembling diarrhoea in sheep given saline water above the upper limit of tolerance.

Apparent retention of water by our deer was 2·84 kg/day, i.e. 1·96 kg difference between intake and total water excretion, after allowing for 0·88 kg/day of metabolic water (Taylor, 1970). As our deer grew very little during the experiment (average total body weight gain was 3·3 kg over the 63 days), and if it is assumed that there was no change in tissue hydration, then this apparent water retention is an estimate of the daily insensible water loss (i.e. sweat and respiratory losses). This is only 0·13 kg/day more than is estimated from Chew (1965, cited by Silanikove (2002)) for insensible water loss in a thermoneutral environment.

Food intake and the water:dry matter intake ratio

When we gave high-saline water, the deer drank more water while maintaining their DM intake, thus increasing the water: DM intake ratio. Food intake responses of ruminants given saline water vary with salinity level, animal species and physiological status, and environmental conditions. Our result is similar to that of Solomon *et al.* (1995) who observed no effect of water salinity on the food intake of Holstein cows, but contrasts with some other studies with ruminants. Red and fallow weaners initially ate more food when the salinity of their drinking water increased (Ru *et al.,* 2004), then food intake decreased by proportionately 0·10 to 0·15 and 0·30, respectively, when salinities increased to 24200 mg NaCl per kg (fallow), and 12200 mg NaCl per kg (red). Kattnig *et al.* (1992) reported that food intake of Holstein steers tended to be higher when they were given 2300 mg TDS per kg saline water compared with 350 mg TDS per kg, and similar results were reported in sheep by Wilson and Dudzinski (1973) and Pierce (1957, 1959 and 1960). However, the food intakes of non-lactating and non-pregnant sheep were slightly reduced when these animals were given high-salinity water (13000 and 15000 mg TDS per kg), and there was a greater reduction in food intake when sheep were given 20000 mg TDS per kg (Pierce, 1957).

N retention and food digestibility

High-salinity water did not affect N retention or the apparent digestibilities of DM, N, and NDF in this study. There were two significant differences between treatments in urinary N excretion, but no consistent trend with water salinity. We cannot explain the inconsistency between these apparent negative N retentions and the small positive live-weight changes in the stags during the experiment. Hadjipanayiotou (1984) observed that DM intake and digestibilities of DM, organic matter and protein did not change in Chios sheep given saline water, while Ghosh *et al.* (1997) reported that Black Bengal kids had increased protein digestibility as the sodium chloride concentration increased to 20 000 mg/kg. Kattnig *et al.* (1992) found that high-saline water containing a combination of Ca^{2+}, Mg^{2+}, Na^{+} and SO_4^{2-} ions at 2300 mg TDS per kg had no affect on *in situ* digestibility compared with normal water when Holstein steers were given low-quality mixed hay. Further, Sager and Casagrande (1998) suggested that the effect of saline water on DM digestion was positive for low-quality forages only.

Mineral balances

It was expected that total Na intake and loss would be increased by increasing the salt concentration in the drinking water. The deer excreted most Na through urine (similar to Hadjipanayiotou (1984)), although a small amount was excreted via faeces. When there are excess Na intakes, animals attempt to regulate the concentration of Na in extracellular fluid by excreting excesses through urine. For example, Meintjes and Englebrecht (1993) noted that excretion of excess Na via the kidney, mediated by an increased glomerular filtration rate, was the principal route of Na excretion in sheep given saline water.

The K, Mg and Ca supplies were mainly from the food, with only small amounts from the drinking water. Most Mg and Ca was excreted in the faeces. Mg and Ca balances were mainly positive, and varied little (Mg) or not at all (Ca) between the salinity level treatments. We conclude that the Mg and Ca balances of rusa deer are not affected by the concentrations of NaCl in drinking water.

K, like Na, was mostly excreted in the urine. Lower K balances tended to be associated with higher water salinities. Published data on the effect of saline water on K balance is ambiguous. Pierce (1957 and 1959) reported slightly reduced plasma Na:K ratios at different times during his experiments, while K excretion in urine was first reduced

then returned to initial levels when rats were given water with 1500 mg NaCl per kg (LangleyEvans and Jackson, 1996). Further, Meintjes and Englebrecht (1993) reported a decrease in the fractional excretion of K when high-salinity water was given. Increased K excretion would suggest a reduction in the intracellular fluid compartment, but Assad and El-Sherif (2002) reported reductions in the extracellular, but not intracellular, fluid compartments when saline water was given to sheep. As there were no significant differences in either urinary or faecal K excretion, the apparent trend in our K balance data is misleading and probably the result of large between-animal variations.

Tolerance of saline water

During our experiment, we found that individual deer showed different responses when they received the highest level of water salinity (8500 mg TDS per kg). Merino sheep showed declines in body weight, occasional diarrhoea, and general weakness when given high-salinity water up to the upper limit of tolerance (Pierce, 1957 and 1959). We did not see these symptoms in our deer, but we observed other signs of water salinity-induced stress such as erratic water intake, soft faeces, orbital gland opening, and head shaking as deer neared their salinity tolerances. Head shaking may have indicated discomfort caused by changes in brain histology. Bobak and Salm (1996) and Ayoub and Salm (2003) reported changes in the hypothalamic supraoptic nucleus and the ventral glial limitans in rats given 20 000 mg/kg saline drinking water. Polioencephalomalacia-like symptoms were observed in cattle given water containing 3875 mg TDS per kg by Beke and Hironaka (1991).

It appears that rusa deer can tolerate drinking water containing up to 6000 mg TDS per kg for at least 9 days, but that higher levels may not be tolerated, at least under the environmental conditions which prevailed during this experiment. These tolerances are much lower than those reported by Ru *et al.* (2004) for fallow and red deer, which may tolerate (for periods of 14 days in cool environmental conditions) salt contents of 15800 mg salt per kg (fallow) and 9200 mg salt per kg (red) in the drinking water. The data of Ru *et al.* (2004) and our own suggest a distinct difference between the *Cervus* and *Dama* genuses in salinity tolerance.

Pierce (1959) showed that Merino sheep were able to adapt well to high-salinity water when the salt concentration was gradually increased, but that their food consumption markedly declined if they were abruptly changed from low-salinity to higher-salinity water. This mechanism may explain the higher salinity tolerances observed by Ru *et al.* (2004) because these authors gave their deer saline water which were increased in salt content each 14 days, beginning with the lowest level (3500 mg salt per kg), whereas we used a randomized block design which did not allow for a gradual adaptation.

Mature animals resist salt toxicity better than young (National Research Council, 1974). Pierce (1968b) and Wilson and Dudzinski (1973) suggested that young sheep or those with no experience of saline water appeared to be less tolerant of high-saline water than mature sheep. Additionally, physiological states such as pregnancy and lactation which increase water demand also increase the risk of harm from saline water. The mature rusa deer stags used in this study are thus likely to be more resistant to salt toxicity than young, pregnant or lactating deer.

High daytime ambient temperatures were experienced during this experiment, especially in periods 2 and 3. Domestic animals need more drinking water to maintain normal body temperature during periods of high ambient temperature, e.g. Winchester and Morris (1956) reported that water intakes of *Bos taurus* and *Bos indicus* cattle increased as ambient temperature increased from 4 to 32ºC; and Merino sheep drink more water during summer than winter (Pierce, 1957 and 1959). We suggest that the symptoms of stress may have occurred at lower levels of water salinity than would have been the case if ambient temperatures had been lower.

Conclusions

This study shows that, while the responses of individual animals vary, some rusa stags can tolerate drinking water containing 8500 mg TDS per kg on a short-term basis without harmful effect, and that deer which show adverse responses at this salinity level recover quickly if their drinking water is changed to normal water after only 2 or 3 days exposure to the high-salinity water. Rusa deer tolerate water with 6000 mg TDS per kg for at least 9 days in daytime ambient temperatures of up to 36ºC. Further study is required to determine if rusa deer can tolerate these salinity levels for longer periods, if 6000 mg TDS per kg is actually the upper limit of salinity tolerance, and to investigate their responses to other ionic substances dissolved in their drinking water.

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