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Water and feed intake responses of sheep to drinking water temperature in hot conditions

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Abstract. When live-export sheep from Australia arrive in the Middle East during the northern summer months, they may be offered drinking water at temperatures exceeding 40°C. There is little published research to indicate whether drinking water temperature is important in managing heat stress in sheep or its effect on their health and welfare. Three studies were conducted with Merino wethers in climate-controlled rooms to investigate: (i) responses to drinking water temperatures of 20°C, 30°C and 40°C in a cool (20°C) and hot (40°C) environment, (ii) preferences for drinking water temperature at 20°C or 30°C when in a hot or cool environment and (iii) effects of water restriction when offered hot water (40°C) in a hot environment. Sheep assigned to the hot room had significantly higher respiration rates than those assigned to the cool room. In the cool environment, water intakes were the same when water temperatures were 20°C, 30°C or 40°C; however, when the sheep were given a choice between drinking water at 20°C and 30°C, they preferred ($P < 0.05$) to drink water at 20°C. In the hot environment, water intake increased as drinking water temperature increased, and sheep preferred to drink water at 30°C rather than 20°C. When the availability of 40°C drinking water was restricted (to ~10% of liveweight) in the hot environment, sheep had higher respiration rates than those offered unlimited water.

Introduction

Australia exports sheep (4.3 million for 2005–06) to the Middle East region (MLA 2007), contributing to an industry worth $1.8 billion annually (Hassall and Associates Australia 2006). The religious festivals creating the greatest demand for mutton, *Ramadān* and *Eid-ul-Fitr*, coincide with the summer months in the Middle East and the winter months in Australia. As a consequence, most of the sheep are exported from Australia in the coolest months and arrive in the Middle East during the hottest months. The average change in ambient temperatures (~18°C to 42°C during the 12-day journey) may result in sheep displaying signs of heat stress. Upon arrival in the Middle East, almost all sheep are inducted into feedlots where they are held for 1 day to 60 days (average 15 days). During the summer months, drinking water temperatures may exceed 40°C. The importance of drinking water temperature for heat stress management in sheep is not well understood. There is little scientific information about the importance of drinking water temperature and water restriction in sheep for the management of heat stress and welfare.

When sheep suffer heat stress, their increased water intake has been attributed to an increased requirement for evaporative heat dissipation (Appleman and Delouche 1958; Baker 1989; Dahlanuddin and Thwaites 1993). However, the temperature of the drinking water offered to animals in high ambient temperatures has rarely been documented (an exception is the study by McGregor 1986), despite evidence that water temperature influences thermoregulation and digestive function in animals in hot environments (Silanikove 1992).

There are no research-based recommendations for drinking water temperature in hot climates for sheep. Therefore, three studies were undertaken with Merino sheep to investigate: (A) responses to drinking water temperatures of 20°C, 30°C and 40°C in a cool (20°C) and hot (40°C) environment, (B) preferences for drinking water temperature in a hot and cool environment and (C) responses to water restriction when offered hot water in hot surroundings.

Materials and methods

Three studies were conducted in climate-controlled rooms at the University of New England, Armidale, Australia. The first two studies were run concurrently, sharing the same climate-controlled rooms. Merino wethers were randomly allocated to individual metabolism crates and offered lucerne chaff (*Medicago sativa*) *ad libitum.* Room temperature and humidity (maintained at ~60%) were controlled using an Enterprise Building Integrator (Honeywell). The rooms had wall-mounted, grated vents to remove the effect of wind. Respiration rates were determined using pressure transducer girths connected to ADInstruments data logging equipment. Data were recorded using Chart 5 (version 5.4.2) software. Rectal temperatures were not reported due to equipment malfunction. Feed and water intake (adjusted for evaporation) were measured over 6-h periods and faecal and urine production were measured daily for each animal. In the first two studies, feed intake and faecal output were determined after analysis of their dry matter (DM) content using standard laboratory procedures (Horwitz 2002); DM analyses failed in the third experiment due

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to an oven malfunction that incinerated the samples. Lighting in the climate rooms was set to simulate day and night conditions; lights came on at 0600 hours and went off at 1800 hours. Sheep were weighed at the commencement and conclusion of each experiment, and at the end of periods when sheep were rotated within each experiment. The experimental protocols were approved by the University of New England Animal Ethics Committee.

For the first study (Study A), six Merino wethers (3-years-old, 47 ± 3.0 kg) were randomly allocated to one of three drinking water temperature treatments (20°C, 30°C and 40°C) in each of two rooms (cool room, 20°C continuously; hot room, 40°C between 0900 hours and 1800 hours and 30°C between 1800 hours and 0900 hours). Sheep were moved within each climate room at the end of each period according to a 3×3 Latin Square design, i.e. 3 sheep $\times$ 3 treatments. There was a 4-day adaptation period followed by three 8-day measurement periods, the latter consisting of one day for adaptation to drinking water temperature followed by 7 days of measurement.

In the second study (Study B), eight Merino wethers (3-years-old, 47 ± 3.5 kg) were randomly allocated to four cages in each of the two climate-controlled rooms (four sheep per room). The rooms had the same temperature regimes as in the first study and each sheep was given a choice of drinking water at 20°C and 30°C. There was a 5-day adaptation period followed by an 8-day measurement period.

In the third study (Study C), four Merino wethers (3-year-old, 49 ± 2.1 kg) were randomly allocated to one of two drinking water treatment groups in the hot room used in the previous two studies (40°C daytime and 30°C night-time). The sheep were offered water at 40°C, either *ad libitum* (two sheep) or restricted (two sheep) to 6 L/day (equating to ~10% liveweight after adjustment for evaporation and spillage). After a 10-day adaptation, measurements were made in two 7-day periods, with 2 days being allowed between periods, whereby sheep were crossed-over at the end of period 1.

Data were analysed for each individual time and summed across times, for the main effects of ambient temperature, drinking water temperature and their interaction. Analysis of variance was undertaken using GENSTAT (2007) and a protected least-significant difference (l.s.d.) test was used to compare the treatments.

Results

Daily water intake of sheep was higher ($P < 0.05$) in the hot room (8275 g) than in the cool room (5826 g). In the cool room, drinking water temperature did not affect water intake. Within the hot room, sheep drank more water at 40°C (9913 g/day) than 20°C (6591 g/day), with water intake at 30°C (8491 g/day) being intermediate (Table 1).

Mean daily DM intake of sheep was higher ($P < 0.05$) in the cool room (1578 g) than in the hot room (1136 g) and DM intake (% liveweight) was also higher ($P < 0.05$) for sheep in the cool room (3.0%) than in the hot room (2.4%). Liveweight change of sheep did not differ ($P > 0.05$) between the hot room and the cool room (Table 1). Daily DM intake, faecal production, DM digestibility and organic matter digestibility were not affected by water temperature ($P > 0.05$). In the hot room, sheep consumed more ($P < 0.05$) feed at night-time (between 1800 and 0900 hours) when offered water at 40°C in comparison to 20°C and 30°C (Table 2).

In the first two studies, daily faecal production (DM basis) of sheep was higher ($P < 0.05$) in the cool room (598 g) than in the hot room (443 g) and in agreement with DM intakes. Daily urine production of sheep was higher ($P < 0.05$) in the hot room (4588 g) than in the cool room (2248 g). Mean respiration rate of sheep in the hot room (40.7°C, 206 breaths/min) was higher ($P < 0.05$) than those in the cool room (20°C, 149 breaths/min).

In the hot room, when sheep had a choice between 30°C and 20°C water, they drank more ($P < 0.05$) 30°C water (6708 g/day) than 20°C water (1185 g/day). In contrast, in the cool room, sheep drank more ($P < 0.05$) 20°C water (4024 g/day) than 30°C water (2646 g/day) (Fig. 1). There was tendency for sheep to drink more of the 30°C water between 1800 and 1200 hours, and less ($P < 0.05$) water during the hottest part of the day (Fig. 2).

In the third study, sheep with *ad libitum* access to 40°C water drank more ($P < 0.05$) water (10 790 g/day) and had lower ($P < 0.05$) respiration rates (184 breaths/min) than those with limited access to water (5815 g/day and 229 breaths/min).

Discussion

In the first two studies, the higher water intake and lower feed intake are typical responses of sheep in hot compared with cooler surroundings. However, the responses in water intake to water temperature found in these studies have not been previously reported in sheep. The lack of response in water intake of sheep to water temperature in a cool environment and a tendency for water intake to increase as water temperature increases in a hot environment are counterintuitive outcomes. The finding from the third study, that higher intakes of hot water in conditions led to

Table 1. Study A. Mean liveweight (LW) change, daily dry matter intake (DMI) and water intake of sheep housed in a cool room (20°C) or a hot room (40°C daytime; 30°C nightime) and offered drinking water at 20°C, 30°C and 40°C

Within rows, means followed by the same letter are not significantly different at $P = 0.05$

	Cool room			Hot room			s.e.d.	Room	Water	Room × water
	20°C	30°C	40°C	20°C	30°C	40°C				
Liveweight change (kg)	−0.9	−1.7	−1.2	0.2	−0.4	−1.2	0.9	0.38	0.69	0.92
DMI (g/day)	1515ab	1620a	1475ab	1096c	1211bc	1073c	156	<0.05	0.68	0.97
DMI (% LW)	2.89ab	3.13a	2.83ab	2.41bc	2.59bc	2.26c	0.25	<0.05	0.54	0.96
Water intake (mL/day)	5237a	5822a	5575a	6591b	8491bc	9913c	1121	<0.05	0.41	0.52

Table 2. Study A. Percentage of daily feed intake consumed between 0900 and 1800 hours by sheep housed in a hot room (ambient temperature 30 to 40°C) or cool room (ambient temperature 20°C) offered drinking water at 20°C, 30°C or 40°C

Within columns, means followed by the same letter are not significantly different at $P = 0.05$

Water temperature	Cool room	Hot room
20°C	42 ± 1.0	44 ± 1.7a
30°C	43 ± 1.0	41 ± 1.4a
40°C	41 ± 1.0	35 ± 1.0b

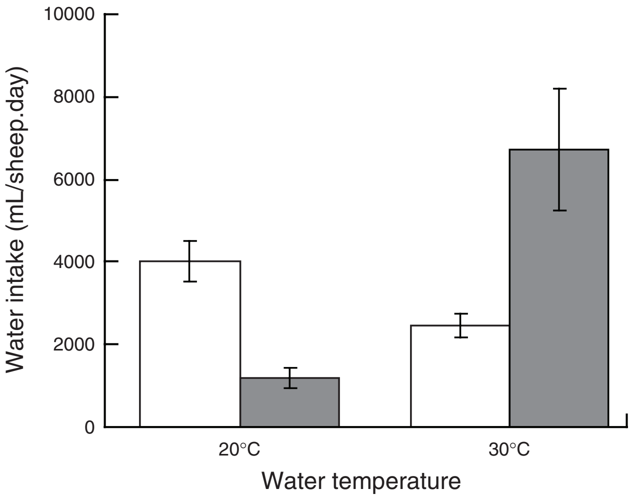

Fig. 1. Study B. Mean daily water intake of sheep housed in a hot room (ambient temperature 30 to 40°C; shaded bars) or cool room (ambient temperature 20°C; white bars) and offered a choice of drinking water at 20°C or 30°C.

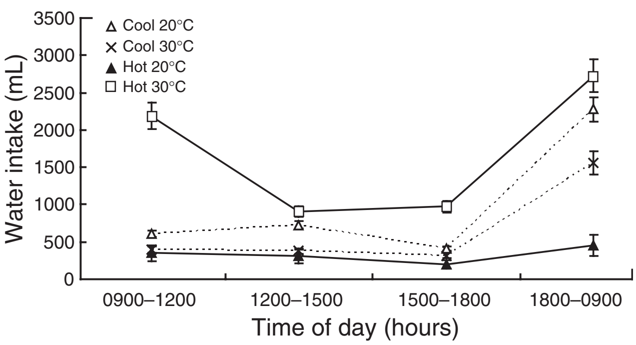

Fig. 2. Study B. Diurnal patterns of water intake of sheep housed in a hot room (ambient temperature up to 40°C) or cool room (ambient temperature 20°C) and offered a choice of drinking water at 20°C or 30°C.

lower respiration rates, suggests that the increase in water consumption with increasing water temperature, observed in all three studies, may be a thermoregulatory response. Increased water consumption in sheep has been identified in other studies as a response to heat stress (Johnson 1987); however, the relationship with water temperature in sheep has not been previously established. Increased water intake in humans exercising, suppresses rise in body temperature, independent of water temperature. However, water temperature influences the mechanism of suppression. The direct cooling effect is dominant during consumption of cool water (1°C and 16°C) whereas evaporative heat loss was dominant during consumption of warm water (37°C) (Niwa 1997).

Changes found in this study in diurnal feeding and drinking patterns in response to changes in drinking water temperature have not been previously reported for sheep, although similar responses to changes in ambient temperature have been reported for beef cattle. Cattle in hot climates reduce the proportion of feed and water ingested during the hotter parts of the day to reduce heat load (Davis *et al.* 2003). It therefore seems reasonable to assume that the similar patterns observed in the current studies are part of a behavioural response by the sheep that reduces their heat load. The tendency for an increasing proportion of daily water and feed consumption to occur during the cooler hours as water temperature increases is more difficult to explain, as limited research in this area of work has been undertaken with sheep. It may be that hotter water in a hotter climate encourages sheep to consume a higher proportion of their daily feed during the cooler hours, reducing metabolic heat production during the hottest hours of the day, contributing to the lower respirations rates found.

The findings from the three studies may have important implications for the sheep industry. The indications are that sheep prefer to drink water closer to ambient temperature, probably as a means of thermoregulation. Several the responses found in these studies have not been previously reported and warrant further research, with larger numbers of animals. These findings suggest that research aimed at developing recommendations for management strategies for sheep in hot climates should include consideration of water temperature as a means of improving production and welfare outcomes.

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