Nutrition during live export of cattle

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Summary

This paper reports work aimed at improving performance and welfare of cattle during live export for long periods aboard ship. Roughage quality was manipulated in pellet diets to promote better nutritional performance and reduced nitrogen excretion. The type of pellet binder was manipulated to decrease urinary pH and consequent ammonia volatilisation. Rooms were established to simulate heat and humidity loads during live export, and feed and water intake and liveweight of *Bos taurus* and *Bos indicus* cattle were monitored in these conditions. Good quality roughage decreased estimated total nitrogen excretion and still maintained cost–effective liveweight gain. Lime produced alkaline urinary pH. Use of gypsum instead of lime, or addition of acid salts such as ammonium chloride or calcium chloride to lime, acidified urinary pH. These dietary manipulations of roughage quality and acid salts reduced atmospheric ammonia under simulated export environments but lucerne diets produced high atmospheric ammonia. Nutritional performance of cattle can be improved cost–effectively by diets containing good quality roughage instead of straw. Atmospheric ammonia can be reduced by addition of acidifying salts such as calcium chloride to export diets. Under high heat and humidity loads the feed intake of *B. taurus* decreased, the feed intake of *B. indicus* did not change, but the water intake of both species increased. *B. indicus* rapidly recovered any liveweight lost under high heat and humidity within six days of recovery but *B. taurus* cattle did not. *B. indicus* cattle cope significantly better with high heat and humidity loads than *B. taurus* cattle.

Key words: cattle, live export, ammonia, heat stress, nutritional performance

Introduction

Australia is the largest exporter of live cattle in the world. The industry has expanded significantly over the last decade and in recent years more than 800 000 head have been exported per year, about one–third to Middle East markets. Although mortality has dropped over the last few years (Norris *et al.* 2000), the sea voyage to these markets after transport to and assembly at the dock can take anywhere between 13 to 31 days with frequent lengthy periods of high temperature and humidity. The long duration of voyage and stressful environmental conditions warrant concern for animal health and performance. Inanition and salmonellosis are the major causes of death in sheep during live export, whereas pneumonia and heat stress are the main causes of death in cattle (Norris *et al*. 2000). It is important that the diets used during voyages promote good performance by cattle because they are priced on liveweight on delivery, whereas sheep are priced on a per head basis.

Cattle from various nutritional and genetic backgrounds are introduced to the export diets without an adaptation period. Therefore it is paramount that the export diet is safe (not rapidly fermentable) and is palatable. For loading and feeding purposes on board it is also important that these diets are compact and have a low dust content. As metabolic heat is one of the main contributors to the heat load on vessels (Stacey 2001) it is desirable that diets have a low thermogenicity. Each of these criteria must be achieved at the least possible cost in cattle undergoing high heat and humidity loads.

In achieving these criteria, the industry has been relying on diets that are high in rumen degradable nitrogen to achieve both palatability and nutritional performance. As a consequence, many of the diets have high urinary nitrogen output. Urinary urea is degraded by bacterial ureases present in the faeces to ammonia that is readily volatilised (James *et al.* 1999). Slurry pH and temperature also influence the volatilisation of ammonia (Cahn *et al.* 1998). High atmospheric ammonia (>25 ppm) has been recorded on some voyages (Stacey 2001) and while critical levels have not been defined, volatile ammonia is thought to be a contributing factor in the development of respiratory problems in not only cattle (Dewes *et al.* 1995) but humans also (Luttrell 2002).

This paper reports some dietary manipulations of roughage inclusion and quality, energy and protein sources, binders, and acid salts, all aimed at both sustaining or improving nutritional performance while reducing atmospheric ammonia. In addition this paper reports some of the physiological effects of high heat and humidity on liveweight, and feed and water intake in *Bos indicus* and *Bos taurus* cattle.

Dietary manipulations to improve performance and reduce atmospheric ammonia

Experiment 1: blood or urine assays to estimate total urinary N excretion

Screening diets for N excretion is not a practical task. An initial experiment using export–based pelleted diets containing three levels of dietary protein (9, 12.5 and 15%) was performed in rumen fistulated steers. From various estimations of nitrogen flow, it was determined that either blood urea or the urinary urea:creatinine ratio could be used to estimate total N excretion (eTUN) using a single, timed sample (Accioly *et al.* 2002a).

Experiment 2: influence of roughage quality on liveweight gain and N excretion

The aim of this experiment was to investigate the best combination of roughage source (straw or hay), barley, protein inclusion (18% or 30%) and protein source (lupins or canola meal) to provide an alternative low–N residue diet to the ones currently used in the trade, without adverse effect on intake and performance. Angus cross heifers about 18 months of age were randomly allocated to individual pens (5 m x 20 m) at Vasse Research Station and fed cereal hay for 5–7 d before being introduced to experimental diets.

Ninety–eight heifers were fed one of seven diets at 2.5% of liveweight: (1) 50% straw, 30% barley and 18% lupins; (2) 50% straw, 18% barley and 30% lupins; (3) 50% straw, 18% barley and 30% canola meal; (4) 50% hay, 30% barley, 18% lupins; (5) 50% hay. 18% barley, and 30% lupins; (6) 50% hay, 18% barley and 30% canola meal; and (7) 98% lucerne and 2% bentonite. All of the diets from 1–6 contained 2% lime as a binder. Daily feed intake and weekly liveweights were recorded. The animals used in this and each subsequent experiment had not previously been exposed to pelleted diets. Cost of the diets and cost of liveweight gain was also analysed (Accioly *et al.* 2002b).

Six animals were removed from the trial for not eating the experimental diet (with no bias toward any one diet). Voluntary feed intake was not significantly different among diets. Cattle fed diets combining hay and high protein inclusion from either lupins or canola meal showed significantly better performance measured as average daily liveweight gain ($P<0.05$) and lower nitrogen excretion ($P<0.001$) measured as eTUN (Table 1). Heifers fed diets combining hay and high protein inclusion showed a significantly better performance in terms of average daily gain ($P<0.05$). There was a highly significant ($P<0.001$) effect of diet on eTUN. Diet 5 was best overall in terms of cost–effective gain as assessed by $/kg of gain, allied to a significant reduction in estimated total urinary nitrogen excretion compared with its equivalent straw diet (Table 1).

Experiment 3: effect of pellet binders on urinary pH

This experiment tested the hypotheses that lime which (initially CaO) is often used as a binder in export pellets produced alkaline urine, and that urinary pH could be decreased by substituting gypsum for lime. Forty heifers were allocated on the basis of liveweight to one of the four experimental diets: basal, basal plus 2% lime, basal plus 2% lime and 1% gypsum, and basal plus 1% gypsum (Table 2). These were fed at a rate of 2.25% of liveweight on a dry matter basis for 19 d when final samples were collected. Urinary pH was measured at the last day of hay feeding period (day 0) and days 5, 14 and 19 of the pellet feeding period.

Table 1 Energy and protein concentrations in diets, estimated total urinary nitrogen excretion, costs of the diets and cost of liveweight gain in cattle fed the seven diets in Experiment 2. Values present are means of the number of animals (n) in the group.

Diet (n)	ME MJ/kg DM	Crude protein %	Gain kg/day	eTUN g/d	Costs $/tonne	Costs of LW gain ($/kg)
1 (13)	8.61	9.72	1.53	56.94	164	0.74
2 (14)	8.61	12.54	1.68	81.27	170	0.71
3 (14)	8.48	12.44	1.37	61.39	215	1.11
4 (13)	8.61	12.85	1.77	55.72	194	0.77
5 (13)	10.44	15.67	2.06	75.51	200	0.70
6 (12)	10.30	15.53	2.22	58.85	245	0.80
7 (13)	9.80	18.80	1.60	99.92	390	1.77

Lime produced an alkaline urinary pH that was significantly reduced by using gypsum as binder (Table 2). However, gypsum in combination with lime was not powerful enough to acidify urine (Table 2). Analysis of variance demonstrated that diet did not significantly (P>0.05) affect intake nor weight gain.

Experiment 4: effect of pellet binders and acid salts on urinary pH

This experiment evaluated the best combination of binders such as lime, and acid salts such as calcium chloride or ammonium chloride, to decrease urinary pH. Six different diets (Table 3) were fed at a rate of 2.25% of liveweight on a dry matter basis to seventy–nine heifers for 21 days when final samples were collected. Urinary pH was measured at the last day of hay feeding period (day 0) and days 7, 14 and 21 of the pellet feeding period.

Calcium chloride and ammonium chloride significantly reduced urine pH compared to gypsum and lime or even gypsum alone (Figure 1). Ammonium chloride and calcium chloride were equally effective in lowering urinary pH compared with diets containing 1% lime. This effect on lowering urinary pH was significant even in the presence of 1% lime. The quality of the hay used in these diets did not significantly affect the urinary pH over the 21 d period of the experiment.

Experiment 5: effect of diet on atmospheric ammonia production in simulated export conditions

Five heifers that averaged 263 kg live weight were housed at five animals per room and fed a lucerne diet (Table 4) under simulated export conditions of heat and humidity for 4–5 days. The other two diets consisted of straw/barley/lupins and either 1.5% lime or 1% lime plus 1% calcium chloride; four animals per room were used and their starting liveweights were 398 and 386 kg respectively (Table 4). Atmospheric ammonia, temperature, humidity and carbon dioxide were measured twice a day in five different locations in the room. The heifers were kept in the rooms for 94 h per experiment. The lucerne diet was repeated four times on the same heifers and the lime and lime plus calcium chloride based diet were repeated five times on the same heifers with two days outdoors before re–entry to the room for another 94 h.

The feed for the animals was a standard commercial shipper pellet similar to the lime/$CaCl_2$ diet described in Table 3. The pellets were all from the same production batch. The amount of feed offered to the animals was 2.25 % of the liveweight measured after 18 h off feed before the animals entered the rooms, and was divided into two equal amounts given at 0700 and 1300 h daily. Residues were cleaned out and weighed before each morning feed. Water was available *ad libitum* and the amount consumed was recorded each day.

Lucerne diets and diets using lime as a binder both resulted in atmospheric ammonia concentrations of 25 ppm or more in rooms maintained under simulated conditions of temperature and humidity for live export (Figure 2). In contrast, addition of acid salts such as calcium chloride significantly lowered atmospheric ammonia under the same conditions (Figure 2).

Table 2 Effect of pellet binders on urinary pH in heifers.

Diet	Urinary pH day 14
18% lupins/30% barley/52%oaten hay	7.99 ± 0.26[a]
18% lupins/30% barley/50%oaten hay/2% lime	8.40 ± 0.08[b]
18% lupins/30% barley/49%oaten hay/2% lime/1% gypsum	8.22 ± 0.11[a]
18% lupins/30% barley/51%oaten hay/1% gypsum	6.84 ± 0.28[c]

Means with different superscripts differ significantly (P<0.05). The results shown are means ± SEM for 10 animals per group

Table 3 Composition of diets for assessment of effects on urinary pH of lime as a pellet binder and either calcium chloride or ammonium chloride as acidifying salts.

Diet (n)	Hay (%)	Barley (%)	Lupins (%)	Lime (%)	Gypsum (%)	$CaCl_2$ (%)	NH_4Cl (%)
1 (13)	49.5	30	18	2	0.5	0	0
2 (15)	51.5	30	18	0	0.5	0	0
3 (12)	48.1	30	18	2	0.5	1.4	0
4 (14)	50.1	30	18	0	0.5	1.4	0
5 (12)	48.5	30	18	2	0.5	0	1
6 (13)	50.5	30	18	0	0.5	0	1

n = number of animals per diet

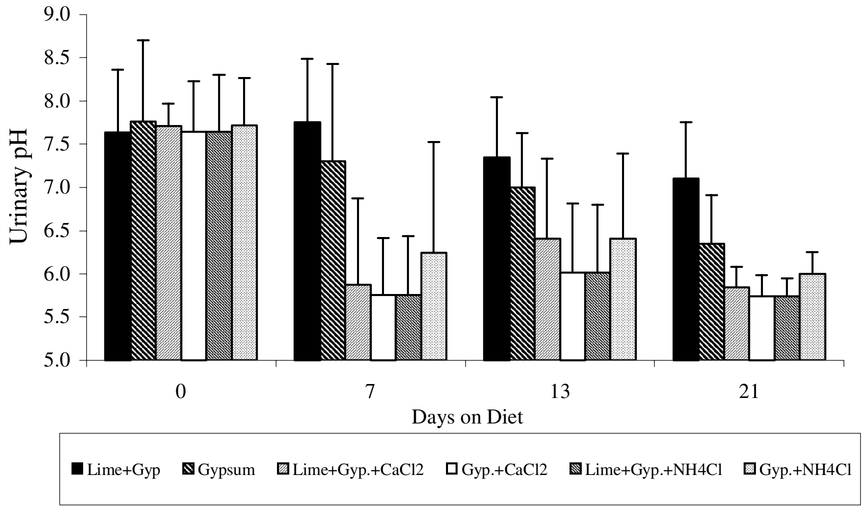

Figure 1 Effect of dietary treatments on urinary pH. The results shown are means ± SEM for animals per group indicated in Table 3.

Table 4 Percent composition of diets for assessment of atmospheric ammonia under simulated conditions of live export.

Diet	Straw	Barley	Lupins	Lime	$CaCl_2$	Lucerne	Bentonite
Lime	55.5	25	18	1.5			
Lime + $CaCl_2$	55	25	18	1	1		
Lucerne						98	2

Effects of heat stress on body temperature and feed and water intake of *Bos indicus and Bos taurus* cattle

Three experiments were made to determine the physiological response of cattle to prolonged heat and humidity, as can occur on live export vessels. The first two experiments used *B. taurus* cattle, namely Angus and Angus cross heifers, and the third used *B. indicus* pure Brahman heifers. These cattle, from southern Western Australia, were about 18 months old and approximately 350 kg. Each experiment involved six animals individually penned in two climate control rooms. Three animals in each room each had a pen space of 2.3 m^2 with additional space in each pen occupied by a feeder and water bucket. The animals could not take feed or water from their neighbours.

The experiments were designed to mimic what can happen on live–export vessels as they sail from southern Australian winter with maxima between 15–20ºC into the Middle Eastern summer where maxima are above 35ºC. Animals were subjected to a warming up period of 5–6 d, then a hot, humid period of 5 d at 32°C wet bulb temperature or higher, followed by a cooling down and recovery period of 3–5 d (Table 5). The 32°C wet bulb temperature is achieved with a temperature of 35ºC and relative humidity between 70 and 80%.

The climate controlled rooms operated adequately to provide the required wet bulb temperatures at around 80% relative humidity. Figure 3 shows the wet bulb temperatures measured in the rooms each day. In the first experiment the heaters and humidifiers were turned down midway through the fifth hot day because of uncertainty about the animal response (day 11, Table 5; Figure 3). However in the second experiment the settings for heaters and humidifiers were sustained throughout the fifth day (day 11, Table 5; Figure 3). In fact in the third experiment the Brahman cattle showed very little clinical response to 32°C wet bulb over four days, and the wet bulb temperature was increased to 34ºC wet bulb on the fifth hot day (day 11, Table 5; Figure 3). Ammonia and carbon dioxide values remained reasonably low, up to approximately 15 ppm ammonia and 0.120% carbon dioxide. The bedding was changed on a regular basis to maintain these low concentrations.

Figures 4 and 5 show the daily feed and water intakes over the length of the experiments, expressed as a percent of liveweight. The feed intake of the *B. taurus* cattle was dramatically reduced as wet bulb temperature increased resulting in liveweight losses, while most of the *B. indicus* cattle maintained feed intake (Figure 4).

Water intake was increased for all three experiments as wet bulb temperature increased, with very large intakes of over 12% liveweight recorded for the animals in Experiment 1 (Figure 5).

Venous blood was taken between one and three times daily via jugular catheters for blood gas analysis and results for bicarbonate are represented in Figure 6.

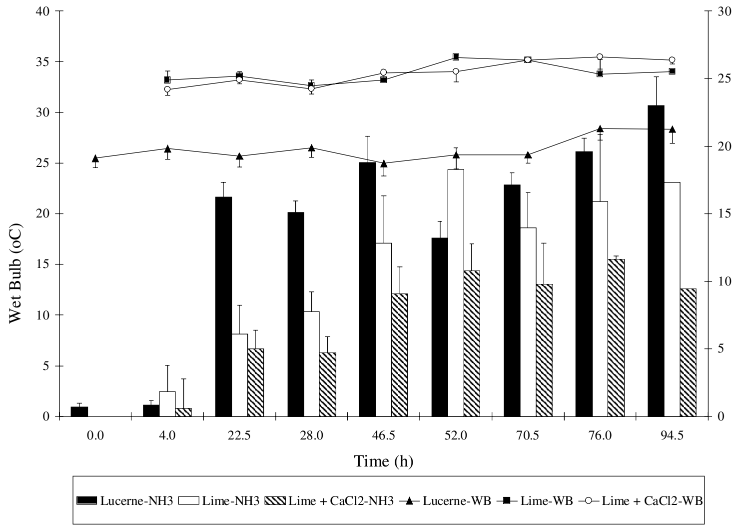

Figure 2 Effect of lucerne, or straw/barley/lupins diets with either 1.5% lime or 1% lime plus 1% calcium chloride on atmospheric ammonia under simulated conditions of heat and humidity for live export. The results shown are means ± SEM for 5 animals per lucerne diet and 4 animals per other 2 diets with either lime or lime plus calcium chloride.

Table 5 Settings for climate control rooms.

Day	Wet bulb (°C)	Dry bulb (°C)	Relative humidity (%)
1–2	ambient		
3–4	26	30	75
5	28	31	80
6	30	33	80
7–11	32	35	80
12	28	31	80
13	26	30	75
14–16	ambient		

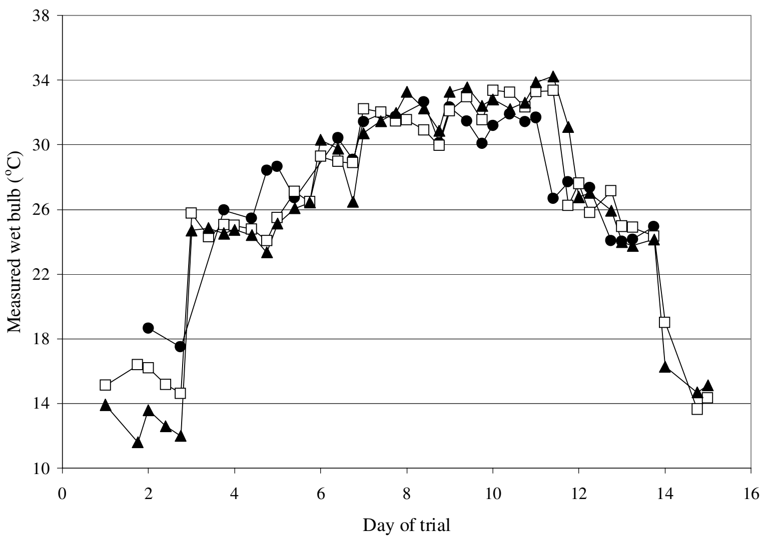

Figure 3 Wet bulb temperatures for the climate controlled rooms for the three heat experiments. Each value is the mean of three measurements in the two rooms.

● Experiment 1 *Bos taurus*, □ Experiment 2 *Bos taurus*,
▲ Experiment 3 *Bos indicus*

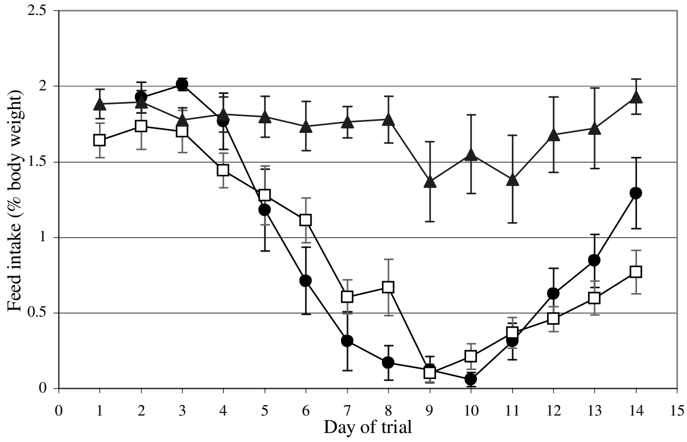

Figure 4 Mean feed intake of cattle in the three heat experiments, expressed as a percentage of their liveweight at the start of the experiment.

● Experiment 1 *Bos taurus*, □ Experiment 2 *Bos taurus*, ▲ Experiment 3 *Bos indicus*

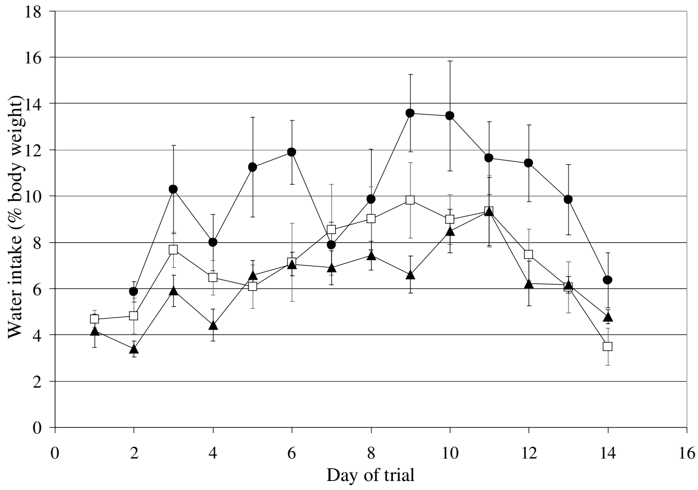

Figure 5 Mean water intake of cattle in the three heat experiments expressed as a percentage of their liveweight at the start of the experiment.

● Experiment 1 *Bos taurus*, □ Experiment 2 *Bos taurus*, ▲ Experiment 3 *Bos indicus*

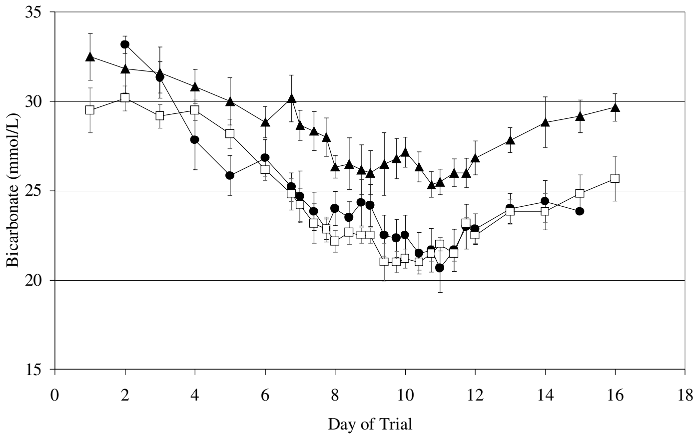

Figure 6 Blood bicarbonate of cattle during and after the experimental period. The *Bos taurus* cattle in Experiment 1 left the rooms at day 14, while the cattle in Experiments 2 and 3 left at day 16.

● Experiment 1 *Bos taurus*, □ Experiment 2 *Bos taurus*, ▲ Experiment 3 *Bos indicus*

In general, responses between experiments are similar with *B. indicus* being less severely affected. Blood bicarbonate was reduced in the lead up to and during the hot period. Once the heat was turned off, the blood bicarbonate was slow to return to preheating concentrations.

The *B. taurus* cattle lost considerable liveweight, which was presumably both gut fill and body tissue, while the *B. indicus* did not lose as much weight and regained weight more rapidly after leaving the rooms (Figure 7).

Conclusions

Traditional diets used by the live export trade can be replaced by alternative diets that result in similar or better performance at the same intake and, more importantly, lower urinary N. The cost of diet should not be the exclusive criterion when choosing a diet for long voyages. Other factors, such as liveweight gain and nitrogen excretion, should also be considered in the redesign of a diet used during live export of cattle.

Using good quality cereal hay instead of straw was a major influence on increasing the acceptance of diets during the transition period. Good quality cereal hay also increased the rates of liveweight gain per unit of feed and cost, and decreased the total urinary nitrogen output. Straw is often used as the basis of diets in the industry because of its availability and consistent nutrient specification. However, good quality cereal hay is preferable to straw if the aim is to reduce the atmospheric ammonia and improve liveweight gain during the voyage.

If the quality of cereal hay is optimised, then high inclusions of cereal hay can be used in export diets, reducing the risk of lactic acidosis during the transition period and the voyage, and possibly the heat load of fermentation.

The industry has used diets based on 2% lime as a binder that result in a urinary pH around 8.0. Even a reduced rate of inclusion of 1% lime still resulted in animals having alkaline urinary pH which is major contributor to the volatization of ammonia from the bedding. Addition of gypsum effectively reduced the urinary pH but only when lime was absent from the pellet. However, gypsum did not perform as well as lime as a binder for these pelleted diets. A better alternative is acid salts such as calcium chloride or ammonium chloride, that is salts that lead to direct acidification of the urine since they can effectively lower pH even in the presence of 1% lime as binder. The decrease in atmospheric ammonia resulting from dietary manipulation can be sustained even under simulated export conditions. Lucerne diets produce significantly greater atmospheric ammonia than diets based on cereal hay and acid salts. Acid salts should be used in combination with 1% lime because they decrease feed intake when used alone.

Although feed reduction is commonly reported in heat stressed cattle (Allbright *et al.* 1971; Beede *et al.* 1986), the reduction by the *B. taurus* cattle in our experiments was much greater than was expected. Those animals were exposed to continuous high heat and humidity unlike much other studies of heat stress where the animals may have an overnight period of 'cooling off. The *B. indicus* cattle maintained their feed intake during the hottest period, with only one animal becoming inappetant.

The aetiology of the reduced feed intake for the *B. taurus* is unknown. The reduction maybe a direct effect of heating the hypothalamus as core temperature rises, or may be hormonally mediated. The resulting weight loss appears to be of great economic concern to the live export industry; losses of between 10 and 44 kg liveweight (mean 23 kg) were recorded over the duration of the experiments.

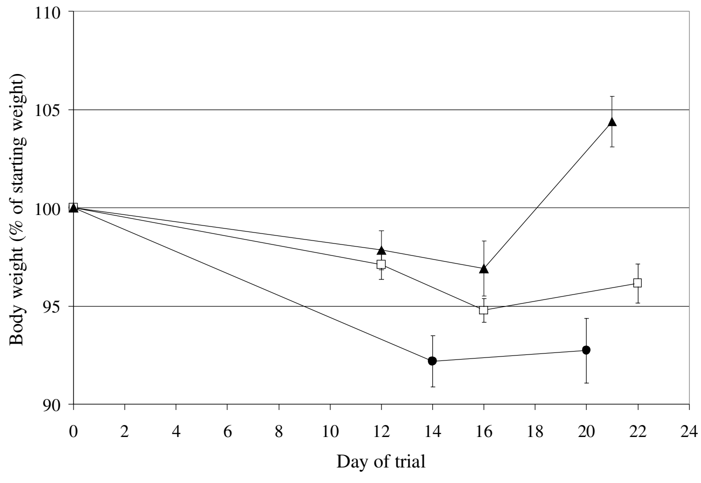

Figure 7 Liveweight of cattle during and after the experimental period, expressed as a percentage of starting weight. The *Bos taurus* cattle in Experiment 1 left the rooms at day 14, while the cattle in Experiments 2 and 3 left at day 16.

● Experiment 1 *Bos taurus*, □ Experiment 2 *Bos taurus*, ▲ Experiment 3 *Bos indicus*

Water intake was increased for all animals as wet bulb temperature increased and there was no evidence of dehydration. It is unknown what behavioural effects there may be on water intake onboard ship where cattle are kept in group–pens. It is very important that all animals have access to plenty of water. The animals also urinated copious volumes of very dilute urine, but it is unclear whether the increased drinking was the cause or the result of this. The slow rate of return to normal of blood bicarbonate showed how long it can take for full compensation of acid–base disturbance during heat stress. In fact the changes in feed and water intake and in general homeostasis in cattle under these exposures of continuous high heat and humidity were greater than expected from other published work.

Acknowledgements

Assistance for the results was provided by the CRC for Cattle and Beef Quality, Meat and Livestock Australia and Livecorp. Ms J.M. Accioly received a PhD Scholarship from CSIRO.

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