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Reducing heat load — nightime feed intake and strategic use of bedding

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Executive summary

Please note that the feedlots wish to remain anonymous and all identifiers have been removed from the data. The project was approved by the University of Queensland Animal Ethics Committee.

The study was undertaken to determine the following:

- **Determine the impact of weather conditions on the feeding behaviour of feedlot cattle during summer.**
- **Determine the relationship between weather conditions, body temperature and feed intake during summer.**
- **Develop feeding strategies that will enhance heat dissipation at night.**
- **Determine the effect of straw bedding as a tool to alleviate heat load in feedlot pens.**

A pilot study was undertaken to determine the best options for video camera placement (for the main study), surgery techniques for i-button placement (for recording body temperature), and hay usage for pen surfaces (strategic use of bedding). The findings from the pilot study are presented in the Milestone 1 report for this study,

Cattle in three commercial feedlot were used in the studies which ran over the summers 2015/16 and 2016/17. A number of animals were implanted with temperature loggers (which were removed at slaughter and the data downloaded). The loggers were set to record at either 1 hour or 10 min depending on the feedlot and the duration of observation. Body temperature profiles were determined and the rate of heat gain/loss was determined.

Two important outcomes from this study are: (i) increase heat load leads to an apparent disruption to the heat/gain regulation in both *Bos taurus* and *Bos indicus* steers, (ii) cattle will self-regulate and the consumption of feed and associated activity appears to lead to a small but significant increase in body temperature eat night. Thus it is somewhat difficult to develop succinct feeding strategies to ameliorate heat load, and (iii) cattle tended to stop eating when body temperature was increasing, and commenced eating when body temperature was decreasing and heat load was decreasing.

The feed intake data is somewhat limited but it appears that once HLI drops below 90 to 95 (there are other factors which make a precise value difficult to define at this time), and it appears to change somewhat from day to day. It also appears that body temperature is the main driver, not so much the magnitude but whether or not body temperature is falling.

Due to logistical and weather factors the bedding component of the study was not completed.

The recommendations arising from this study are:

1. Determine how the observed changes in body heat/gain will influence the calculation of the accumulated heat load. Adapt the model as required.
2. Further investigate the body temperature profiles of *Bos indicus* cattle.
3. Evaluate the body temperature data form FLOT.0157 to further investigate changes in body heat/gain. Data is available from climate rooms as well as outdoor feedlot pens.
4. Further investigate how body heat/gain is affected by heat waves.
5. In regards to conclusion 2 – need to determine if the slow release of heat at night can be speeded up to ensure optimal body temperature as cattle enter a new day.
6. In regards to conclusion 4 - biologically we are not sure what this means but it needs further investigation

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1 Background

Research at Gatton over the summer 2012/13 (B.FLT.0150: Impact of night-time cooling on heat load in feedlot cattle) and 2013/14 used small video cameras to record behaviour of feedlot cattle for 24 h each day over 120 days. Observations from the Gatton studies revealed significant feed intake between 0200 h and 0400 h on 'hot' nights. It is not clear if there are a couple of large meals or multiple small eating bouts at night.

There is a fairly large body of data from the USA supporting the use of straw bedding in winter time. There is anecdotal evidence (nothing in the scientific literature) that the strategic use of straw bedding during periods of high heat load will ameliorate the impact of hot dry conditions.

2 Project objectives

Three feedlot studies were undertaken to determine the effect of weather conditions on body temperature of feedlot steers in summer.

The objectives of this study were to determine:

- **Determine the impact of weather conditions on the feeding behaviour of feedlot cattle during summer.**
- **Determine the relationship between weather conditions, body temperature and feed intake during summer.**
- **Develop feeding strategies that will enhance heat dissipation at night.**
- **Determine the effect of straw bedding as a tool to alleviate heat load in feedlot pens.**

3 Methodology

3.1 Materials and Methods

The commercial feedlots used in this study wish to remain anonymous, and as such they are only identified by the letters A, B or C. All identifiers have been removed from the data. The research undertaken was approved by the University of Queensland animal ethics committee (SAFS/453/14).

3.1.1 Study 1 (Feedlot A)

The study ran from mid-December 2015 to mid-March 2016. Six pens of mixed genotypes (466.30 ± 10.2 kg LW at commencement) were used in a 100 d study. The steers were classified as either *Bos indicus* (n = 17) or *Bos taurus* (n = 18) (Table 1). The cattle were being fed for the 100 DOF market (Table 1). The steers did not have access to shade during the study period. Body temperature (BT) of the steers was obtained at 1 h intervals over the duration of the study. The steers were implanted with the body temperature loggers on day 1 of the study (induction into the feedlot).

Body temperature profiles of the steers in Study 1 were examined as: (i) 66 days over summer, (ii) hot conditions (max HLI>90 units AHL >20 units) (19 days) and (iii) under heat wave conditions (max HLI>98 units, AHL >50 units) (3 days).

Table 1. Breed type, coat colour, hormonal growth promotants (HGP) used (Yes, No) and liveweight (LWT, kg) at the commencement of the study.

Breed	Coat Colour	HGP	LWT, kg
Bos indicus			
Santa X	Red	Yes	460
Santa X	Red	Yes	388
Santa X	Red	Yes	436
Santa X	Red	Yes	422
Santa X	Red	Yes	482
Santa X*	Cream/Yellow	No	446
Santa X*	Red	No	498
Charbray	Brindle	Yes	410
Charbray	Cream	Yes	392
Charbray	Cream	Yes	468
Charbray	Cream	Yes	492
Charbray	Cream	Yes	498
Droughtmaster X	Red	Yes	422
Droughtmaster X	Red	No	508
Brahman X	Black	No	464
Brangus	Brindle	Yes	426
Brangus*	Black	Yes	432
Bos taurus			
Hereford	Red/White	No	470
Hereford	Red/White	No	534
Limousin X	Red	No	406
Shorthorn X	Red	No	504
Angus	Black	No	518
Angus	Black	No	498

Angus	Black	No	478
Angus	Black	No	488
Charolais X	Cream/Grey	Yes	462
Charolais X	Cream/Yellow	No	484
Charolais X	Cream	No	518
Charolais X	Cream	No	514
Charolais X	Cream	Yes	502

X next to the breed indicates a cross bred animal; *Logger failed – no body temperature data

3.1.2 Study 2 (Feedlot B)

Body temperature of 30 Angus steers was obtained over 52 days (10 min intervals) (December 2016 to January 2017 – unfortunately the study was completed before the major heat wave in February 2017). Six pens were observed, average number of steers (mixed genotypes) was 160 per pen (range 157 to 166). All pens were unshaded. Body temperature loggers were implanted into 5 Angus steers per pen (Table 2). Steers were implanted 7 days prior to first data collection. Data was collected on: 27, 28, 34, 35, 67, 68, 71, 76, 78 and 79 days on feed. Portable video cameras (see below) allowed panting score data to be collected from 3 of the 6 pens at any one time. Pen panting scores were assessed on data collection days at 0800, 1100, 1300, 1500 and 1800 h by visual assessment. Panting scores at 2000, 2200, 0000, 0200 and 0400 h were obtained from analysis of videos. This was done by scanning the video 10 min prior to and 10 min after the hour. The data at 0500 and 0600 h could not be adequately assessed because the rising sun faded out the video. Unfortunately due to a presumed power surge in the camera unit data was not obtained for days 78 and 79.

Table 2. Breed, pen number, coat colour, liveweight (LWT, kg)* at induction and body condition score (BCS) at induction.

Breed	Pen	Coat Colour	LWT**, kg	BCS
Angus	1	Black	354	3
Angus	1	Black	373	2.5
Angus X	1	Black	378	3
Angus	1	Black	370	3
Angus	1	Black	358	3
Angus	2	Black	364	2.5
Angus	2	Black	384	3
Angus	2	Black	350	3
Angus	2	Black	372	2.5

Angus	2	Black	373	3
Angus	3	Black	362	3
Angus	3	Black	368	3
Angus XX	3	Black	378	2.5
Angus	3	Black	402	3
Angus	3	Black	404	3.5
Angus	4	Black	370	3
Angus	4	Black	340	2.5
Angus	4	Black	398	3
Angus	4	Black	356	3
Angus	4	Black	370	3
Angus	5	Black	372	2.5
Angus X	5	Black	354	3
Angus	5	Black	380	3
Angus	5	Black	378	3
Angus XX	5	Black	399	3
Angus	6	Black	368	2.5
Angus	6	Black	377	3
Angus	6	Black	382	3
Angus	6	Black	379	3
Angus	6	Black	353	2.5

X white on belly; XX woolly coat; * cattle were lighter weight than normally inducted for the domestic market

3.1.3 Study 3 (Feedlot C)

Body temperature of 20 Angus steers was obtained over 24 days (10 min intervals) from 1 January to 24 January. All pens had shade (approximately 2.8 m^2/animal). No live weights or carcass data were obtained for these animals. However the estimated starting weight was 345 kg. All cattle were implanted with HGP. Weather data was collected on site at 10 min intervals. This site was to be used for the strategic use of bedding component of the study but for various reasons it was not implemented.

3.2 General Materials and Methods

3.2.1 Implantation of body temperature loggers

The first step was to develop a calibration system for iButtons (Figure 1). The iButtons are calibrated during the manufacturing process and came with individual certification for the stated accuracy range. This calibration is carried out on a reference instrument that is in accordance with the National Institute of Standards and Technology (US) and accurate to ± 0.035°C, over a range of -100°C to +200 °C (Maxim Integrated, Dallas, Texas). These devices are small (3.3 g + wax = 5 g) and are capable of storing data for up to 6 months (or longer depending on recording interval). In the current study the loggers were set to record body temp at predetermined times (see specific studies for details).

The iButtons used in this trial were tested in the lab prior to use to "double check" the calibration, and to determine any errors or malfunction of individual loggers. The calibration was conducted using a water bath (Julabo F12-ED John Morris Scientific Pty Ltd, Germany). The iButtons were suspended in the water bath at 28 °C and this temperature increased in 1 °C increments until a maximum of 42 °C; the iButton logged at 1 min intervals and each temperature was held for at least 20 min to allow temperature stabilisation. The temperature of the water bath was also verified using a calibrated thermometer (Eutech Instruments Ecoscan, Singapore). Data from the iButtons was then downloaded and the recordings checked for a 'step-like' progression through the temperatures. Any iButton that had errors in the data code or showed a variation from the stated accuracy was discarded. To prevent a tissue reaction when implanted, each logger was coated in elvax/paraffin wax (20:80 w/w) solution, and re-tested.

Figure 1. An IButton that has been coated in wax and is reading for implanting (note size relative to $2 coin)

The steers were implanted with peritoneal (flank) body temperature loggers (on induction) by qualified veterinarians. To prevent a tissue reaction, each logger was previously coated with elvax/paraffin wax (20:80 w/w) solution and prior to surgical implantation sterilized for 10 min in a Perasafe (instrument sterilizer) solution before being rinsed in sterile saline. All surgical procedures were performed by an experienced large animal veterinarian. Each animal was weighed and walked into a crush which allowed access to the flank. Following local infiltration of the flank incision site with 2% lignocaine hydrochloride, a standing left paralumbar laparotomy was performed. A small incision (6 cm) was made in the muscle layer and a sterile wax coated IButton was then sutured into the muscle at a depth of approximately 20 mm. Both muscle layers were then sutured using catgut using a simple continuous method. The skin layer was sutured with polydioxanone using horizontal mattress method and 'Cetrigen' wound aerosol will be applied to the surgical site. Post-surgical pain relief was a standard cattle dose (0.5 mg meloxicam/kg bodyweight) of Metacam administered IM. All animals also received a standard course of antibiotics (Betacam) administered IM. The iButtons were removed after slaughter.

3.2.2 Observational Data

When undertaken the following visual data collected were: respiration rates (Individual), panting scores (Individual), location in pen (Pen basis only: feed bunk, water trough, elsewhere), activity (Pen basis only: eating, drinking), and posture (Individual and Pen: standing, lying).

3.2.3 Feeding Times

Although feeding times did vary slightly between feedlots the differences were not great. All feedlots typically finished the first run by 1100 h, and the second run by 1500 h.

3.2.4 Video cameras

Optimal video camera placement and the best types of cameras to be used was determined in the pilot study. The unit can be towed to any location and is ideal for short to medium term data collection in the field (Figure 1). The unit has the following characteristics: Solar powered with battery bank back-up (can go 4 days with no light); Can use WiFi if available; 3G and 4G communication (this proved to be somewhat problematic, so we reverted to manual downloading); On board computer for data storage; Remote access (cameras can be controlled and data downloaded from any location) (worked well); PTZ (pan, tilt, zoom) camera (36x zoom); Infrared camera (night); Thermal camera; 7.5 m mast (cameras mounted on top) – this gave a panoramic view of feedlot. In addition a weather station has been added to the unit.

Figure 1 Stand-alone portable camera unit

Large amounts of video data was collected and stored on external hard drives until scanned. Day time scanning was relatively easy – activity and panting was assessed at 10 min to the hour and 10 min after the hour. Night time assessment was not as easy and we will need to re-think aspects of this. The intention was to re-visit the data for more in-depth analysis but unfortunately during the initial scanning process we inadvertently erased that data.

3.2.5 Carcass Data

These data are only available for Feedlot A. Cattle were transported to a commercial abattoir (approximately 3.5 h from the feedlot) when they were 100 days on feed. Carcass data collected was; dentation, P8 fat depth, fat class, butt score and HSCW.

3.2.6 Statistical Analysis

Respiration rates (RR), body temperatures (BT) and panting scores (PS) obtained from the cattle over the duration of the studies were analysed by a repeated measures model (PROC MIXED; SAS Institute, Cary, NC) using REML (residual maximum likelihood) estimation. The specified term for the repeated statement was animal within hour. The model included the effect of genotype (*Bos taurus* or *Bos indicus*), individual animals (ID), period of the day (0600 to 1000 h; 1001 to 1400 h and 1401 to 1800 h), hour of the day on respiration rate (on specific sites and days), panting score (on specific days) and body temperature. Pen was used as a fixed effect for all studies. The observational data was also analysed using the PROC GLM procedure of SAS. These data was normalised before being analysed. The statistical model investigated the effect of genotype and period on cattle posture (standing, lying) and cattle location in pen (at water, at feed, elsewhere). For all models statistical significance was indicated by $P \leq 0.05$.

4 Results

4.1 Feedlot A

4.1.1 Cattle description

Details of the cattle are presented in Table 1.

4.1.2 Weather conditions

Due to a failure of the weather station data for November and December were patchy. Daily maximum and minimum ambient temperature data from a Bureau of Meteorology weather station located approximately 30 km from the feedlots was used (Figure 2). The weather conditions were close to the long term averages over the study period.

4.1.3 Body Temperature – Overall Summer Profile

The body temperatures are presented in Figure 3. These data represent the overall summer profile of the steers. Further analysis of these data will be discussed below. Mean body temperature was higher ($P<0.0001$) for the *Bos taurus* steers compared with the *Bos indicus* steers at 38.9 ± 0.02 ^{o}C and 38.7 ± 0.02 ^{o}C respectively. The mean maximum body temperature occurred at 1400 h (39.3 ^{o}C) for *Bos taurus* steers and at 2000 h (38.9 ^{o}C) for the *Bos indicus* steers. Minimum body temperature occurred at 0600 h (38.6 ^{o}C) for the *Bos taurus* steers and at 0700 h (38.5 ^{o}C) for the *Bos indicus* steers. The range in body temperature i.e. the difference between maximum and minimum body temperature were 0.69 ^{o}C for *Bos taurus* steers and 0.39 ^{o}C for the *Bos indicus* steers.

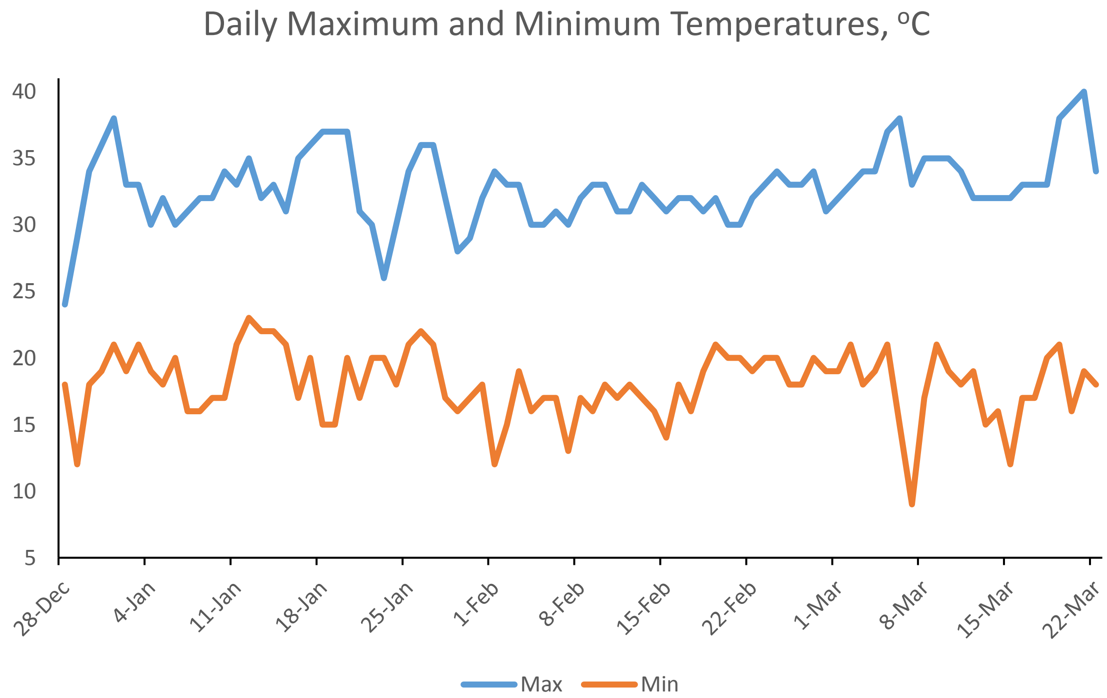

Figure 2. The daily maximum and minimum ambient temperature (°C) for the period 28 December 2014 to 22 March 2015.

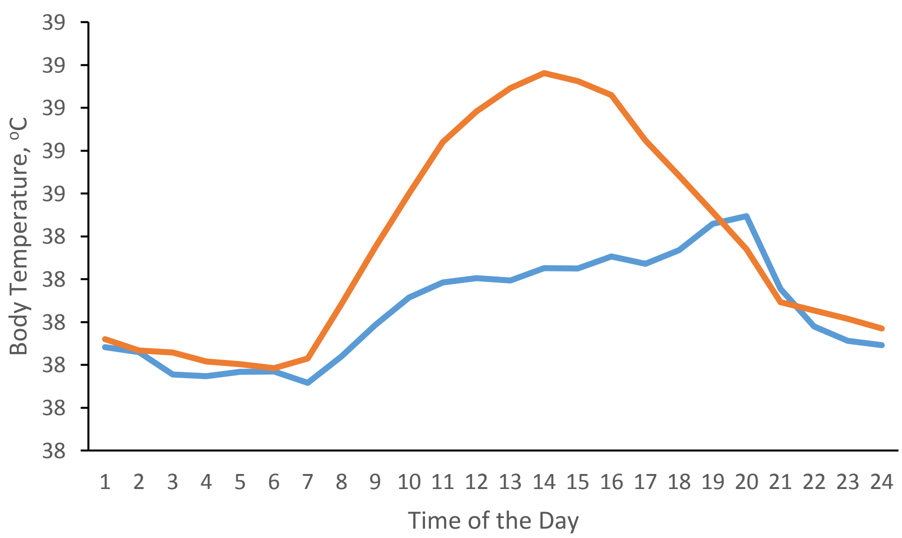

Figure 3. Mean hourly body temperature (°C) for *Bos taurus* and *Bos indicus* steers over 66 days during summer. The red line is the body temperature for *Bos taurus* steers and the blue line is the body temperature for *Bos indicus* steers.

The mean body temperature (BT; °C) for *Bos indicus* and *Bos taurus* cattle over 5 time periods (period 1 = 0600 to 1000 h; period 2 = 1100 to 1500 h; period 3 = 1600 to 2000 h; period 4 = 2100 to 0100 h and period 5 = 0200 h to 0500 h), are presented in Figure 4. The between breed type differences in body temperature are within each period different (*P<0.0001*), with *Bos taurus* cattle always having a higher body temperature. The difference in body temperature from lowest to highest was 1.1° C for *Bos taurus* and 0.91° C for *Bos indicus*.

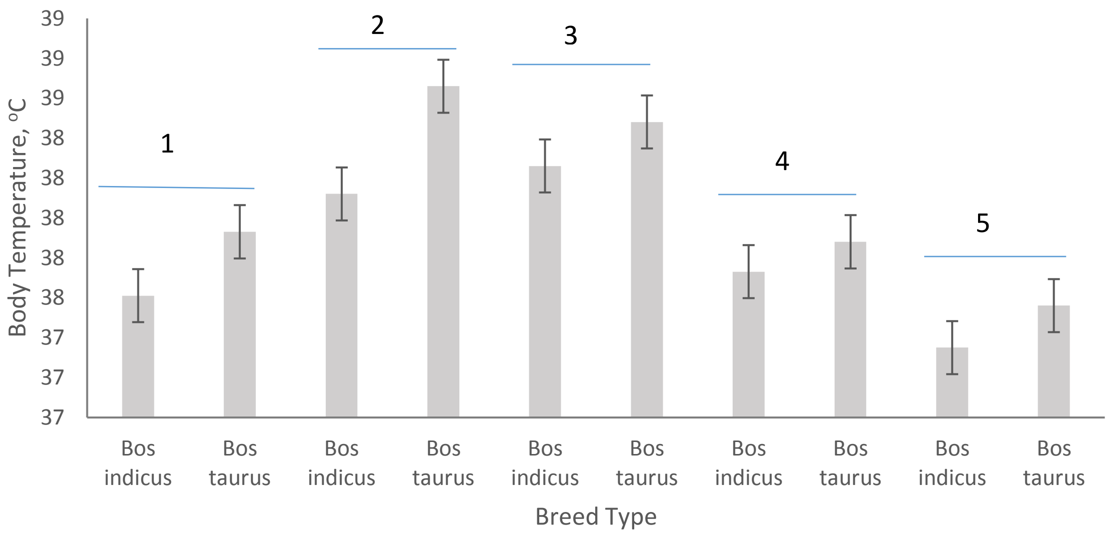

Figure 4. The mean body temperature (BT; °C) for *Bos indicus* and *Bos taurus* cattle over 5 periods (period 1 = 0600 to 1000 h; period 2 = 1100 to 1500 h; period 3 = 1600 to 2000 h; period 4 = 2100 to 0100 h and period 5 = 0200 h to 0500 h). The mean BT between breed type within each period are significantly different (*P<0.0001*).

The mean body temperature for each breed type is presented graphically in Figure 5. As expected the *Bos taurus* steers had a higher (*P<0.0001*) body temperature during each period when compared with the *Bos indicus* steers.

Figure 5. The mean body temperature (BT; °C) for *Bos indicus* and *Bos taurus* cattle over 5 periods (period 1 = 0600 to 1000 h; period 2 = 1100 to 1500 h; period 3 = 1600 to 2000 h; period 4 = 2100 to 0100 h and period 5 = 0200 h to 0500 h). The mean BT between breed type within each period are significantly different (**P<0.0001*).

The body temperature profiles for a Charbray steer and an Angus steer are presented in Figures 6 and 7 respectively. These data are presented to highlight breed type differences in body temperatures. Additional body temperature profiles (not all steers) can be found in the appendix.

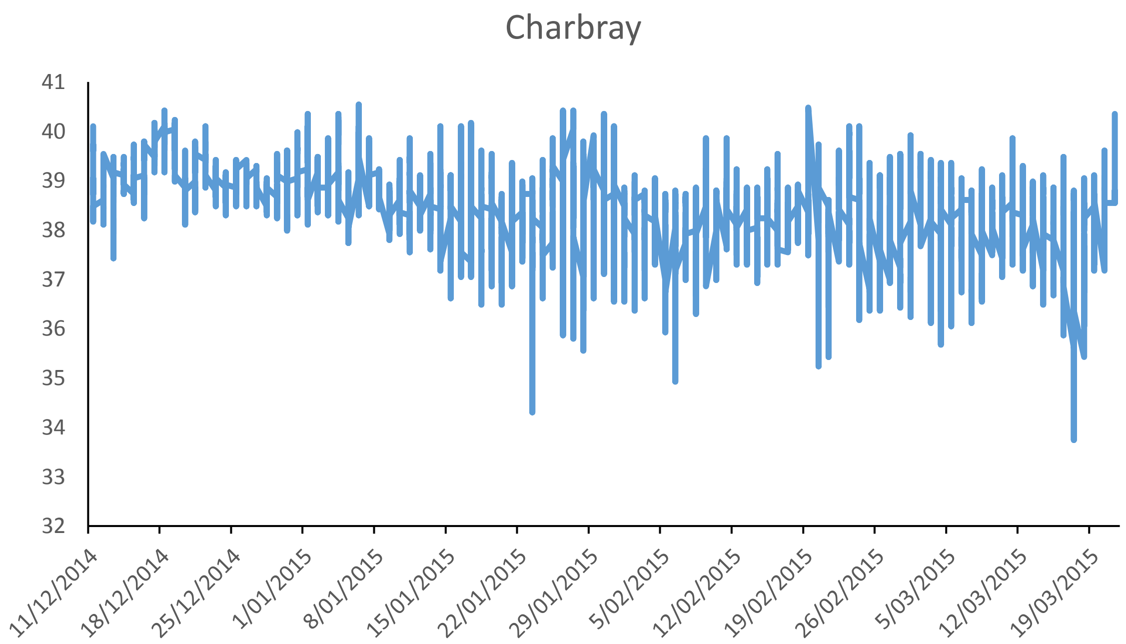

Figure 6. Hourly body temperature (°C) of a Charbray steer (mean body temperature = 38.6 ± 0.02°C).

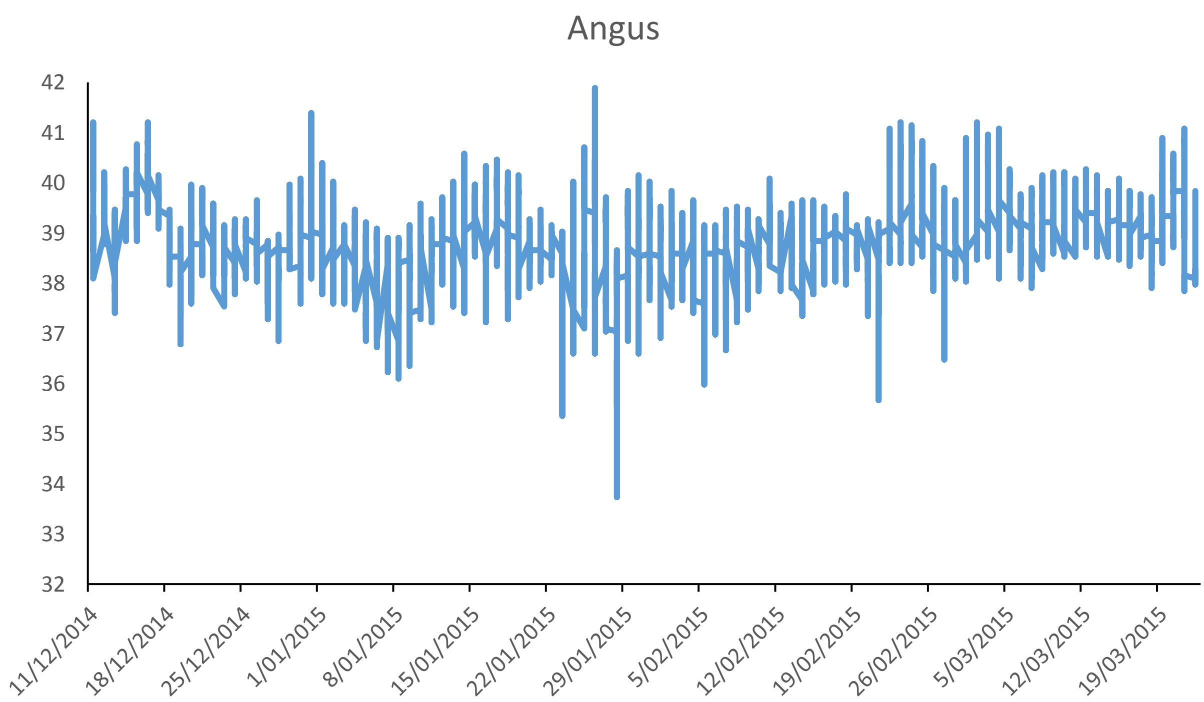

Figure 7. Hourly body temperature (°C) of an Angus steer (mean body temperature = 39.0 ± 0.02°C).

4.1.4 Body Heat Gain/Loss

The pattern of heat gain/loss was not a uniform change through the day or at night. There are also clear breed type effects. The rate of change in body temperature and the overall dynamics are influenced not just by breed type but also by the amount of heat load to which the animals are exposed to.

4.1.4.1 Defining heat gain/loss

Heat gain/loss is assessed by looking at hourly changes in body temperatures. When the change in body temperature is greater than zero the steers will be gaining heat, and when it is below zero they will be losing heat. If body temperature is decreasing when the change is below zero: then the rate of heat loss is increasing, if body temperature is rising, then the rate of heat loss is decreasing, however the animal is still dissipating heat. Heat gain/loss is not an indication that body temperature has returned to normal.

4.1.4.2 Body temperature profiles

Body temperature profiles were examined for: (i) 66 days over summer (overall summer profile), (ii) hot conditions (HOT: max HLI>90 units AHL >20 units) (19 days) and (iii) under heat wave conditions (HW: max HLI>98 units, AHL >50 units) (3 days).

4.1.4.3 Overall summer body temperature profile

Changes in the body temperature of the *Bos taurus* steers followed a consistent period of increase and a consistent period of decrease. Body temperature increased by 0.69 °C in the *Bos taurus* steers between 0700 h to 1400 h (Figure 8). This represents a mean increase of 0.09 °C/h, over 7 h. The greatest rate of heat gain occurred between 0800 h and 1100 h (0.50 °C; 0.13 °C/h). The steers lost body heat between 1500 h and 0600 h at the rate of 0.04 °C/h. This highlights that the rate of cooling is much slower (44%) than the rate of heat gain. The biological implications of this are not known. In contrast to the *Bos taurus* steers the change in the body temperature of the *Bos indicus* steers was not as consistent. There were small increase in body temperature at 0500 h and 0600 h, followed by a small decrease at 0700 h. Body temperature then increased from 0800 h to 1200 h (0.25 °C; 0.05 °C/h). From 1300 h to 2000 h there was a net heat gain of 0.15 °C in body temperature during this period. From 2100 h to 0400 h there was a net heat loss of 0.37 °C (0.05 °C/h). There was very little change in the body temperature of *Bos indicus* steers.

4.1.4.4 Feeding Activity

Feeding activity was a function of time of feeding, heat load (in particular the HLI) and body temperature. The main focus of the study was on eating behaviour in the afternoon and night. The video camera allowed some data to be collected at night, but the technology did not work as well as was expected. Broadly – afternoon eating activity was a function of current ambient conditions essentially the HLI, and body temperature of the steers. The data is somewhat limited but it appears that once HLI drops below 90 to 95 (there are other factors which make a precise value difficult to define), and it appears to change somewhat from day to day. It also appears that body temperature is the main driver, not so much the magnitude but whether or not body temperature is falling.

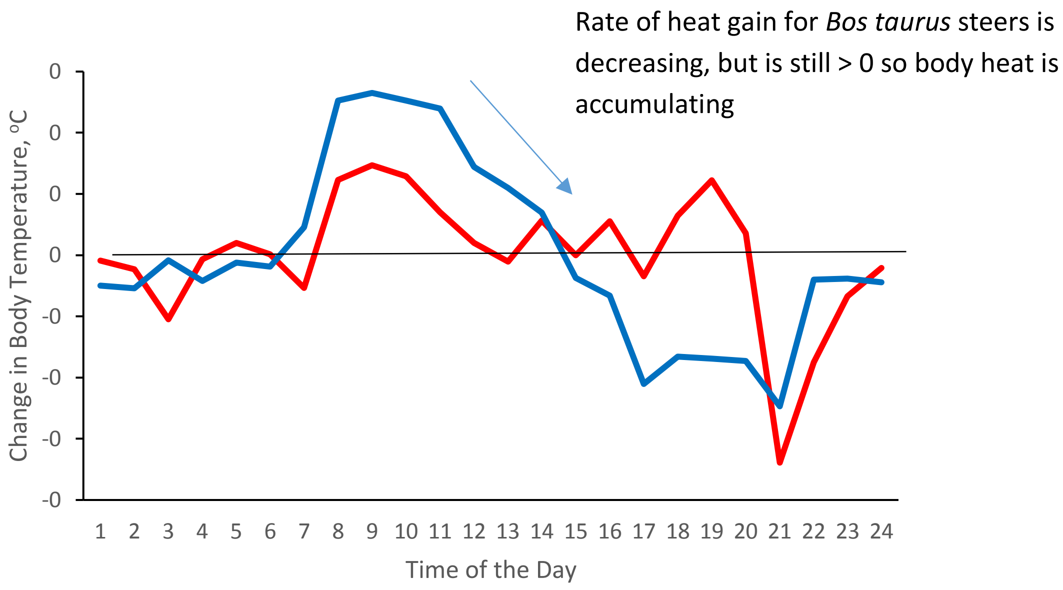

Figure 8. Mean hourly change in body temperature (°C) for *Bos taurus* and *Bos indicus* steers over 66 days during summer. The blue line is the body temperature for *Bos taurus* steers and the red line is the body temperature for *Bos indicus* steers. If the line is above zero the animal is gaining heat, and if below zero the animal is losing heat.

4.1.5 Body Temperature – Profile during Hot Weather

The body temperatures during the periods classified as HOT are presented in Figure 9. Mean body temperature was higher (*P<0.001*) for the *Bos taurus* steers compared with the *Bos indicus* steers at 39.5 ± 0.04 °C and 39.4 ± 0.04 °C respectively. The mean maximum body temperature occurred at 1500 h (39.8 °C) for *Bos taurus* steers and at 0500 h (39.4 °C) for the *Bos indicus* steers. Minimum body temperature occurred at 1100 h (39.3 °C) for the *Bos taurus* steers and at 2100 h (39.3 °C) for the *Bos indicus* steers. The range in body temperature (difference between maximum and minimum) were 0.42 °C for *Bos taurus* steers and 0.12 °C for the *Bos indicus* steers. Maximum body temperature of the *Bos indicus* steers occurred much earlier that the *Bos taurus* steers (1000 h *vs.* 1500 h).

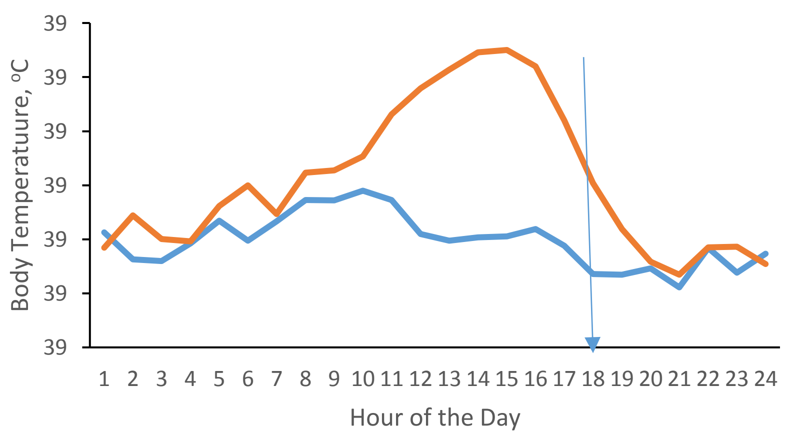

Figure 9. Mean hourly body temperature (°C) for *Bos taurus* and *Bos indicus* steers during periods of hot weather. The red line is the body temperature for *Bos taurus* steers and the blue line is the body temperature for *Bos indicus* steers. The arrow shows were eating activity commenced.

When exposed to hot conditions there was greater variability in the hourly change in body temperature than what was seen over summer as a whole. The slight increase in the body temperature of both breed types at 2200 h is thought to be associated with fermentation of feedstuffs in the rumen. In general cattle started eating at their afternoon feed between 1800 and 1900 h. The increase in body temperature from 0300 to 0400 h is thought to be due to increased activity of the cattle. There was, based on video footage, an increase in feeding activity during this period, and cattle were more active in general.

The heat loss/gain profile is less predictable when the weather is classified as HOT (Figure 10). In both breed types there is a continual change in the rate of heat gain/loss over the course of the day. The steers have a cyclic gain and loss of body heat between 0100 and 1000 h. The response is similar between the breed types, with changes (increase or decrease in body temperature) in *Bos indicus* steers occurring about 1 h before similar changes in the *Bos taurus* steers. A divergence then occurs (1000 h) with the *Bos indicus* steers being below 0 until 1400 h when there is a small but positive heat balance. During the same period the *Bos taurus* steers were in continuous heat gain. There was then a period of rapid decrease in the body temperature of the *Bos taurus* steers.

The overall heat gain in the *Bos taurus* steers was 0.02 °C/h (2100 h to 1500 h). The heat gain at night, which was not overtly evident in the whole of summer data is an indication of a lack of adequate nightime cooling when conditions were HOT. The maximum heat gain (0.04 °C/h) occurred between 0700 and 1500 h (8 h), and maximum heat loss occurred over 6 h (0.07 °C/h). Overall heat loss occurred over an 18 h period (0.04 °C/h).

The dynamics of heat gain/loss during the hot periods was somewhat different to the overall summer profile. The heat gain (0.02 °C/h) was considerably lower during HOT than for the summer profile (0.09 °C/h). However the rate of heat loss were similar at 0.04 °C/h and 0.05 °C/h for summer and HOT respectively. Although the rate of heat gain is lower, the cattle are starting from a higher body temperature during HOT. During HOT the mean body temperature of *Bos taurus* and *Bos indicus* steers were 1.6 and 0.7 °C higher than their overall summer means. Therefore their base line body temperature is greater during HOT. This has implications for modelling heat/loss and gain over summer (e.g. AHLU) because the assumption has been that heat loss and heat gain are constant at a given HLI threshold.

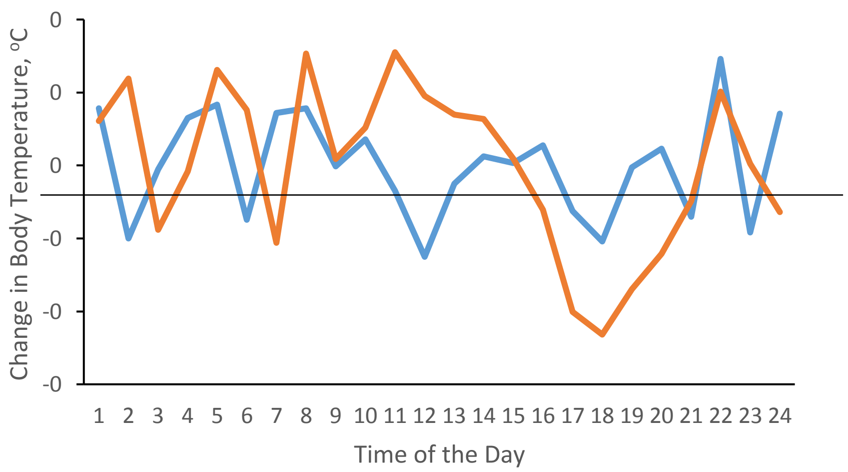

Figure 10. Mean hourly change in body temperature (°C) for *Bos taurus* and *Bos indicus* steers when conditions were defined as HOT. The red line is the body temperature for *Bos taurus* steers and the

blue line is the body temperature for *Bos indicus* steers. If the line is above zero the animal is gaining heat, and if below zero the animal is losing heat.

4.1.6 Heat Waves – Body Temperature Profiles

During heat wave events the body temperatures of both breed types is somewhat erratic (Figure 11). Mean body temperature was higher (*P<0.0001*) for the *Bos taurus* steers compared with the *Bos indicus* steers at 40.4 ± 0.12 °C and 40.2 ± 0.08 °C respectively. The mean maximum body temperature occurred at 1500 h (40.5 °C) for *Bos taurus* steers and at 1600 h (40.5 °C) for the *Bos indicus* steers. Minimum body temperature occurred at 2100 h (40.1 °C) for the *Bos taurus* steers and at 0700 h (40.0 °C) for the *Bos indicus* steers. The range in body temperature were 0.39 °C for *Bos taurus* steers and 0.47 °C for the *Bos indicus* steers.

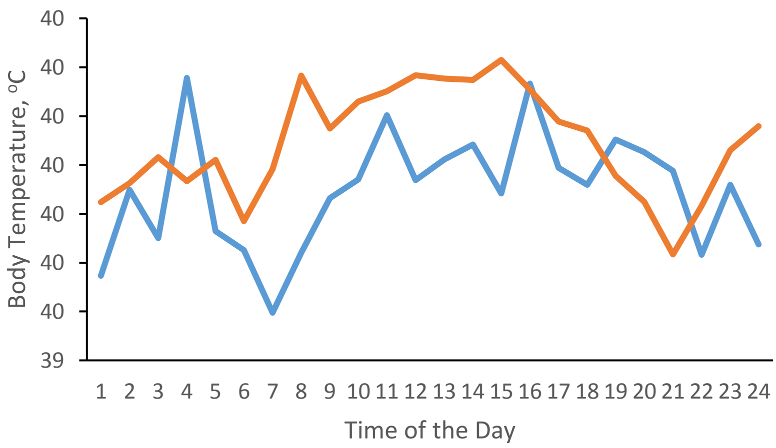

Figure 11. Mean hourly body temperature (°C) for *Bos taurus* and *Bos indicus* steers during periods classified as heat waves. The red line is the body temperature for *Bos taurus* steers and the blue line is the body temperature for *Bos indicus* steers.

The rate and direction of change in body temperature for the *Bos indicus* steers is characterised by a series of peaks (body temperature increasing) and troughs (body temperature decreasing) (Figure 12). Of note is the reduction in body temperature that occurred between 0400 h and 0500 h (-0.30 °C). A net gain in body temperature did not occur until after 0800 h. Overall the reasons for these changes are not clear. This is an area that needs further investigation.

In contrast the change in body temperature of the *Bos taurus* steers is more stable through the hottest parts of the day (1000 to 1600 h). The heat in these steers from 0500 h is likely associated with movement of cattle around the pens (associated with sun rise and human activity at this time) and feeding activity.

There is an obvious difference between the *Bos taurus* and *Bos indicus* steers in terms of body temperature regulation during heat waves. Although not unexpected the *per se*, the dynamics of het gain/loss was unexpected. Heat waves appear to disrupt the heat loss mechanisms in both breed types, but it may also be evidence of a coping mechanism. The disrupted heat loss mechanisms (if this is the case) in the *Bos taurus* steers highlights the importance of nightime cooling. In the present case the steers were able to dissipate some heat at night. However there was an increase in heat gain after 2100 h, again associated with feed intake.

During the heat wave the body temperature of the *Bos taurus* steers was 0.9 °C greater than during HOT and 1.5 °C greater than the summer mean. Similarly for *Bos indicus* body temperature was 0.8 °C and 1.5 °C greater compared with HOT and the summer mean. For both cattle types body temperature increased over a 9 h period, resulting in an increase of 0.04 °C/h and 0.05 °C/h respectively for *Bos taurus* and *Bos indicus* steers.

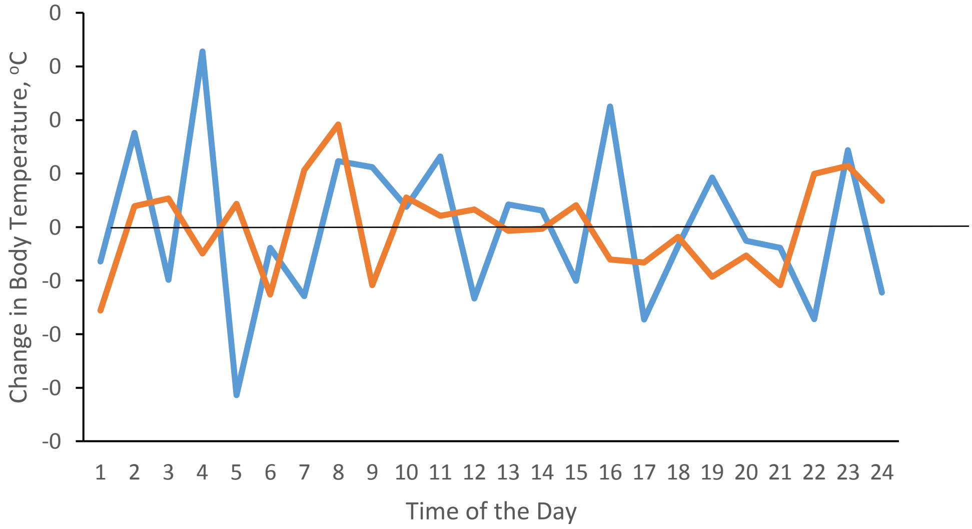

Figure 12. Mean hourly change in body temperature (°C) for *Bos taurus* and *Bos indicus* steers during a heat wave. The red line is the body temperature for *Bos taurus* steers and the blue line is the body temperature for *Bos indicus* steers. If the line is above zero the animal is gaining heat, and if below zero the animal is losing heat.

4.1.7 Performance and Carcass Data

There were no between breed type differences (P=0.7013) for live weight at the start of the study, days on feed (P=0.8713) or P8 fat depth (P=0.4700) (Table 3). However the *Bos taurus* cattle tended to have a greater carcass weight (P=0.0572) and a greater ADG (P=0.0570) compared with the *Bos indicus* cattle.

Table 3. Liveweight (LWT, kg) and the start and at the end of the study, days on feed, average daily gain (ADG; kg/day), hot standard carcass weight (HSCW, kg) and P8 fat depth (mm) for *Bos indicus* and *Bos taurus* breed types.

	Bos indicus	*Bos taurus*	*P-value*
LWT start, kg	463.20 ± 13.06	469.40 ± 9.23	0.7013
LWT end, kg	653.30 ± 16.46	693.29 ±11.64	0.0573
Days on feed	98.2 ± 0.59	98.6 ± 0.41	0.8713
ADG, kg/day	1.93 ± 0.13	2.27 ± 0.09	0.0570
HSCW, kg	346.3 ± 8.73	367.5 ± 6.17	0.0572

P8 Fat depth, mm	14.3 ± 1.56	12.9 ± 1.10	0.4700

4.2 Feedlot B

4.2.1 Cattle Description

The cattle information has been presented in Table 2.

4.2.2 Weather Conditions

The weather conditions for the location were for the duration of the study close to the long-term averages, except for rainfall. There was no rainfall during the study. There were no heat waves during the data collection period. The mean ambient temperature was 31.0 ± 0.31 ^{o}C during the day (0600 to 1800 h). During the night (1900 to 0500 h) the mean temperature was 21.8 ± 0.32 ^{o}C. The corresponding relative humidity was 52.1 ± 0.99% and 76.3 ± 1.0% respectively for day and night.

4.2.3 Body Temperature, Mean Panting Score (MPS) and Pen Effects

Period of the day (day or night, where day is 0600 h to 1800 h, and night is 1900 h to 0500 h) had an effect (*P<0.0001*; pen was a fixed effect) on body temperature at 39.3 ± 0.05 ^{o}C and 38.8 ± 0.05 ^{o}C respectively for day and night.

Period of the day also had an effect (*P<0.0001*) on MPS. During the day MPS was 0.69 ± 0.05 units and at night it was 0.03 ± 0.05 units.

There were pen effects on both body temperature and MPS (Table 4). The cattle in Pen 2 had greater body temperatures at night (39.2 ± 0.11 ^{o}C; *P<0.001*) relative to the other pens. Similarly during the day mean body temperature for cattle in Pen 2 was greater (39.8 ± 0.11 ^{o}C; *P<0.01*) relative to the other pens. There was considerable between pen variations for MPS. During the day MPS was greatest in Pen 1 (1.62 ± 0.08 ^{o}C; *P<0.01*). The MPS for Pen 6 steers was 0.23 ± 0.08 which was 86% lower than the MPS for Pen 1. There were no pen effects (*P=0.4736*) for MPS during the night.

Table 4. Body temperature (BT, ^{o}C) during the day and at night, and mean panting score (MPS) for Angus steers in pens 1 to 6.

	1	2	3	4	5	6	SE
BT (Day)	39.3	39.8	39.4	39.5	39.1	39.0	0.11
BT (Night)	38.7	39.0	38.7	28.8	28.7	38.7	0.11
MPS (Day)	1.62	1.06	0.67	0.46	0.32	0.23	0.08

4.2.4 Change in Body Temperature

There was a net gain in body temperature over a 7 h period each day (0800 to 1500 h) and a net loss of body heat over a 17 h period (1600 to 0700 h) (Figure 13). On average body temperature increased by 0.15^{o} C/h between 0800 h and 1500 h (Figure 14). With the greatest increase occurring between 1100 h and 1500 h when the increase was 0.41^{o} C/h. There was a substantial loss of heat (0.97 ^{o}C) between 1800 and 2000 h. The gain in body temperature (0.12^{o} C) at 2200 h was largely attributed to fermentation of feed consumed around 1800 h. Typically this (1800 h) was the time when cattle commenced eating following abatement of daytime ambient temperature.

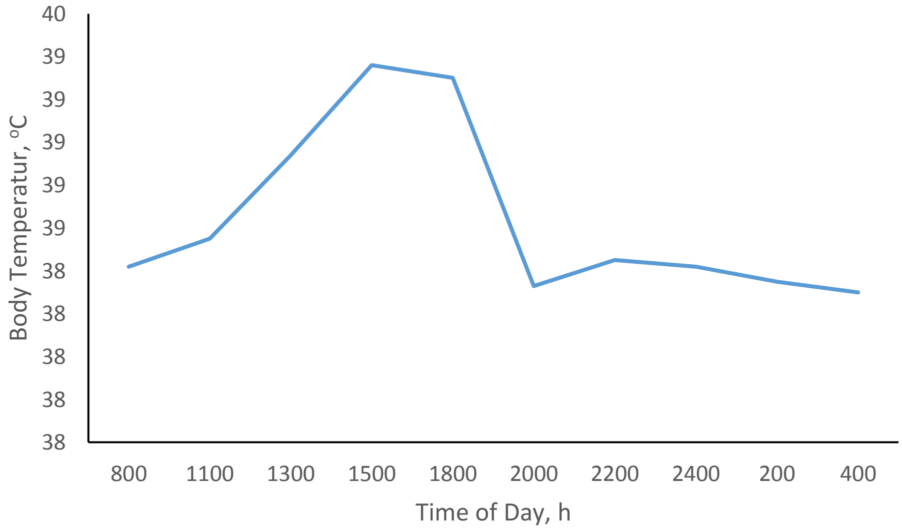

Figure 13. The change on body temperature of Angus steers over 24 hours.

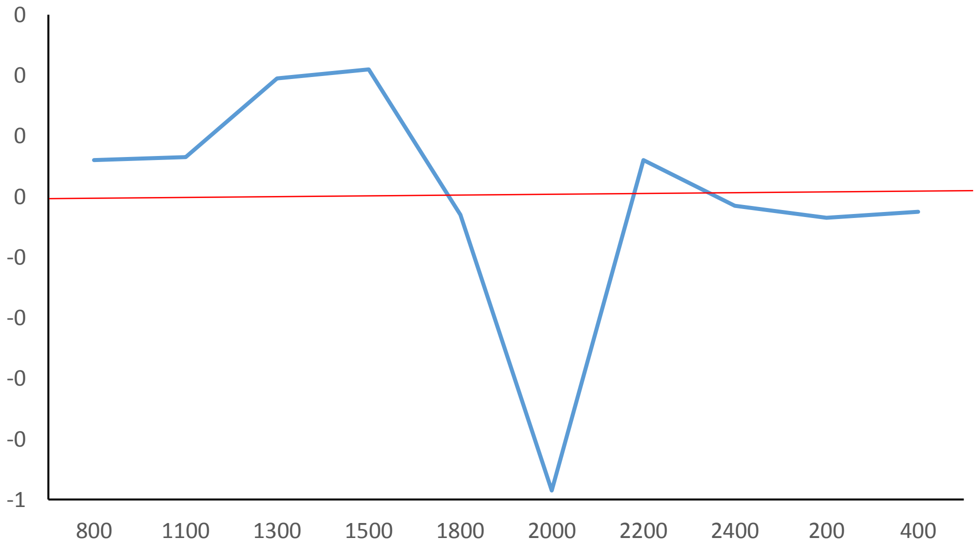

Figure 14. The net hourly change in body temperature of Angus steers. Above the red line indicates that the steers are accumulating heat and below the red line they are dissipating heat.

There is considerable variation between animals in terms of body temperature over 4 none continuous days (day 27, 28, 34 and 35) (Figure 15). Maximum ambient temperatures ranged from 35 to 38 °C on each of the 4 days between 1300 and 1500 h each day. The minimum ambient temperature range was 17 to 22 °C. Over the first 3 days there was sufficient nightime cooling to allow (on average) steers to return to normal body temperature.

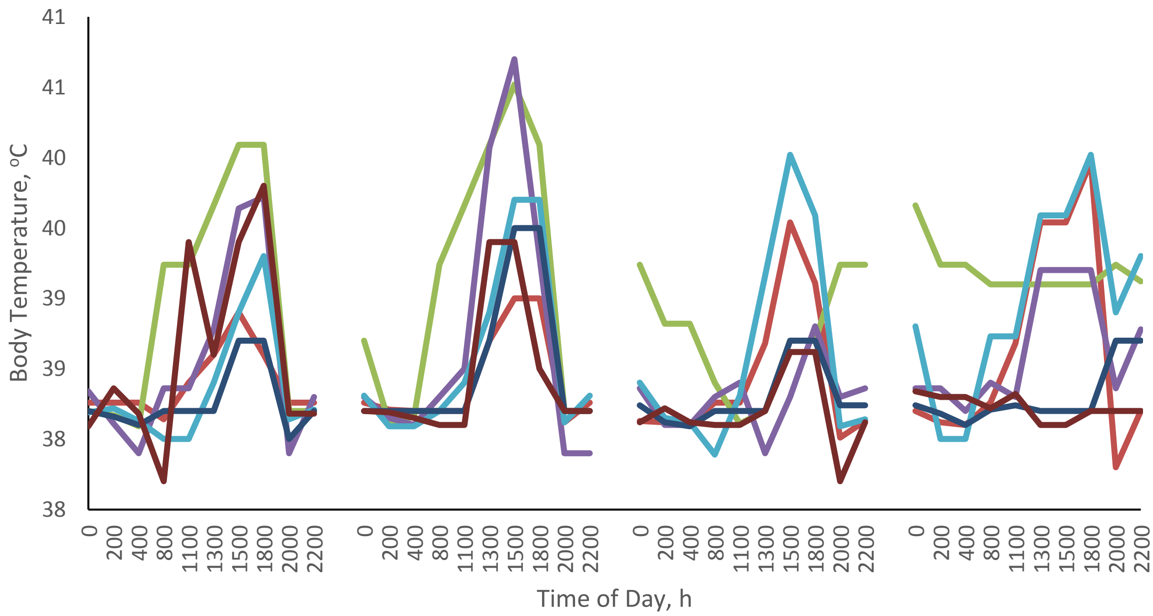

Figure 15. The mean body temperature (each line is the mean for a pen) at set time points on days 27, 28, 34 and 35.

4.2.5 Days on Feed

Days on feed (DOF) had a significant effect (*P<0.0001*) on body temperature i.e. as DOF increased body temperature increased. However this outcome is confounded by a number of factors (i) body condition score increased with DOF, and (ii) increasing heat load was associated with DOF – heat load was lower at the commencement of the feeding programme.

4.3 Feedlot C

4.3.1 Background

The steers in this study were to be part of the strategic bedding component of the study. However due to unforeseen events the data was not obtained due to a failure to layout the bedding.

For the purposes of analysis in this section the day was divided into four periods (1 = 0600 to 1100 h; 2 = 1200 to 1700 h; 3 = 1800 to 2300 h; 4 = 0000 to 0500 h).

4.3.2 Cattle Description

Twenty Angus steers were used in the study, 4 per pen. No live weights or carcass data were obtained for these animals. However the estimated starting weight was 345 kg. All cattle were implanted with HGP prior to the commencement of the study.

4.3.3 Weather conditions

Hot conditions were experienced during the data collection period. The mean hourly heat load index (HLI) is presented in Figure 16. There was a sharp increase in the HLI between 0900 h and 1100 h.

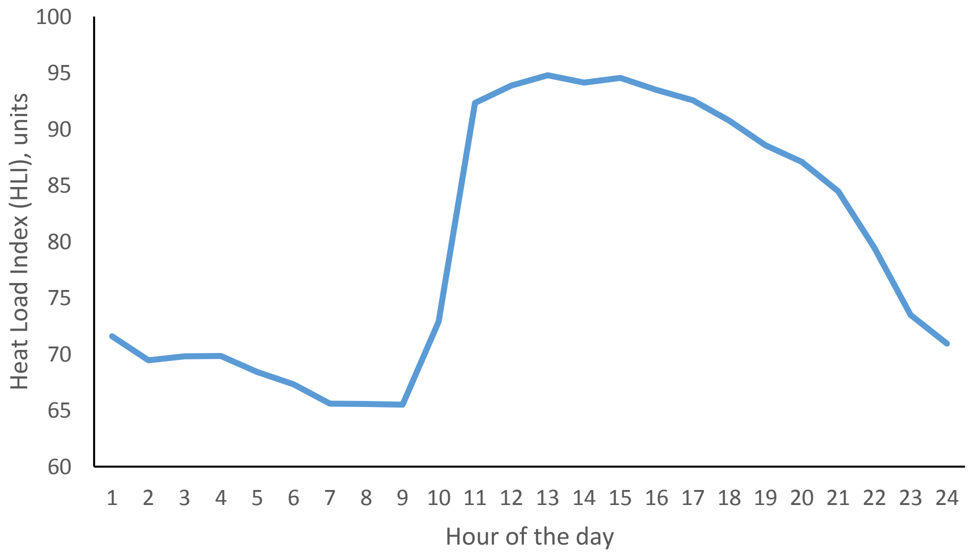

Figure 16. The mean hourly heat load index (HLI, units) over 24 days (1/1/17 to 24/1/17).

The mean HLI during the daily periods (see above) were as follows: Period 1 = 70.00 ± 0.23; 2 = 85.95 ± 0.23; 3 = 91.18 ± 0.23; 4 = 67.75 ± 0.23. The HLI during periods 1 and 4 were lower (P=0.01) than periods 2 and 3. There were no between period differences for periods 1 and 4, and for periods 2 and 3.

4.3.4 Body Temperature

The mean body temperature (°C) for all animals combined is presented in Figure 17. When assessed on an individual animal basis there were period effects (*P<0.0001*), individual animal (ID) effects (*P<0.0001*) and period × ID effects (*P<0.0001*) on body temperature. However when all animals were combined there were no period effects (*P>0.05*) on body temperature, although there was a trend for body temperature to be lower in period 4 (39.5 ± 0.06 °C).

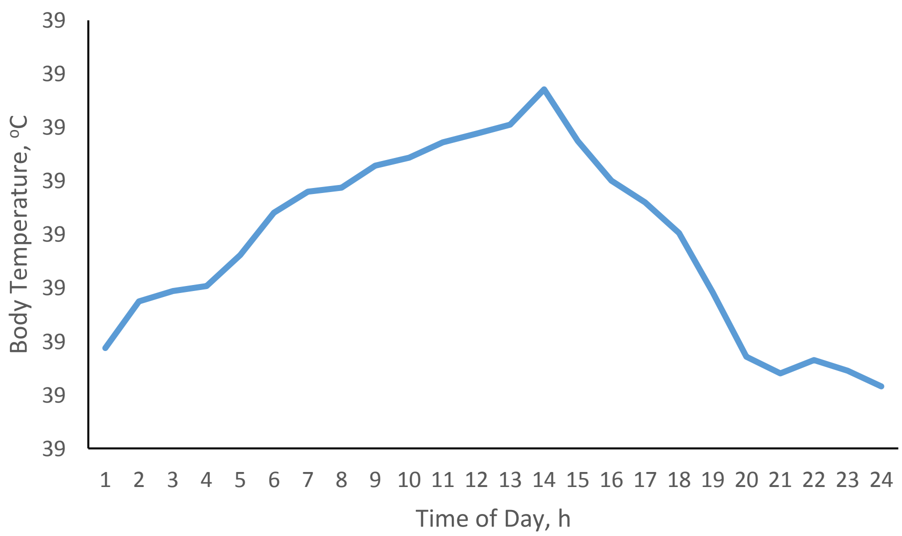

Figure 17. The mean body temperature of 20 Angus steers for the period 01/01/17 to 21/01/17.

The rate of change from minimum body temperature (39.5 °C; midnight - 24 in Figure 17) to maximum body temperature (39.7 °C at 1400 h) was 0.01 °C/h. Body temperature fell from 1400 h to midnight (0.02 °C/h).

5 Discussion

5.1 Body Temperature

Body temperature is influenced by a number of factors including ambient conditions (in particular nightime conditions – can the animal cool down), feeding activity, diet, housing (variations in micro-climate between pens), access to shade, phenotypic and genotypic variation, duration of exposure to hot conditions, health status to name a few. Obviously it is difficult to account for each of these factors when assessing changes in the magnitude and rate of change in body temperature.

In the current study the magnitude and rate of change in body temperature were of interest. It is evident from the data presented in this report that the rate of body heat accumulation is typically greater than that of heat loss. This has implications for calculation of accumulated heat load.

There is an apparent disruption in body temperature regulation when cattle (*Bos indicus* and *Bos taurus*) – see Section 4.1.6. Until now the assumptions used in the calculation of the AHLU have been that body temperature gain, and body temperature loss occur at a uniform rate. The data presented here show that this is not always the case, especially when cattle are faced with hotter than normal conditions e.g. heat waves.

The overall change in body temperature, the rate of change and magnitude of change during heat waves suggests a disruption to body temperature regulation. The importance Although limited by numbers there are some interesting findings for the *Bos indicus* steers in this study. Overall they showed considerable variation in terms of heat gain/loss (see Figure 12). As far as can be determined this has not been previously reported.

The rate of body heat gain of the *Bos taurus* steers was typically characterised by a fairly rapid but variable increase in body temperature. For example at Feedlot A body temperature increased by 0.13 °C/h over 3 hours (maximum gain) but the overall increase was 0.09 °C/h over 7 hours. Heat loss (possibly we could say it is a reduction in heat gain as well as heat loss – this is an area that needs further clarification) is typically of longer duration. Again this has implications as to how the accumulated heat load is calculated.

5.2 Feeding Activity

One of the aims of the current study was to develop feeding strategies which may help to ameliorate some of the effects of high heat load. The observational data suggests that irrespective of feeding time cattle will on hot days and during heat waves (although to a lesser extent) self-regulate feed intake. The main finding was that cattle would commence eating as soon as ambient conditions abated. Often there is a small but significant increase in body temperature around 2100 to 2200 h. We postulate that this is due to the fermentation of feedstuffs consumed earlier. This is only likely to be a problem if it restrict the ability of cattle to dissipate heat at night. The cattle at Feedlot C (Figure 17) were under high heat load during the day and moderate heat load at night. Body temperatures remained elevated throughout the study period. These cattle tended to eat about 2100 h on hot days. Whether or not this was a contributing factor to the rise in body temperature from 0100 h is not known.

At this stage there is not a definitive answer in this area. Encouraging cattle to eat during the afternoon especially when it is hot will be difficult, if not impossible.

5.3 Strategic Use of Bedding

This part of the study was not successful. There were a number of logistical and climatic issues which could not be overcome.

6 Conclusions/recommendations

6.1 Conclusions

- Increase heat load (e.g. heat waves) leads to an apparent disruption to the heat/gain ability in both *Bos taurus* and *Bos indicus* steers.
- The pattern of heat gain/loss is not uniform through the day or at night.
- On average, over summer the *Bos taurus* steers gained heat at 0.09 ^{o}C/h (over 7 h), and lost heat at 0.04 ^{o}C/h (over 17 h). Thus heat loss is some 44% slower than heat gain. Maximum heat gain (0.13 ^{o}C/h) occurred between 0800 and 1100 h. This demonstrates the importance of nightime cooling.
- The similarity in mean body temperature between the *Bos taurus* and *Bos indicus* steers Is not something that has been previously observed.
- On average, over summer there was very little change in the body temperature of *Bos indicus* steers.
- Time of feeding is important – however cattle will self-regulate and the consumption of feed and associated activity appears to lead to a small but significant increase in body temperature eat night.
- The data is somewhat limited but it appears that once HLI drops below 90 to 95 (there are other factors which make a precise value difficult to define), and it appears to change somewhat from day to day. It also appears that body temperature is the main driver, not so much the magnitude but whether or not body temperature is falling.

6.2 Recommendations

7. Determine how the observed changes in body heat/gain will influence the calculation of the accumulated heat load. Adapt the model as required.
8. Further investigate the body temperature profiles of *Bos indicus* cattle.
9. Evaluate the body temperature data form FLOT.0157 to further investigate changes in body heat/gain. Data is available from climate rooms as well as outdoor feedlot pens.
10. Further investigate how body heat/gain is affected by heat waves.
11. In regards to conclusion 2 – need to determine if the slow release of heat at night can be speeded up to ensure optimal body temperature as cattle enter a new day.
12. In regards to conclusion 4 - biologically we are not sure what this means but it needs further investigation

7 Key messages

From this study we have a better understanding of the dynamics of body heat gain/loss during periods of hot weather. This will help in the development of a more robust calculation of accumulated heat load, and will allow development of management strategies to enhance heat loss from feedlot cattle.

8 Appendix

The Appendix material will be sent as a separate document