MEAT & LIVESTOCK AUSTRALIA

On farm

Refinement of the Heat Load Index Based on Animal Factors

Project number FLOT. 319
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Feedlots

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ABSTRACT

This report details the results of a study investigating the panting scores, feed intake and behavioural responses of *Bos taurus* (Angus, Murray Grey, Hereford) and *Bos indicus* (Droughtmaster and Brahman) and *Bos taurus x Bos indicus* cross cattle in two Queensland feedlots from January to March 2003. Shaded and un-shaded cattle were observed at each feedlot.

The cattle responses to hot climatic conditions were used to refine the heat load index (HLI) (FLOT.316), by incorporating genotype and behavioural effects. New HLI threshold values were established, and the importance of accumulative heat load (HLI-Hours) confirmed.

Genotype differences within the *Bos taurus* cattle were recorded but it was not clear if the results were due to genotype, coat colour or a genotype by coat colour interaction.

Variations in feedlot design, location and aspect lead to some confounding behavioural observations especially in un-shaded pens.

EXECUTIVE SUMMARY

INTRODUCTION

In Australia climatic conditions will sometimes impact on the performance and welfare of feedlot cattle. High ambient temperature, relative humidity, solar load and low wind speed can result in production losses and in extreme cases death. In order to cope with environmental stressors, cattle can within limits adjust physiologically and behaviorally to cope with the stressors.

Livestock managers need to recognize these responses and use them as an aid in combination with the heat load index and panting scores. Managers can then make informed decisions on when to use heat stress reduction strategies in an effort to minimise production losses.

The assessment of the heat load status of cattle is difficult. Managers have tools such as the heat load index, the accumulated heat load index and panting scores to assess the impact of climate changes on their animals.

By using a combination of local climatic conditions and animal responses to the climate (e.g. panting scores and animal behaviour) feedlot management will be well placed to implement strategies to reduce the impact of severe hot weather conditions on their cattle.

However, changes in livestock behavioural due to prevailing weather conditions are not well understood. In addition, behavioural of cattle with access to shade have not been fully studied.

(i) Objectives

The objectives of this study were:

1. To refine the HLI (FLOT.316) by the incorporation of appropriately weighted animal factors.

2. Further refine the HLI-hours concept using the weighted animal factors.

3. To identify behavioural patterns of cattle that could be used by feedlot personnel to better manage heat load of cattle.

(ii) Brief Methodology

The project studied cattle behaviour responses of cattle exposed to hot conditions at two Queensland feedlots between January and March 2003.

Feedlot A – The feedlot has a capacity of 18,000 head. The average stocking density of the study pens was 16.87 m^2/head. Two shaded and 2 un-shaded pens were observed.

Feedlot B – The feedlot has a capacity of 10,000 head, with a pen size of approximately 3000 m^2. The average stocking density of the study pens was 20 m^2/head. Three un-shaded pens were observed.

The climatic data was recorded by weather stations located at each feedlot. Cattle were observed three times a day to determine behaviour (standing, laying, eating or drinking), location in pen (at water trough, at feed bunk, in shade), and panting scores.

The major conclusions from this study are:

- The revised HLI is a suitable index for assessing the heat load status of cattle. HLI = 34.1 + (0.26 x RH) + (1.33 x BGT) - $(0.82 \times WS)^{0.1}$ - Log(0.4 x (0.0001 + WS^2))
- HLI-hours can be used to assess heat load status. Cattle (*Bos taurus* ~ black or grey coat colour, CS >3) exposed to more than 15 HLI-hours will be under extreme heat load.
- Due to micro-climate and management differences between feedlots behaviours such as standing, lying, eating, drinking and location in pen can not be quantified as indicators of heat load.
- Panting score remains the best visual tool for assessing heat load.
- Body condition score appears to be more important in terms of susceptibility to heat than days on feed or coat colour.
- Thresholds values have been revised taking BCS and coat colour into account.
- The best times to assess heat load on feedlot cattle are at 0600 h, 1500 h and 1800 h.

The major recommendations from this study are:

- Feedlot managers use the HLI, HLI-Hours in conjunction with Panting Scores to assess the heat load status of cattle.
- Cattle should be visually monitored daily at approximately 0600 h (or prior to morning feed), and again at 1500 h and 1800 h when HLI exceeds 84 units or HLI-hours is approaching or has exceeded 10 hours.
- HLI-hours should be used as a management tool for assessment of heat load. Strategies to alleviate heat load will need to be considered where HLI-hours exceeds 15 hours and little or no night-time relief is likely.

INTRODUCTION

1.1 Project Background

Over the summer 2001/2002 the MLA funded project FLOT.316 developed a photo guide for panting score, and a new Heat Load Index (HLI) for use by the Australian feedlot industry. This index incorporated wind speed, solar radiation, ambient temperature and relative humidity into a single index. The previous index ~ temperature humidity index (THI) did not take into account solar radiation or wind speed. Therefore it was possible that the impact of heat load on cattle could be over or underestimated.

While the new HLI is an improvement over THI there is a need for further refinement of the index based upon animal factors. These factors include:

- Genotype (breed) ~ % *Bos indicus*
- Coat colour ~ black vs. red vs. white
- Coat type
- Days on feed ~ 70 – 100 d vs. 250 d
- Degree of finish
- Health status
- Body temperature
- Respiration rate

Stocking density, pen aspect and access to shade will also impact on the animal. In the current study only the shade or no shade aspect was specifically investigated.

Management factors will also play a role, e.g. time of feeding, types of ingredients used and heat load alleviation strategies. These were not investigated as part of this study.

1.2 Project Objectives

- To refine the HLI (FLOT.316) by the incorporation of appropriately weighted animal factors.

- Further refine the HLI-hours concept using the weighted animal factors.

- To identify behavioural patterns of cattle that could be used by feedlot personnel to better manage heat load of cattle.

2.0 METHODOLOGY

2.1 Study Feedlots

The project studied the response of cattle to climatic conditions at two Queensland feedlots from the 8th January to 27th March 2003. The feedlots are designated by letter, namely Feedlot A and Feedlot B.

Feedlot A – The feedlot has a capacity of approximately 18,000 head. The average stocking density of the study pens was 16.87 m^2/head. Four pens were used in the study, 2 shaded ~ 180 and 133 head/pen; 2 unshaded ~ 117 and 155 head/pen)

Pen 1 and 2 were un-shaded and had an area of 2984 m^2 each. The feed bunk in each pen was 49 m long. Each pen had one float-activated water trough.

Pen 3 and 4 were shaded and had an area of 2010 m^2 each. The feed bunk in each pen was 33 m long. Each pen had one float-activated water trough. The shade structure covered an area of approximately 430 m^2.

Feedlot B –The feedlot has a capacity of approximately 10,000 head, with a pen size of approximately 3000 m^2. The average stocking density of the three study pens was 17.6 m^2/head.

The pen sizes, stocking rates, bunk space, water trough space, shade design and area under shade were not standardized between the feedlots, and there were differences in the type of ration fed (e.g. feedlot B used a summer ration), the ingredients used and feeding times. Commercial in confidence prevents detailed description of diets used, in general the DM = 70 % and ME = 14 MJ/kg, DM.

2.1.1 Areas and Shade Structures

The shade structure used at Feedlot was as follows.

- Feedlot A – Permanent 13 m wide x 4.5 m tall shade structures composed of galvanized iron sheets. The sheets were placed to give approximately 5.4 m^2 of shade interspaced by a 0.5 m gap. The shade structure ran the length of the pen.
- Feedlot B – Permanent galvanised shade structure 15 m wide with a maximum height of 5.4 m and a minimum height of 4.8 m. The roof of the structure is angled with approximately 5° with the low side to the west The Shade structure is composed of galvanised iron sheets placed to give approximately 5.4 m^2 of shade interspaced by about the same area gap.

Differences in the stocking rates between the two feedlots are summarized in Table 2.1.

Table 2.1 Pen and shade areas in the four feedlots studied.

	Head/pen (#)	Pen Area (m^2)	Stocking Rate (m^2/head)	Shade Area (m^2)	Shade/head (m^2/head)
A Un-shaded	136	2984	21.9	**-**	**-**
	198	2984	15.0	**-**	**-**
A Shaded	126	2010	16.0	429	3.4
	131	2010	15.3	429	3.3
B Un-shaded	194	3000	15.4	-	-
	174	3000	17.2	-	-
	149	3000	20.1	-	-
B Shaded	180	3000	16.7	370	2.1

2.2 Project Duration

The field study ran from the 1st January to 30th March 2003. Data collection was carried out at Feedlot A – 0600 and 1600 hours (Eastern Standard Time) each day from 8th Jan until the 23rd Feb 2003 (46 days), and at Feedlot B – 0600 and 1500 hours (Eastern Standard Time) each day from 9th Jan 2002 until 26th March 2003 (76 days).

In addition data was also collected every 2 hours on 25 days at Feedlot A. The collection days correspond to days when excessive heat load was anticipated, based on the Katestone proprietary web-based forecast of the HLI for that region.

At Feedlot B data was also collected every 2 hours on 11 days. The collection days correspond to days when excessive heat load was anticipated, again based on the Katestone proprietary forecast of HLI for that region.

2.3 Animal Data Collected

Respiration rate and panting score were assessed three times each day (0600, 1200 and 1800 h). Feed intake was recorded daily on a pen basis.

On days where the HLI was predicted to exceed 79 respiration rate and panting scores and location of cattle in the pen were recorded at 2 h intervals.

At Feedlot B body surface temperature was measured at 1400 h on 37 occasions

Four video cameras were placed in one shaded pen at Feedlot A and the information was stored in a time-lapse recorder from the 3rd January to the 10th February 2003.

The genotype, coat colour, expected days on feed, body condition score and/or live weight were recorded at the start of the study, and the number per pen (done daily to keep track of pulls) were recorded throughout the study.

Each day at the times outlined in Section 2.2 the number of cattle at the feedbunk, at the water trough, standing or laying under shade (shaded pens) or standing or laying in sun were recorded. Standing was defined as the upright posture and lying was defined as body contact with pen surface.

Cattle were determined to be at the water trough when their head was over or in the water trough even if they were not drinking and when they were within two metres of the water trough and facing it. Cattle were determined to be at the feed bunk when their head was over or in the feed bunk even if they were not eating or when they were within one metre of the feed bunk and facing it. Daily feed intake was also recorded, and average dry matter intake determined.

Any specific abnormal behaviour patterns (e.g. milling around, bunching, water splashing) were noted.

In addition panting scores (PS) were recorded. The PS's were determined with reference to the photo guide developed and provided to each feedlot (see FLOT.316). The number of animals in a pen with panting scores of 0 to 4.5 was determined by counting cattle at the times outlined above for each feedlot (Table 2.2).

A total of 1329 observations were made (639 at Feedlot A and 690 at Feedlot B).

Additional data collected at Feedlots A and B involved the mapping of the distribution of cattle within a pen. Pen ambient temperature, relative humidity, wind speed, pen surface temperature and cloud cover were also measured.

Table 2.2. The panting scores for observed breathing condition.

Breathing Condition	Panting Score
No panting.	0
Slight panting, mouth closed, no drool or foam.	1
Fast panting, drool or foam present.	2
As for 2 but with occasional open mouth.	2.5
Open mouth + some drooling, neck extended and head usually up.	3
As for three but with tongue out slightly.	3.5
Open mouth tongue out + drooling Neck extended and head up.	4
As for 4 but head held down.	4.5

2.4 Weather Data

Climatic data **–** ambient temperature, relative humidity, air speed, solar radiation and black globe temperature were collected at each feedlot via an automatic weather station (Table 2.3). Rainfall data was also collected. The data from the weather station will be used to further test the robustness of the Heat Load Index (HLI) developed as part of FLOT.316.

Table 2.3 Interval and periods of collection for weather data at Feedlots A and B.

Interval	Feedlot A		Feedlot B*	
	From	To	From	To
10 min.	7 Feb 10:20	12 Feb 12:20	3 Jan 0:00	27 Feb 7:00
	16 Mar 3:40	16 Mar 18:40	1 Mar 11:00	21 Mar 17:00
Every hour	27 Jan 19:00	12 Feb 17:00	As above	As above
	5 Mar 13:00	21 Mar 11:00		
Daily	3 Jan	21 Mar	3 Jan	20 Mar

* Black Globe Temperature was recorded from 1 March 2003 to 20 March 2003.

Solar radiation was recorded on Feedlot A during the periods shown in Table 2.3. The weather data was downloaded at the end of the study.

Where weather data was missing information from nearby weather stations were used.

2.5 Heat Load Index

The following Heat Load Index (HLI) was used:

Heat Load Index = 33.2 + (0.24 x RH) – (0.62 x Ws) + (1.2 x BGT)

RH = relative humidity (%)
Ws = wind speed (m/s)
BGT = black globe temperature (^{o}C)

2.6 HLI-hours (Accumulative Heat Load)

The accumulative time of exposure to high thermal loads is crucial to determining the thermal status and well-being of cattle. Hence the accumulative heat load (AHL) for HLI was determined and is expressed as HLI-hours, which is the number of hours above or below set HLI thresholds.

The thresholds used in this study where 79 and 84 HLI units. When cattle are exposed to a HLI above 84 they will “absorb” heat, and when below 79 dissipate heat. The range between 79 and 84 is considered a transition zone, and for this study it was assumed that no heat would be gained or lost while exposed to a HLI within this range.

The threshold values are determined on the basis of the animals vulnerability to high heat load. The upper HLI threshold for this study was determined on the basis of previous studies that have shown *Bos taurus* cattle exposed to HLI >84 demonstrate an increase in respiration rate (to levels above 90 breaths per minute).

2.7 Calculating the Accumulative Heat Load

The calculation of accumulated heat load as HLI-hours has been previously described in FLOT.316 (MLA, 2002).

2.8 Definition of Thermoneutral, hot and very hot days

A thermoneutral days were defined as days when HLI < 74, hot days when 74 < HLI >78, and very hot days when HLI > 79. A day ran from 0600 h to 1700 h, which was basically the observational period.

Within each day the effects of a cool hour or hot hour were also examined. The purpose of this was to determine the effect of a cool hour within a hot day i.e. where the mean HLI over a 1 h period was below 74, but the daily mean HLI was greater than 79. Conversely the effect of a hot hour in a thermoneutral day were also examined.

2.9 Statistical analysis

For the behavioural data differences among locations were determined using the mixed procedure in SAS (1996). The model included effects of shade nested into location, hour HLI level nested into day HLI level, and day HLI level as covariates with pen as the experimental unit

The percentage of cattle recorded for each behaviour was transformed to a normalized distribution using squared root-arcsine transformation. The transformed data was then analysed using all observations (All Times), observations between 0550 h and 0700 h (0600 h) and observations between 1450 h and 1600 h (1500 h). In each case data were analysed as a complete random design.

3.0 RESULTS

3.1 Climatic Data

The climatic data over the study period, 8th January – 27th of March 2003 is summarised in Table 3.1.

Table 3.1. Climatic ranges and means (± s.d) for un-shaded pens during the study period

	Feedlots	
Variable	A	B
Days	80	78
T_a (°C)	11.8 – 39.7 (24.5 ± 2.5)	11.5 – 37.3 (22.8 ± 2.1)
BG (°C)	9.5 – 51.5 (26.7 ± 3.0)	17.5 – 34.2 [B] (27.5 ± 3.3)
Average day SR (W/m^2)	52.9 – 411.0	NA
WS (ms^{-1})	0 – 10.8 (2.6 ± 0.7)	0 – 58.7 (10.2 ± 3.3)
RH (%)	13 – 100.0 (65.2 ±13.2)	20.6 – 100.0 (68.2 ± 11.0)
Average day THI	63.9 – 80.1 (72.6 ±2.8)	63.2 – 76.5 (70.3 ± 2.7)
Average HLI	63.2 – 83.0 (71.3 ± 4.2)	[B] 61.4 – 80.2 (70.4 ± 3.9)
Days[A] HLI <74 (Thermoneutral)	62	71
Days[A] 74>HLI<78 (HOT)	10	13
Days[A] HLI>78 (VERY HOT)	8	2

[A] day average HLI was used. [B] due to missing data, some values were calculated . 86 days were taken into account.

3.1.1 Heat Load Index Hours

HLI-Hours was calculated for a number of days over the summer months. Cattle panting scores and respiration rates were used to assess the reliability of the HLI-hours, and to develop thresholds. From these data it was determined that an accumulated heat load of 15 hours would be putting black *Bos taurus* cattle under extreme heat load. Five and a half days of data are presented in Figure 3.1. During this period, accumulated heat load returned to zero on the first three nights and close to zero on the fourth night. Even though HLI-Hours were greater than 20 on the first three days and over 40 on day four the cattle had adequate night–time relief. However, on the night of day 5 the cattle did not have adequate night relief, and entered day 6 with a carry over heat load. On day 6 extreme climatic conditions plus the carry over heat load induced severe heat stress on the cattle.

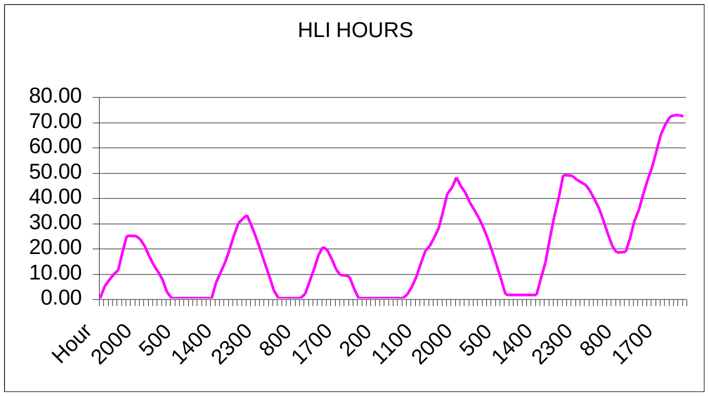

Figure 3.1 Accumulated HLI-Hours over a five and a half day period.

3.2 Panting Scores

High heat load days are defined as those days when some cattle exhibit a panting score (PS) greater than zero (Table 3.2), and/or respiration rate greater than 80. During the study the number of cattle with a PS > 0 was generally low. However, more cattle exhibited a PS > 0 in the un-shaded pens then in the shaded pens.

- Feedlot A - Shaded cattle – (52 days of study only). On 39 days PS's greater than 0 were observed, on 19 days PS 2's were observed, on 7 days PS 2.5's were observed, on 2 days PS 3's were observed and on 9 days PS 3.5's were observed. No PS 4's or PS 4.5's were observed.

  - Un-shaded cattle – (52 days of study only). On 40 days PS's greater than 0 were observed, on 29 days PS 2's were observed, on 10 days each PS2.5's and PS3 's were observed, on 12 days PS3.5 were observed and on 3 days PS 4's were observed. No PS 4.5 were observed.

- Feedlot B - Shaded cattle (77 days of study only). On 30 days PS's greater than 0 were observed. On 29 of these days cattle with PS 1's were observed, for 22 days PS 2's were observed, for 12 days PS 2.5 were observed and for 3 days only PS 3 were observed. No PS 3.5, PS 4, or PS 4.5 were observed.

  - Un-shaded cattle (77 days of study). On 40 days PS's greater than 0 were observed. On 27 days PS 2's were observed, on 18 days PS 2.5's were observed, on 5 days PS 3's were observed and on 1 day only PS 3.5's was observed. No PS 4's or PS 4.5's were observed.

Table 3.2. The number of observations and their cumulative total (%) with panting scores of either 0, 1, 2, 3 or 4 for each feedlot over the study period.

	PS 0	PS 1	PS 2	PS 2.5	PS 3	PS 3.5	PS 4	PS 4.5
A Shaded	**41977 (95.0)**	**2044 (4.7%)**	**127 (0.3%)**	**13**	**2**	**12**	**0**	**0**
A Un-shaded	43211 (91.8)	3348 (7.1%)	318 (0.7%)	60 (0.1%)	44 (0.1%)	34 (0.1%)	4	1
B Shaded	**18880 (83.9%)**	**2963 (13.2%)**	**595 (2.6%)**	**56 (0.3%)**	**6**	**0**	**0**	**0**
B Un-shaded	59410 (91.2%)	3612 (5.6%)	1688 (2.6%)	340 (0.5%)	38 (0.1%)	1	0	0

3.3 Cattle Behaviour

3.3.1 Behavioural pattern differences among feedlots

There were differences (P<0.05) between the feedlots for the observed behavioural traits. These differences are shown for each behavioural pattern.

3.3.1.1 Standing behaviour

At 0600 h the number of cattle standing was greater (P<0.05) in both the shaded and un-shaded pens at Feedlot A than in the shaded and un-shaded pens at Feedlot B. However, there were no differences between shaded and un-shaded pens within a feedlot.

At 1500 h the number of cattle standing was greater (P<0.05) in the shaded pens at Feedlot B than in the un-shaded pens at Feedlot A, and also greater in unshaded pens than in unshaded pens of Feedlot A.

Thus a greater number of cattle were observed standing at Feedlot B at 1500 h than in Feedlot A, irrespective of whether they had access to shade or not.

3.3.1.2 Standing at the water trough

At all observation times, the number of cattle standing at the water through was greater (P<0.05) in un-shaded pens at Feedlot B than in any other pen type of both feedlots. At 0600 h more cattle were standing at the water trough in un-shaded pen at Feedlot B than in shaded pens. Conversely more (P<0.05) cattle were standing at the water trough in the shaded pens at Feedlot A than in un-shaded pens at 0600 h.

At 1500 h more cattle were standing at the water trough in the un-shaded pens of Feedlot B than in any other pens irrespective the location or pen type. Again, as seen for 0600 h, a reverse situation was seen at Feedlot A were more cattle from the shaded pens were standing at the water trough.

At both 0600 h and 1500 h cattle in the un-shaded pen at Feedlot B had a greater ($P<0.05$) proportion of cattle at the water trough when compared to the shaded pens at both feedlots. There were no differences between the un-shaded pens at either feedlot.

3.3.1.3 Lying at the water trough

At both 0600 h and 1500 h the number of cattle lying at the water trough was greater in the un-shaded pen at Feedlot B than in the shaded pens. However, fewer cattle were lying at the water trough in the un-shaded pens at Feedlot A at 1500 h than at 0600 h.

3.3.1.4 Standing or lying at the feed bunk

The number of cattle standing or lying at the feed bunks were not influenced by feedlot.

3.3.1.5 Standing or lying under the shade

At all observation times proportionally more ($P<0.05$) cattle were standing in the shade at Feedlot A. There were no differences ($P>0.05$) between feedlots for laying in the shade.

3.3.1.6 Standing in the sun

In general proportionally more cattle (shaded and un-shaded) were observed standing in the sun at 0600 h and at 1500 h at Feedlot A than at Feedlot B. As expected, cattle without access to shade spent more time standing than those with access to shade. There were differences between feedlots with a greater ($P<0.05$) proportion of cattle in the un-shaded pens standing at 0600 h at Feedlot A then at Feedlot B.

At Feedlot A in the shaded pens a greater ($P<0.05$) proportion of cattle were standing in the sun at 1500 h than at Feedlot B. At the same time there were no differences between feedlots for standing behaviour in the un-shaded pens.

3.3.2 Behavioural pattern differences between feedlots

Due to the behavioural differences described above it was necessary to determine relationships between cattle behaviour and weather data at each feedlot, rather than a combination of data from both.

This section examines differences in cattle behaviour between the two feedlots, using climatic variables, specifically daily and hourly HLI values using a pen as a covariate.

FEEDLOT A

3.3.2.1Standing behaviour

A greater (P<0.05) proportion of cattle were observed standing during the cool hours of Hot days than during hot hours of Hot (H) or Very Hot (VH) days. During cool hours of Thermoneutral days (TN) a greater (P<0.05) number of cattle were standing than during hot hours of H or VH days, or during very hot hours of TN or VH days. There were no differences in un-shaded pens.

3.3.2.2 Standing at the water trough

At all observations a higher proportion of animals were standing at the water trough in very hot hours of H or TN days and in hot hours of TH days than in cool hours of TN days.

In the un-shaded pens a higher proportion of animals were standing in the very hot hours of H days and in hot hours of TN days than in cool hours of TN or H days. When compared to the shaded pens, cattle in the un-shaded pens spent more time standing at the water trough during the hot hours of TN days and the very hot hours of H days.

Overall, at 0600 h and at 1500 h more (P<0.05) of the cattle in the shaded pens were standing at the water trough than in the un-shaded pens. This pattern of behaviour was particularly seen at 1500 h during hot hours of H days and during hot and very hot hours of TN days.

3.3.2.3 Lying at the Water trough

Lying at the water trough did not appear to be influenced by climatic conditions.

3.3.2.4 Standing or lying at the feed bunk

At all observation times on cool days more cattle were standing at the feed bunk on VH than on H days. In the shaded pens on TN days a greater proportion of cattle were standing at the feed bunk than in the un-shaded pens on VH days.

Observations at 0600 h showed that a higher proportion of cattle in un-shaded pens were standing at the feed bunk on H days than on TN days.

At 1500 h on during very hot hours, and on TN days a greater (P<0.05) proportion of cattle in the shaded pens would be standing at the feed bunk than in the un-shaded pens.

Mean daily HLI level did not appear to affect this behaviour.

3.3.2.5 Standing or lying under the shade

At all times more animals were laying in the shade on H and VH days than on TN days. This behaviour was largely influenced by hourly HLI values. During hot hours of H or VH days and during very hot hours of VH days more (P<0.05) cattle would be laying in the shade than during cool hours of any day type. Overall, more cattle were in the shade at 1500 h during H days rather than TN days.

3.3.2.6 Standing or lying in the sun

In the shaded pens more cattle were observed standing in the sun during cool hours of any day type. However, the trend was to stand in the shade on H and VH days even if the hourly HLI value was below 74.

In the un-shaded pens a higher proportion of cattle were standing in the sun during cool hours of hot days than during cool hours of hot and very hot hours of H days.

Observations at 1500 h found a higher proportion of cattle in un-shaded pens standing in the sun during hot hours of TN days than during hot hours of VH days. In the shaded pens, a lower proportion of animals were standing in the sun during very hot hours of VH days when compared to any hour type of the TN days.

Generally more cattle would be lying in the sun on TN days than on H or VH days, but the differences were not significant on a day level.

FEEDLOT B

3.3.3.1 Standing behaviour

In both the shaded and un-shaded pens standing behaviour was influenced by increasing HLI, i.e. more cattle would stand as HLI increased. However, there were no differences in numbers standing between H and VH days. During H and VH days proportionally ($P<0.05$) more cattle would be standing in the un-shaded pens than in the shaded pens.

In general hourly climatic values were more important in terms of their impact on behaviour than the daily means. Across all observation times more ($P<0.05$) cattle would be standing during hot hours of H days than during cool hours of TN days or during cool hours of VH days. A similar result was seen for standing behaviour during hot hours of TN days, and very hot hours of TN days.

In the un-shaded pens more animals were standing during hot hours of TN days than during the cool hours of TN days. When exposed to hot hours during a H day a greater proportion of cattle would be standing than when exposed to hot or cool hours of TN days. This proportion of animals was also significantly higher when compared against shaded pens in cool hours of TN or VH days and hot hours of TN days.

3.3.3.2 Standing at the water trough

More ($P<0.05$) cattle were standing at the water trough on H days, and when exposed to hot hours during a H day the numbers increase ($P<0.05$) further. A greater number of cattle were observed standing in the un-shaded pen during hot hours of H days than in the shaded pens.

The number of cattle standing at the water trough at 0600 h in un-shaded pens could serve as an indicator that the day will be hot. The number of cattle at the water trough at 0600 h were higher (P<0.05) on days that turned out to be hot.

At 1500 h the number of cattle at the water trough was greater (P<0.05) in unshaded pens than in shaded pens irrespective of the mean daily HLI level.

More cattle were observed standing at the water trough in shaded pens on H days than on TN days. However, on VH days there were generally less cattle at the water trough than on H days, possibly because they preferred to stay in the shade. On an hourly basis, the number at the water trough was greater during hot hours of H days than during cool or hot hours of TN days.

Hourly HLI levels had a major influence on this behaviour. Cattle in un-shaded pens during hot or very hot hours on a H day, and during cool hours on a VH day were found in greater (P<0.05) numbers at the water trough than under any other combinations.

3.3.3.3 Lying at the water trough

This behaviour for cattle in un-shaded pens was primarily a function of HLI levels. The number of cattle lying at the water trough was greater (P<0.05) during very hot hours of H days than during hot or cool hours of TN days.

In both shaded and un-shaded pens more cattle would be laying at the water trough at 1500 h during H days. When hourly HLI values were considered a greater (P<0.05) proportion of cattle were lying at the water trough in shaded pens than in un-shaded pens during very hot hours of H days.

3.3.3.4 Standing or Lying at the feed bunk

In general more (P<0.05) of the shaded cattle were observed standing at the feed bunk on TN days than on H days. At 1500 h a greater proportion of cattle were standing at the feed bunk during hot hours than in very hot hours of TN days. On VH days there were fewer shaded cattle were at the feed bunk at any given time when compared to TN and H days. However, this was a function of hourly HLI values, with a greater proportion of cattle standing at the feed bunk during hot hours of TN days.

In the shaded pens more (P<0.05) cattle were standing at the feed bunk during hot hours of TN days. In the un-shaded pens more (P<0.05) cattle were observed standing at the feed bunk during cool hours of H days.

In the un-shaded pens a greater (P<0.05) proportion of cattle were lying at the feed bunk on H days than in shaded pens.

Hourly HLI values influenced the number of cattle laying at the feed bunk. More (P<0.05) cattle would be lying at the feed bunk during very hot hours of H days than during hot or cool hours of TN days. Generally a greater number would by lying at the feed bunk at 1500 h on H days than on TN days. This was influenced by pen, with more cattle in the shaded pens lying at the feed bunk at 1500 h. Again there was an hourly HLI value affect. In the shaded pens cattle were observed at the feed bunk when hourly HLI values were hot or very hot but only on H days. No hourly effects were seen in the un-shaded pens.

3.3.3.5 Standing or lying under the shade

The use of shade was not always a function of immediate climatic conditions. Observations taken at 0600 h showed that a greater number of cattle would be under shade on days that turned out to be H days than on days that turned out to be TN days, even though the climatic conditions at 0600 h for each day type were similar. Again, hourly HLI values were important. A greater proportion of cattle were standing in the shade during hot hours of TN days than during cool hours of TN days. When they were exposed to TN conditions fewer cattle would be under shade.

Shade seeking behaviour was not always predictable. Fewer cattle were under shade during cool hours of H days than during very hot hours of TN or H days. It would appear that when HLI exceeded 78 some cattle would move into the sun, possibly due to crowding under the shade structure.

3.3.3.6 Standing or lying under the sun

Standing in the sun is a function of immediate climatic conditions. Using HLI, the results also show that on cold hours of H days more cattle in both shaded and un-shaded pens stood in the sun than during hot or very hot hours of any day type.

The relationships between climatic conditions and cattle in the sun (standing or laying) are summarised below:

- More cattle stood in cool hours of TN days (shaded and un-shaded pens).
- More cattle stood in cool hours of H days (shaded and un-shaded pens).
- Fewer cattle stood during hot hours and very hot hours of H days.
- More cattle were standing in un-shaded pens on TN days than on H days.
- More cattle were standing in un-shaded pens during cool hours of TN days than during very hot hours of TN days and hot hours of H days

Table 3.3. The number and percentage[A] of cattle either standing or lying in the sun, standing or lying in the shade, at the water trough or at the feed bunk for observations three times daily.

Feedlot	Stand/ Sun	Stand/ Shade	Ly/Sun	Ly/Shade	Lying water	Water	Lying feed	Feed
A Shaded	**34 (26.5%)**	**37 (28.8%)**	**17 (13.5%)**	**3 (2.3%)**	**4 (2.9%)**	**3 (2.2%)**	**32 (25.3%)**	**27 (21.3%)**
A Un-shaded	99 (60.8%)	-	42 (26.4%)	-	1 (0.4%)	5 (3.1%)	0	15 (9.2%)
B Shaded	**46 (30.7%)**	**35 (23.4%)**	**32 (21.6%)**	**2 (1.3%)**	**3 (2.0%)**	**4 (2.9%)**	**34 (22.6%)**	**9 (5.8%)**
B Un-shaded	89 (52.2%)	-	51 (29.7%)	-	1 (0.5%)	6 (3.5%)	0 (0.1%)	22 (13.4%)

[A] The percentages are based on the average number of animals per pen.

3.4 New Heat Load Index

Using the heat load index developed in FLOT.316 as the starting point, a new index was developed. This new index was developed after consideration of animal factors such as coat colour, body condition scores, days on feed and genotype. Days on feed did not appear to have an impact on susceptibility to heat stress and was therefore not considered. Body condition score (BCS), coat colour and genotype did however have an impact on the animals' tolerance to heat. There may also be coat colour x genotype interactions, and coat colour x BCS interactions.

There were not enough white-coated cattle in the study to make any valid conclusions.

The new index developed primarily for black or grey *Bos taurus* cattle with a BCS < 3.5 is:

$$\mathbf{HLI = 34.1 + (0.26 \times RH) + (1.33 \times BGT) - (0.82 \times Ws)^{0.1} - Log(0.4 \times (0.0001 + Ws^2))}$$

Although the index is slightly different for red cattle, and for *Bos indicus* cattle irrespective of coat colour, the same index will be used. However, the threshold values will be different (see below). Acclimitization is a confounding factor. It is likely that cattle with some degree of heat acclimitization will have higher thresholds than similar non-acclimitized cattle.

3.5 Heat Load Index (HLI) Thresholds

The HLI thresholds developed in FLOT.316 have been refined (Table 3.4). The thresholds reflect the animals heat tolerance (see below).

Above the HLI threshold values cattle will have a net gain of body heat, and, below the HLI threshold values they will have a net loss of heat.

The thresholds are difficult to predict due to a large number of interacting factors influencing the animals response to a given climatic condition. It is therefore important that feedlot management use cattle observations (i.e. panting scores) in conjunction with the estimates shown below.

Table 3.4 Estimated HLI thresholds[A] for various classes of *Bos taurus* cattle with or without access to shade (up to 250 days on feed).

	HLI Threshold Values	
	Un-shaded	Shaded
Newly arrived < 2 weeks	74	74
Sick or recovering	73	73
Dark coated (black/dark red)	79	82
Light coated (white/grey)	82	85
Body condition score 3 – dark coat	79	82
Body condition score 3 – light coat	82	84
Body condition score 4 – dark coat	76	80
Body condition score 4 – light coat	78	82
No acclimitization	72	76
Acclimitized	84	88

[A] Lower thresholds may be appropriate for heifers (not spayed). when HGP's are used, type of shade structures and ration type will also influence the threshold.

Definition of heat tolerance: *Heat tolerance is defined by use of cattle parameters. Cattle exposed to similar micro-climatic conditions (e.g. in the same pen) are determined to have high or low heat tolerance based on panting score and respiration rate. For example, if PS > 2, and/or RR > 100 than these animals are deemed to have low heat tolerance. Cattle in same pen with PS <1 and/or RR < 80 are deemed to have high heat tolerance. This is a very subjected measure and further work will be needed to refine the definition of heat tolerance.*

3.6 Genotype Differences

The following genotypes were evaluated in the study: Hereford, Murray Grey, Angus, Angus x Charolais, Brahman, Droughtmaster, Brahman x Hereford, Brahman x Angus.

On H and VH days where cattle had access to shade, it was common to see the majority of *Bos taurus* cattle under the shade while the cattle with 25 –100 % *Bos indicus* content were in the sun. The *Bos indicus* cattle observed in this study rarely showed elevated respiration rates (maximum seen was 55 bpm), and PS >1 where not seen.

There were breed/genotype differences between the *Bos taurus* cattle. The differences in body surface temperature presented in Figure 3.2 are a reflection of coat colour rather than genotype. Differences in genotype performance and meat quality (Figure 3.3 & 3.4, Table 3.5, Figure 3.5) suggest that there are genotype differences. However, it is not clear from this study if these are true genotype differences or due to coat colour or coat colour x genotype interactions.

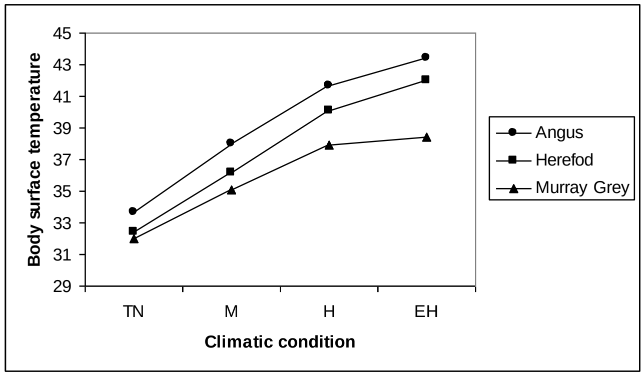

Figure 3.2 Body surface temperatures of three *Bos taurus* genotypes on thermoneutral (TN), mild (M), hot (H) and very hot (EH) days.

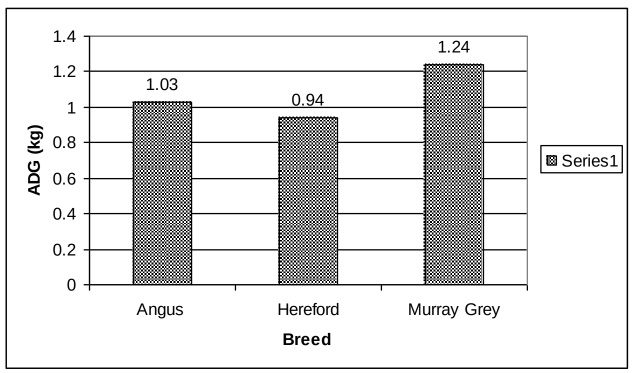

Figure 3.3 Average daily gain (ADG) of Angus, Hereford and Murray Grey cattle.

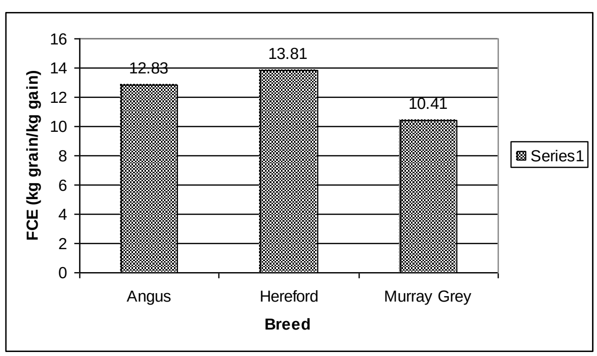

Figure 3.4 Feed conversion efficiency (FCE) of Angus, Hereford and Murray Grey cattle.

Table 3.5 Carcass characteristics (means ± s.e.) for Angus, Hereford and Murray Grey (160 – 175 days on feed).

Traits	Angus	Hereford	Murray Grey
Initial wt (kg)	436 ± 4.0[a]	427 ± 3.3[a]	386 ± 20.3[b]
Final wt (kg)	599 ± 7.44	592 ± 8.32	577 ± 20.3
HCW (kg)	359.7± 5.3	362.9 ± 3.6	338 ± 16.8
Dressing (%)	60 ± 0.7[a]	62 ±1 [a]	58 ± 1.4[b]
EMA (cm²)	79.6 ± 1	79.8 ± 0.8	78.1 ± 2.7
P8 fat (mm)	19.7 ± 0.7[a]	19.5 ± 0.6[a]	14.4 ± 1.1[b]
Marbling	1.6 ± 0.09	1.56 ± 0.07	1.52 ± 0.14

[a] P>0.05. [B] P<0.01

Non-significant differences in regard to meat colour were seen (Figure 3.5).

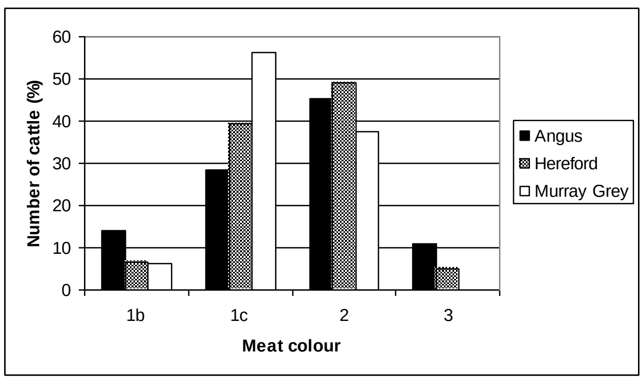

Figure 3.5. The frequency distribution of the AUSMEAT meat colour scores between Angus, Hereford and Murray Grey after 160 – 175 days on feed.

3.7 Body Condition Score

Body condition score (BCS) and an impact on cattle behaviour on H and VH days (Table 3.4). On VH days 80.1% of cattle with a BCS between 3 and 4 were standing, while only 22.8% of cattle with a BCS >3.0 were standing.

Table 3.6 Least square means (% observations) for behaviour of unshaded cattle with body condition scores of >3.0 or 3.0 – 4.0 very hot conditions.

	Body Condition Score		
Behaviour and Location	>3.0	3.0 – 4.0	
Standing at Feedbunk	0.6	0.5	NS
Standing at Water Trough	7.2	23.6	**
Standing Elsewhere	15	56	**
Lying at Feedbunk	1.6	0	NS
Lying at Water Trough	3.4	2.3	NS
Lying Elsewhere	72.2	17.6	**

NS = not significant, ** P<0.01

General Conclusions;

- There is considerable within breed/genotype variation. Within a breed/genotype cattle could have high or low heat tolerance.

- Although difficult to quantify because of the numbers involved it would appear that where cattle contain at least 25% *Bos indicus* they will have a high degree of heat tolerance compared to those with < 25% Bos indicus content.

- Black cattle with a white face appear to have lower heat tolerance (this is likely a genotype x coat colour effect) when compared to black faced black cattle.

- Murray Grey's appear to have better heat tolerance than Angus or Hereford.

- Dark red cattle appeared to have similar heat tolerance to black cattle. There where not enough light red cattle to make a valid comparison.

4.0 DISCUSSION

4.1 The New HLI

The major difference between the new HLI and the previous equation is a major correction for wind, and a slight adjustment for RH and BGT.

It was evident from previous studies and observations that wind has a positive effect on cattle (usually seen by reductions in respiration rate). Observations of cattle exposed to hot conditions in windy conditions suggest that the response is probably linear with wind speeds up to 3 m/s, and then plateaus. The new index takes this into account by incorporation of the items in bold.

$$HLI = 34.1 + (0.26 \times RH) + (1.33 \times BGT) \mathbf{- (0.82 \times Ws)^{0.1} - Log(0.4 \times (0.0001 + Ws^2))}$$

4.2 HLI-Hours

The use of HLI-Hours to assess heat load status is a very useful management tool. The accumulative effects of heat are more important than any spot HLI value. Therefore development of predictive models will need to incorporate HLI-Hours. More work is required to establish thresholds for accumulative heat.

4.3 Behavioural differences between feedlots

The behavioural differences of cattle exposed to similar macro-climatic conditions in different feedlots suggest that feedlot characteristics such as structures (e.g. shade and shade type), pen layout and aspect (e.g. does it slope to the west or east), management (e.g. feeding times, stocking rates) and micro-climate will have an influence on cattle behaviour. It is often claimed that hot cattle will stand more than cool cattle (Mitlöhner *et al.* 2001). However, results for total standing behaviour in the present study are not consistent with this claim. In Feedlot A for example, standing behaviour was more related to cool hours than to hot or very hot hours, however in Feedlot B standing was related, but not consistently to, hot or very hot hours within any day type. Behavioural differences suggest that these types of behaviours may not serve as useful indicators of heat load.

Heat stressed grain-fed cattle are also believed to increase drinking and body splashing (Mitlöhner *et al.* 2001), therefore it could be assumed that heat stressed cattle will spend more time standing or lying at the water trough. Using this assumption the cattle in the un-shaded pens of Feedlot B appeared to be more stressed than cattle in shaded pens at Feedlot B, and also in both shaded and un-shaded pens of Feedlot A. This may be a function of genotype, where some *Bos indicus* cattle were located in pens at Feedlot A. When only the Angus cattle were examined the differences between the feedlots were not evident.

On hot days the standing behaviour of cattle in un-shaded pens of Feedlot B may be a result of their attempts to “cool” down. Standing at the water trough may be done to ensure access to water, however drinking was not always associated with proximity to the trough. Cattle would often stand with their head over the trough. Standing at the feed bunk was not a suggestion that they were ready to eat but more likely it was shade seeking behaviour. Cattle would try to stand in what shade was being offered by the feed bunk, sometime lowering their head into the trough, again to seek shade. This type of behaviour was not seen in the un-shaded pens at Feedlot A, again this is probably a genotype effect where *Bos indicus* cattle were predominant.

Cattle will seek the most comfortable area in a pen. Where this is in a pen is dependant on the macro-climate, micro-climate, social interactions, pen aspect etc. In some cases cattle may “sense” the opportunity to cool down by standing. For instance if wind speed is high while at other times they will attempt to dissipate heat by laying on the ground, in shaded or on wet surfaces.

4.3.1 Social interactions

Using the feed bunk for shade may be affected by herd social interactions and individual characteristics of the pen. In shaded pens, cattle low in the hierarchy may be push from under the shade structure and away from the water trough and therefore move less comfortable locations to obtain shade. In un-shaded pens, cattle at the top of the hierarchy may use the water trough and feed bunk as shading structures.

4.3.2 Shade effects

In this study standing in the shade was influenced by the movement of the shade during the day and this is influenced by the orientation of the shade structure. The shade structure at Feedlot A had a northeast to southwest orientation while at Feedlot B the orientation was north to south. Shade structures will also vary in the amount of shade provided. For example at Feedlot A the gaps between galvanized iron sheets were smaller than at Feedlot B, therefore more sunlight was reaching the ground under the structure at Feedlot B than at Feedlot A. This could explain some of the behavioural differences seen between the two feedlots.

Shade may reduce the ability of cattle to acclimatize to hot conditions. Therefore behavioural responses during periods of high heat load may be difficult to predict. The cattle in the shaded pens at Feedlot A may be less adapted to high heat load conditions due to the protection given by the shade structure. This may in part explain why so many cattle were observed standing at the water trough and why there was not a difference between shaded and un-shaded pen behaviour at Feedlot A at 1500 h.

4.3.3 Other factors affecting animal behaviour

Standing in the shade results were not consistent, and contrary to expectations more cattle were often in the shade when it was cool. At Feedlot A for example when it was cool, and the feed bunk was empty cattle were standing under the shade waiting for feed, any truck that drove by the feed bunks resulted in a general movement towards the bunks to check for feed.

4.3.4 Behaviour as a tool to assess heat load

This present study suggests that some behavioural patterns can be used to assess heat load in feedlot cattle. However feedlot operators will need to determine which behaviour(s) can be used in their lot.

When cattle in the un-shaded pen at Feedlot B were studied, it was found that standing at the water trough was related to high HLI levels. However, the relationship between behaviour, the pen and the micro-climate is complex.

Assessment of heat load status in feedlot cattle with access to shade is difficult. This behaviour must be analysed taking in to account other factors such as movement of the shade, social interactions, feeding time and feed bunk scores.

4.4 Conclusions

The new HLI equation has been developed taking into account genotype differences and cattle behaviour in un-shaded pens. Due to the difficulty in drawing conclusions for shaded cattle data from shaded pens was not used in the new index. Factors such as respiration rate and panting scores will remain important criteria for assessment of cattle.

4.5. Success in meeting project objectives

The only problem in meeting the experimental objectives of the study was the lack of hot weather during the trial period. However, contractual problems resulted in a 6-week delay in finalising the project.

4.6. Impact on meat and livestock industry

Adoption of the new heat load index (HLI), the accumulative heat load model (HLI-Hours), panting scores, and threshold values by the Australian feedlot industry will improve summertime management of cattle. When incorporated with on site weather stations managers will be able to assess the cattle thermal load at approximately 0600 h (or earlier if desired), and again at 1500 h and 1800 h on days where HLI > 84, and in conjunction with weather conditions make decisions to implement heat load alleviation strategies.

These tools as well as the implementation strategies should be part of feedlot QA systems.

Use of these tools will not prevent cattle death. However, with these tools in place, and with adequate documentation individual feedlots should be able to show that in the case of feedlot deaths from high heat load that all reasonable steps were taken to manage the problem. (NB. Individual feedlots should develop and document their heat load alleviation strategies).

5.0 FUTURE RESEARCH

The following are areas were more work is need.

1. Further develop the HLI-Hours concept ~ what is the critical level.
2. How many animals with a PS > 2 constitute a problem? This is a welfare issue.
3. Effect of heat stress on meat quality.
4. Genotype and genotype x coat colour interactions.
5. Identification of heat tolerant animals.
6. Shade dynamics ~ may be a welfare issue.
7. There is still the question of what do we do. Ground wetting as a management tool?

A basic fundamental questions worth pursuing is:

1. Does an increase in RR and/or RT mean that cattle are coping with the heat load?

6.0 BIBLIOGRAPHY

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