final**report**

FEEDLOTS

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Assessment of varying allocations of shade area for feedlot cattle – Part 1 (120 days on feed)

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Abstract

A 120 d finisher feedlot study using 126 Angus heifers (BW = 350 ± 45 kg) was undertaken to determine the optimal shade area to alleviate heat stress. Four shade treatments (70% solar block) were used: no shade, 2.0, 3.3 and 4.7 m^2/animal. The shade was 4 m high with a north-south orientation. Cattle were randomly allocated to a pen (9/pen; 19.2 m^2/animal). Climatic conditions (ambient temperature, relative humidity (RH), black globe temperature (BG), wind speed (WS)) were recorded every 10 min.

From these data the heat load index and accumulated heat load units (AHLU) were determined. The HLI and the AHLU were combined to determine climatic stress: low stress: HLI<70; AHLU<1, moderate stress: HLI 70.1-77; AHLU 1-10, high stress: HLI 77.1-86; AHLU 20-50, and extreme stress: HLI>86; AHLU>50. Individual panting score were obtained every 2 h from 0600 to 1800. Treatment mean panting scores (MPS) were then determined. A MPS of 0 to 0.4 indicates no stress; 0.4 to 0.8 low stress; 0.8 to 1.2 high stress, and >1.2 extreme stress. Treatment differences were examined using repeated measures analysis. Within treatment MPS increased ($P < 0.01$) when climatic stress shifted from low to moderate. There were no between treatment differences. There were small changes in MPS between moderate and high climate stress, and larger increases ($P < 0.01$) between high and extreme. The MPS was greatest (MPS = 1.72; $P < 0.001$) in the un-shaded cattle under extreme conditions. There were no differences ($P > 0.05$) between the shaded treatments (MPS = 1.03) when climatic stress was extreme. The provision of shade reduced the effects of extreme climatic stress conditions.

There were no statistical differences in terms of carcass quality or carcass weight. However the mean carcass weight of the un-shaded cattle was 12 kg lighter than the mean for the 4.7m^2 group. The un-shaded cattle had a feed efficiency of 11:1 compared to approximately 8:1 for the shaded treatments.

Pen maintenance was greater for the 4.7 m^2 treatment cv to all other treatments because less of the ground under the 4.7 m^2 shade was exposed to sun. Largely due to holes and manure build up on the pen surface under the shade.

Executive Summary

The objectives of this project were to:

- Provide a scientific basis for shade usage for feedlot cattle through: (i) studying the impact of the provision of various shade area (m^2/animal) on production and welfare of feedlot cattle, and (ii) develop firm recommendations on the amount of shade needed to achieve the desired animal welfare outcomes, and production benefits, if they exist, in a cost-effective manner, and
- Make recommendations, based on both a review of the scientific literature and the study outcomes, on changes required to the thresholds for the various shade areas used in the Risk Analysis Program (RAP).

The study was conducted between the 23 December 2006 and the 30 April 2007 using 126 Angus heifers (350 kg at induction). The heifers were on feed for 119 days. Four shade areas were used: 0.0, 2.0, 3.3 and 4.7 m^2/animal (the shade area represents the amount of shade available at 1200 h (EST). The following data were collected:

Climatic data:

- Ambient temperature (°C)
- Relative humidity (RH; %)
- Wind speed (WS; m/s)
- Wind direction
- Solar radiation (w/m^2)
- Black globe temperature in the sun (BG; ^{o}C)
- Black globe temperature under shade in pen 6 (BG; ^{o}C)
- Rainfall (mm)

From these data the heat load index (HLI) and the accumulated heat load units (AHLU) were calculated. The relationships between the animal data (see below) and the HLI/AHLU were determined by categorizing the HLI and AHLU. The HLI was divided to 4 categories: (1) Cool, (2) Moderate (3) Hot and (4) Very Hot. The AHLU was divided into 4 heat load categories: (1) Low heat load (2) Moderate (3) High and, (4) Very High when the AHLU > 50. In addition HLI and AHLU were combined to produce 4 risk categories. The following categories were used: Low (low: HLI < 70; AHLU < 1), Moderate (mod: HLI 70.1 – 77; AHLU 1 - 10), High (high: HLI 77.1 – 86; AHLU 20 – 50) and Extreme (ext: HLI > 86; AHLU > 50).

Animal data:

- Individual panting score ~ collected at 0600, 1200 and 1800 h on cool days, and every 2 h between 0600 and 1800 h on hot days.
- Location and posture in yard (standing or lying – in shade or sun, eating or drinking) ~ collected at 0600, 1200 and 1800 h on cool days, and every 2 h between 0600 and 1800 h on hot days.
- Liveweight (start, 3 occasions during the study, end of study)

- Blood samples (3 occasions during study corresponding with weighing)
- Feed intake (weekly) ~ pen basis
- Feed to gain ratio ~ calculated from liveweight and feed intake (treatment basis)
- Carcass weight
- P8 fat depth

Climatic summary
Three major heat events occurred during the study. Rain was recorded on 26 days. Most rain fell during January which was characterized by localized storms. The maximum ambient temperature was greater than 35°C on 18 days. There were 13 days during January when maximum ambient temperature exceeded 35°C. The highest ambient temperature recorded during January was 39.9°C. During February the maximum ambient temperature was 34.7°C. During March, 35°C was exceeded on 5 occasions, with a maximum of 38.8°C being recorded. During the study period mean monthly maximums reported by the Bureau of Meteorology were slightly above the long term averages (1913 – 2007; January +1.7°C, February +1.4°C, March +2.9°C and April +2.1°C). Overall the summer period was mild with a few intermittent very hot days.

HLI: The maximum HLI > 85 on 100 of the 119 days (84.0%) the cattle were in the feedlot; HLI > 90 on 58/119 (48.7%) days; HLI > 95 on 31/119 (26.1%) days; HLI > 100 on 5/119 days (4.2%) (Figure 3). The minimum HLI was below 60 units each day. ***AHLU:*** *Shaded cattle* ~ The AHLU for the shaded cattle were greater than 0 and less than 10 on 28 occasions, were between 10 and 25 on 7 occasions and exceeded 25 on 6 occasions. The highest AHLU recorded for the shaded pens was 36.2. *Un-shaded cattle* ~ The AHLU for the un-shaded cattle were greater than 0 and less than 10 on 29 days; were greater than 10 and less than 25 on 12 days; were greater than 25 and less than 50 on 16 days; and were greater than 60 on 11 of the days. On 4 days the AHLU > 60 < 80, on 2 days the AHLU > 80 < 100, on 2 days the AHLU > 100 < 120, and on 3 days the AHLU >120.

Panting Score
Panting score (PS) was used as an indicator of the stress imposed by the climatic conditions. Panting scores were similar between treatments under cool, moderate and hot conditions. When conditions were classified as very hot or extreme (HLI >86) differences were seen. Under very hot conditions the mean panting score was greatest ($P < 0.001$) in the un-shaded cattle. There were no differences ($P > 0.05$) between the shaded treatments under any of the HLI categories. A mean PS (MPS) greater than 1.2 is indicative of excessive heat load and high levels of stress. The MPS of the un-shaded pens exceeded 1.7 on very hot - extreme days. The MPS of the shaded pens did not exceed the high heat load or moderate stress category (MPS = 0.8 – 1.2).

Cattle Performance
There were no statistical differences in terms of carcass quality or carcass weight. However the mean carcass weight of the un-shaded cattle was 12 kg lighter than the mean for the 4.7m^2 group. The un-shaded cattle had a feed efficiency of 11:1 compared to approximately 8:1 for the shaded treatments (mean of all shade treatments). The ADG of the un-shaded cattle was lower ($P<0.05$) 0.91 kg/d cv. the shaded cattle at 1.03 kg/d for.

Recommendations
The recommendations arising from this study are:

Recommendation 1. Shade should be used to over the summer months. This will improve the welfare and performance of *Bos taurus* cattle during periods of high heat load. However, at this time no firm recommendation can be made on the optimal area of shade needed for optimal performance. Further studies are required to determine optimal shade area.

Recommendation 2. Further studies be undertaken to establish the effect of variation in stocking density, and days on feed on the welfare and performance of *Bos taurus* cattle fed over the summer months. Any recommendation for minimum shade area needs to be made with a stocking density recommendation.

Recommendation 3: A minimum 70% solar block be used.

Recommendation 4: Pen surface under shade structures be monitored and cleaned or repaired as required. A statement to this affect should be added to the Risk Analysis Program.

Recommendation 5: Maintain the current shade thresholds in the Risk Analysis Program and add the following: "These values are based on 70% solar block, and are suitable for Angus cattle"*.*

Recommendation 6: The recovery time of cattle exposed to high heat load be further examined.

Contents

1 Background

1.1 Literature review[1]

Temperate regions of the world experience changing climatic conditions that can be stressful to *Bos taurus* cattle. Cattle have a remarkable ability to cope with environmental stressors, and within limits can adjust to minimize adverse effects (Hahn 1999). However, a combination of high temperature and humidity, with high solar load and low air movement can exceed stressor limits with resulting loss of productivity and under extreme conditions the death of cattle (Hahn and Mader 1997; Lefcourt and Adams 1996; Mader et al. 1999). Methods of environmental modification to reduce stress include temperature reduction by spraying, reduction of solar load, and in some cases increased air movement. The use of sprays to cool feedlot cattle is not generally recommended in Australia because high heat load events are often preceded by rainfall. Any additional water application is likely to exacerbate an already adverse pen micro-climate. The use of shade as a method of reducing solar load has received attention as one way of mediating summer heat load (Bond and Laster 1975; Paul et al. 1998; Brown-Brandl et al. 2001; Gaughan et al. 2001). Shade structures have the advantage of being passive i.e. there is no need to switch something on or off, and animals are able to choose shade as required

Identifying the extent of a heat stress event and providing access to shade can reduce loss. Physiological responses to heat load are dynamic and complex, involving genetic diversity (within and between breeds), life stage, conditioning, nutrition, and health status (Hahn 1999). Cattle respond to environmental conditions by generating physiological responses which allow it to cope or adapt. Physiological responses measured during research include behaviour, DMI, rate of gain, carcass traits, immune responses, core body temperature and respiratory dynamics (e.g. respiration rate, and panting score). Measurement of respiration rate and/or panting score provides non invasive and practical assessment of heat stress in feedlot cattle (Brown-Brandl et al. 2005; Mader et al. 2006; Gaughan et al. 2008).

The shade advantage: The provision of shade for *Bos taurus* feedlot cattle is a somewhat contentious issue in Australia. There is conflicting information on the production benefits of providing shade for feedlot cattle. However, there is little doubt as to the merit of providing shade, in some areas of Australia in terms of improved animal welfare. In recent years some work has been undertaken in regards to shade structures and material. However there is little or no scientific information available as to the optimal area of shade that is required to either provide a production response and/or optimize welfare outcomes.

It has been stated that the provision of shade can maintain animals' productivity (Blackshaw and Blackshaw 1994) and welfare (Silanikove 2000) by reducing the heat load related to direct solar radiation. Bond et al. (1967) reported that a simple shade is able to reduce the radiant heat load of an animal by 30% or more because of its ability to intercept radiation from the sun (Figure 1). However, artificial shade does not reduce ambient temperature or relative humidity (Esmay 1982; Buffington et al. 1981; Hahn et al. 1970; MLA 2001; Gaughan et al. 2004). Relative humidity and ammonia may in fact be greater under shade structures due to the accumulation of manure, urine and cattle relative to the remainder of the pen (MLA 2001). This may be exacerbated where the shade structure results in a reduction in air movement (Mader et al. 1999; MLA 2001) or is orientated so that the pen surface under the shade can not be dried by sunlight e.g. shade running east-west rather than north-south.

[1] The contribution of Dr Roger Eigenberg (USDA-ARS, MARC) to parts of this review are acknowledged.

In terms of feedlot cattle performance the advantage of shade provision is inconsistent. Mithlöhner et al. (2002) reported that shaded cattle (heifers) had a 6.1% greater ADG a 2.9% greater DMI and a greater final body weight than un-shaded cattle. They reported that the provision of shade also reduced the incidence of dark-cutting beef. However, Clarke and Kelly (1996) reported that provision of shade (10 m^2/animal) gave no improvement in feed intake, average daily gain, feed efficiency or meat characteristics of feedlot cattle. Mader et al. (1997) and, Brown-Brandl et al. (2005) found inconsistent results in terms of the advantage of shade on feed intake. In both of these studies shade was provided by a "barn". The shade had 100% solar block. In dairy cows however, provision of shade has consistently resulted in increased milk yield and reproductive efficiency (Buffington et al. 1983).

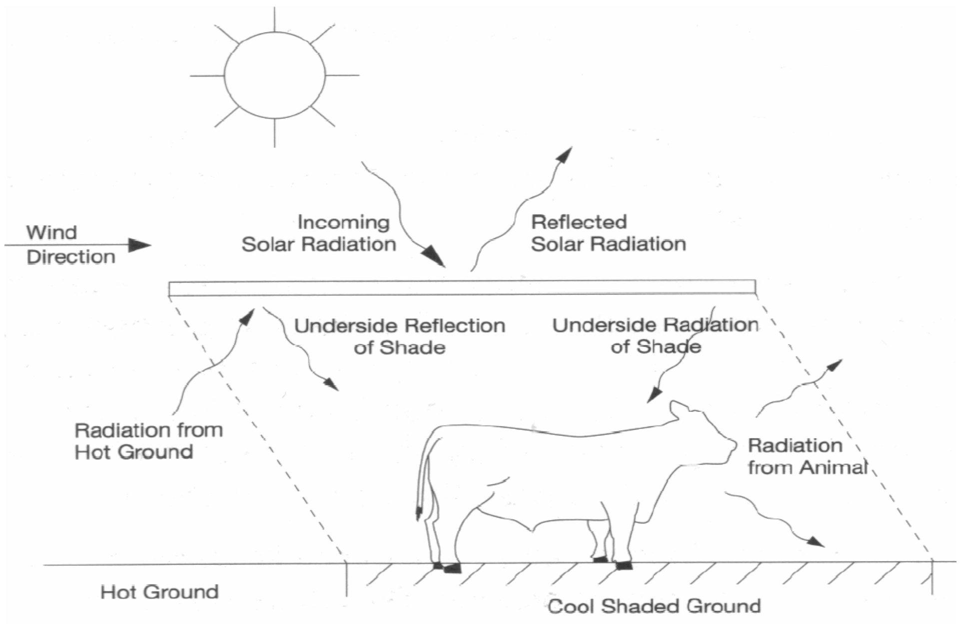

Figure 1 Radiation energy balance of a horizontal shade structure (MLA 2006)

While there is inconsistency in results; in that shade will not always improve performance of feedlot cattle, there are very consistent results showing reductions in core body temperature, panting score and respiration rate (Table 1), as well as reduced incidence of open-mouthed breathing (Brown-Brandl et al. 2005; Gaughan et al. 2004; Mader et al. 1997, 1999; Valtorta et al. 1997; Clarke and Kelly 1996). The reported differences may be due to the lack of consistency between studies in terms of animal type, nutrition, days on feed, shade area, shade type and overall shade design. Cattle will seek shade in high temperatures particularly when it is combined with high solar radiation (Bennett et al. 1985; Buffington et al. 1983; Gaughan et al. 1998).

Reductions in mortality of feedlot cattle with access to shade have been reported. In the USA, Busby and Loy (1996) reported that the death loss among cattle with access to shade was 0.2% (35 feedlots) compared to 4.8% (46 feedlots) amongst un-shaded cattle. Similar results from a single feedlot in Australia were reported by Entwistle et al. (2000). They reported a 0.2% mortality in shaded pens compared to 5.8% in un-shaded pens. Clearly this is important in terms of cattle welfare and has significant financial implications.

Table 1 Treatment means for respiration rate (breaths per minute; bpm) for daytime 1000 h to 1900 h) and nighttime (solar radiation = 0) for shaded and un-shaded Angus cattle in an Australian study and a USA study during summer

	Australian Study[1]		USA Study[2]	
	Shade	No-Shade	Shade	No-Shade
Daytime RR (bpm)	71.9[a] ± 0.57	92.0[b] ± 0.56	85.9[a] ± 2.3	103.8[b] ± 2.3
Nighttime RR (bpm)	55.6 ± 0.54	52.6 ± 0.52	55.3 ± 1.2	62.7 ± 1.2
Mean RR (bpm)	63.2 ± 0.38	71.1 ± 0.39	72.0 ± 1.5	81.3 ± 1.5

[1]Adapted from Gaughan et al. (2004), [2]Adapted from Brown-Brandl et al. (2001)

High Heat load and tissue damage: Exposure to high heat load leads to tissue damage in many animals. When this happens there are changes in serum enzyme activity (Barrow and Clark, 1998). Creatine kinase (CK) is an enzyme that will increase when an animal is exposed to high heat load (as well as other stressors). While it is easy to measure CK in serum the peak levels usually occur within 48 h following the heat episode (Terblanche and Nel 1998). Physical activity (e.g. walking, standing for long periods) will also lead to an increase in CK (Terblanche and Nel 1998; Kaneko et al. 1997). There is little data on the normal range of CK in cattle. Fraser et al. (1991) gives CK reference values for cows as 14.4 – 107 U/L. Wright et al. (1981) reported 10.5 ± 4.5 U/L for non stressed cattle. When the cattle were stress (infected with *B. bovis*) levels rose to 5250 U/L 10 days after exposure. Serum levels of 43.5 – 77 U/L were reported by Ruhland et al. (1999) for cattle in cool alpine environment. Radostits et al. (2000) suggests that the range for cattle is 35 – 280 U/L. However Kaneko et al. (1997) reported much lower normal values (7.4 ± 2.4 U/L). A mean level of 105 U/L was reported by Knowles et al. (1999) for cattle prior to transport. The transport event increased CK levels to 140 – 190 U/L. In another transport study Warriss et al. (1995) measured levels as high as 1039 U/L.

There is little or no data available to make recommendations on the area of shade (m^2/animal) that is required to optimize cattle welfare and production. Two studies using Angus cattle will be undertaken over summer 2006/07 and 2007/08 in an effort to provide scientific data that will allow recommendations on shade area to be provided to the feedlot industry. The first study will be a 120 day on feed study using Angus cattle, and the second cattle will be fed for 180 – 220 days.

1.2 Project background

This project – B.FLT.0337 – "*Assessment of varying allocations of shade area for feedlot cattle – Part 1 120 days on feed*" – was conducted with funding support from Meat and Livestock Australia Ltd. The study was undertaken at The University of Queensland Gatton Campus between December 2006 and April 2007.

Predictions from climate change models are suggesting that there will be more extreme thermal events and that the duration of these events will be longer. Severe heat episodes resulting in significant cattle losses (estimates in brackets) that have occurred in Australia include: January/February 2000 – Queensland and New South Wales (24 human, 1,600 cattle); December 2002 – South Australia; September 2003 – northern New South Wales; February 2004 – New South Wales and Queensland (900 cattle); December 2004 – South Australia; February 2006 – Queensland; October 2006 – central New South Wales.

The cost of cattle mortality is easy to determine. However, production losses are not easy to determine especially on a national basis. It has been estimated that Australian feedlots lose $16.5 million (due to reductions in animal performance) over summer (Sackett et al. 2006). The 1995 US heat wave resulted in production losses of over $20 million. There is little understanding of the effects on feedlot cattle during and following prolonged exposure to high heat load. Despite its importance there are few effective strategies for combating heat stress in feedlot cattle. Recent and on-going research suggests that the effects of heat stress in cattle can be reduced by nutritional management (timing of feeding and ingredients), selection of heat tolerant genotypes, using fans, water application via sprinklers, and the provision of shade. Under intensive conditions, shade, fans and sprinklers may be effective in reducing heat load, but have (apart from shade) little direct application to feedlots.

1.3 Previous research

There has been a number of research projects conducted in the area of heat load management in the Australian feedlot industry. A list of previous research projects funded by Meat and Livestock Australia Ltd. is shown below.

- FLOT.307, 308 & 309 – Recommendations for reducing the impact of elements of the physical environment on heat load in feedlot cattle.
- FLOT.310 – Measuring microclimate variations in two Australian feedlots.
- FLOT.312 – Heat stress software development.
- FLOT.313 – Forecasting feedlot thermal comfort.
- FLOT.315 – Applied scientific evaluation of feedlot shade design.
- FLOT.316 – Development of an excessive heat load index for use in the Australian feedlot industry.
- FLOT.317 – Measuring the microclimate of eastern Australian feedlots.
- FLOT.327 – Reducing the risk of heat load for the Australian feedlot industry.
- FLOT.330 – Validation of the new Heat Load Index for use in the feedlot industry
- FLOT.335 – Improved measurement of heat load in the feedlot industry.

Major outputs from these projects include the development of new measures of heat load including the Heat Load Index (HLI), the Accumulated Heat Load Units (AHLU) and a computer based risk assessment package, the Risk Analysis Program (RAP).

2 Project objectives

The objectives of Project B.FLT.0337 were to;

1. Provide a scientific basis for shade usage for feedlot cattle by: (i) studying the impact of the provision of various shade area (m^2/animal) on production and welfare of feedlot cattle, and (ii) develop firm recommendations on the amount of shade needed to achieve the desired animal welfare outcomes, and production benefits, if they exist in a cost-effective manner, and
2. Make recommendations, based on both a review of the scientific literature and the study outcomes, on changes required to the thresholds for the various shade areas used in the Risk Analysis Program (RAP).

3 Methodology

3.1 Feedlot

The study was undertaken at The University of Queensland, Gatton between 23rd December 2006 and the 30th April 2007. Cattle arrived on the 23rd December (Day 1) and remained in a paddock until induction on the 2nd January 2007 (Day 11). Sixteen pens (7.5 x 23 m) were used at the UQ Feedlot (NFAS 977). A 2 tonne self feeder (Warwick Cattle Crush Company, Forest Hill, Queensland) was shared between two pens (same treatment) ~ 32.5 cm feeder space/animal. Each pen had a 1200 L water trough (Rapid Plas 1200 L Pro Tub) ~ 31.1 cm trough space/animal. Shade cloth was erected over 12 of the pens (1 – 12). There was no shade over pens 13 – 16. Cattle yards and a crush are located opposite pens 11 and 12. Two automated weather stations were located on site. One was located between pens 6 and 11. The second was located on the northern side of pen 9. See Appendix 1 for a layout of the facility.

3.2 Animals

One hundred and twenty six Black Angus (350 ± 45 kg; 2nd January 2007 – induction) yearling heifers were used in a 129 day study (10 days post feedlot + 119 days on feed). The cattle were sourced from the Armidale district NSW, and were therefore un-adapted to Queensland climatic conditions. The cattle had a 10 day (23/12/06 – 01/01/07) adjustment period (paddock) before entering the feedlot (02/01/07) where they remained for 119 days. On induction into the feedlot (02/01/07) the cattle were weighed, ear tagged, treated against internal and external parasites (Cydectin; Fort Dodge Australia P/L, Baulkham Hills, NSW), vaccinated against clostridial disease (7 in 1; Pfizer Animal Health, West Ryde, NSW), bovine ephemeral fever (Fort Dodge Australia P/L, Baulkham Hills, NSW) and trivalent tick fever (Tick Fever Centre, Wacol, Qld).

3.3 Treatments

Cattle were randomly allocated (9/pen:19.17 m^2/animal) to one of four treatments:

(i) no shade,
(ii) 2.0 m^2
(iii) 3.3 m^2, and
(iv) 4.7 m^2.

The area of shade was defined as *the shade provided at mid day (1200 h Eastern Standard Time)*. The no shade treatment was replicated twice, and all shade treatments were replicated four times. The no shade treatment was only replicated twice due to animal welfare concerns. The approving Animal Ethics Committee was concerned that un-shaded cattle could die. Shade was provided by 70% solar block shade cloth attached to a 4 m high frame located in the middle of each shaded pen with a north-south orientation. The shade orientation allowed the shade to move across the pens (west to east) during the day.

3.4 Nutrition

3.4.1 Feed

From the 23rd December 2006 (Day 1) to the 1st January 2007 (Day 10) the cattle had access to pasture (mostly African Star Grass ~ *Cynodon nlemfluensis* and *C. plectostachyus*, with some Gatton panic ~ *Panicum maximum* and Rhodes grass ~ *Chloris gayana*). Shade was provided by trees. On the 2nd January 2007 (Day 11) the cattle were moved to the feedlot. They were stepped up to a feedlot finisher ration over a 21 day period. From 2nd January 2007 (Day 11) to the 6th January 2007 (Day 15) the cattle had *ad-libitum* access to barley (*Hordeum vulgare)* hay and a starter ration (Table 2). From the 7th January 2007 (Day 16) to the 13th January 2007 (Day 22) the cattle had *ad-libitum* access to the starter ration. During this period the barley hay offered was gradually reduced so that by the 14th January 2007 (Day 23) the cattle had no access to the hay. From the 14th January 2007 (Day 23) to the 19th January 2007 (Day 28) the cattle had *ad-libitum* access to the starter ration. On the 20th January 2007 (Day 29) the finisher ration was introduced over the top of the starter ration. By the 22nd January 2007 (Day 31) all of the cattle were on the finisher ration. Both the starter and finisher rations were sourced from a commercial feed mill. Feed intake was recorded on a treatment basis.

Table 2 Ingredients used in the starter and finisher diets

Ingredient	Starter (days 11 – 28) (kg)	Finisher (days 29 – 129)
Wheat – cracked	139	300
Sorghum - cracked	749.7	225
Barley	-	430.7
Millrun	150	150
Legume hulls	150	150
Canola Meal	-	150
Molasses	30	30
Soybean hulls	180	-
Limestone	20	22
Urea	11	0
Salt	7.5	7.5
Potassium Chloride	1.0	3.0
Bentonite	60	30
ANP Custom Beef/Sheep Pre-mix	1.5	1.5
Rumensin 100	0.3	0.3

Table 3 Nutrient composition[A] (as a % of dry matter) of diets used during the study

	Starter (days 11 – 28)	Finisher (days 29 – 129)
Dry matter,%	90.1	90.3
ME, MJ/kg	10.4	10.8
Ash, %	8.1	6.7
Crude fat, %	2.1	2.2
Crude protein, %	13.2	13.7
ADF, %	12.0	11.4
NDF, %	17.3	17.5
Na, %	0.29	0.25
K, %	0.64	0.70
P, %	0.38	0.36
Cl, %	0.51	0.50
S, %	0.15	0.16
Ca, %	0.74	0.79
DCAD, mEq/100 g DM[B]	5.27	4.74

[A]Determined by proximate analysis
[B]DCAD = mEq (K/0.023 + Na/0.039) – (Cl/0.0355 + S/0.016)/100 g DM; mEq = milliequivelants.

A feed sample (500 g) was taken at each feed delivery. A sub-sample (approx. 100 g) was removed and the percentage dry matter, and nutrient content determined by proximate analysis. These analysis served as a check on feed quality and consistency. The remaining 400 g was frozen at -20°C. The frozen samples were thawed at the end of the study and then thoroughly mixed within feed type i.e. starter samples were mixed together and finisher samples mixed. Sub-samples of these were removed and nutrient composition determined by proximate analysis (Table 3).

3.4.2 Dry matter intake

Due to the feeding method used (self feeders) dry matter intake could not be measured on a daily basis. Instead a weekly measure was made. Dry matter intake was calculated from the weekly weight of feed added to each feed bin. See 2.4 for the sampling procedure.

3.4.3 Water usage

Water usage was recorded via water meters on a pen basis. Water usage rather than intake is used due to evaporative water loss and losses due to splashing. Changes in the volume of water in the water troughs following rain events was taken into consideration i.e. additional water added to the total.

3.5 Climatic data

Climatic data were obtained from two automated weather stations. Data was collected at 10 min intervals from one station (Esidata MK-3; Environdata Australia P/L, Warwick, Qld. Australia) and at 15 min intervals from the second (Vantage Pro 2; Davis Instruments, Hayward, California, USA) from the 23rd December 2006 (Day 1) until 30th March 2007 (Day 99). However only the climatic data from the Esidata MK-3 were used. The two weather stations were used to ensure no data was lost in case of malfunction of one of the weather stations. The Davis weather station transmitted weather data to a monitor which allowed continuous observations of climatic conditions. In addition an official Bureau of Meteorology (BOM) site was located 1.5 km to the north of the feedlot. The BOM site collected weather data at 1 h intervals.

The weather variables recorded on site were:

- Ambient temperature (°C)
- Relative humidity (RH; %)
- Wind speed (WS; m/s)
- Wind direction
- Solar radiation (w/m^2)
- Black globe temperature in the sun (BG; °C) (Esidata MK-3 only)
- Black globe temperature under shade in pen 6 (BG; °C) (Esidata MK-3 only)
- Rainfall (mm) (Vantage Pro 2 only)

The ambient temperature and relative humidity sensors of the Esidata MK-3 were located 1.5 m above the ground. The BG located in the sun was 2 m above the ground and the shaded BG in pen 6 was 2 m above the ground and located so that it could not be licked by the cattle. The anemometer and the solar radiation sensor of the Esidata MK-3 were located 2 m above the ground.

The ambient temperature and relative humidity sensors of the Vantage Pro 2 were located 2 m above the ground. The anemometer, solar radiation sensor and the rain gauge were located 2.5 m above the ground.

The sensors of both weather stations were cleaned at least weekly, and more often if conditions were dusty. The sensors were calibrated at the start and at the end of the study.

The weather data was downloaded daily from each weather station at 0800 h. At this time the heat load index (HLI)[2] and the accumulated heat load unit (AHLU)[3] for the previous 24 h were calculated (Gaughan et al. 2008). The Katestone website (www.katestone.com/MLA) was then accessed and the predictions for the current day and next 3 days were observed. Decisions on whether 3 times a day or two hourly data collection would be undertaken were made on the basis of the predicted HLI and AHLU, the actual HLI on site, the AHLU as at 0800 h, and animal observations (e.g. if panting score >1 at 0800 h, two hourly observations would be made).

The cattle were observed and their location in the pen (in shade, in sun, at water or at feed), their posture (standing or lying) and their panting score (0 – 4.5) were recorded three times each day (0600 h, 1200 h and 1800 h) on low heat load days (HLI < 86; AHLU < 20) and seven times each day (0600 h, 0800 h, 1000 h, 1200 h, 1400 h, 1600 h and 1800 h) on hot days (HLI > 86; AHLU ≥ 50; or where panting score > 1 at 0800) throughout the study.

Pen surface temperatures were measured using an infrared temperature sensor (Raynger MX, Raytek, Santa Cruz, California) on 22 occasions (4th January 2007, 22nd January 2007 – 31st January 2007; 7th February 2007 – 14th February 2007; 10th March 2007 – 13thMarch 2007. These occasions were determined on the basis of the day e.g. cool, hot or following rain. Pen surface temperature was measured on dry, wet, shaded and un-shaded surfaces within the shaded pens, and dry, wet and un-shaded surfaces within the un-shaded pens. Surface temperature was measured by holding the infrared senor 1 m above and facing the ground. On each occasion measurements were made between 1200 h and 1400 h. Pen surface temperature was measured in each pen on each occasion and the mean of readings relating to each surface type (e.g. dry) were calculated.

3.6 HLI thresholds

The HLI thresholds used were determined on the basis of the previously developed thresholds (Gaughan et al. 2008). The base threshold of 86 was adjusted by +2 (HLI threshold = 88) for both the shaded and un-shaded cattle for the first 80 days on feed 2nd January – 21st March 2007. In addition the threshold was further adjusted (+5) for the shaded pens giving a threshold of 93 (88 + 5). From the 22nd March 2007 (Day 90 ~ 80 days on feed) the HLI used was 86 for the un-shaded pens and 91 for the shaded pens. The +5 used for the shaded pens was the average adjustment for the shaded pens. Based on the previously developed thresholds the 4.7 m^2 pen would have an adjustment of +7, the 3.3 m^2 +2 and the 2.0 m^2 + 3.

[2] The HLI consists of 2 parts based on a BG threshold of 25 °C: $HLI_{BG>25} = 8.62 + (0.38 \times RH) + (1.55 \times BG) - (0.5 \times WS) + [e^{(2.4 - WS)}]$, and $HLI_{BG<25} = 10.66 + (0.28 \times RH) + (1.3 \times BG) - WS$. Where e = the base of the natural logarithm (approximate value of e = 2.71828).

[3] See Appendix 2

3.7 Cattle

3.7.1 Liveweight

Cattle were weighed at the start of the study (2nd January 2007 – Day 11; entry into feedlot), three times during the study (7th February 2007 – Day 47[4]; 22nd February 2007 – Day 62; 22nd March 2007 – Day 90) and the day before exiting the feedlot (29th April 2007 – Day 128). All weighing commenced at 0800 h. There was no water or feed curfew prior to weighing.

3.7.2 Blood samples

Blood samples (2 x 10 ml samples/animal) were initially collected from 4 randomly selected animals from each pen (16 per treatment) on Day 47. Samples were also collected on Day 62 and Day 90 which corresponded with the weighing of cattle. The same 4 animals were then bled on each occasion giving a total of 3 samples per animal. Blood was collected from the caudal vein by vacutainer® (Beckton Division, New Jersey USA). Serum (tubes with lithium heparin used for biochemical analysis) and plasma (tubes with EDTA anti coagulant for haematological assay) were then separated following centrifugation for 15 min at 3000 rpm. Centrifugation took place within 20 min of collection. The serum and plasma were removed immediately and stored at -20°C until analysed for the concentration of glucose, lactate dehydrogenase (LDH), creatine kinase (serum) (CELL-DYN 3700, Abbott Diagnostics Division, Nth Ryde, NSW)) and insulin (plasma) (IMMULITE, Bio-Mediq DPC, USA).

3.8 Panting score

Panting scores were visually assessed using the 0 – 4.5 scale, with panting score 0 being an animal under no heat load, and 4.5 being a severely heat stressed animal. The indicators for each panting score are shown in Table 4.

Table 4 Panting Score system used during data collection

Panting Score	Breathing Condition
0.0	No panting – normal. Difficult to see chest movement
1.0	Slight panting, mouth closed, no drool or foam. Easy to see chest movement
2.0	Fast panting, drool or foam present. No open mouth panting
2.5	As for 2 but with occasional open mouth panting, tongue not extended
3.0	Open mouth + drooling. Tongue not extended. Neck extended and head usually up
3.5	As for 3 but with tongue out slightly & occasionally fully extended for short periods + excessive drooling
4.0	Open mouth with tongue fully extended for prolonged periods + excessive drooling. Neck and head up.
4.5	As for 4.0 but head down. Cattle "breath" from flank. Drooling may cease.

(Modified from Mader et al. 2006).

Panting score was the key physiological and behavioural factor used in development of the HLI, and in establishing the heat load thresholds. Mean panting score was calculated according to the following formula;

4.5

[4] This weighing was originally scheduled for January 29th but was postponed due to heat wave conditions.

$$\text{Panting Score} = \frac{\sum_{i=0} N_i \times i}{\sum_{i=0}^{4.5} N_i} \qquad \text{Eq. 1}$$

where

N_i = the number of cattle observed at panting score i

The effect of mean panting score (MPS) on cattle was assessed as follows: 0 to 0.4 minimal heat load – no stress; 0.4 to 0.8 moderate heat load – slight stress; 0.8 to 1.2 high heat load – moderate heat load; >1.2 extreme heat load cattle highly stressed (Gaughan et al. 2008).

3.9 Animal ethics approval

The use of animals in this study was approved (SAS/769/05/MLA) by The University of Queensland Animal Ethics Committee in accordance with the Queensland Animal Care and Protection Act and the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes.

3.10 Statistical analysis

The HLI was divided into 4 categories: (1) Cool, when HLI is < 70.0; (2) Moderate, when the HLI is 70.1 to 77.0; (3) Hot, when the HLI is 77.1 to 86.0; and (4) Very Hot when the HLI is > 86.0.

The AHLU was divided into 4 heat load categories (Gaughan et al 2008): (1) Low Load, when the AHLU is < 10; (2) Moderate Load, when the AHLU is 10.1 to 25; (3) High Load, when AHLU is 25.1 to 50; and (4) Very High Load, when the AHLU > 50.

In addition HLI and AHLU were combined to produce 4 risk categories which were used to gain a better understanding of the relationship between climatic conditions, body heat content and mean panting scores. The following categories were used: Low (low: HLI < 70; AHLU < 1), Moderate (mod: HLI 70.1 – 77; AHLU 1 - 10), High (high: HLI 77.1 – 86; AHLU 20 – 50) and Extreme (ext: HLI > 86; AHLU > 50).

Mean panting score data, location in pen, posture (standing or lying) were analysed using repeated measures in PROC MIXED of SAS (SAS Inst., Inc., Cary, NC). The model for mean panting score included HLI, AHLU, HLI categories, AHLU categories, HLI category × AHLU category. The effects of treatment, pen and treatment × pen, time of day (0600, 0800, 1000, 1200, 1400, 1600, 1800 h), period of the day (period 1: 0600 – 0900 h; period 2: 0901 – 1200 h; period 3: 1201 – 1500 h; period 4: 1501 – 1800 h) dry matter intake (treatment basis) on mean panting score were determined using PROC GLM of SAS. Blood data was also analysed using PROC GLM. The effects of treatment and treatment × collection period (i.e. 1st, 2nd or 3rd collection) were determined.

Differences between treatments were separated using PDIFF procedure of SAS. P values ≤ 0.05 are termed significant.

4 Results and discussion

4.1 Climatic conditions

Rainfall during the period of data collection is presented in Appendix 3. Rain was recorded on 26 days between 1st January 2007 and 30th April 2007. Most rain fell during January which was characterized by storm rain on the 4th January (10.8 mm), 25th January (44 mm) and 26th January (31.8 mm). The maximum ambient temperature was greater than 35°C on 18 days between 1st January 07 and 30th March 07. There were 13 days during January when maximum ambient temperature exceeded 35°C. The highest ambient temperature recorded during January was 39.9 on the 29th. During February the maximum ambient temperature was 34.7°C (10th February 2007). During March 35°C was exceeded on 5 occasions, with the maximum of 38.8°C being recorded on the 11th. During the study period mean monthly maximums reported by BOM were slightly above the long term averages (1913 – 2007; January +1.7°C, February +1.4°C, March +2.9°C and April +2.1°C). Overall the summer period was mild with a few intermittent very hot days which tended to increase the mean monthly temperature.

The weather data was collected at the feedlot for 100 days. The daily black globe temperature, relative humidity and wind speed are presented in Figure 2. The major climatic feature over the 100 days was the high relative humidity. On 33 days relative humidity ranged between 60 and 100 %. The periods of high heat load where largely driven by high relative humidity. On 47 days the maximum BGT > 40. Wind direction was mostly from the east and south-east.

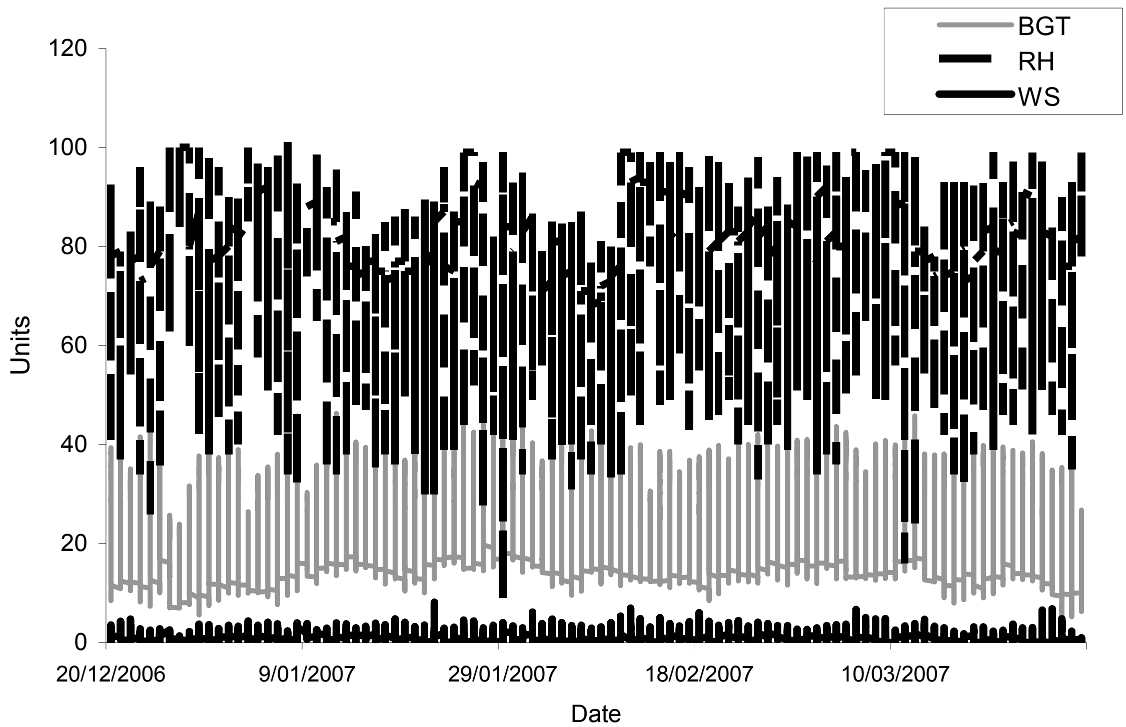

Figure 2 The daily black globe temperature (BGT; °C), relative humidity (RH; %) and wind speed (WS; m/s) recorded at the UQ feedlot at 10 min intervals from 20 December 2006 to 30 March 2007

4.2 Heat Load Index

The maximum HLI > 85 on 100 of the 119 days (84.0%) the cattle were in the feedlot; HLI > 90 on 58/119 (48.7%) days; HLI > 95 on 31/119 (26.1%) days; HLI > 100 on 5/119 days (4.2%) (Figure 3). The minimum HLI was below 60 units each day.

4.3 Accumulated Heat Load Units

4.3.1 Shaded cattle

The AHLU for the shaded cattle was greater than 0 and less than 10 on 28 occasions, was between 10 and 25 on 7 occasions and exceeded 25 on 6 occasions. The highest AHLU recorded for the shaded pens was 36.2 (January 26th 2007). The shaded cattle returned to 0 AHLU each night (Figure 4).

4.3.2 Un-shaded cattle

The AHLU for the un-shaded cattle was greater than 0 but less than 10 on 29 days; was greater than 10 and less than 25 on 12 days; was greater than 25 and less than 50 on 16 days; and was greater than 50 on 16 days (Figure 5). The maximum AHLU was greater than 60 on 11 of the days. On 4 of these days the AHLU > 60 < 80, on 2 days the AHLU > 80 < 100, on 2 days the AHLU > 100 < 120, and on 3 days the AHLU >120 (27th January 2007 – Day 36, 12th March 2007 – Day 80 and 13th March 2007 – Day 81) (Figure 6). High temperature and humidity between 24th January 2007 (Day 33) and 30th January 2007 (Day 39) led to the maximum AHLU recorded during the study (128.8; 27 January). From 0530 h on 24th January 2007 (Day 33) to 0030 h on 30th January 2007 (Day 39) the cattle where in a positive heat load (AHLU > 0), except for a 30 min period (0515 h – 0545 h) on the 25th January 2007 (Day 34). The period from 24th January 2007 (Day 33) to 27th January 2007 (Day 36) was a severe 4 day period for the un-shaded cattle but for a significant increase in wind speed (due to a frontal change) on the afternoon of the 26th January 2007 (Day 35) and an 8°C drop in temperature in 30 minutes (30.5°C at 1700 h and 22.4°C at 1730 h) the feedlots heat load management plan would have been instigated. Although the maximum AHLU occurred on the 27th January 2007 (Day 36) the cattle did not appear to be as "stressed" on this or subsequent days, probably due to the large reduction in DMI which occurred on the 25th January 2007 (Day 34) and 26th January 2007 (Day 35).

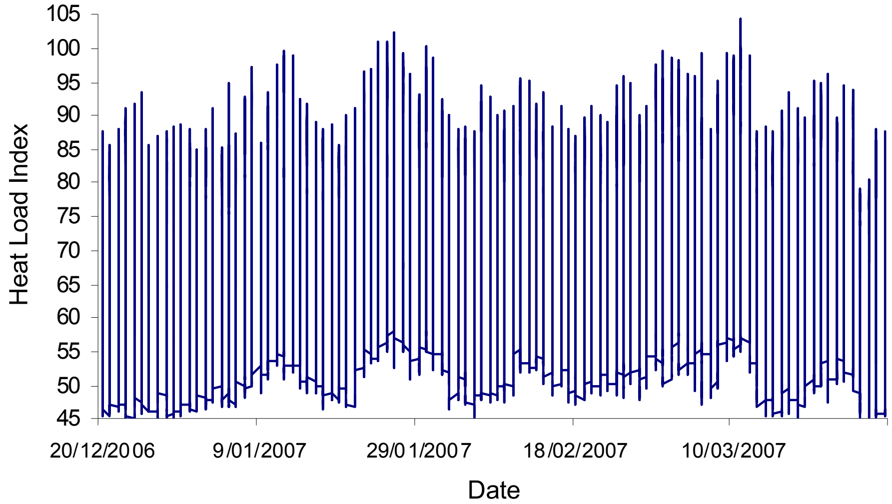

Figure 3 The maximum and minimum daily heat load index recorded at the UQ feedlot at 10 min intervals from 20 December 2006 to 30 March 2007

The 104 units recorded on the 26th January 2007 (Day 35), the 128 units on 27th January 2007 (Day 36) and the 110 units on the 28th January 2007 (Day 37) were exacerbated by high humidity (> 80%) which resulted from 44 mm of rain which fell between 1400 h and 1420 h on the 25th January 2007 (Day 34) from a localized cloudburst. The BOM weather station located 1.5 km to the north of the feedlot did not record any rainfall on 25th January 2007. A further fall of 25 mm occurred on the 26th January 2007 (the BOM site recorded 31 mm). In addition to the rainfall a high maximum ambient temperature (39.8 °C) was recorded on the 27th January 2007 (over the previous 5 days maximum temperatures exceeded 35 °C). A second major heat wave occurred between 8th March 2007 (Day 76) and 13th March 2007 (Day 81). The maximum AHLU exceeded 120 on the 12th March 2007 (Day 80) and 13th March 2007 (Day 81). During this event the un-shaded cattle where exposed to AHLU > 0 from 0700 h on the 10th March 2007 (Day 78) until 0200 h on the 14th March 2007 (Day 82).

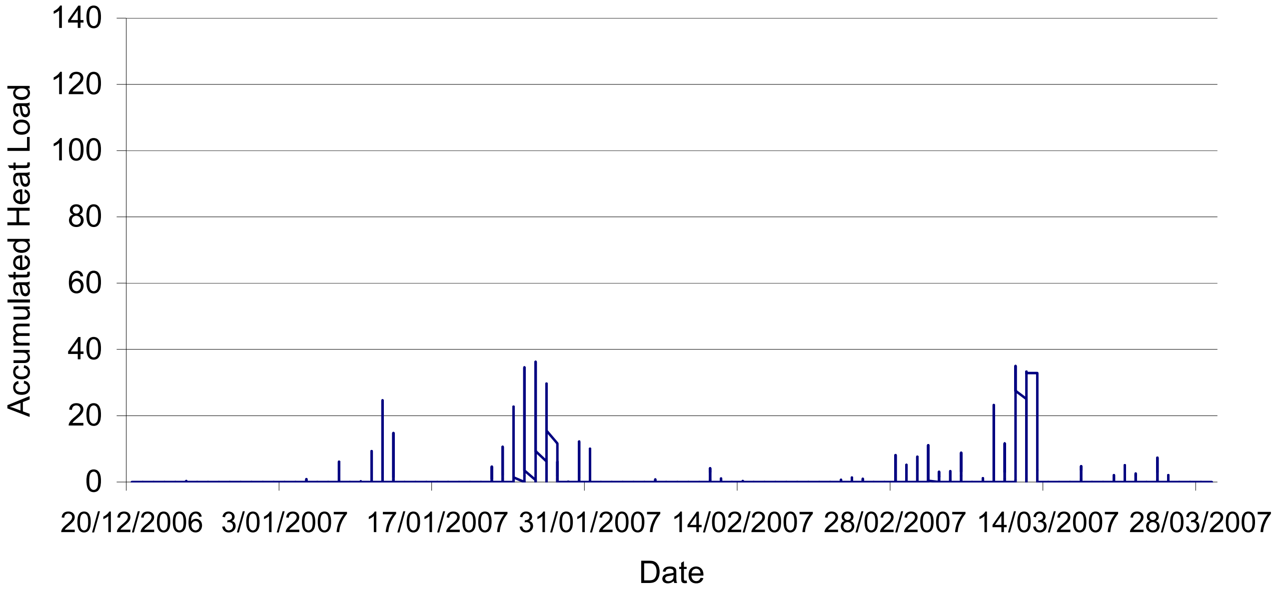

Figure 4 The accumulated heat load units for shaded cattle (heat load index threshold = 93 from 20/12 – 11/3; threshold = 91 after 11/3) from 20 December 2006 to 30 March 2007

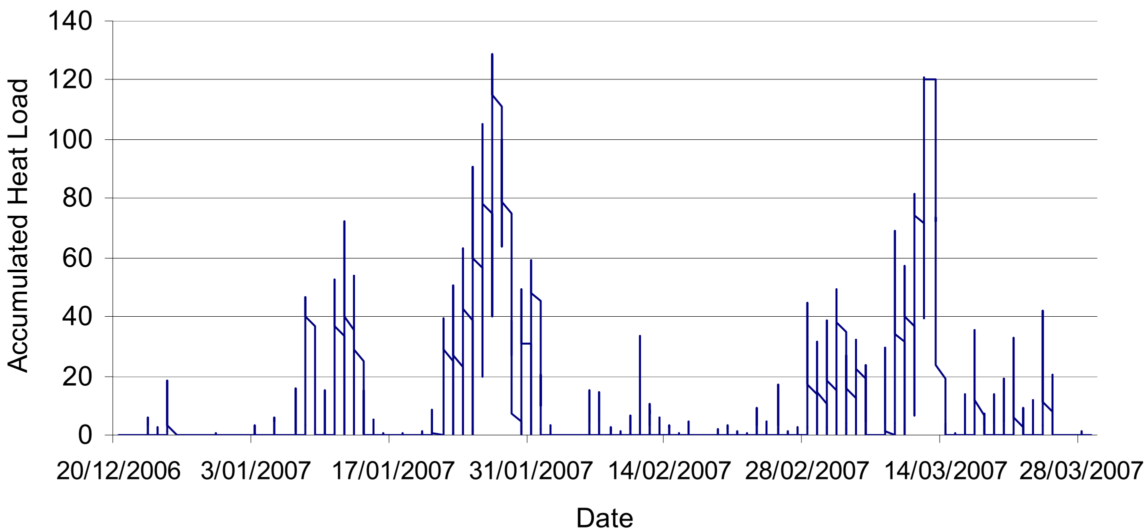

Figure 5 The accumulated heat load units for un-shaded cattle (heat load index threshold = 88 from 21/12/11/3; threshold = 86 after 11/3) from 20 December 2006 to 30 March 2007

4.4 Pen surface

4.4.1 Pen surface temperature

Direct sunlight penetration under the shade was 72% lower than un-shaded areas. The mean un-shaded pen surface temperature was 56.7^{o}C (range 43 – 64^{o}C). In the shaded pens the mean pen surface temperature in the sun was 55.9^{o}C (range 39 – 62^{o}C). The pen surface temperature under the shade was close to 20^{o}C lower. The mean surface temperature under shade was 38.4^{o}C (ranged from 32 – 39^{o}C). The mean temperature in un-shaded grassed pens (no cattle) was 44^{o}C. When possible wet ground under the shade and in the sun were also assessed. The mean surface temperature of wet areas was lower than that recorded in dry areas. The mean temperature of the wet surfaces in the un-shaded areas was 41.2^{o}C (range 37.6 – 44.8^{o}C). Similar values were obtained for un-shaded sections of the shaded pens. Wet areas under shade were approximately 6^{o}C lower than the dry surfaces. When the day was categorized as cold (n = 4) the fully exposed surface temperatures rarely exceeded 35^{o}C. On rainy days or days immediately following a rain event (n = 3) the pen surface temperature was 30.2^{o}C (range 28 – 33^{o}C).

4.4.2 Pen surfaces – General

The pens were cleaned approximately every 30 days. In addition fence lines were cleaned weekly, and areas around water troughs and feed troughs were cleaned as required. Holes in the pen surfaces were repaired as necessary. In the shaded pens holes developed under the shade structures. Generally the area under the shade remained wetter for longer following a rain event. The area under the 4.7 m^2 shade remained wetter for longer cv. the 2.0 and 3.3 m^2 pens. Manure tended to build up under the shade, around the feed troughs and the water trough. The un-shaded cattle had a tendency to make wallows especially during periods of high heat load.

4.5 Panting score

4.5.1 Heat Load Index

Mean panting score increased in all treatments when the HLI category shifted from cool to moderate (Figure 6). There were inconsistent but small changes in mean panting score when conditions moved from moderate to hot and larger increases when conditions changed from hot to very hot. The largest increase was seen in the un-shaded cattle. Panting scores were similar ($P > 0.05$) between treatments under cool, moderate and hot conditions. It was only when conditions were classified as very hot or extreme (HLI >86) that differences were seen. Under very hot conditions the mean panting score was greatest ($P < 0.001$) in the un-shaded cattle. There were no differences ($P > 0.05$) between the shaded treatments under any of the HLI categories.

4.5.2 HLI & AHLU risk categories

In most cases when conditions were classified as very hot or extreme the driving factor was high humidity. The difference between the shaded and un-shaded pens is the impact of reducing solar load. A mean panting score greater than 1.2 is indicative of excessive heat load and high levels of stress. The MPS of the un-shade pens exceeded 1.7 on the very hot - extreme days (Figure 7). A large number of cattle in this group had an individual PS 3 or more. Cattle with a PS of 4 were only observed on a few occasions. The MPS of the shaded pens did not exceed the high heat load or moderate stress category (MPS = 0.8 – 1.2).

4.5.3 Time of the day

As expected the period of the day also had an effect ($P < 0.05$) on MPS, but only when days were classified as hot or extreme (Figure 8). The MPS of the un-shaded cattle was greater ($P < 0.05$) than the MPS of the shaded cattle for period 2 (0901 h – 1200 h), period 3 (1201 h – 1500 h) and period 4 (1501 h – 1800 h). There were no treatment differences ($P > 0.05$) during period 1. There were no differences ($P > 0.05$) between shade treatments during any of the periods.

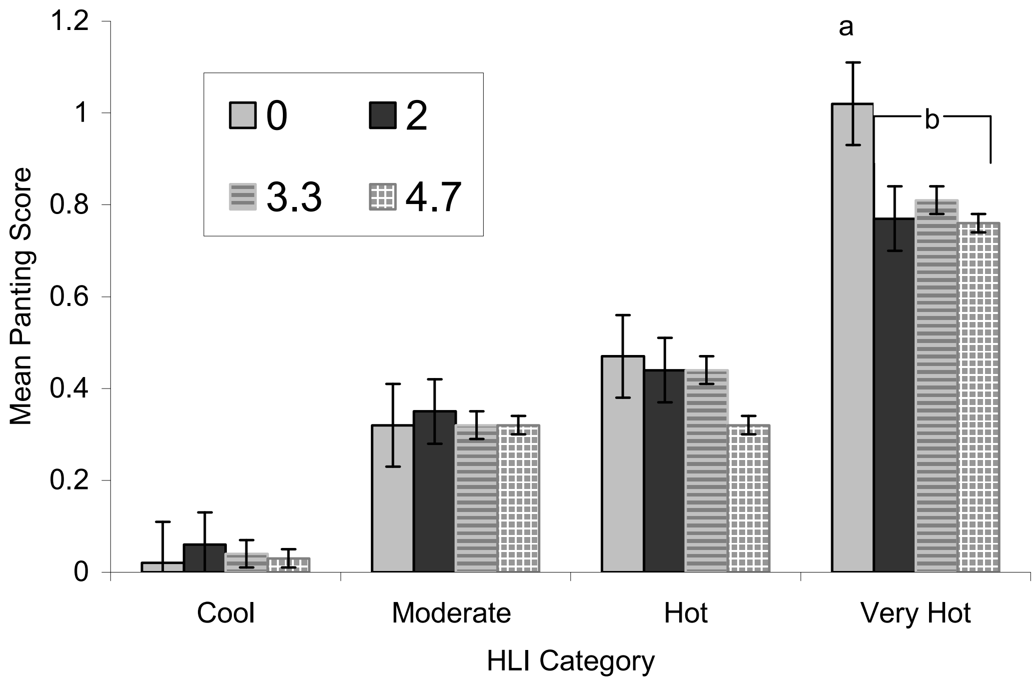

Figure 6 Mean panting score for cattle with no access to shade (0), access to 2.0 m^2 of shade per animal (2), access to 3.3 m^2 of shade per animal, and access to 4.7 m^2 of shade per animal, when HLI was classified as cool (HLI < 70.0), moderate (HLI 70.1 – 77.0), hot (HLI 77.1 – 86.0) and very hot (HLI > 86)

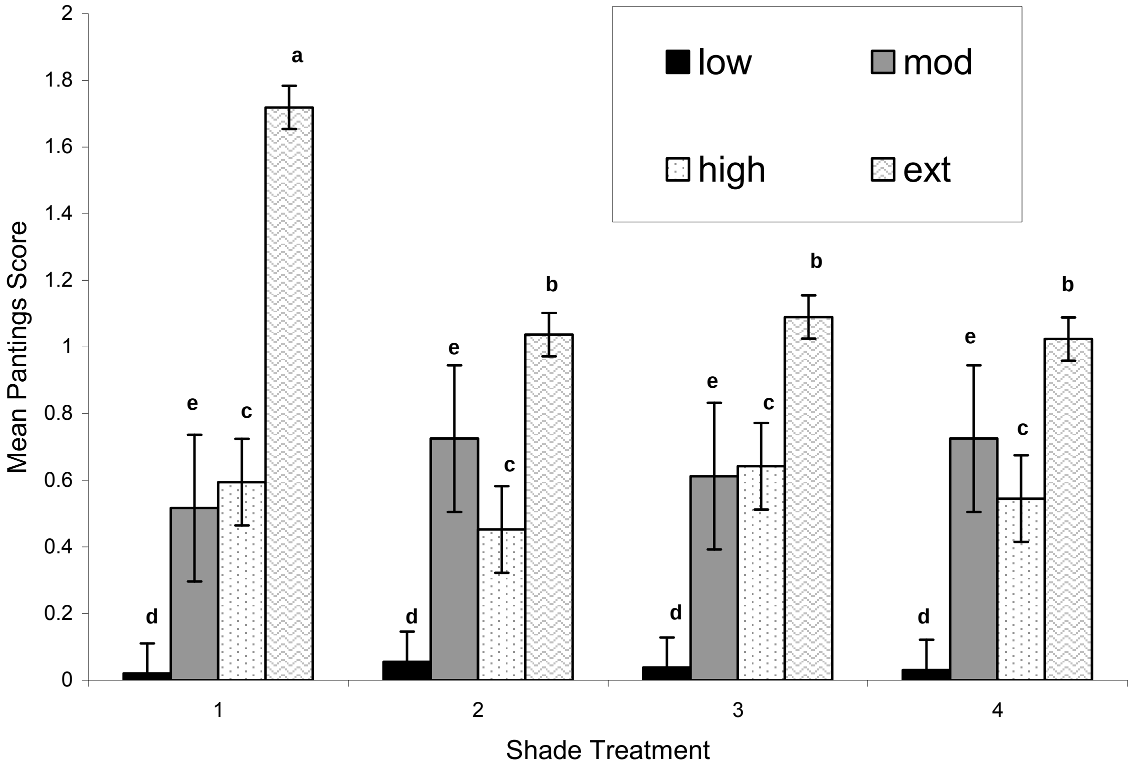

Figure 7 Mean panting score for cattle with no access to shade (1), access to 2 m^2/animal (2), access to 3.3 m^2/animal (3) or access to 4.7 m^2/animal (4) on days when the combined HLI and AHLU were classified as low (low: HLI < 70; AHLU < 1), moderate (mod: HLI 70 – 77; AHLU 1 - 10), high (high: HLI 77 – 86; AHLU 20 – 50) or extreme (ext: HLI > 86; AHLU > 50)

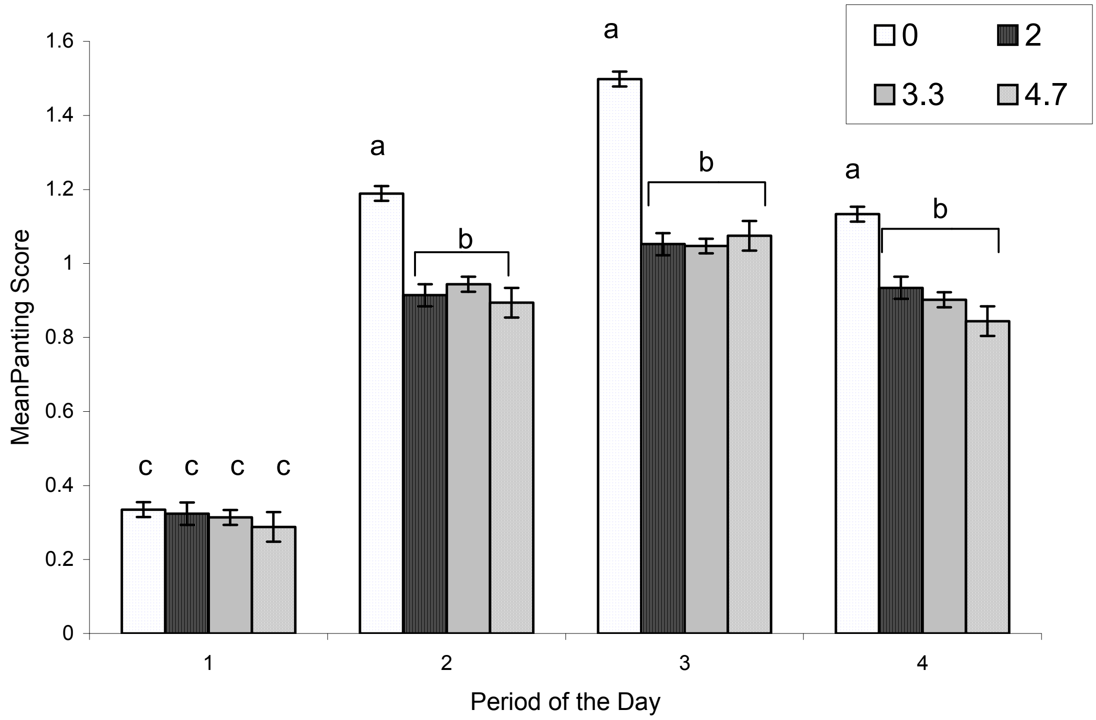

Figure 8 Mean panting score within four periods of the day (period 1 = 0600 – 0900; period 2 = 0901 – 1200; period 3 = 1201 – 1500; period 4 = 1501 – 1800) for each shade treatment (0, 2.0, 3.3 and 4.7 m^2/animal) on days classified as very hot (HLI > 86; AHLU > 50). Means are significant ($P<0.001$) where the letters a b c differ between the treatment means within a period. All treatment means in periods 2, 3 and 4 are greater ($P<0.001$) than in period 1

4.6 Dry matter intake, feed efficiency, water usage, growth performance and carcass data

4.6.1 Dry matter intake

There were DMI differences (weekly mean treatment intakes converted to a per head per day basis) between treatments. The un-shaded and 4.7 m^2 group had similar intakes, which were greater ($P<0.05$) than the 2.0 and 3.3 m^2 groups (Figure 9). Daily DMI was affected by HLI. In the un-shaded group DMI – on a pen basis – fell from approximately 9 kg/animal/d to less than 5 kg/animal/d in weeks that included days classified as very hot. Over the first 80 d in the feedlot the DMI of the un-shaded pens was lower ($P<0.05$) than the shaded groups. However over the last 29 days when climatic conditions were milder the DMI of the un-shaded group increased markedly, whereas there was little change within the shaded groups. Overall the DMI of the un-shaded and 4.7 m^2 group were close to the predicted intakes. The DMI of the 2.0 and 3.3 m^2 groups however were lower than expected. No clear reason for this was apparent.

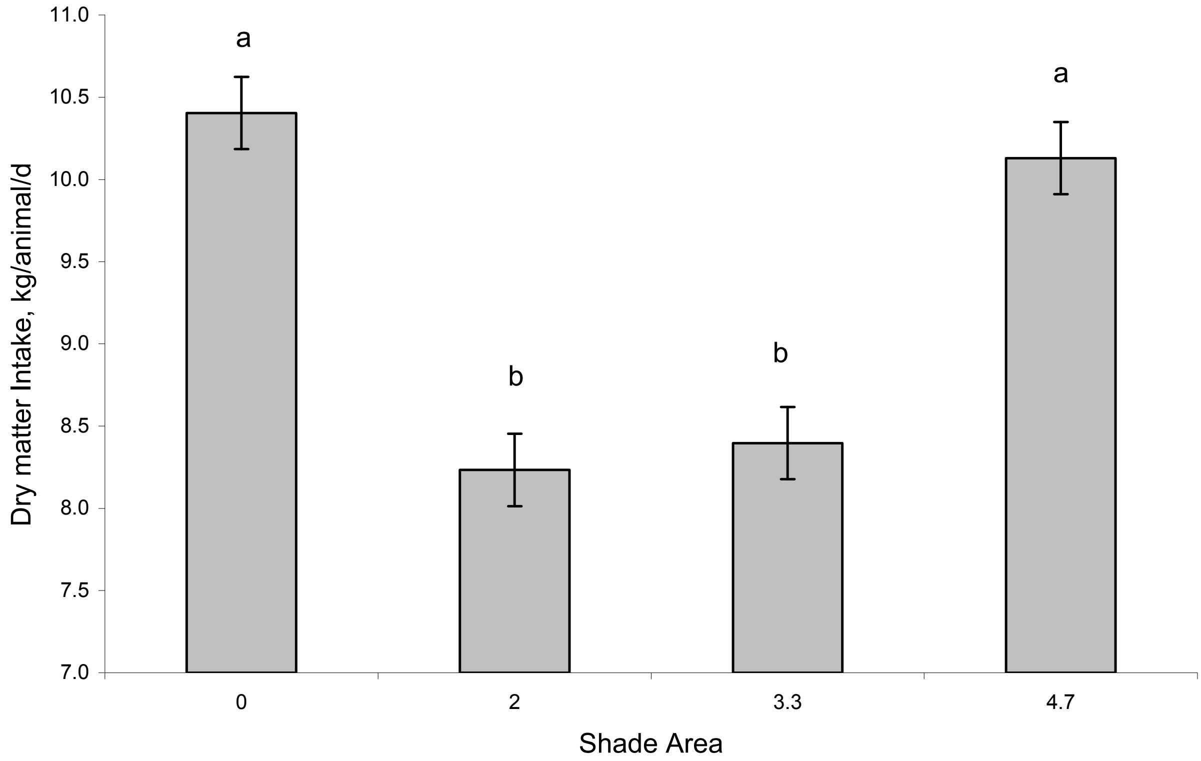

Figure 9 Mean DMI (kg/animal) over 119 days in the feedlot

4.6.2 Feed efficiency

Feed efficiency (feed to gain) is a major profit driver. Based on the type of cattle and the feeding methods used in this study a feed to gain ratio of 6:1 was expected. The 2.0 and 3.3 m^2 groups had the best feed to gain at 5.7:1 and 5.8:1 respectively (Figure 10) and were close to the expected. The un-shaded cattle had the poorest (P>0.01) performance at approximately 10.5 kg of feed to 1 kg of gain which was 46 % more feed than 2.0 m^2 group or $3.69/kg vs. $2.00/kg gain (based on feed cost of $0.351/kg on a DM basis), followed by the 4.7 m^2 group at 7.4:1 ($2.59/kg gain). It is not clear why feed efficiency of the 4.7 m^2 group was not as good as the 2.0 and 3.3 m^2 groups

4.6.3 Water usage

On two occasions following rain events water troughs overflowed. On those occasions water usage could not be determined. Water splashing was evident in all treatments but more so in the un-shaded pens when day was categorized as very hot. There were no treatment differences for water usage across the shaded pens. When the day was categorized as cool there were no differences between shaded and un-shaded pens for water usage at (22 L/animal/day). Similar intakes were reported by Yousef et al. (1968). Under moderate and hot conditions water usage was higher in the un-shaded pens at 43 L/animal/day compared to 38 L/animal/day for shaded pens. When day was categorized as very hot, water usage increase markedly to approximately 54 L/animal/day for the shaded pens and was slightly lower at 49 L/animal/day for un-shaded pens. These values were lower than the 70 L per animal (*Bos taurus* cattle) when night time ambient temperature was 30 ^{o}C (Yousef et al. 1968). The same authors reported intakes of 120 L per animal when ambient temperature was 30 °C during the day. When exposed to high relative humidity water consumption tends to drop (Yousef et al. 1968).

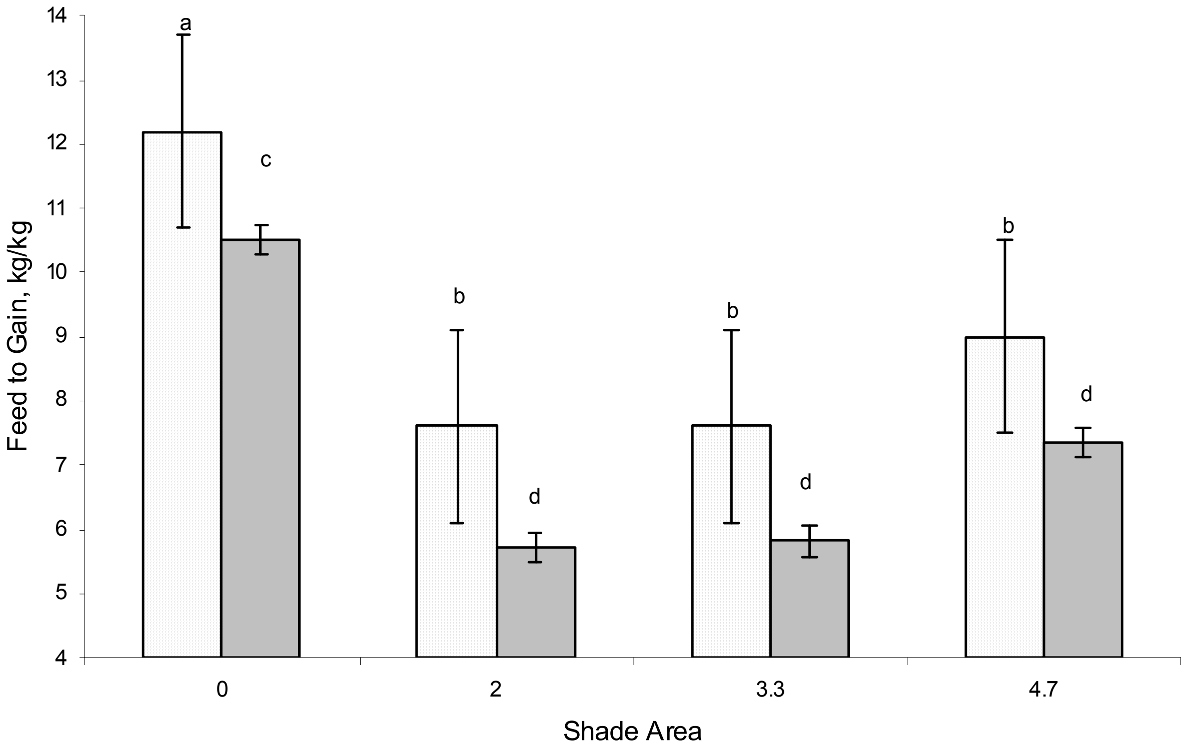

Figure 10 Mean feed to gain (kg/kg) over the first 80 days in the feedlot (speckled bars) and over the entire 119 days in the feedlot (gray bars). ***Bars within feeding period with different letters are significantly different (P<0.01)***

Growth performance and carcass: There were no between treatment differences (P<0.05) for mean liveweight at the commencement of the feeding period (Table 5). Over the first 80 days the un-shaded pens gained the least weight, followed by the 2.0 m^2 group. The 4.7 m^2 treatment had the best (P<0.05) weight gain. The ADG was lowest (P<0.05) in the un-shaded group (0.84 g/animal/day). There were no differences (P>0.05) between the shaded pens. By the end of the study there were no treatment differences (P>0.05) in terms of live weight (although cattle in the 4.7 m^2 treatment were 10 – 20 kg heavier than the other treatments), carcass weight, dressing percentage or P8 fat depth. During the last month of the study the un-shaded cattle under went compensatory gain. DMI of this group increase significantly over the previous 3 months due to the cooler weather experienced during April 2007. However the growth performance of the cattle was at the expense of feed efficiency (Figure 10).

Table 5 Mean treatment (TRT) live weight (LW, kg) ± SE at induction (Induct), 80 days on feed (DOF; LW1), 119 DOF (LW2), average daily gain (ADG, kg/d), for the period induction to 80 DOF, for the period induction to 119 DOF, for the period 80 DOF to 119 DOF, carcass weight (kg), dressing percentage and P8 fat depth (mm) for un-shaded cattle (0), and cattle with access to shade at 2.0, 3.3 or 4.7 m²/animal

TRT	Induct	LW1	ADG[1] kg/d	LW2	ADG[2] kg/d	ADG[3] kg/d	Carcass kg	DR %	P8 mm
0	347.6[a]	413.3[a]	0.84[a]	463.6[a]	0.99[a]	1.36[a]	270.4[a]	58.3[a]	14.6[a]
2.0	343.4[a]	436.5[a,b]	1.17[b]	472.9[a]	1.10[a,b]	0.98[b]	277.1[a]	58.7[a]	16.4[a]
3.3	335.4[a]	435.9[a,b]	1.26[b]	466.3[a]	1.12[a,b]	0.82[b]	272.0[a]	58.4[a]	15.1[a]
4.7	348.7[a]	448.2[b]	1.25[b]	483.6[a]	1.15[b]	0.95[b]	282.6[a]	58.4[a]	16.5[a]
SE	7.33	8.20	0.05	8.50	0.05	0.10	5.07	0.26	0.79

[1]ADG from induction to 80 DOF; [2]ADG from induction to 119 DOF; [3]ADG from 80 DOF to 119 DOF. Cattle were slaughtered on day 119. Means in a column with different superscripts are significantly different (P<0.05).

4.6.4 Animal posture/shade usage in relation to HLI and AHLU

The use of shade by cattle is obviously influenced by climatic conditions. The major climatic factors appear to be a combination of ambient temperature and solar radiation (basically black globe temperature), and to a lesser degree relative humidity. However cattle responses to environmental conditions are complex.

Shade usage was assessed on the basis of the previously mentioned categories of HLI (Table 6) and AHLU (Table 7). There are clear response differences (P < 0.001) between un-shaded and shaded cattle in terms of numbers standing in the sun under all HLI categories. However the biggest differences were seen when HLI was categorized as very hot (HLI > 86). These data show that Angus cattle used the available shade especially when HLI > 86. Similarly as AHLU increased cattle spent more time under the shade. The AHLU under shade did not exceed 50 (Figure 4). However there was a small increase (P < 0.1) in the number of cattle using shade when the AHLU (based on BG in the sun) of un-shaded pens exceeded 50.

The posture (standing or lying) of the un-shaded cattle was not affected (P>0.05) by HLI category. Within the shade treatments fewer (P < 0.01) of the 2.0 m² group were lying in the shade compared to the 3.3 and 4.7 m² groups. This was due to a lack of space under the shade. It was not possible for all 9 animals to lie down and be under the 2.0 m² shade during the middle of the day (1100 – 1500 h). All cattle in the 3.3 and 4.7 m² treatments could lie under the shade at the same time. It did not appear however that this was a problem in terms of welfare (panting score) or performance. Another confounding factor in regards to animals under the shade was with shade movement due to positional change of the sun. Cattle would be observed lying in the shade at one observation, but would be in the sun at the next observation. There were no differences between shade treatments for animals standing in the sun.

The HLI at a point in time and the AHLU at the same time are obviously not independent. Cattle responses (in this case shade seeking) are a factor of both HLI and AHLU, and are further influenced by the direction the HLI and AHLU are moving. Thus if HLI is 86 and falling cattle responses may be very different to when they are exposed to a HLI of 86 when the HLI is increasing. The same can be said for the AHLU. We have previously discussed some of the behavioural results of cattle based on HLI/AHLU relationship (Casteneda et al. 2004).

The un-shaded cattle also exhibited shade seeking behaviour. These animals tended to find shade where ever they could. For example the feed bin, fence posts and from other animals. These animals also tended to crowd the water trough and bunch during periods of high heat load.

Table 6 Mean number of animals standing (no shade or shade) or lying (no shade or shade) within the un-shaded pens (0 m^2/animal), 2.0 m^2, 3.3 m^2 or 4.7 m^2 of shade when the heat load index (HLI[A]) is categorized as (1) cool, when HLI is < 70.0; (2) moderate, when the HLI is 70.1 to 77.0; (3) hot, when the HLI is 77.1 to 86.0; and (4) very hot when the HLI is > 86.0

		HLI Category			
Treatment	Posture/position	Cool	Mod	Hot	VHot
	Standing – no shade				
0		7.22[a]	7.80[a]	6.80[a]	6.91[a]
2.0		6.54[a,b]	6.79[a,b]	5.25[b]	3.09[b]
3.3		6.12[a]	6.72[b]	5.30[b]	2.91[b]
4.7		5.51[b]	6.99[a]	5.29[b]	2.96[b]
SE		0.40	0.29	0.13	0.10
	Standing - shade				
0		-	-	-	-
2.0		0.69[a]	0.85[a]	1.50[a]	3.69[a]
3.3		0.94[a]	0.89[a]	1.51[a]	3.36[b]
4.7		1.29[a]	0.96[a]	1.41[b]	3.24[b]
SE		0.32	0.26	0.11	0.08
	Lying – no shade				
0		1.78[a]	1.20[a]	2.20[a]	2.09[a]
2.0		1.52[a]	0.85[a,b]	1.26[b]	0.73[b]
3.3		1.25[a]	0.64[b]	1.00[c]	0.58[c]
4.7		1.49[a]	0.49[b]	0.98[c]	0.51[c]
SE		0.21	0.16	0.07	0.05
	Lying – shade				
0		-	-	-	-
2.0		0.24[a]	0.51[a]	0.99[a]	1.48[a]
3.3		0.69[a]	0.74[a]	1.18[a,b]	2.14[b]
4.7		0.71[a]	0.57[a]	1.33[b]	2.29[b]
SE		0.26	0.21	0.09	0.06

[A]$HLI_{BG>25} = 8.62 + (0.38 \times RH) + (1.55 \times BG) – (0.5 \times WS) + [e^{2.4 – WS}]$; $HLI_{BG<25} = 10.66 + (0.28 \times RH) + (1.3 \times BG) – WS$.
[abc]Means in a column within posture/position classification with different superscripts are significantly different (P<0.05).

Table 7 Mean number of animals[1] standing (no shade or shade) or lying (no shade or shade) within the un-shaded pens (0 m^2/animal), 2.0 m^2, 3.3 m^2 or 4.7 m^2 when accumulated heat load units (AHLU[2]) is classified as cool (Cool; AHLU < 10), moderate (Mod; AHLU 10.1 – 25), hot (Hot; AHLU 25.1 – 50) or extreme (Ext; AHLU>50.1)

Treatment, m^2 shade/animal	Posture/position	AHLU Category			
		Cool	Mod	Hot	Ext[A]
	Standing – no shade				
0		6.67[a]	7.41[a]	7.20[a]	7.54
2.0		4.24[b]	2.99[b]	4.69[b]	4.88
3.3		4.17[b]	3.03[b]	3.66[c]	3.72
4.7		4.15[b]	3.18[b]	3.83[b,c]	3.91
SE		0.09	0.24	0.39	0.33
	Standing - shade				
0		-	-	-	-
2.0		2.59[a]	3.88[a]	2.39[a]	2.44
3.3		2.33[b]	3.72[a,b]	3.56[b]	3.59
4.7		2.30[b]	3.33[b]	3.08[a,b]	2.93
SE		0.07	0.19	0.31	0.36
	Lying – no shade				
0		2.33[a]	1.59[a]	1.80[a]	1.46
2.0		1.00[b]	0.56[b]	0.50[b]	0.44
3.3		0.83[c]	0.28[b]	0.29[b]	0.36
4.7		0.74[c]	0.49[b]	0.37[b]	0.27
SE		0.04	0.12	0.18	0.26
	Lying – shade				
0		-	-	-	-
2.0		1.17[a]	1.57[a]	1.42[a]	1.24
3.3		1.68[b]	1.96[a]	1.48[a]	1.33
4.7		1.81[b]	2.00[a]	1.72[a]	1.89
SE		0.06	0.15	0.24	0.28

[1]Based on 4,750 observations. [2]The AHLU is a 2 dimensional function incorporating time and animal heat balance i.e. the amount of time that the animal is exposed to a HLI above a threshold (i.e. the threshold for an un-shaded Angus is 86) (Gaughan et al. 2008). [A]The actual AHLU under shade never exceeded Hot, the values shown here are based on the AHLU experienced by cattle in the un-shaded pens.

4.6.5 Blood parameters

The concentrations of glucose, insulin, sodium, potassium and chloride were within the normal range for bovines (Table 8). The higher ($P < 0.05$) CK levels for cattle housed under 0 and 2.0 m^2 suggest that these animals have been exposed to a higher level of stress compared to the 3.3 m^2 and 4.7 m^2 cattle. However it also appears at least based on the values presented by Kaneko et al. (1997) that cattle in all treatments have been stressed.

Table 8 Mean serum levels for creatine kinase (CK), glucose (GLU), insulin (INS), sodium (Na), potassium (K) and chlorine (CL) for un-shaded cattle (0), cattle with access to shade at 2.0, 3.3 or 4.7 m^2/animal

	0	2.0	3.3	4.7	SE
CK, U/L	118.2[a]	108.1[a]	76.2[b]	79.6[b]	13.47
GLU, mmol/L	3.9	4.1	4.3	3.8	0.21
INS, µU/ml	3.3	4.3	4.5	4.7	0.75
Na, mEq/L	146.4	143.4	145.4	139.9	1.77
K, mEq/L	4.7	4.9	5.0	4.7	0.79
Cl, mEq/L	107.3	105.8	107.3	103.1	1.22

5 Success in achieving objectives

Although the summer period was milder than expected there were sufficient hot days during the study to elicit a heat stress response in the cattle. The objectives of the study were achieved in part. The study has shown that the use of shade will provide a strong positive welfare outcome, and a moderate production response for Angus cattle fed over the summer months. However it is not possible to recommend an optimal shade area (Objective 1 part (ii)). The study verified that the current shade thresholds of the Risk Analysis Program be maintained – thus the second objective has been met.

6 Impact on meat and livestock industry – now & in five years time

This study has shown that there are positive well defined welfare outcomes by providing shade to Angus steers fed for 120 days over the summer months, in areas of the country where high heat load is likely. In the short term the industry will be able to demonstrate to the general community its intent to improve welfare of *Bos taurus* cattle in feedlots by provision shade. The industry will also be able to provide scientific based evidence to support the use of shade. Although not as definitive as the welfare outcomes the use of shade has also shown production benefits. The benefits may be more pronounced in long fed cattle. In the longer term improved productivity over the summer months will increase financial returns, but this needs to be assessed in relation to the cost of erecting and maintaining shade structures. Further studies over the summer of 2007/08 will provide more information in relation to the optimal area of shade for longer fed cattle. In the longer term this may

7 Conclusions and recommendations

7.1 Conclusions

The following conclusions are made based on the animal performance and panting score, the climatic conditions experienced, the nutrition and the type of cattle used.

- Using panting score as a welfare indicator it is clear that a lack of shade has a negative impact on the welfare of cattle during periods of high heat load.
- A lack of shade had a negative impact on performance of cattle (based on feed efficiency).

- Access to hade had a positive affect on cattle welfare (based on panting scores). Access to shade did no completely eliminate stress.
- Access to shade had a positive affect on cattle performance (based on feed efficiency).
- There were no differences in terms of welfare or production for the shade areas used (2.0, 3.3 and 4.7 m^2) in the current study (stocking density of 19.17m^2).
- Feed intake decreases during periods of high heat load and there is a subsequent reduction in average daily gain. Un-shaded cattle are affected to a greater extent than shaded cattle. Un-shaded cattle will compensate, by eating more when climatic conditions are mild. However this is at the expense of feed efficiency.
- The pen surfaces under shade cloth tends to stay wetter longer following rain compared to the surfaces of un-shaded pens.
- More pen maintenance was required for the 4.7 m^2 shade.
- The north-south alignment of the shade is adequate.

7.2 Recommendations

The following recommendations are made based on the animal performance and panting score, the climatic conditions experienced, the nutrition and the type of cattle used.

Recommendation 1. Shade should be used to over the summer months. This will improve the welfare and performance of *Bos taurus* cattle during periods of high heat load. However, at this time no firm recommendation can be made on the optimal area of shade needed for optimal performance. Further studies are required to determine optimal shade area.

Recommendation 2. Further studies be undertaken to establish the effect of variation in stocking density, and days on feed on the welfare and performance of *Bos taurus* cattle fed over the summer months. Any recommendation for minimum shade area needs to be made with a stocking density recommendation.

Recommendation 3: A minimum 70% solar block be used.

Recommendation 4: Pen surface under shade structures be monitored and cleaned or repaired as required. A statement to this affect should be added to the Risk Analysis Program.

Recommendation 5: Maintain the current shade thresholds in the Risk Analysis Program and add the following: “These values are based on 70% solar block, and are suitable for Angus cattle”.

Recommendation 6: The recovery time of cattle exposed to high heat load be further examined.

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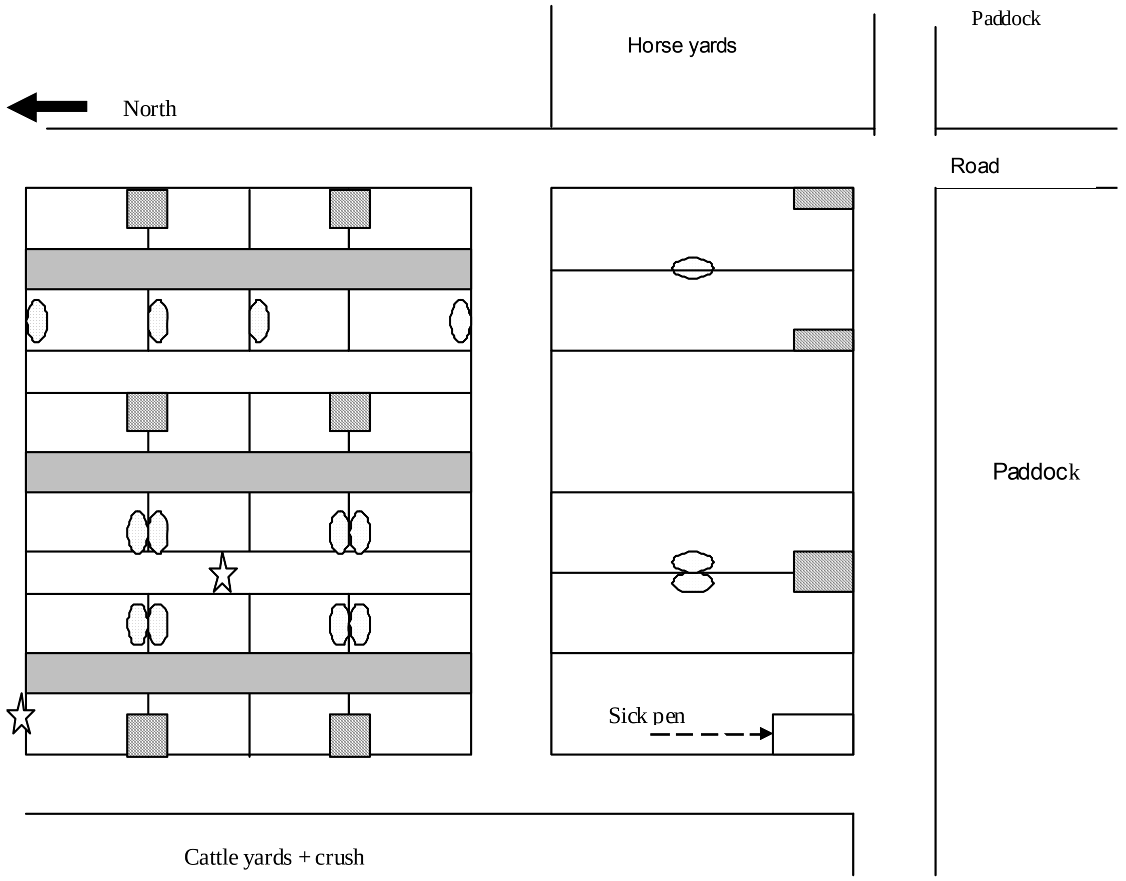
9 Appendices

9.1 Appendix 1



Notes:

Water trough

Self-feeder

Shade structure (70% solar block out shade cloth) (Shade runs north – south)

Weather station

Yards and Dimensions:

Total number of yards = 16
Pen dimensions = 7.5 m x 23 m (172.5 m^2)

Stocking density and Standard Cattle Units:

Animals per pen (max) = 9 (stocking density = 19.2 m^2)
Max SCU on site = 131 max turnoff weight 600 kg.

9.2 Appendix 2

The following equation was used to calculate the AHL (in Excel);

$$IF\ (HLI_{ACC} < HLI_{Lower\ Threshold},\ (HLI_{ACC} - HLI_{Lower\ Threshold})/(Mx2),\ IF\ (HLI_{ACC} > HLI_{Upper\ Threshold},\ (HLI_{ACC} - HLI_{Upper\ Threshold})/M,\ 0))$$

Where HLI_{ACC} = the actual HLI value at a point in time; $HLI_{Lower\ Threshold}$ = the HLI threshold below which cattle in a particular class will dissipate heat e.g. 77 for the reference animal;

$HLI_{Upper\ Threshold}$ = the HLI threshold above which cattle in a particular class will gain heat e.g. 86 for the reference animal; and M = measures per h i.e. how often HLI data is collected per h. If every 10 min then M = 6.

Because cattle do not dissipate heat at the same rate that they gain heat the M value in first part of the equation is multiplied by 2 – this slows the rate of heat loss in the equation.

9.3 Appendix 3

Rainfall (mm) from the 1st January 2007 to 30th April 2007

	January	February	March	April
1	0	0	0	0
2	0	0	0	0
3	0.2	3.0	0	0
4	11.2	0	0	0
5	0	0	0	0
6	0	0	11.2	0
7	0	0	1.0	0
8	0	0	0	0
9	0	0	15.0	0
10	0.1	0	19.8	0
11	0	10.2	0	0
12	0	0	0	0
13	0	9.6	0	0
14	0	1.0	0	0
15	0	0.5	0	0
16	0	0.6	0	0
17	0	4.8	0	0
18	0	0	0	0
19	0	0.1	0	0
20	0	0	0	0
21	0	0	0	0
22	0	0	0	0
23	6.8	0	0	0
24	0	0	0.2	0
25	44.1	0	0	0
26	31.8	0	0.6	3.2
27	0.5	0	0	0
28	0	0	0	0
29	0	-	0	0
30	0	-	0	0
31	0	-	0	-