

## Heat stress in farm animals

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### ABSTRACT

Heat stress affects production and welfare in farm animals. In warm weather animals will change their behaviour in order to cool down, for example by seeking shade or other cooler microclimates, and by altering activity patterns, body postures and feed intake. In addition to behavioural changes, physiological mechanisms will occur, such as increased respiration and body temperature. There is consistent evidence that the reduced productivity in association with heat stress can be alleviated by providing different types of cooling. However, more research is needed in order to explore how to best cool farm animals and appropriate cost benefit analyses of providing different types of cooling in New Zealand conditions needs to be carried out to improve profitability and welfare. Animals change their behaviour before changes in production can be detected, therefore animal behaviour can provide insight into when and how to cool animals.

**Keywords:** cattle; deer; heat stress; pigs; sheep.

### INTRODUCTION

High ambient temperatures, solar radiation and humidity, and low wind movement are environmental factors that can cause heat stress in animals. If they are able to, animals will alter their behaviour in order to cool down, for example by

seeking cooler microclimates and by changing activity patterns and body postures. In addition to behavioural adaptations, energy demanding physiological responses as well as a decrease in feed intake will occur to reduce heat production and maintain homeothermy. There is consistent evidence across farm species that hyperthermia is harmful to

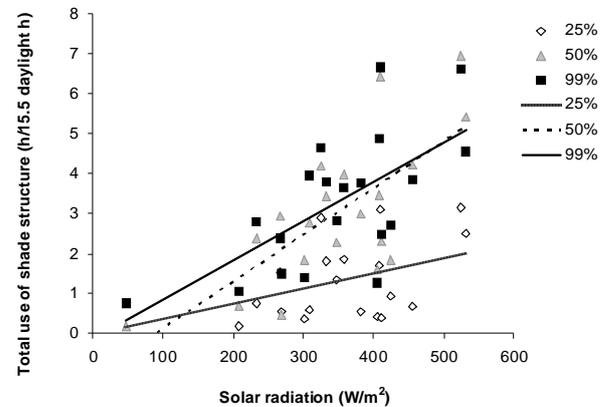
production. Although changes in production can be useful to determine when an animal is unable to adapt to a situation, animals will change their behaviour in order to cope with the situation well before production is compromised. Therefore, behaviour can provide insight into how animals immediately respond to environmental conditions, making it a useful tool for examining animal preferences for different cooling methods. This paper reviews some of the existing literature about heat stress and ways to alleviate negative effects of heat load in cattle, sheep, pigs and deer, from the viewpoint of animal welfare and with recommendations for future research. There are many factors other than weather that influence how susceptible animals are to heat stress, including breed, acclimatisation, production levels, nutrition, health status, age and coat or fleece but these are not further discussed in this paper.

## CATTLE

The majority of published research regarding heat stress in cattle has been carried out on dairy cattle and beef cattle in feedlot systems, which limits our understanding of heat stress in beef cattle in extensive systems in temperate climates, such as New Zealand. Increased heat load increases body temperature and respiration rate and can reduce feed intake, milk and meat production (Hahn, 1999; Ominski *et al.*, 2002) and fertility (Roman-Ponce *et al.*, 1977). In New Zealand, a reduction in milk production started to occur at a three-day average temperature-humidity index of 68, equivalent to 21°C and 75% humidity, in Holstein-Friesian cattle (Bryant *et al.*, 2007). Cattle without access to cooling adopt behavioural strategies, such as changing grazing times (Kendall *et al.*, 2006), body postures (Mitlöhner *et al.*, 2002) and increased water consumption (Mader *et al.*, 1997). Indeed, access to cooled drinking water (18.3 versus 31.2°C) improved weight gain in feedlot cattle in warm weather (mean air temperature: 29.7°C, Ittner *et al.*, 1951).

There is evidence that dairy cattle are highly motivated to use shade in warm weather (Schütz *et al.*, 2008) and consider shade a valuable resource that they are willing to compete for (Schütz *et al.*, 2010). Shade use in dairy cattle increases with higher ambient air temperature and solar radiation (Schütz *et al.*, 2009; Tucker *et al.*, 2008). The provision of shade improves daily milk production by 0.5 kg/cow in late lactation (Kendall *et al.*, 2006), with protection from solar radiation an important design feature of shade. Dairy cows are able to distinguish between different levels of solar radiation blockage, and when given a choice, prefer at least 50% blockage (Schütz *et al.*, 2009). Dairy cows with

**FIGURE 1:** Relationship between daily average solar radiation ( $\text{W/m}^2$ ) and total use of the shade structures that blocked 25, 50 or 99% of solar radiation and were freely available to dairy cattle ( $n = 9$  groups, 3 groups per treatment) during 20 days of summer.

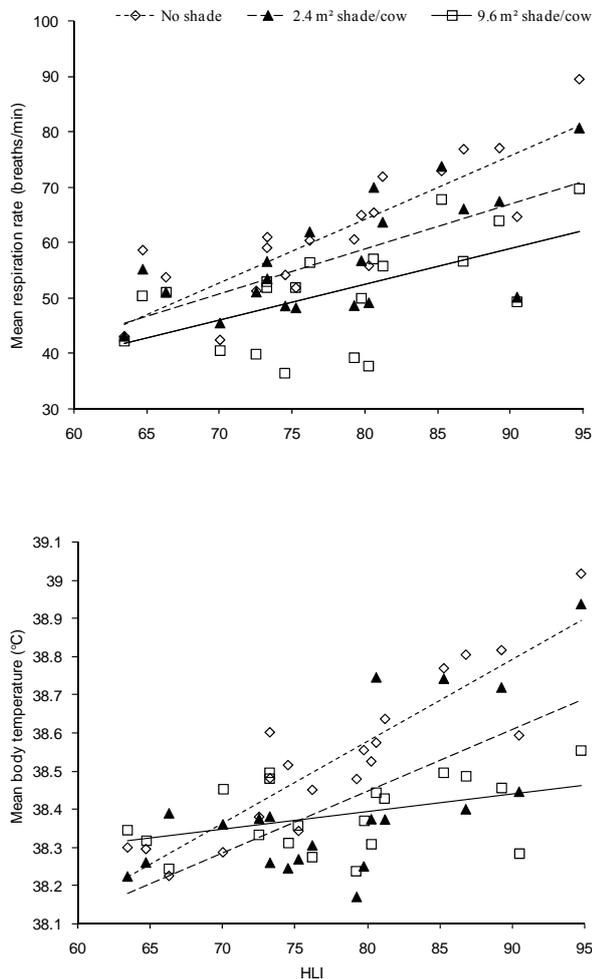


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access to shade cloth that provided more protection from solar radiation spent more time using this resource than cows with access to shade that provided less protection. Shade use was directly related to solar radiation levels (Tucker *et al.*, 2008, Figure 1).

Few studies have compared the effects of the amount of shade and the focus is often on production parameters of shaded versus unshaded groups of cattle. These studies recommend 3.5-5.6  $\text{m}^2$  shade/cow for dairy cattle (Buffington *et al.*, 1983; Collier *et al.*, 2006) and 2.3-5.6  $\text{m}^2$  shade/cow for beef cattle (Ittner *et al.*, 1954; Garrett *et al.*, 1962). There is some evidence, however, that changes in production may be relatively “downstream” indicators of heat stress, in comparison to immediate physiological responses, such as respiration rate. For example, Mader *et al.* (1997) demonstrated that beef cattle that had access to 3.5  $\text{m}^2$  shade/animal had higher feed intake and lower respiration rates than animals with less shade but found no difference in weight gain. We have shown that the benefits of shade are greater when all cows can use the resource simultaneously, for example by preventing a rapid increase in respiration rate and body temperature (Schütz *et al.*, 2010, Figure 2). Shade use was more than twice as high when all cows could use it simultaneously and increased with heat load (Figure 3). These results indicate that cattle will use shade to prevent an increase in internal body temperature, but this heat mitigation strategy is only effective if a sufficient

**FIGURE 2:** Relationship between Heat Load Index (HLI) and mean respiration rate (top) and body temperature (bottom) of dairy cows with no access to shade or access to 2.4 m<sup>2</sup> or 9.6 m<sup>2</sup> shade/cow at pasture (10:00 to 15:50 h) in summer (n = 4 groups per treatment, 10 cows/group, 5 days/group)



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amount of shade is provided. Additional information is needed to make specific recommendations about the amount of shade needed by a given group size.

Although it is clear that shade is beneficial and seems to be valuable to cattle, cooling with water is more efficient in reducing respiration rate and body temperature than shade alone (Correa-Calderon *et al.*, 2004). In New Zealand, the body temperature of dairy cattle often reaches a peak around afternoon milking (Kendall *et al.*, 2006), in part, because the cows often walk considerable distances to the milking parlour. The use of sprinklers at the milking parlour in the afternoon can be an effective way to reduce heat load at this time and approximately 40% of New Zealand dairy farms use sprinklers at the milking shed (Tucker *et al.*, 2005). However, little is

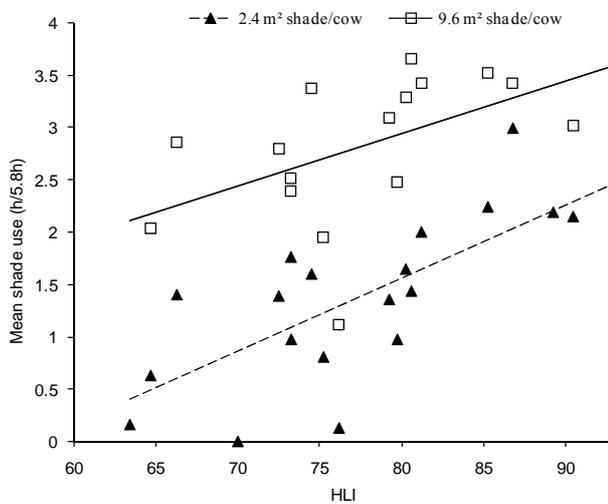
known regarding voluntary use of water cooling. Dairy cows preferred to use shade over sprinklers or no cooling in New Zealand; 62% of the cows preferred shade over sprinklers and 65% preferred shade over ambient conditions, despite sprinklers being more efficient in reducing respiration rate and insect avoidance behaviours (Schütz *et al.*, 2011).

In contrast, we found that non-lactating dairy cows in California will use a “cow shower” for, on average, three hours per day at temperatures >20°C (Legrand *et al.*, 2011). The shower use increased by 0.3 hour with every 1°C increase in temperature (Legrand *et al.*, 2011). These results indicate that water may be heavily used in specific situations. Further work investigating preferences for specific design features of water cooling, such as droplet size and impact, and the role of previous experience and control over delivery are needed in order to best deliver water cooling to cattle.

## SHEEP

Increased heat load in sheep is associated with an increase in respiration rate, body temperature (Lowe *et al.*, 2002), water intake and a reduction in feed intake, milk yield (Abdalla *et al.*, 1993) and liveweight gain (Dixon *et al.*, 1999). Other negative effects of warm weather include impaired reproduction (Shelton & Huston, 1968) and lower birth weights in lambs (Brown *et al.*, 1977). Behavioural adaptations to warm weather include a change in activity patterns, for example by spending more time near water (Thomas *et al.*, 2008), and body postures (Pollard *et al.*, 2004). Merino sheep showed a preference for cool drinking water (20 versus 30°C) when kept at 20°C, however this preference changed in a hot environment (30-40°C, Savage *et al.*, 2008), indicating that sheep prefer to drink water with temperature close to that of ambient temperature, which possibly is favourable for thermoregulation. Sheep readily use shade if given access to it and there are benefits in providing shade to sheep in terms of reducing respiration rate and body temperature (Pollard *et al.*, 2004) and improving lamb birth weights (Stephenson *et al.*, 1984) and growth rates (Cloete *et al.*, 2000). In New Zealand, Romney crossbred ewes spent a different amount of time in shade during daytime depending on if conditions were warm and dry (43% in Otago; mean daily temperature 18.5°C, humidity 49%), or warm and humid (67% in Waikato; mean daily temperature 22.0°C, humidity 67%) (Pollard *et al.*, 2004). Sheep that had access to shade had lower body temperatures and respiration rates at both locations and shade was efficient in reducing body temperature at temperatures >20°C. Weather conditions altered the behaviour of the sheep. High air temperature in the Waikato was associated with

**FIGURE 3:** Relationship between mean time spent in shade and Heat Load Index (HLI) of dairy cows with access to 2.4 m<sup>2</sup> or 9.6 m<sup>2</sup> shade/cow at pasture (1000 to 1550 h) in summer (n = 4 groups per treatment, 10 cows/group, 5 d/group)



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reduced grazing and sheep without shade spent less time lying compared to sheep with access to shade, which is consistent with findings of Lowe *et al.* (2002). In contrast, with increasing temperatures in Otago, both sheep with and without shade increased their lying activity and reduced grazing activities (Pollard *et al.*, 2004). This is consistent with findings of Merino sheep in the Mackenzie country in the South Island which also has a dry climate (Scott & Sutherland, 1981).

Respiration rate has been used as an indicator of heat load in sheep and Silanikove (2000) suggested a scale based on respiration rate to quantify heat stress. According to this, respiration rate of 80-120 breaths per minute indicates high levels of heat stress, and more than 200 breaths per minute indicates severe heat stress. The unshaded sheep in the study by Pollard *et al.* (2004) had respiration rates of 121 breaths per minute and 226 breaths per minute in the dry and humid conditions, respectively, which would put them into the category of high to severe levels of heat stress.

## PIGS

There is a large body of literature exploring the effects of warm weather on the health and welfare of pigs. General responses include an increase in respiration rate and body temperature (Fraser, 1970), and a reduction in daily feed intake and growth rates (Nienaber *et al.*, 1987). Pigs may experience difficulties to adapt to high ambient

temperatures due to their inability to sweat and lack of insulating fur. Therefore, most temperature loss occurs by evaporation through skin and secondarily from lungs and nose.

In response to warm weather pigs seek shade (Blackshaw & Blackshaw, 1994) or other cooler microclimates, such as wallows or wet floor areas where heat dissipation is high due to conduction (Aarnink *et al.*, 2001). The latter behavioural adaptation can cause an undesired increased proportion of pigs using the dung area for resting, or urinating and defecating in the lying area to moisten the floor. Pigs spend a large proportion of their day resting and it has been shown that growing pigs' preference for a bedded or cooler concrete floor depend on air temperature (Fraser, 1985). Domestic pigs in indoor systems cool down by increasing their time spent lying on their sides to maximize body surface to the floor, and physical contact to other pen-mates is avoided (Sällvik & Walberg, 1984). Aarnink *et al.* (2001) demonstrated that the relative number of pigs lying laterally increased by 1.8% for each 1°C rise in temperature. Also, the number of pigs lying in physical contact with each other fell by 3.7% for each 1°C increase over the range of 16 to 32°C. Thus, it is important for pigs housed indoors to have sufficient space to be able to respond in an adaptive manner. Indeed, in the Ministry of Agriculture and Forestry (2010) Code of Welfare for Pigs it is suggested that the current industry guidelines for space requirements are reviewed as 10-50% more space may be required to provide for all pigs' needs, depending on their level of activity and thermal conditions.

There is little research about heat stress in pigs in New Zealand and minimum standards and best practice recommendations are based on international research. Different cooling methods in the pig industry include the use of wallows, cool pads, foggers, spraying, sprinklers, and mechanical and natural ventilation. Current cooling systems used in the swine industry internationally generally rely on increased convection with increased air flow or snout coolers, or evaporation with mist/sprinkling or water drips to increase heat loss (Bull *et al.*, 1997). New Zealand indoor systems are usually managed with fully enclosed environmentally controlled sheds that are well insulated and fan ventilated. Water cooling may be provided by the use of spays or drippers to provide evaporative cooling. Other systems will be naturally ventilated with curtains opening up to provide air movement. Outdoor systems typically provide man-made or natural shade or shelter and/or water cooling, such as wallows or drippers in the paddock.

## DEER

Warm weather is associated with increased respiration rate, body temperature and skin temperature in deer (Parker, 1988), but there is little research regarding the effect of heat stress on the production and welfare of farmed deer. Behavioural responses to warm weather include seeking shade or other favourable microclimates (Pollard *et al.*, 2003). It is for example, well-known that deer wallow but it is unclear about any potential benefits in terms of cooling or production. However, the benefits of providing shade and shelter to deer is well recognised by New Zealand producers. Seventy-nine percent of New Zealand deer farmers believed that shade is beneficial to deer health and there have been some suggestions from producers on the type of shade and its location in the paddock (Pollard *et al.*, 2003). In a survey 72% of the producers believed that shade was best placed along the edges of the paddock. Shelter use of red deer calves increased with daily maximum temperature over the range of 18 to 28°C, and the calves were observed more than twice as often in the shelter during the warmest part of the day compared to in the morning (Hodgetts *et al.*, 2002). Furthermore, White-tailed deer fawns chose bedsites with lower ambient temperature than the surrounding area at air temperatures >24°C (Huegel *et al.*, 1986). However, there is very little science based evidence of heat stress in deer and on the benefits of cooling. More research is needed to clarify the benefits of providing different cooling methods for farmed deer.

## RECOMMENDATIONS FOR FUTURE RESEARCH

There is consistent evidence that heat stress is negative for the productivity and health and welfare of farm animals. Despite New Zealand having a temperate climate that in general is well suited for extensive livestock production, warm weather is likely to impair the welfare and productivity of animals. Future research in New Zealand should focus on how to best cool animals in New Zealand conditions, including specific information regarding species, management systems, breed and thermal environment. In addition to measures of biological function, measures of an animals' affective state and ability to perform natural behaviours should be taken into account. It would also be beneficial to perform accurate cost benefit analyses of providing different cooling options to animals, taking into account economical restriction in applying measures to relieve heat stress in relation to any welfare and production benefits.

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