



Livestock Heat Stress: Recognition, Response, and Prevention

WASHINGTON STATE UNIVERSITY EXTENSION FACT SHEET • FS157E

Introduction

Livestock can experience heat stress during hot weather, particularly if the heat is prolonged or temperatures are extremely high. Heat stress can reduce livestock feed intake, growth, production, reproduction, welfare, and health. In 2003, annual losses to the livestock and poultry industries attributable to heat stress were calculated to be between \$1.69 billion and \$2.36 billion annually (St-Pierre et al. 2003). Thus, it is essential to understand heat stress, its signs, and management practices that can mitigate its effects on livestock.

The Thermoneutral Zone

The Thermoneutral Zone (TNZ) is the environmental temperature range in which the least effort is required by an animal to regulate body temperature. In the TNZ, an animal is most comfortable, has the fastest growth rate,

Table 1. Livestock thermoneutral zones. (Source: USDA Natural Resource Conservation Service National Range and Pasture Handbook 2003.)

Species	TNZ Temperature Range (°F)
Cattle	41–68
Calves	50–68
Sheep	70–88*
Goats	50–68

*Highly variable, depends on age and fleece thickness

and achieves the most efficient feed-to-gain ratio. This temperature zone is highly variable and depends on factors such as species, humidity, time of year, age, acclimation, amount of fat or hair coat insulation, level of production, wind, and other factors. Table 1 provides examples of the TNZ for cattle, sheep, and goats, but vastly different data from other credible sources also exist. Figure 1 depicts the

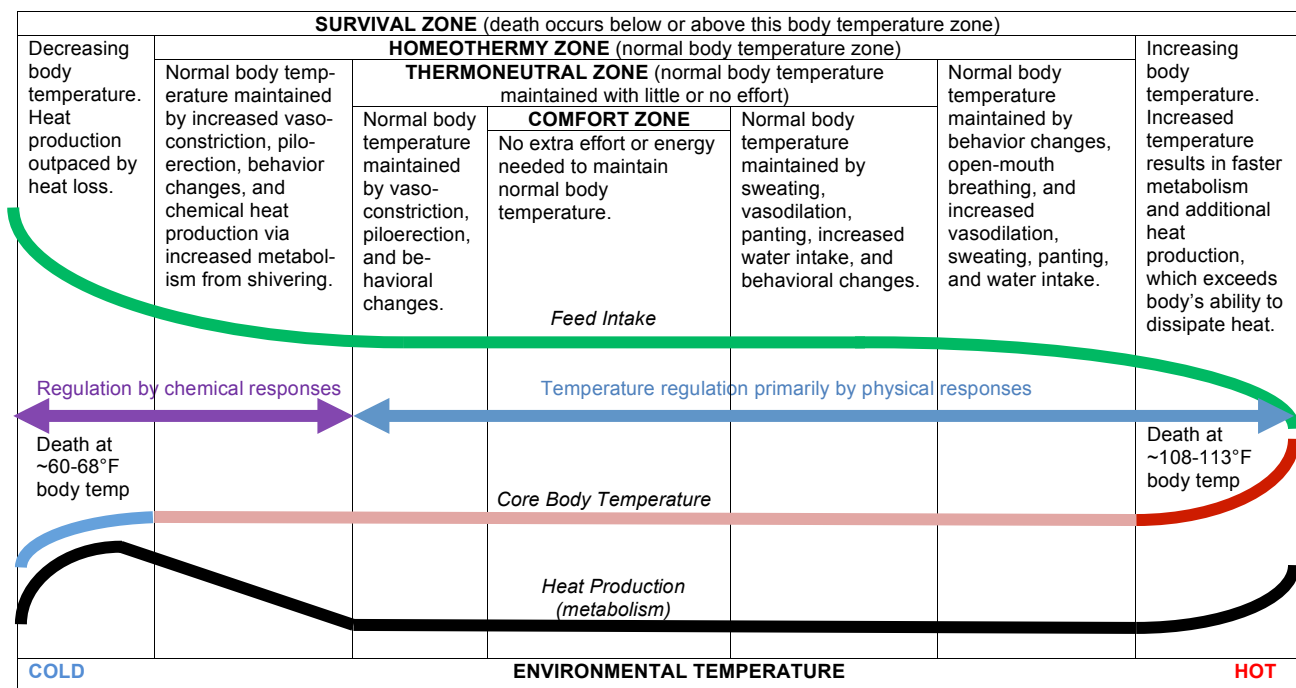


Figure 1. Mechanisms of body temperature regulation in mammals in response to various environmental temperatures. (Adapted from Brody 1945; Bianca 1968; McLean 1991; and Silanikove 2000.)

Temperature		% Relative Humidity																				
°F	°C	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
72	22.0	64	65	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72	72
73	23.0	65	65	66	66	66	67	67	68	68	68	69	69	70	70	71	71	71	72	72	73	73
74	23.5	65	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74
75	24.0	66	66	67	67	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
76	24.5	66	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76
77	25.0	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	77
78	25.5	67	68	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	76	77	77	78
79	26.0	67	68	69	69	70	70	71	71	72	73	73	74	74	75	76	76	77	77	78	78	79
80	26.5	68	69	69	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78	79	79	80
81	27.0	68	69	70	70	71	72	72	73	73	74	75	75	76	77	77	78	78	79	80	80	81
82	28.0	69	69	70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82
83	28.5	69	70	71	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	82	83
84	29.0	70	70	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84
85	29.5	70	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85
86	30.0	71	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
87	30.5	71	72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	85	85	86	87
88	31.0	72	72	73	74	75	76	76	77	78	79	80	81	81	82	83	84	85	86	86	87	88
89	31.5	72	73	74	75	75	76	77	78	79	80	80	81	82	83	84	85	86	86	87	88	89
90	32.0	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
91	33.0	73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89	90	91
92	33.5	73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90	91	92
93	34.0	74	75	76	77	78	79	80	80	81	82	83	85	85	86	87	88	89	90	91	92	93
94	34.5	74	75	76	77	78	79	80	81	82	83	84	86	86	87	88	89	90	91	92	93	94
95	35.0	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
96	35.5	75	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94	95	96
97	36.0	76	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92	93	94	95	96	97
98	36.5	76	77	78	80	80	82	83	83	85	86	87	88	89	90	91	92	93	94	95	96	98
99	37.0	76	78	79	80	81	82	83	84	85	87	88	89	90	91	92	93	94	95	96	98	99
100	38.0	77	78	79	81	82	83	84	85	86	87	88	90	91	92	93	94	95	96	98	99	100
101	38.5	77	79	80	81	82	83	84	86	87	88	89	90	92	93	94	95	96	98	99	100	101
102	39.0	78	79	80	82	83	84	85	86	87	89	90	91	92	94	95	96	97	98	100	101	102
103	39.5	78	79	81	82	83	84	86	87	88	89	91	92	93	94	96	97	98	99	101	102	103
104	40.0	79	80	81	83	84	85	86	88	89	90	91	93	94	95	96	98	99	100	101	103	104
105	40.5	79	80	82	83	84	86	87	88	89	91	92	93	95	96	97	99	100	101	102	103	105
106	41.0	80	81	82	84	85	87	88	89	90	91	93	94	95	97	98	99	101	102	103	104	106
107	41.5	80	81	83	84	85	87	88	89	91	92	94	95	96	98	99	100	102	103	104	106	107
108	42.0	81	82	83	85	86	88	89	90	92	93	94	96	97	98	100	101	103	104	105	107	108
109	43.0	81	82	84	85	87	89	89	91	92	94	95	96	98	99	101	102	103	105	106	108	109
110	43.5	81	83	84	86	87	89	90	91	93	94	96	97	99	100	101	103	104	106	107	109	110
111	44.0	82	83	85	86	88	90	91	92	94	95	96	98	99	101	102	104	105	107	108	110	111
112	44.5	82	84	85	87	88	90	91	93	94	96	97	99	100	102	103	105	106	108	109	111	112
113	45.0	83	84	86	87	89	91	92	93	95	96	98	99	101	102	104	105	107	108	110	111	113
114	45.5	83	85	86	88	89	92	92	94	96	97	99	100	102	103	105	106	108	109	111	112	114
115	46.0	84	85	87	88	90	92	93	95	96	98	99	101	102	104	106	107	109	110	112	113	115
116	46.5	84	86	87	89	90	93	94	95	97	98	100	102	103	105	106	108	110	111	113	114	116
117	47.0	85	86	88	89	91	93	94	96	98	99	101	102	104	106	107	109	111	112	114	115	117
118	48.0	85	87	88	90	92	94	95	97	98	100	102	103	105	106	108	110	111	113	115	116	118
119	48.5	85	87	89	90	92	94	96	87	99	101	102	104	106	107	109	111	112	114	116	117	119
120	49.0	86	88	89	91	93	95	96	98	100	101	103	105	106	108	110	111	113	115	117	118	120
121	49.5	86	88	90	92	93	96	97	98	100	102	104	105	107	109	111	112	114	116	118	119	121
122	50.0	87	89	90	92	94	96	97	99	101	103	104	106	108	110	111	113	115	117	118	120	122
123	50.5	87	89	91	93	94	97	98	100	102	103	105	107	109	110	112	114	116	118	119	121	123
124	51.0	88	90	91	93	95	97	99	100	102	104	106	108	109	111	113	115	117	119	120	122	124
125	51.5	88	90	92	94	96	97	99	101	103	105	107	108	110	112	114	116	118	119	121	123	125
126	52.0	89	90	92	94	96	98	100	102	103	105	107	109	111	113	115	117	119	120	122	124	126
127	53.0	89	91	93	95	97	99	100	102	104	106	108	110	112	114	116	118	119	121	123	125	127
128	53.5	90	91	93	95	97	99	101	103	105	107	109	111	113	115	116	118	120	122	124	126	128
129	54.0	90	92	94	96	98	100	102	104	106	108	109	111	113	115	117	119	121	123	125	127	129
130	54.5	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	122	124	126	128	130
131	55.0	91	93	95	97	99	101	103	105	107	109	111	113	115	117	119	121	123	125	127	129	131
132	55.5	91	93	95	97	99	101	104	106	108	110	112	114	116	118	120	122	124	126	128	130	132
133	56.0	92	94	96	98	100	102	104	106	108	110	112	114	117	119	121	123	125	127	129	131	133

Figure 2. Revised Temperature Humidity Index for lactating dairy cattle. (From Smith et al. 2012, used with permission.)

TNZ and a mammal's bodily response to changing environmental temperatures.

Effective Environmental Temperature

The Temperature Humidity Index (THI) provided in Figure 2 shows how environmental temperature and humidity combine to create an “effective temperature,” which is a measure of how hot it feels at various levels of humidity. In 2012, Smith et al. revised the existing THI chart for dairy cattle to reflect changes in the TNZs of high-producing cattle on energy-dense diets. Genetic selection has resulted in highly-productive animals with high metabolic rates; however, these animals experience heat stress at lower temperatures than previous generations of dairy cattle. The THI shows that higher humidity equates with higher effective temperatures at lower thermometer readings, putting animals into heat stress at lower environmental temperatures.

Table 2 shows the degree of heat stress with corresponding THI values for dairy cattle and non-dairy cattle livestock. Note that dairy cattle experience heat stress at lower environmental temperatures than other species. For example, at a THI of just 68, dairy cattle reduce milk production by an average of 4.4 lb per day and experience increased fetal death rates (Smith et al. 2012).

Mechanisms of Heat Loss and Gain

There are four means by which a body can gain or lose heat from the environment: radiation, conduction, convection, and evaporation.

Table 2. Degree of heat stress with corresponding Temperature Humidity Index value for dairy cattle and non-dairy cattle livestock (Adapted from Smith et al. 2012 and National Pork Board 2014.)

Degree of heat stress	THI, non-dairy cattle livestock	THI, dairy cattle
No significant heat stress	≤69	≤67
Stress threshold; monitor livestock and be alert for problems	70–74	68–71
Mild—signs of heat stress widely evident but most animals coping	75–78	72–79
Moderate—danger zone; some animals will be significantly affected	79–83	80–89
Severe—emergency situation; most animals severely heat stressed and struggling	84–90	90–98
Extreme—fatalities expected	≥91	≥99

and evaporation. Examples of these mechanisms are shown in Figure 3. In hot environments, cooling via evaporation is the most effective means of heat loss, but it is much less effective in high humidity.

Body Temperature Regulation

Temperature receptors in the skin, brain, and body core receive information from the environment and the body

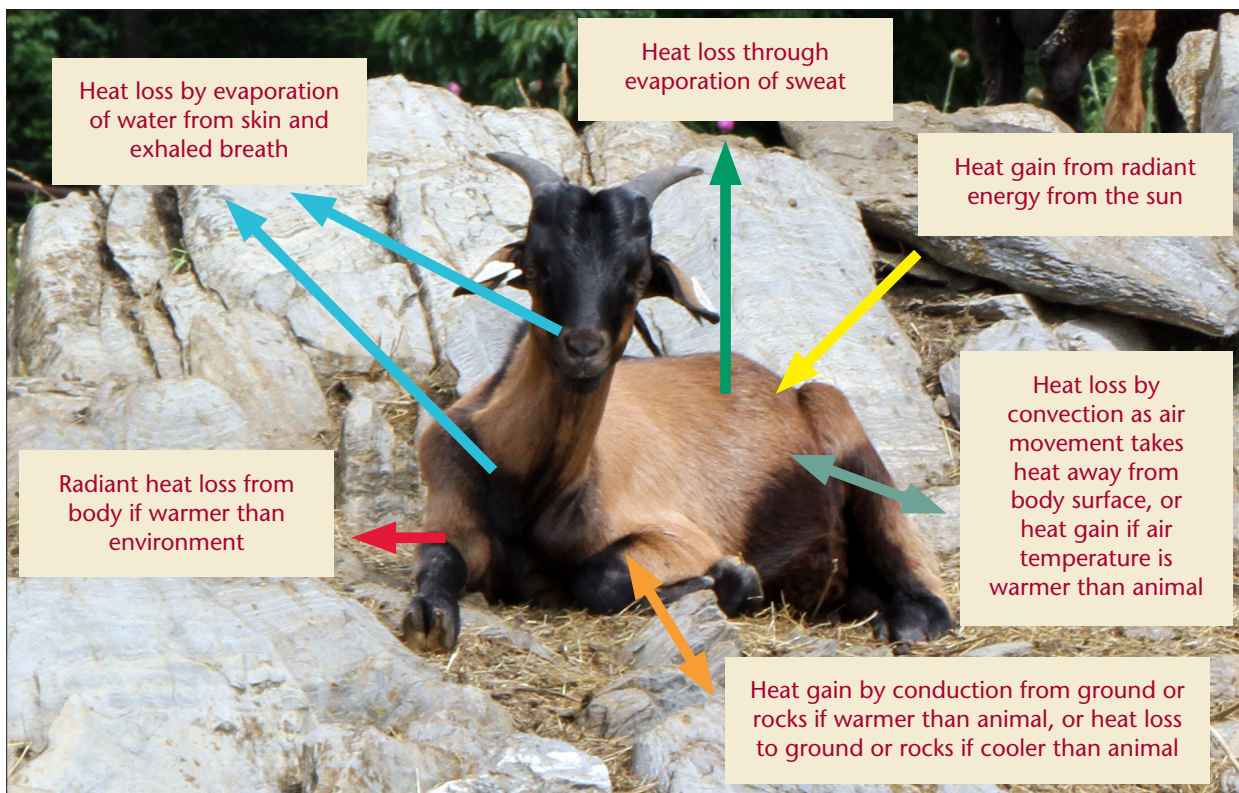


Figure 3. Mechanisms of heat exchange between mammals and their environment via radiation, conduction, convection, or evaporation. (Photo courtesy of Susan Schoenian, University of Maryland Extension.)

itself (Robertshaw 2004). These receptors send messages to the part of the brain called the hypothalamus, which determines the set point for normal body temperature. A feedback loop between temperature receptors and the hypothalamus maintains normal body temperature through physiological and behavioral changes that increase or decrease heat loss or production (Robertshaw 2004). For example, if incoming messages indicate increasing temperatures, the hypothalamus will signal the body to increase heat loss through blood vessel dilation (vasodilation) and sweating.

When the environmental temperature increases, animals can maintain a core body temperature within the thermoneutral zone by seeking shade, drinking water, changing posture, and/or reducing feed intake. They can dilate blood vessels (especially on extremities) and increase the amount of heat released through water vapor from nasal passages through increased respiratory rates (Robertshaw 2004). Cattle, sheep, goats, and horses can also regulate body temperature to some extent by sweating, but pigs lack this ability. Animals in heat stress not only seek shade and water, but also flatten their coats to reduce heat retention and absorption and may extend their bodies to allow as much evaporation and ventilation as possible. Paradoxically, they may huddle in groups, perhaps in an effort to reduce exposure to the sun if no shade is available.

If the environmental temperature continues to rise, mammals lose the ability to keep their body temperature within normal limits. The very high respiratory rates and panting that occur when an animal tries to cool itself increases muscular activity, which generates more body heat. Additionally, metabolic processes are faster at higher temperatures and increased metabolism generates even more heat as a by-product of bodily reactions. With no respite from heat, combined with an increasing metabolic rate and increased efforts to stabilize body temperature, livestock can be trapped in an upward heat spiral that can be fatal above a body temperature of 108°F to 113°F (McLean 1991).

Black or dark-colored animals may be even more severely affected than lighter-colored animals because they absorb more heat and may have more trouble dissipating it. Gaughan et al. (2008) found that white animals were able to tolerate three more degrees of heat load before experiencing heat stress when compared to black animals.

Livestock nearing slaughter readiness, obese, sick, or convalescing animals, high-producing dairy animals, and recently transported animals are also at increased risk of heat stress.

Signs of Heat Stress

Monitoring animal behavioral and physical cues can help producers determine if livestock are heat stressed. Signs of heat stress can include:

- Crowding around water tanks or shade
- Lethargy
- Poor appetite
- Increased respiratory rate

- Elevated rectal temperature
- Elevated heart rate
- Immobility or aimless wandering
- Staggering
- Drooling or slobbering
- Open-mouth breathing
- Collapse
- Non-responsiveness
- Seizures
- Death

Normal rectal temperatures and respiratory rates of domestic livestock species are shown in Table 3. These ranges can be used as a baseline for comparison when determining the degree of heat stress.

Table 3. Normal rectal temperatures and resting respiratory rates of domestic livestock. (Adapted from Robertshaw 2004; Merck Veterinary Manual 2010; Smith and Sherman 2009.)

Species	Normal Temperature (°F)	Resting Respiratory Rate (breaths per minute)
Beef cattle	98 to 102.4	26–50
Dairy cattle	100.4 to 102.8	26–50
Goat	101.5 to 104*	10–30
Horse	99 to 100.5	10–14
Pig	101.6 to 103.6	32–58
Sheep	100.9 to 103.8*	16–34

*Temperature can be even higher yet still considered normal in very hot weather.

Observing animal behavior can also help assess the degree of heat stress: if animals never cease eating or being active, they are not demonstrating significant heat stress; if animals return to eating/grazing and normal activity within a few hours following the hottest time of the day, they probably are not experiencing residual heat stress they cannot dissipate. However, if animals remain off feed and inactive through the next morning, they are being seriously affected by the heat. Unless night temperatures drop below 75°F, cattle will experience constant hyperthermia (McLean 1991) and begin the next day with an accumulated heat load (Gaughan 2008).

Measuring respiratory rate is a practical and effective way to assess the level of heat stress. Indeed, "...qualifying the severity of heat stress according to panting rate...appears to be the most accessible and easiest method for evaluating the impact [of] heat stress on farm animals under extensive conditions; all it requires is direct observation and a watch" (Silanikove 2000).

Table 4 depicts the association between respiratory rate and degree of heat stress in cattle and sheep. Table 5 presents a scoring system for panting developed by the Meat and Livestock Australia organization. Interestingly, a study of feedlot cattle documented highest environmental temperatures at 3 p.m. and highest panting scores at 5 p.m.,

Table 4. Correlation of respiratory rate with degree of heat stress in cattle and sheep (Adapted from Silanikove 2000.)

Degree of Heat Stress	Respiratory Rate (breaths per minute)
Low	40–60
Medium high	60–80
High	80–120
Severe	>150 (cattle), >200 (sheep)

Table 5. Cattle panting scoring system, adapted from Meat and Livestock Australia (2006).

Panting Score	Breaths per Minute	Description
0	<40	Normal, no panting. Hard to see chest moving.
1	40–70	Slight panting, mouth closed, easy to see chest moving.
2	70–120	Fast panting with drooling or foam from mouth.
2.5	70–120	Same as 2 with occasional open-mouth panting.
3	120–160	Open-mouth panting, some drooling. Neck extended, head up. THRESHOLD FOR CONCERN IF LASTS MORE THAN TWO HOURS.
3.5	120–160	Same as 3 with tongue somewhat extended, significant drooling.
4	>160	Open mouth with tongue fully extended for prolonged periods, significant excessive drooling. Neck extended, head up.
4.5	Very low to very high	Same as 4 but head down, +/- drooling. Labored abdominal breathing.

Recommendations from Meat and Livestock Australia regarding panting scores:

- Assess panting scores of at-risk cattle during periods of predicted heat stress beginning at 6 a.m. and every two hours thereafter until 6 p.m. or later.
- If >10% of animals have panting scores >2, do not handle or move cattle.
- A score of >3.5 indicates cattle are at risk of death from heat stress if not provided relief.
- In very hot weather, it may take less than two hours for panting scores to progress from 2.5 (serious) to 4.5 (possibly fatal).

indicating a lag time between heat gain and heat dissipation (Mader et al. 2006).

Research results reported by Mader et al. in 2006 quantified the effects of wind speed and solar radiation on THI. They used this information to create a formula to predict panting scores based on data from local weather stations. Predicted panting scores can be calculated and used proactively to closely monitor cattle for heat stress, take steps to reduce the degree of heat stress, and be prepared in advance to respond quickly.

Effects of Heat Stress

Some effects of heat stress are obvious within a short period of time, such as reduced milk production or reduced rate of weight gain. However, other effects are not immediately evident. Heat stress studies demonstrated that heat-stressed cows had gestation lengths four days less than average, gave birth to calves with reduced body weight, and had reduced colostrum (first milk) quality. Calves born to heat-stressed cows also had compromised immunity (Tao et al. 2012). Male fertility can be reduced for weeks after significant heat stress (Meyerhoeffler et al. 2002), so reduction of heat stress is of particular importance for fall breeding species, such as sheep and goats.

Heat stress also decreases uterine blood flow due to peripheral vasodilation, resulting in increased fetal abnormalities and mortality (McLean 1991). An increase of uterine temperature of just 1.8°F to 2.7°F can kill a fetal calf (McLean 1991). A 2014 study by Schüller et al. showed a drop in dairy cattle conception rates from 31% to 12% when the THI was at least 73 before and after the day of breeding.

Pigs with two copies of the Porcine Stress Syndrome gene are particularly sensitive to heat. They can die when stressed, or they may produce a carcass with undesirably pale, soft, and exudative (weepee) meat. Heat-stressed slaughter cattle are more likely to have abnormally dark carcasses (“dark cutters”), with diminished meat quality and value. A heat stress study of pregnant and lactating sows revealed reduced feed intake, decreased milk production, and decreased piglet weaning weights in heat-stressed sows (Williams et al. 2013).

Management Practices for Mitigating Heat Stress

Managing water supply and availability

In hot weather, unlimited cool, fresh water is essential for every animal. Heat loss through evaporation requires significant amounts of water above maintenance requirements. Dehydrated animals have difficulty regulating body temperature (Silanikove 2000). Water needs can increase substantially during hot weather. For example, beef cattle may need two gallons per 100 lb of body weight *per hour* when temperatures reach 80°F (Mader et al. 2007). Additional watering locations and/or water pressure may be needed to accommodate many animals drinking simultaneously.

Size-appropriate water sources are very important for young animals to access all the water they need. If waterers do not automatically refill, frequent monitoring will be required throughout the day. Stagnant ponds are poor sources of high quality cool water on hot days and can also be a source of diseases such as mastitis and botulism.

Erecting shade over water tanks or moving watering sources to shady areas will decrease water temperature, increase consumption, and reduce internal body temperatures. In small-scale settings, ice can be added to water tanks periodically to keep water cool and encourage intake.

Managing shade requirements

Shade is essential for animal comfort during hot weather and can increase the heat load feedlot cattle are able to tolerate by as much as seven degrees (Gaughan 2008). Barns are not necessarily more comfortable than outdoor shaded areas, especially if there is poor air quality in the barn. Light-colored roofs with insulation below will help buildings reflect heat. Animals might be most comfortable outdoors under shade trees with a light breeze; trees can be planted to provide long-term natural shade. Calves housed in hutches can benefit from additional shade, perhaps by locating hutches under shade trees. Elevating the back of a hutch approximately six inches will also improve ventilation and decrease the temperature within the hutch (Moore et al. 2012).

Temporary shade can be provided by tarps, shade cloths, wagons, lean-tos, and the like. Figure 4 shows an inexpensive example of supplemental shade. Make sure such temporary structures do not become a safety hazard for livestock, especially curious goats. Any shading structures should provide enough space for all livestock without creating counterproductive crowding under the structure or exclusion of some animals. Low social status animals may not have access to shade if it is limited. A short structure with solid walls will not allow adequate ventilation and condensation could develop, so be sure the structure is tall enough to allow good airflow and dissipation of animal body heat—approximately 8 ft to 14 ft is recommended (Mader et al. 2007).



Figure 4. Goats under supplemental shade during significant summer heat. (Photo courtesy of The Kerr Center for Sustainable Agriculture.)

Solid roof structures offer the greatest protection from the sun's radiant heat energy, but portable structures with a shade cloth may be more affordable and practical in pasture conditions (Figure 5). Orienting structures east to west will allow greater access to shade throughout the day, but north to south orientation should be considered if mud accumulation is a challenge (Mader et al. 2007).

Managing nutritional needs

One of the primary ways animals manifest heat stress is to stop eating. Ensuring adequate feed intake is particularly

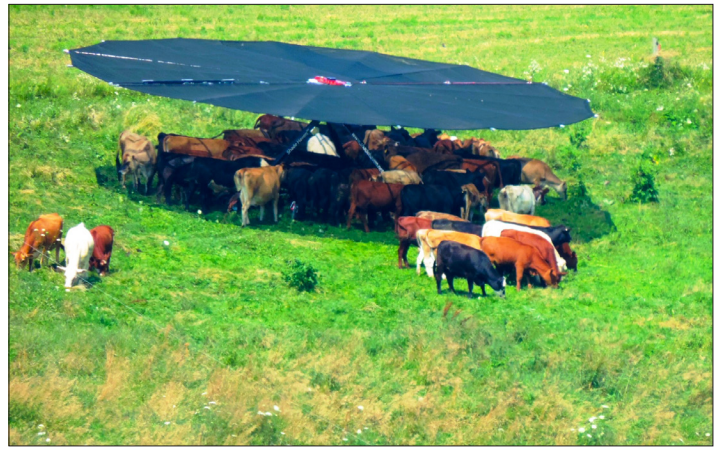


Figure 5. A commercially produced portable shade structure for livestock. (Photo courtesy of Shade Haven LLC.)

important for lactating and growing animals to meet their high nutritional needs. Anything that interferes with feed intake will affect growth rates and production.

Because animals experience an increase in body temperature after meals (heat increment), feed 70% of the ration in the evening as animals head into the cooler part of the day (Mader 2007). Animals can be encouraged to consume the rest of their ration by offering frequent, small, fresh meals. This approach can work well with nearly-finished market animals, because they can be seriously affected by heat due to their fat cover, which increases heat retention.

Unweaned youngstock sometimes stop consuming grain starters in hot weather, but they may continue to consume milk or milk replacer. It may be necessary to increase the milk component of their diet to meet the nutritional needs that were met by starter. Increase the likelihood of starter consumption by offering multiple small feedings throughout the day. This keeps feed fresh, stimulates interest, and helps prevent mold development in stagnant feed. Again, keep plenty of cool, fresh water available and accessible to young animals at all times.

Rations may need to be adjusted during hot spells. Some recommendations call for reducing dietary energy from grains by 5% to 7% during periods of heat stress (Mader 2007); fat content can be increased to increase ration palatability and maintain required caloric levels with less heat increment. The fiber and roughage portion of rations may need to be temporarily reduced during extremely hot weather so animals continue to meet their nutritional requirements through a more nutrient-dense ration (Bianca 1976). Roughage causes increases in body heat as a result of digestive processes, which is an advantage in winter but not in hot weather. Providing more digestible fiber during hot weather should reduce the body heat increment that results from fiber digestion. Never reduce roughage to the point that rumen health is affected and make all ration changes slowly and carefully. Monitor week-long weather forecasts and adjust rations for hot weather accordingly.

Keep trace mineral salt and water available for free-choice consumption, so animals can maintain proper fluid and electrolyte balance. Loose salt will encourage consumption more than block forms. Dairy cattle nutritionists may need to reformulate the mineral content of rations and include more sodium and potassium to account for electrolyte losses.

Managing ventilation

In hot weather, air flow can increase animal comfort significantly by increasing the amount of body heat lost by convection. In some horse and small herd situations, fans can keep air moving and animals feeling cooler. The traditional British system for summertime equine care involves stalling horses with fans during the day and turning them out to pasture to graze in the cool of the evening.

Ceiling vents and ceiling fans can route rising hot, humid air up and out of barns. Ventilation fans in barns must exchange air at a rate in keeping with animal density to ensure a barn does not become oppressively humid and uncomfortable—hot air holds more moisture and impedes the cooling effect of evaporating sweat.

A 2012 study of dairy cattle under heat stress found that applying 1/3 gallon of water to cows' backs every five minutes in the presence of fans was very effective in reducing heat stress, more so than either approach alone or longer intervals between soakings (Smith et al. 2012).

Tall earthen mounds are often provided in feedlots to help cattle distribute themselves at various levels, allowing greater airflow among animals. Wind speeds are usually a little higher on elevated mounds, as well.

Managing fly populations

Livestock often gather in tight groups in response to heavy fly populations. This can reduce airflow around animals, increase local humidity, elevate body temperature, and increase heat stress. Flies can also stimulate unnecessary animal movement, which generates additional body heat. Remove fly habitat, including manure, and use integrated pest management strategies to control fly populations and increase animal comfort.

Managing animal handling and transportation during hot weather

Animal-handling practices during hot weather involve simple common sense—do not overcrowd animals, move them slowly if at all, and work them in the early morning if absolutely necessary. When possible, delay any work, treatment, transportation, or handling until hot temperatures abate—moving cattle can increase their body temperature by 0.5°F to 3.5°F. Decrease animal numbers in pens by 10% to 15% to allow more room per animal, more ventilation, and less humidity from respiration.

If transportation during hot weather cannot be avoided, follow these guidelines:

- Load quickly but minimize animal-handling stress
- If high temperatures already exist, sprinkle pigs and cattle with large water droplets for a few minutes before loading; sprinkle again en route if possible
- Be sure animals are well watered before loading
- Move animals so they are at their destination by 10 a.m.
- Reduce the number of animals in trailers by 10% to 20% of normal capacity (Grandin 2013a)
- For trips greater than three hours, provide enough space for pigs and sheep to lie down (Grandin 2013a)
- Open all trailer air vents to maximize passive ventilation and air movement to remove heat and moisture. Be sure animals do not block air vents. Install active ventilation systems (fans) if passive ventilation is insufficient
- Prevent diesel fumes from venting on livestock by extending the tractor exhaust stack above the trailer roof
- Bed with 1 inch of wet sand or 2 inches of wet sawdust. Do not use straw—this is particularly important for pigs (Grandin 2013b)
- Do not make unnecessary stops. If a stop is unavoidable, park in the shade and crossways to prevailing winds for maximum ventilation. A stopping duration of at least eight hours is recommended for sheep to give them adequate time for water intake after eating (Grandin 2013a)
- Unload promptly at destination and quickly house animals in the shade with access to cool water. Sprinkle livestock with water if indicated.

Managing special cases

Pigs are of special concern in hot weather because they cannot cool themselves by sweating, which makes them especially vulnerable to heat stress. Concern about swine heat stress and hyperthermia generally increases with their age and weight. Table 6 depicts the thermal comfort zone of pigs at various weights and ages. Pigs can experience significant heat stress at just 60°F (Grandin 2013a).

Table 6. Thermal comfort ranges of swine at various stages (Adapted from 2003 Swine Care Handbook, National Pork Board.)

Age or Weight	Environmental Temperature (°F)
Newborn	90–95
+10–30 lb	80–90
30–75 lb	65–80
75–150 lb	60–75
150–220 lb	50–75
Adult	60–75
Lactating sow	60–80



Figure 6. Pigs on pasture at the Kerr Center in Oklahoma with wallow cooled by overhead tarp. (Photo courtesy of The Kerr Center for Sustainable Agriculture.)

However, pigs respond well to periodic wetting with sprinklers to help them stay cool via evaporation. This becomes critical when the effective environmental temperature is equal to or greater than 80°F (Grandin 2013b), or if animals are showing signs of heat stress. Thoroughly wetting them periodically with large water droplets and allowing them to dry between applications is more effective than misting, and proactive intervention is more effective than trying to cool pigs that are already heat stressed. As the environmental temperature increases, increase the wetting frequency, but always allow time for evaporation between applications—the evaporation process removes heat from pigs' bodies. Never apply cold water directly to a pig's body. Do not add so much water to the environment that humidity increases because evaporation becomes less effective in high humidity. If resources are limited, focus cooling efforts on lactating sows (Williams et al. 2013).

Pigs create and access wallows (muddy areas with standing water), but wallows become ineffective if they accumulate too much heat. Shade wallows to keep them cool. Figure 6 shows an example of a low-cost shade option. One advantage of providing a wallow is pigs may keep their water source cleaner, instead of lounging in it to keep cool.

Sheep can also be affected by heat stress. Wool is an excellent insulator and protects sheep from extreme hot and cold temperatures. Although shearing is not absolutely essential for sheep to be comfortable during hot weather, animals will have less work to do if they do not have to carry ten or more extra pounds of fleece around. Annual shearing is a best practice for wool breeds, and most producers do this before lambing for cleanliness purposes; shorn ewes therefore usually have short fleeces during the summer anyway. Sheep are able to regulate their temperature somewhat by sweating, but primarily by increasing respiratory rate to increase evaporative heat loss through water vapor. Sheep show the smallest change in body temperature with increasing environmental temperature and can stay relatively comfortable over a wide range of environmental temperatures (Bianca 1968).

Acclimation to High Temperatures

Animals can adapt to higher temperatures with time. They shed their hair coat; reduce thyroid hormone production and therefore metabolic rate; increase sweating; and expand their blood volume to maintain peripheral vasodilation and promote heat loss (Robertshaw 2004). Successful acclimatization adaptations are evident in *Bos indicus* cattle (Brahman and Zebu-type breeds). *B. indicus* cattle concentrate fat stores in a single subcutaneous location—their hump—thereby having less overall insulation. They also have short and light-colored coats, lower metabolic rates, and long legs and large folds of skin to increase surface area for heat dissipation (Robertshaw 2004). *B. indicus* cattle can withstand up to 95°F before experiencing an increase in core body temperature, whereas the internal temperatures of *B. taurus* breeds (for example, Holstein, Jersey, Brown Swiss) begin to rise at effective environmental temperatures of 70°F, 75°F, and 81°F, respectively (McLean 1991).

Response to Heat-Stressed Animals

Producers who raise livestock in areas that can experience high THI values should be prepared to treat clinically-affected individuals. Caution should be exerted so these animals are not further stressed by treatment.

Individual animals needing treatment will show severely elevated respiration rates, open-mouthed breathing, salivation, unwillingness to move, collapse, and other signs described in the section on signs of heat stress in this publication. Affected animals should not be forced to walk to a treatment area or be separated from the herd. Effective shade should be provided promptly. A veterinarian should be consulted immediately to determine the most effective actions to take on the farm while awaiting veterinary treatment. A veterinarian can administer intravenous fluids and other appropriate medications to increase the likelihood of a successful treatment outcome.

Prevention is the key to managing heat stress in livestock. Even if severely affected animals survive treatment, they can manifest long-term health, reproductive, performance, and/or carcass quality issues in the future.

Heat Stress Prediction Tools

Keep a close eye on weather forecasts, temperature, and humidity, and adjust management practices and feeding plans accordingly. Precipitation followed by hot weather is cause for concern, especially if temperatures do not drop below 70°F overnight. Plans for heat stress reduction should be set in motion before animals show signs of heat stress. In other words, put the emphasis on prevention instead of response.

Heat stress forecast maps for cattle are available on the USDA website at www.ars.usda.gov/Main/docs.htm?docid=21306. These heat stress forecast maps are based on predictions of temperature, humidity, wind speed, and cloud cover. The maps are produced through a partner-

ship of the National Oceanic and Atmospheric Administration, National Weather Service, and USDA Agricultural Research Service. Also, a free livestock and poultry heat stress app developed by the Ontario Ministry of Agriculture and Food, the Ministry of Rural Affairs, and the University of Guelph is available at www.omafra.gov.on.ca/english/engineer/facts/heat-app.htm.

Additionally, the University of Missouri has created a free app called ThermalAid to help beef and dairy cattle producers detect, monitor, and reduce heat stress in their livestock. It is available at <http://thermalnet.missouri.edu/ThermalAid/index.html>.

Conclusion

Hot weather can tax livestock managers' abilities to keep animals comfortable and eating well. Implementing proactive measures to reduce the effects of hot weather on livestock is much more effective than treating overheated animals. Ensure animals have adequate water, shade, nutrition, space, and ventilation. Watch closely for signs of heat stress in individual animals and respond accordingly, consulting a veterinarian as needed. Keeping animals eating, growing, producing, and comfortable during hot weather is a challenge, but can contribute to the sense of accomplishment and satisfaction that comes from being a compassionate, effective, and successful animal caretaker.

Action Items in a Heat Stress Emergency

1. Provide shade immediately.
2. Soak the animal's body with lukewarm to cool water.
3. Increase airflow around the animal using fans if possible.
4. Provide cool drinking water.
5. Minimize handling, transportation, and stress.
6. Call veterinarian for consultation.

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Further Reading

- **Cattle and Swine Trucking Guide**
<http://www.ams.usda.gov/AMSV1.0/getfile?dDocName=STELDEV3008268>

- **Heat Stress in Beef Cattle**
<http://vetmed.iastate.edu/vdpam/extension/beef/current-events/heat-stress-beef-cattle>
<http://tinyurl.com/p7kd3h5> (by Stephen Boyles, Ohio State University Extension beef specialist)
- **How to Reduce Heat Stress in Your Pigs**
www.extension.umn.edu/agriculture/swine/components/pdfs/heat_stress_souza.pdf
- **Kentucky Agriculture Water Quality Planning Tool, Plans, and Drawings**
<http://www.bae.uky.edu/awqpt/plans.htm>
- **Guide to the Ventilation of Livestock During Transport**
www.teagasc.ie/faol/NR/rdonlyres/67A8D66A-ED2F-4D86-B875-4C3A0ACCE54D/46/TransportVentilation.pdf
- **Heat Stress in Dairy Calves**
<http://tinyurl.com/krksasb>
- **Summerizing Hog Barns**
<http://nationalhogfarmer.com/facilities/summerizing-hog-barns> (by Larry Jacobson, Extension Agricultural Engineer, University of Minnesota)
- **Combating the Heat in Dairy Herds**
<http://igrow.org/news/combating-the-heat-in-dairy-herds>
- **Shade Options for Grazing Cattle**
<http://www.bae.uky.edu/Publications/AEUs/aeu-91.pdf>
www.bae.uky.edu/publications/AENs/AEN-99.pdf (with plans)
- **University of Missouri Thermalnet Heat Stress Site**
<http://thermalnet.missouri.edu>



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