Influence of Hot-Humid Environment on Growth Performance and Reproduction of Swine[1]

Robert Myer and Ray Bucklin[2]

Environmental temperatures above the zone of thermoneutrality (comfort zone) for swine are frequent in tropical and subtropical regions, and during the summer months in temperate regions. These warm environmental conditions do not usually result in death losses, but they can cause reduced growth performance in growing-finishing pigs and decreased reproduction in the breeding herd.

Optimum temperatures for housed swine are shown in Table 1. In general, as the pig gets older and larger, its optimum temperature decreases. Thus, the effects of heat stress are more of a concern with older finishing swine (>50 kg or 110 lb) and with sows and boars than with younger pigs. Sows, boars, and finishing pigs begin to feel the negative effects of heat stress at about 20°C (68°F).

Table 1. Optimum temperatures for housed swine of all ages.

Animal	Optimum Temperature °C (°F)	Desirable Limits °C
Litter—newborn	35 (95)	32–38
Young pigs (2–5 kg)	30 (85)	27–32
Young pigs (5–20 kg)	27 (80)	24–30
Growing pigs (20–55 kg)	21 (70)	16–27
Finishing pigs (55–110 kg)	18 (65)	10–24
Gestating sows	18 (65)	10–27
Lactating sows	18 (65)	13–27
Boars	18 (65)	10–27

If temperatures remain above 27°C (80°F) for more than a short period of time (2 to 4 days), substantial losses in performance and reproductive efficiency can result unless some type of cooling relief is provided.

Effects of Heat Stress

In general, pigs try to minimize the effects of heat stress by two major methods. These include an increase in heat dissipation and a reduction in heat produced from body metabolism. To increase heat dissipation, pigs will increase their body surface area by sprawling out to increase contact with a cool surface like a floor. Pigs will also increase heat dissipation by increasing respiration rate (panting). The increase in respiration rate will increase the amount of air going in and out of the lungs. The increase in air flow increases evaporation of water from the lungs. The pig is thus cooled via a process called evaporative cooling. In humans, evaporative cooling takes place via sweating on the skin; pigs do not sweat.

Because eating, digestion, and nutrient absorption all generate heat (the heat increment of feeding), pigs can reduce their metabolic heat production by eating less feed. Thus, voluntary reduction in feed intake by the pig is an effort to lower the heat increment of feeding and thereby decreases the amount of heat that will need to be dissipated into the environment. Unfortunately, a reduction in feed

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2. Robert Myer, professor emeritus, Animal Science, UF/IFAS North Florida Research and Education Center; and Ray Bucklin, professor emeritus, Deptartment of Biological Engineering; UF/IFAS Extension, Gainesville, FL 32611.

intake results in reduced growth and, in lactating sows, a reduction in milk production.

Growing-Finishing Pigs

The most noticeable effect of high temperatures on growing-finishing pigs (25 to 110 kg) is a reduction in feed intake (Table 2). With finishing swine (>50 kg), feed intake is reduced at temperatures above 20°C (68°F). The reduction in feed intake will result in reduced daily gain. At temperatures above 30°C (86°F), feed conversion (amount of feed required per unit of weight gain) is adversely affected. With growing pigs (25 to 50 kg), the negative effects of heat stress are not as great as with heavier finishing pigs, but temperatures above 30°C can result in reduced performance.

Table 2. Effect of temperature on finishing pig performance.[a]

Temperature °C	Feed Intake kg/d	Wt Gain kg/d	Feed/Gain kg/kg
15	3.2	0.79	3.99
20	3.2	0.85	3.79
25	2.6	0.72	3.65
30	2.2	0.45	4.91
35	1.5	0.31	4.87

[a] Nichols et al. (1980). Initial average weight was 70 kg per pig, 28-study. Relative humidity average 50%.

Research conducted in Guadeloupe, West Indies, summarized in Table 3, clearly demonstrates the negative effect that a hot climate in a tropical country has on growing-finishing pig performance. This negative effect was more apparent with older finishing pigs than with younger growing pigs. This research also noted changes in the pig's physiology in an effort by the pig to cope with the heat stress. Changes included increased body temperature, increased respiration rate, and decreased thyroid hormone production (Christon 1988). The decrease in thyroid hormone production is an apparent effort by the pig to slow its metabolism and thus its heat production.

Research conducted in North Florida also clearly shows the negative effect that a hot-humid environment has on performance of growing-finishing pigs when raised under farm-like conditions (Table 4; Myer et al. 1998). In this research, pigs reared during the summer grew 11% slower and required 5% more feed per unit of weight gain than a comparable group of pigs raised during the fall when the environmental temperatures were mostly within the pig's thermoneutral zone (comfort zone).

Table 3. Effect of a tropical climate on performance of growing and finishing pigs.[a]

Item	Growing 20 to 50 kg		Finishing 55 to 80 kg	
	Control [b]	Tropical[c]	Control[b]	Tropical[c]
Feed intake, kg/d	1.56	1.50	2.55[e]	2.12[f]
Wt gain, kg/d	0.56[e]	0.42[f]	0.93[e]	0.57[f]
Feed/gain, kg/kg	2.56[e]	3.23[f]	2.50[e]	3.57[f]
Rectal temperature, °C[d]	38.4[e]	40.6[f]	39.0[e]	40.3[f]
Respiration rate,No./min[d]	22[e]	102[f]	33[e]	120[f]

[a] Christon (1988).
[b] Growing, 20°C; finishing, 17°C; relative humidity, 73 to 79%.
[c] Average low temperature, 22°C; average high temperature, 29°C; relative humidity, 69 to 91%.
[d] Average at 1300 h.
[e,f] Differ significantly ($P < .05$ or $P < .01$).

Table 4. Performance of growing-finishing pigs raised in confinement during the summer and fall months in North Florida.[a]

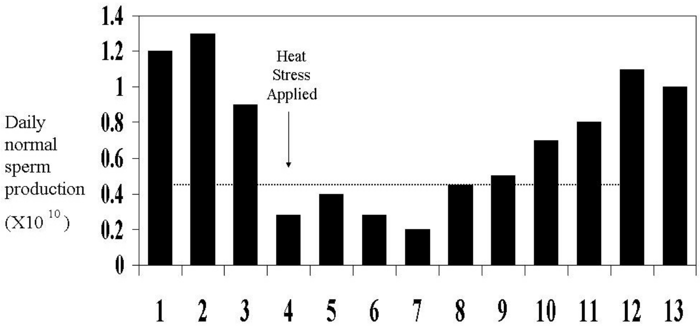
Item	Summer-reared[b]	Fall-reared[c]
Avg daily gain, kg	0.85	0.95
Avg daily feed intake, kg	3.08	3.28
Feed/gain, kg/kg	3.63	3.46

[a] Myer et al. (1998). Nine pens per season with 10 pigs per pen (0.72 m^2 floor space per pig). Pigs reared in pens with solid concrete floors with an open water flush gutter across rear 20% of pen. Pigs on experiment from 28 to 113 kg average weight per pig.
[b] Mid-June to mid-September; average high temperature, 32°C; average low temperature, 21°C; average relative humidity, 81%.
[c] Late September to mid-January; average high temperature, 21°C; average low temperature, 8°C; average relative humidity, 84%.

Reproduction Performance

Heat stress has a detrimental effect on efficient swine reproduction. In the sow, temperatures higher than 27°C (80°F) will delay or prevent the occurrence of estrus, reduce conception rate, and increase early embryonic death (Table 5). Heat stress during embryonic implantation (first 13 days postmating) can reduce embryonic survival by 30% to 40% (Curtis 1981). Also, heat stress during the last few weeks before farrowing can result in a higher number of stillbirths. Surprisingly, sows are rather tolerant of heat stress during mid-gestation (14 to 90 days postmating).

The boar's fertility is also adversely affected by heat stress. High temperatures of 29°C (85°F) or more have been shown to decrease sperm production and decrease sperm quality. Furthermore, the negative effects of heat stress persisted for 4 to 6 weeks after the heat stress was removed (Figure 1) (Curtis 1981; Stone 1982). This delayed return to normal results because it takes 6 weeks for sperm production and maturation in the testes and epididymis.



[a] Stone (1982). Dash represents minimum required for successful fertilization.

Figure 1. Effect of heat stress on boar fertility.[a]

In lactating sows, temperatures above 25°C (75°F) have been observed to result in reduced feed intake (Table 6). The resulting decrease in appetite causes a decrease in milk production and an increase in sow weight loss. Thus, smaller pigs are weaned, and the ability of the sow to return to production after weaning is compromised because of her large weight loss.

Table 5. Effect of temperature on reproductive performance in sows.[a]

Item	26–27°C (80°F)	30°C (86°F)	33°C (92°F)
No. of sows	74	80	80
No. in estrus	74	78	73
No. in anestrus	0	2	7
No. returning to estrus	2	8	8
No. of sows conceived	67	67	62
Conception rate, %	90	85	78

[a] From Serres (1992).

Table 6. Effect of farrowing house temperature on sow and litter performance.[a]

Item	Temperature, °C (°F)		
	18 (64)	25 (77)	30 (86)
Litter weaning wt, kg	63[b]	61[b]	53[c]
Weaning number	8.1	8.9	8.3
Pig weaning wt, kg	7.8[b]	6.9[c]	6.4[c]
Mortality, %	20[b]	12[c]	19[b]
Sow feed intake, kg/d	6.5[b]	6.1[b]	4.2[c]
Sow wt change, kg/lactation	-3.1[b]	-7.9[b]	-24.2[c]

[a] Stansbury et al. (1987). 29 or 30 litters' per treatment.
[b,c] Means in the same row with different superscripts differ ($P < .05$).

Methods to Minimize Heat Stress

Adequate Floor Space

Recommended minimum floor space allowances for growing-finishing pigs are given in Table 7. Under conditions of heat stress, it is desirable to increase the minimum floor space allowed for pigs, in particular for larger pigs (given in parentheses in the table). The number of pigs per pen should also be reduced.

Table 7. Recommended minimum floor space allowances per pig for growing-finishing swine raised in confinement.[a]

Wt of Pig, kg (lb)	Partial or Total Slotted Floor, m^2 (ft^2)	Solid Concrete Floor, m^2 (ft^2)	No. per Pen, maximum
10–20 (33)	0.25 (2.5)	0.35 (4)	20–30
20–50 (33)	0.35 (4)	0.55 (6)	20–30
50–70 (132)	0.55 (6)	0.80 (9)	10–20 (8–12)[b]
70–110 (198)	0.75 (0.85)[b] (8(10)[b])	1.10 (1.20[b]) (10(12)[b])	10–20 (8–12)[b]

[a] Pork Industry Handbook PIH-55, and Pond and Maner (1984).
[b] Numbers in parenthesis are recommendations during warm weather (average temperature of 25°C (77°F) or greater).

Shade

The use of shades in pastures and outside lots is an effective method in helping to cool pigs (Table 8). Shades can cut the radiant heat load from the sun by as much as 40%. Shades with straw roofs are best because they have a high insulation value and a reflective surface. Uninsulated aluminum or bright galvanized steel roofs are also good. The best shades have white or reflective upper surfaces.

Table 8. Dirt lot (pasture) and shade space recommendations.[a]

Dirt lot space (depends upon rainfall, soil type, and slope):
20 gestating sows per hectare (8 per acre)
14 sows with litters per hectare (6 per acre)
100 to 200 growing-finishing pigs per hectare (40 to 80 per acre)
Shade space:
1.5 to 2.0 m^2 per sow (15 to 20 ft^2)
2.0 to 2.5 m^2 per sow and litter (20 to 30 ft^2)
0.35 m^2 per pig for pigs to 50 kg (4 ft^2)
0.55 m^2 per pig for pigs over 50 kg (6 ft^2)

[a] Pork Industry Handbook PIH-55.

Adequate Insulation

In confinement (enclosed) buildings, insulation is desirable in the roof or ceilings. The insulation will help to minimize solar heat build-up.

Adequate Ventilation

Rapid air movement over animals aids in dispersing heat. Increased ventilation is particularly important in confinement buildings. Air velocity of at least 5 kph (3 mph) over the animals raised in confinement is desirable during warm weather.

Water Supply

Swine must have access to large quantities of water during periods of high environmental temperatures. Much of the water is needed for evaporative heat loss via respiration to help the pig cool off. Table 9 lists water requirements for swine reared under warm conditions.

Table 9. Typical warm weather requirements of water for swine.[a,b]

Type	Water per Head per Day, liters (gal)
Sow and litter	32 (8)
Starting pig (5–20 kg)	4 (1)
Growing pig (20–55 kg)	12 (3)
Finishing pig (55–110 kg)	20 (5)
Gestation sow	24 (6)

[a] Pork Industry Handbook PIH-87.
[b] Includes water use for drinking and moderate water wastage. Water cooling systems may increase usage.

Wet-Skin Cooling

It is possible to substantially reduce heat by wetting the pig's skin and allowing the water to evaporate. Under natural conditions, pigs will cool themselves by wallowing in mud. As the mud dries, it cools the pig via evaporative cooling. At the same time, the mud protects the pig's skin from the sun. In many swine production systems, however, mud wallows can lead to many health problems. Concrete-lined wallows are quite effective and are much cleaner. Also, water flush waste removal system can be designed so that pigs can wet themselves during warm periods.

Water sprinkler systems are also quite effective for wet-skin cooling. Sprinkling water is preferred to fogging. Fogging uses small water droplets. Sprinkling uses larger water droplets that cool the pig by evaporating off the skin. Fogging cools the air, and the air must then cool the pig. Results of research testing the effectiveness of fogging or sprinkling on cooling and thus improving performance of finishing swine are summarized in Table 10. Pigs cooled with sprinklers should also be provided access to shade to prevent them from being sunburned. Also, air movement across the pig increases the evaporation rate and improves cooling.

Table 10. Effect of wet-skin cooling on performance of finishing pigs during warm weather.[a]

Item	Control	Fogger	Sprinkler
Wt gain, kg/d	0.65	0.71	0.79
Feed intake, kg/d	2.67	2.66	3.22
Feed/gain, kg/kg	4.05	3.94	4.06

[a] Kansas State University (1978). Average initial weight was 65 kg per pig, 42-d experiment. Average temperature was 29°C, and average relative humidity was 50%.

Many water sprinkler systems operate by thermostat-controlled timers that wet the pig and then allow the pig to dry. Sprinkler systems are usually designed to run for 1- to 2-minutes each 30-minute period (a few operations use 1- to 2-minutes each 10-minute period) when the temperature is above some set value (typically in the 25°C to 30°C (75°F to 85°F) range).

Water-Drip Cooling

Dripping water on the necks and shoulders of sows along with air movement has been shown to be an economically effective way to cool lactating sows in a farrowing house. Best results are usually obtained with drip rates of 2 to 3 L (0.5 gal) of water per hour and with the water dripping for a short time (i.e., 10- to 15-seconds) every 1- to 2-minutes. In one university study, drip-cooled sows consumed 1.7 kg (3.7 lb) more feed per day, and lactation weight losses averaged only 33% of that of the control sows (McGlone et al. 1988; Table 11). There are commercially made systems that can be purchased and installed at relatively low cost. These systems work best in farrowing pens in which the sow is kept in a farrowing crate and the pen flooring is perforated (e.g., plastic-coating expanded metal) so that the pen stays dry.

Table 11. Effect of water-drip cooling on sow and litter performance during warm weather.[a]

Item	Control	Water-drip Cooled[b]
Daily sow feed intake, kg	5.0[c]	6.6[d]
Sow wt. change, kg/lactation	-27.1[c]	-9.2[d]
Respiratory rate, breaths/min	79[c]	42[d]
No. of pigs born alive	10.2	10.6
No. of pigs weaned	8.5	8.8
Avg pig weaning wt., kg	6.6	7.0
Litter weaning wt., kg	55.0[c]	60.3[d]
Preweaning mortality, %	18	14

[a] McGlone et al. (1998). 22 or 32 sows and litters per treatment. Average temperature was 30°C and average relative humidity was 45%.
[b] Drip on for 3 min each 10 min.
[c,d] Differ significantly (P<.05).

Nutritional Adjustments

Since pigs will decrease their feed intake at high environmental temperatures, a more nutrient-dense diet will help to minimize production losses due to the high temperatures. Incorporation of fat (e.g., beef tallow, vegetable oil) into the pig's diet will increase energy (calorie) density and help maintain energy intake during times of high temperatures. Fat contains much more energy (calories) per unit of weight than carbohydrates (starch, sugar). Typically, fat is added at a level of 2% to 6% of the diets. If the energy density of the diet is increased by the addition of fat, the other nutrients (e.g., protein) will also have to be increased to prevent nutrient deficiencies (i.e., maintain constant energy to nutrient ratios). Conversely, the use of fibrous feeds for pig diets should be minimized during times of heat stress. Fibrous feeds, such as ground hay, wheat midds, etc., produce much heat when they are digested by the pig, whereas fats produce little heat. A research trial comparing pigs fed diets containing an added fibrous feed or a diet with added fat during the warm and cool seasons in the southeastern United States is summarized in Table 12.

Table 12. Effect of season and diet type on growth performance of growing-finishing swine.[a]

Season[b]	Diets with Fibrous Feed Added, kg/d[c]	Diets with Fat Added, kg/d[d]
Cool	0.76	0.74
Warm	0.69	0.79

[a] Coffey et al. (1982). Pigs were on trial from 22 to 94 kg average body weight. Pigs were in pens in groups and housed in a modified open-front building.
[b] Average outside low and high temperatures were 1°C and 12°C for cool season and 20°C and 31°C for the warm season; relative humidity averaged 75%.
[c] Diets contained 5% to 10% ground bemudagrass hay or 5% alfalfa meal.
[d] Diets contained 5% animal (poultry) fat.

The method by which pigs are fed may also influence pig growth efficiency during times of high environmental temperatures. Growing-finishing pigs, at least in the United States, are typically fed ad libitum (self-fed). The practice of restrictive feeding (feeding 80% to 90% the amount the pig would eat ad libitum) is not widely practiced since growth rate of restricted fed pigs is slower. However, in a hot climate, research results seem to indicate that restricted feeding produces a substantial physiological advantage in the pig, and thus may be of practical interest for pig production within tropical and subtropical areas (Table 13; Christon 1988).

Table 13. Effect of method of feeding on performance of finishing pigs reared in a tropical climate.[a]

Item	Control[b]		Tropical[c]	
	Restricted	Ad libitum	Restricted	Ad libitum
Feed intake, kg/d[d]	2.06	2.56	2.16	2.12
Wt gain, kg/d[e]	0.72	0.93	0.69	0.57
Feed/gain, kg/kg[f]	2.63	2.50	2.86	3.57

[a] Christon (1988). Pigs were on experiment for 54 to 79 kg.
[b] 17°C; relative humidity, 73% to 79%
[c] Average low temperature, 22°C; average high temperature, 29°C; relative humidty, 69% to 91%.
[d] Significant effect of temperature and feeding method (P<.01).
[e] Significant effect of temperature (P<.01). Significant temperature by feeding method interaction (P< .05).
[f] Significant effect of temperature (P<.05)

Effect of Humidity

High humidity in itself does not have a negative effect on swine performance. Combined with high temperatures, however, high humidities can enhance the negative effects of the high temperatures. Since the pig must rely heavily on evaporative heat loss to try to stay cool when it is hot, humidity level is very important. The higher the humidity level in the air, the less effective is the process of evaporative cooling (less moisture can evaporate into humid air than dry air). Thus, when relative humidity is 50% or higher, the pig will feel the effects of heat stress at a lower temperature than when the air is drier. At temperatures above 30°C (86°F), an 18% increase in relative humidity is equivalent to 1°C (2°F) rise in air temperature. For example, when air temperature is 28°C (82°F) and relative humidity is 80%, the effective temperature is about 30°C (86°F) (NRC 1981).

The question arises about the effectiveness of wet-skin cooling methods described above during times of high temperature combined with very high humidity. The effectiveness of these systems are decreased as humidity rises. However, research conducted in Florida indicated that water sprinkling is still effective in helping to cool pigs during the hot summer months (Harrison et al. 1983). Florida is noted for high humidity in addition to high temperatures during the summer months.

Summary

One of the first major consequences of heat stress is reduced feed intake. Heat stress decreases reproductive performance in both the sow and boar. The negative effects can be minimized by the use of artificial cooling (e.g., water sprinkler system). Cooling systems need not be sophisticated or expensive to be effective, but they must be reliable and easy to maintain. Increasing the nutrient and energy density of the diet can also help to minimize the effects of high temperatures.

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