Minimizing the impact of heat stress on pigs: Common ventilation errors, how to correct them and how to prevent them

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Impact of heat stress
The influence of heat stress on swine performance has been well-documented and seasonal variability continues to be a challenge.

- Reduced Feed Intake
- Welfare concern
- Reduced Growth Performance
- Mortality
“Decreased performance resulting from seasonality represents substantial productivity and economic losses for swine operations and the U.S. swine industry”

If the finishing weight could be increased by 1 lb during those months, a producer could have $550 in increased revenue for every 1,000 pigs marketed.
Additional impact on the breeding herd…

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<thead>
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<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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<td>Heat stress</td>
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<td>Litters affected by heat stress on sows</td>
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<td>Reduced boar fertility</td>
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Adapted from Stalder, 2015 - Pork Industry Productivity Analysis
What is heat stress?
**Survival Zone** (death occurs below or above this core body temperature zone)

**Homeothermy Zone** (normal core body temperature zone)

**Thermoneutral Zone** (minimal effort)

**Comfort Zone**

*Feed Intake*

*Core Body Temperature*

*Heat Production* (metabolism)

*Effective Environment*

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**Goal of Ventilation System**

*Increased vasoconstriction, piloerection, behavioral changes, shivering*

*Regulation by vaso-modification, pilo-modification, behavioral changes*

*Increased vasodilation, water intake, panting, behavioral changes*

Adapted from Kerr, 2015 (Washington State University Fact Sheet - FS157E)
### Survival Zone
(death occurs below or above this core body temperature zone)

### Homeothermy Zone
(normal core body temperature zone)

<table>
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<tr>
<th>Thermoneutral Zone</th>
<th>Comfort Zone</th>
<th>Feed Intake</th>
<th>Core Body Temperature</th>
<th>Heat Production (metabolism)</th>
<th>Effective Environment</th>
<th>Heat Stress</th>
</tr>
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<tr>
<td>Increased vasoconstriction, piloerection, behavioral changes, shivering</td>
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Thermal exchange
Animals generate heat due to many processes and strive to maintain their body temperature at a near-constant level.

A single 220 lb pig at 61°F produces ~876 BTU/hr
There are four modes of thermal energy exchange between an animal and its surroundings inside a building.

- Conduction
- Natural convection
- Forced convection
- Evaporation
- Radiation
The four measurable parameters to estimate the thermal capacity of the environment are:
Quantifying Heat Stress
Thermal Environment Sensor Array (TESA): features dry-bulb temperature, relative humidity, airspeed, and black globe thermometer sensors.
Housed Swine Heat Stress Index (HS2I)

- My solution to problematic indices (like THI)
- Combines the effects of T, RH, airspeed, sprinklers, and body weight to simple index value
How do we translate this information to ventilation/cooling systems?
Cooling systems

Airspeed Control by Tunnel Ventilation

Evaporative Cooling

Floor cooling

Low Pressure Sprinkling

Source: Mike Brumm
Airspeed control using tunnel ventilation
Goal: develop guaranteed wind speed for improved convective cooling

Effect of airspeed assuming a 95°F air temperature

Effect of airspeed assuming a 61°F air temperature

Area to Weight Ratio (ft²/lb)

Surface area (ft²)

Weight (lb)

Effective Temperature (°F)

AirSpend (fpm)

Effective Temperature (°F)

AirSpend (fpm)
Temperature rise vs tunnel airspeed

Assume 60 ft wide and 8 ft high = 408 ft²
Convective heat loss benefit vs. cost and fans

Key assumptions:
- 55’ × 8’ cross section
- 52” fan @ 0.05 in. wc: 27,200 cfm & 21.4 cfm/W
- $0.12/kWh @ 1,000 h of run time
Common Errors:

• Room temperature >4°F compared to outside temperature
• Too much airflow restriction
• Insufficient fan capacity
• High animal density » animal heat
• Solar radiation
• Fan stage settings (temperature differentials)
• Fan shutters not fully open » dirty or the pressure is excessive.
Prevention:

- Measure temperature down the length of the building
- Verify airspeed at tunnel inlet
- Verify airspeed 5 to 10 ft from side wall
- Check fan belt tightness (can significantly reduce airflow)
- Clean dirty fans and shutters
- Verify variable speed control settings
- Verify tunnel curtain opening, static pressure, and temperature
Temperature control using evaporative cooling

Goal: provide a drop in air temperature by evaporating water.
Temperature control using evaporative cooling

Ames Iowa USA Nighttime

Yucatan Peninsula, Nighttime

Ames Iowa USA Daytime

Yucatan Peninsula, Daytime

Amarillo, TX
Evaporative cooling pad performance
Common Errors:

• Pad streaking
• Improperly sized pumps
• Clogged strainers and filters
• Pad cleanliness
• Poor water pressure
• Poor water quality (algae growth/mineral deposits)
Prevention:

**Weekly** recommendations
- flushing the in-line strainer
- clean return water filter screen
- check for dry streaks and debris on pad material

**Monthly** recommendations:
- cleaning the foot valve, control sensor, panel distribution pipe holes
- drain and clean sump tank
- clean/check float valve.

Photo credit: Mike Czarich
Direct cooling using sprinklers
Goal: water on animal’s surface area evaporated using sensible heat directly from the animal

Evaporation of water requires \( \sim 1000 \text{ BTU/lb}_{\text{water}} \)
Direct cooling using sprinklers

Goal: Water on animal’s surface area evaporated using sensible heat directly from the animal

\[ A_{\text{wetted}} = 10\% \]

\[ A_{\text{wetted}} = 20\% \]

Evaporation Heat Loss Potential

\[
\begin{align*}
\text{Airspeed (fpm)} & \quad \text{Evaporation Heat Loss, W} \\
0 & \quad 0 \\
100 & \quad 50 \\
200 & \quad 100 \\
300 & \quad 150 \\
400 & \quad 200 \\
500 & \quad 250 \\
600 & \quad 300 \\
700 & \quad 350
\end{align*}
\]

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\end{align*}
\]

- \( T = 77^\circ F, \, RH = 60\% \)
- \( T = 95^\circ F, \, RH = 60\% \)
Problems direct cooling sprinkler control systems…

High humidity leads to insufficient evaporation -> needs more time
Problems direct cooling sprinkler control systems…

Water evaporates quickly -> water could be applied again sooner
Problems direct cooling sprinkler control systems…

Low airflow leads to insufficient evaporation -> needs more time
Common Errors:

- Clogged strainers and filters
- Poor water pressure
- Clogged strainers and filters
- Missing sprinklers
- Insufficient pen coverage
- Directional sprinklers pointing the wrong direction
Prevention:

- Verify about 2/3 pen coverage
- Measure water from several sprinklers
**Floor cooling**

Goal: sensible heat is conducted away from the pig to water circulating in the floor

- Core-to-floor temp difference
- Conductivity of floor
- Contact area between pig & floor
- Supply water temperature
- Heat accumulation
Key take-home points

- Air temperature maintenance is critical
- Airspeed control alone is insufficient
- Direct cooling is very powerful
- Airspeed control with direct cooling is best
- Use the pigs as feedback – do they look comfortable?
- Understand how that cooling system removes heat from the pig
- Understand the mechanical aspects of the cooling system
- You don’t know until you measure

These are guidelines...What works best in your facility? Depends on other thermal stresses dictated by climate and barn design
ABE - APSE Swine Research Update
Enhancing the Health and Well-being of Preweaning Piglets

Hongwei Xin¹, Tami Brown-Brandl², John Stinn³, Jeff Vallet², Anna Butters-Johnson¹, Yang Zhao⁴, Suzanne Leonard¹, Brett Ramirez¹, Kai Liu⁵

¹Iowa State University. ²USDA-ARS Meat Animal Research Center. ³Iowa Select Farms Inc. ⁴Mississippi State University. ⁵University of Pennsylvania.

Objectives:

• Evaluate the impact of different farrowing crate sizes and layouts with one vs. two localized heat sources on pre-weaning piglet health and mortality
• Quantify the postural behaviors of sows as affected by crate size and localized heat source location; and distribution of piglets in the crate
• Assess the relationship between surface temperature of the piglets and their health status
ENHANCING THE HEALTH AND WELL-BEING OF PREWEANING PIGLETS

- 3 farrowing stall layouts:
  - 1.5 m x 2.1 m, 0.6 m sow width
  - 1.8 m x 2.4 m, 0.6 m sow width
  - 1.8 m x 2.4 m, 0.7 m sow width
- 1 vs 2 heat lamps in creep area
- 60 farrowing stalls

Analyze images for:
- Sow posture (lying, sitting, standing, kneeling) and behaviors (lying R or L side, udder or back to HL, feeding, drinking)
- Piglet distribution in farrowing stall
ENHANCING THE HEALTH AND WELL-BEING OF PREWEANING PIGLETS

Outcomes: compare 6 treatments vs sow and piglet behavior and preweaning mortality

<table>
<thead>
<tr>
<th>Posture</th>
<th>Percentage of Day</th>
<th>Hours of Day</th>
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<tbody>
<tr>
<td>Sitting</td>
<td>3.3</td>
<td>0.79</td>
</tr>
<tr>
<td>Standing</td>
<td>10.7</td>
<td>2.54</td>
</tr>
<tr>
<td>Kneeling</td>
<td>1.2</td>
<td>0.33</td>
</tr>
<tr>
<td>Lying</td>
<td>84.8</td>
<td>20.34</td>
</tr>
</tbody>
</table>

Outcomes: compare 6 treatments vs sow and piglet behavior and preweaning mortality
SOW SPACE STUDY

Hongwei Xin\textsuperscript{1}, John Stinn\textsuperscript{2}, Anna Butters-Johnson\textsuperscript{1}, Suzanne Leonard\textsuperscript{1}, Brett Ramirez\textsuperscript{1}, Kai Liu\textsuperscript{3}

\textsuperscript{1}Iowa State University \textsuperscript{2}Iowa Select Farms Inc. \textsuperscript{3}University of Pennsylvania

Objectives:

- Determine commercial sows’ static and dynamic space requirements when housed in a pen
SOW SPACE STUDY

Digital Image

Raw Depth Image

Processed Depth Image
SOW SPACE STUDY

Standing

Lateral recumbent lying

Lying Down Overlay

Standing Up Overlay
Design and Assessment of a Novel Cooling Control Algorithm and System for Swine Heat Stress Alleviation

Steven J. Hoff, Jay D. Harmon, John F. Patience, and Brett C. Ramirez

Objectives:

• Develop a real-time control algorithm that maximizes heat loss by automatically optimizing cooling equipment selection and operation
• Specifically for sprinkler systems, develop a control logic that dynamically changes the ‘off’ interval based on time required to evaporate water
• Implement the control system described in objectives 1 and 2 in a commercial facility to evaluate
The image depicts a layout of an agricultural facility with various labeled components:

- **Evaporative pad**
- **Fan bank**
- **Attic T/RH sensor**
- **Thermal Environment Sensor Array (TESA)**
- **Attic barrier**
- **Office & load-out**
- **Pen Size (~90 to 100 pigs)**
- **Ambient T/RH**

The layout includes sections labeled NE, NW, SE, SW, and NE & NW are designated for Cool Cell Treatment. SE & SW are designated for Sprinklers Treatment.
The diagram shows a comparison of temperature (T) and relative humidity (RH) in various locations, including Attic 1, Attic 2, and Attic 3. The graph indicates the temperature difference (°F) and RH difference (%) between different locations.

- **Outer**: 126 fpm, CC (CC), Attic 1, Attic 2, Attic 3
- **Middle**: 57 fpm, 69 fpm, 69 fpm
- **Inner**: 99 fpm, 66 fpm, 60 fpm

The graph also shows a temperature difference of +3.7 °F (HS2I = 3.7) and a RH difference of X %.
HS2I = 7.3
Thank you!

Questions?

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