Factors that impact the stress and immune responses of beef cattle and swine

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Natural Variations
- Breed Effects
- Sexual Dimorphism
- Animal Temperament

Management Influences
- Health Programs
- Weaning Strategies
- Dietary Effects

Environmental Influences
- Cold Stress
- Heat Stress
- Drought

Variations in Stress & Immune Responses
Seminar Outline

- Effect of cold stress on the innate immune response of neonatal pigs
- Effect of heat stress on the innate immune response in beef cattle
- Cattle Temperament: Effect on the stress, immune and metabolic responses to an immune challenge
Seminar Outline

- Effect of cold stress on the innate immune response of neonatal pigs
- Effect of heat stress on the innate immune response in beef cattle
- Cattle Temperament: Effect on the stress, immune and metabolic responses to an immune challenge
What role, if any, does environmental temperature play in the neonatal pig’s pro-inflammatory response to an immunological challenge?
Materials and Methods

Male pigs (n = 36) were taken from their dams at 24 hr of age.

Body weights (1.52 ± 0.053 kg) and rectal temperatures were recorded before moving the pigs to environmentally controlled chambers that were maintained at 50% relative humidity and at either 18°C (64.4°F; n=18 pigs) or 34°C (93.2°F; n=18 pigs).

Immediately upon entering their respective chamber, pigs received an i.p. injection of either saline (n = 7 pigs/temperature group) or LPS (150 ug/kg; n = 11 pigs/temperature group).

Rectal temperatures were recorded every 15 min for a 3-hr period after which time all pigs were humanely sacrificed for blood and tissue collection.
Results

Physiological parameters:
Rectal temperatures
Body weight loss

Activation of the stress axis:
Serum cortisol

Activation of the immune system:
Serum TNF-α
Rectal Temperatures

Time X ET X LPS
(P < 0.0001)

Rectal Temperature (°C)

18, Cont
18, LPS
34, Cont
34, LPS

USDA

36.5
37.0
37.5
38.0
38.5
39.0
39.5
40.0
40.5
41.0

0.25 hr
0.5 hr
0.75 hr
1 hr
1.25 hr
1.5 hr
1.75 hr
2 hr
2.25 hr
2.5 hr
2.75 hr
3 hr

Crate Temp
Body Weight Loss

ET X LPS
(P < 0.015)

Body Weight Loss (kg)

Cont
LPS
Serum Concentration of Cortisol

ET X LPS
(P < 0.002)
Serum Concentration of TNF-α

Serum TNF-α (pg/ml)

ET X LPS (P < 0.016)

Cont
LPS

18
34
Exposure to a cold (18°C) environmental temperature resulted in a more severe response to the LPS challenge.

Pigs maintained in a warm (34°C) environment exhibited no visual signs and only minimal endocrinological or immunological activation associated with the LPS challenge.

The significant impact of the cold environment alone was evident by the elevation in basal cortisol and the reduction in rectal temperatures in saline treated pigs.
These results indicate that, when combined, cold stress and exposure to endotoxin induce a rapid and potentially dangerous loss of body heat in the neonatal pig.

Though routine management practice includes supplying a supplemental heat source (e.g., heat lamps and/or heat pads) to newborn pigs, the overall advantage of this practice may not be fully appreciated.

It’s possible that providing the additional heat source may reduce the severity and or duration of illness.
Seminar Outline

- Effect of cold stress on the innate immune response of neonatal pigs
- Effect of heat stress on the innate immune response in beef cattle
- Cattle Temperament: Effect on the stress, immune and metabolic responses to an immune challenge
Does environmental temperature play a role in the beef calf’s pro-inflammatory response to an immunological challenge?
Angus (ANG; n=11; 306.7 ± 25.9 Kg BW) heifers were housed in the Brody Environmental Chambers for 21 days.

Heifers were split between 2 chambers, maintained in cycling heat stress (HS; 24-38°C; n = 6), or at thermoneutral (TN; 18.5-23.5°C; n = 5) ambient temperature conditions.

One day prior to the endotoxin challenge (Day 19), all heifers were fitted with indwelling jugular catheters and rectal temperatures probes that recorded rectal temperatures at 1-min intervals.

On the day of the challenge (Day 20), blood samples were collected at 30-min intervals from -2 to 8 hours, and then at 24 hours. At 0 hour a blood sample was collected and then all heifers immediately received an i.v. injection of LPS (0.5 ug/Kg BW).
Results

Physiological Responses

Sickness Scores

Rectal Temperatures
Sickness Scores: Thermoneutral vs Heat Stress

Angus 18.5 – 23.5 °C
Angus 24.0 – 38.0 °C

LPS challenge (0.5 ug/kg BW)

Temp: P < 0.05
Time: P < 0.001
Rectal Temperature: Thermoneutral vs Heat Stress

18.5 – 23.5 °C
24.0 – 38.0 °C

LPS challenge (0.5 ug/kg BW)

Pre-LPS
Temp: P < 0.01
Time: P < 0.05

Post-LPS
Temp: P < 0.001
Time: P < 0.001

Angus

Rectal Temperature vs Time Relative to LPS Challenge
Results

Stress Response

Serum Cortisol
Serum Cortisol: Thermoneutral vs Heat Stress

**Angus TN** 18.5 – 23.5 °C

**Angus HS** 24.0 – 38.0 °C

**Pre-LPS**
- Temp: P > 0.10
- Time: P < 0.05

**Post-LPS**
- Temp: P < 0.05
- Time: P < 0.001

LPS challenge (0.5 ug/kg BW)
Results

Pro-inflammatory Cytokine Response

Tumor Necrosis Factor-alpha
Interleukin 6
Interferon-gamma
Serum TNF-α: Thermoneutral vs Heat Stress

- **Angus 18.5 – 23.5 °C**
- **Angus 24.0 – 38.0 °C**

**Pre-LPS**
- Temp: P > 0.10
- Time: P > 0.10

**Post-LPS**
- Temp: P < 0.05
- Time: P < 0.001

LPS challenge (0.5 ug/kg BW)
Serum IL-6: Thermoneutral vs Heat Stress

Angus 18.5 – 23.5 °C
Angus 24.0 – 38.0 °C

Pre-LPS
Temp: P > 0.10
Time: P > 0.10

Post-LPS
Temp: P < 0.05
Time: P < 0.001

LPS challenge (0.5 ug/kg BW)
Serum IFN-γ: Thermoneutral vs Heat Stress

Angus 18.5 – 23.5 °C
Angus 24.0 – 38.0 °C

Pre-LPS
Temp: P > 0.10
Time: P > 0.10

Post-LPS
Temp: P < 0.01
Time: P < 0.001

LPS challenge (0.5 µg/kg BW)
Exposure to heat stress reduced overall sickness scores while prolonging the actual febrile response to LPS.

Serum concentrations of cortisol were actually reduced by exposure to heat stress during the LPS challenge.

While serum concentrations of TNF-α and IL-6 were increased by heat stress, serum concentrations of IFN-γ were reduced.
Implications

These data demonstrate even a highly conserved biological response, such as the innate immune response, can be altered by exposure to environmental stressors.

Altering these basic immunological responses most likely reflect the animal’s attempt to re-prioritize biological activities in a manner that enhances their chances of survival.

Understanding these alterations will aid in our ability to more effectively manage the health and well-being of livestock under diverse environmental conditions.
Seminar Outline

- Effect of cold stress on the innate immune response of neonatal pigs
- Effect of heat stress on the innate immune response in beef cattle
- Cattle Temperament: Effect on the stress, immune and metabolic responses to an immune challenge
Does cattle temperament influence an animal’s stress, innate immune, and metabolic profiles?
Materials and Methods

At 10 mo of age, twenty-four Brahman bulls were selected from a pool of 60 based on temperament score (average of exit velocity - EV, and pen score - PS) measured 28 days prior to weaning:

8 most Calm (0.87 ± 0.15 EV and 1.00 ± 0.00 PS)
8 most Temperamental (3.70 ± 0.29 EV and 4.88 ± 0.13 PS)
8 Intermediate (1.59 ± 0.12 EV and 2.25 ± 0.16 PS)

Bulls were fitted with indwelling rectal temperature monitoring devices, loaded onto trailer and transported approximately 770 km; 9 hours.
Materials and Methods

The following day bulls were fitted with indwelling jugular catheters approximately 24 hr before the beginning of the study for serial blood collection to evaluate their response to a LPS administration (0.5 μg/kg).

Blood samples were collected at 30-min intervals from -2 to 8 hr and at 24 hr relative to the LPS challenge at time 0.
Results

Physiological Response

Rectal Temperature Response to Endotoxin

Sickness Scores
Rectal Temperature Response: LPS Challenge

Temp (P < 0.001)

- Calm
- Intermediate
- Temperamental
- Calm Baseline
- Intermediate Baseline
- Temperamental Baseline

LPS
Results

Stress Response

Cortisol

Epinephrine
Serum concentration of Cortisol

Temp x Time (P > 0.10)

Cortisol (ng/mL)

Calm
Intermediate
Temperamental

Time Relative to LPS Challenge (hr)
Serum concentration of Epinephrine

Temperament: (P ≤ 0.004)

- Calm
- Intermediate
- Temperamental

LPS
Results

Cytokine Responses

Tumor Necrosis Factor-alpha
Interleukin-6
Interleukin-4
Serum concentration of TNF-α
Temp x Time (P < 0.005)

- Purple: Intermediate (n=4)
- Blue: Calm (n=4)
- Red: Temperamental (n=5)

LPS

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Serum concentration of IL-6
Temp x Time (P < 0.005)

- Purple squares: Intermediate (n=5)
- Blue diamonds: Calm (n=4)
- Red triangles: Temperamental (n=6)

IL-6, ng/mL vs Time, h

LPS
Serum concentration of IL-4
Temp x Time (P < 0.005)

- Intermediate (n=4)
- Calm (n=4)
- Temperamental (n=5)

Serum concentration of IL-4 over time. The chart shows the response to LPS (lipopolysaccharide) stimulation. The y-axis represents IL-4 concentration in pg/mL, and the x-axis represents time in hours. The chart indicates significant differences in IL-4 concentration between groups, with the Temperamental group showing the highest concentration at 27.02 pg/mL at approximately 2.5 hours.
What is potentially modulating the differences observed between calm and temperamental cattle?
Results

Metabolic Response

Glucose

Insulin

Non-esterified fatty acids (NEFAs)

Blood urea nitrogen (BUN)

Insulin Sensitivity (RQUICKI)
Glucose

Time Relative to LPS Challenge (hr)

Glucose (mg/dL)

Temp (P < 0.001)

- Calm
- Intermediate
- Temperamental

LPS

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*

0 50 100 150 200 250 300

-4 -2 0 2 4 6 8 10 12 14 16 18 20 22 24
NEFAs

Temp (P < 0.001)

Calm
Intermediate
Temperamental

LPS

Time Relative to LPS Challenge (hr)
Insulin Sensitivity (RQUICKI)

Time Relative to LPS Challenge (hr)

- Calm
- Intermediate
- Temperamental

Temp (P < 0.001)

RQUICKI

LPS
Summary - Implications

- Temperamental calves (Immune and stress parameters):
  - Elevated basal body temperature (exacerbated during handling).
    - False febrile diagnosis
  - Reduced body temperature response to LPS.
    - Use of body temperature as indicator of health status could be misleading
  - Limited to no sickness behavior response to LPS.
    - Could make actual detection of disease difficult
  - Elevated basal cortisol and epinephrine concentrations.
    - False indication of stress response
Summary - Implications (cont.)

- Temperamental calves (Metabolic parameters):
  - Significantly lower glucose response to LPS.
    - Perhaps suggesting less of a need for glucose??
  - Increased basal concentrations of NEFAs.
    - Increased lipolysis/reduced lipogenesis?
    - NEFAs being used as an energy source??
  - Reduced BUN concentrations.
    - Indicative of less protein degradation?
  - Reduced insulin sensitivity.
    - Overall metabolic shift/re-programming??
Overall Conclusion

Clearly, significant variations exist within the livestock populations related to stress regulation, metabolic responses, and overall immunity that can be attributed to environment, animal management, and naturally occurring variations (i.e., sexual dimorphism, breed effects, animal temperament).

By utilizing this knowledge, we may be able to improve animal health and well-being by specific trait selection or pre-programming of animals in a manner that is more suitable for specific production environments.

Development of animal-type specific management practices/nutritional strategies/vaccination protocols will lead to enhanced health, well-being, and overall productivity in the beef industry.
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