Effects of Heat Stress on Post-Absorptive Metabolism and Bioenergetics in Lactating Dairy Cows

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Temperature Humidity Index (THI)
Easy way to measure and evaluate heat stress

Heat Stress is a Global Problem

January 2003, NASA
July 2003, NASA

2007 forecast to be hottest year yet

Charlie Staples, U of FL

Dairy Cows Respond to Heat in Several Ways:

- Reduced feed intake over 78°F (> 10 – 15%)
- Increased respiration rate (> 80 breaths per minute)
- Increased body temperature (> 102.5°F)
- Changed blood hormone concentration
- Increased water intake
- Increased evaporated water loss
- Reduced activity
Results of Heat Stress

Decrease in milk production
Reduced body condition
Annual loss to American Dairy Industry is $897 MILLION!
St-Pierre et al., 2003 J. Dairy Sci. E52-E77.

Rumen acidosis
Significant drop in pregnancy rate
High incidence of abortions
High death loss
Added all up … costly!

Heat Stress Induced Rumen Acidosis

• Originates via:
  – 1) Altered respiration
    • Loss of systemic buffering capacity
  – 2) Changes in feed and feeding behavior
    • Reduced feed intake
    • Increased concentrates
    • "sorting"
    • "bout/slug" feeding
    • Drooling
    • Less saliva production

Seminar Outline

• Heat Stress
  – Definition
  – Production effects
  – Rumen health
• U of Arizona heat stress trials
• Heat Stress vs. Transition Period
• Metabolic Summary
• Summary
• Conclusions
Heat Stress Questions??

Does the decrease in feed intake explain the reduced milk yield when cows are heat stressed?

What dietary and management strategies can help alleviate some of the negative side effects of heat stress?

If we have a better understanding of the biological reasons **WHY** heat stress reduces milk yield, we'll have a better idea of how to alleviate it.

**U of Arizona Trials**

**Study 1**

- Heat stressed cows to mimic an AZ July day: cyclic temps = 80 to 104 ºF
- Pair-fed a thermal-neutral group to keep nutrient intake similar
  - 9 days
- Heat stress variables
  - Body temps averaged 104.9 ºF
  - Respiration rates went from 44 to 89 breaths/min

**Effects of Heat Stress on Feed Intake**

[Rhoads et al., 2007]

**Effects of Heat Stress on Milk Yield**

[Rhoads et al., 2007]

Heat stress ↓ feed intake by ~30%

Heat stress ↓ yield ~45%
Underfeeding ↓ yield by ~19%

Thus, ↓ feed intake only accounts for 50% of the reductions in milk yield.
Effects of Heat Stress on Adipose Tissue Mobilization

What are heat stressed cows oxidizing for energy?

Rhoads et al., 2007

Glucose Tolerance Test

Heat stressed cows are more insulin sensitive: But WHY?

Wheelock et al., 2006

U of Arizona Trials

Study 2

- 22 Multiparous Holstein cows (99.8 ± 20.2 DIM) were balanced for parity and production, and then randomly assigned to 1 of 2 trts
  - 1) Heat Stress (HS): cyclical temps (80-104°F)
  - 2) Underfeeding (UF): constant temp (70°C)
- Cows assigned to the UF trt were pair-fed with the HS cows to eliminate confounding effects of dissimilar nutrient intake
- Cows underwent 3 periods (21 d total)
  - Acclimation (7 d)
  - HS or UF (7 d)
  - HS or UF with rbST supplementation (7 d)
  - rbST: POSILAC, Monsanto Inc., St. Louis MO

Heat Parameters

Respiration rate

Rectal Temperature

Dry Matter Intake

Milk Yield

P1 P2 P3

P1 P2 P3

rbST increased milk yield by ~15% in both treatments.
**Energy Balance**

- Heat stress reduces milk yield (~40-50%)
- Decreased feed intake only accounts for ~50% of the reductions in milk yield
- Both underfeeding and heat stressed cows enter similar negative energy balances (~ -3.5 Mcal/d)
  - Anything that enhances digestion and thus increases energy availability would improve EBAL
- Heat stressed cows become hypersensitive to insulin
  - Decreased NEFA
  - Increased glucose disposal
- Heat stressed cows require EXTRA ENERGY!
  - Especially glucose
  - Enhanced glucose utilization by the body may limit glucose availability to the mammary gland = ↓ lactose production

**Daily Metabolites**

**Circulating Insulin**

**Glucose vs. Fat**

**Energetic Summary**

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**Glucose vs. Fat**

- Glucose: 2.62 kcal ATP, 38.17 g glucose, 1.12 kcal heat loss, 42.75 kcal of metabolic heat
- Fat: 6.35 kcal ATP, 15.7 g fat, 3.13 kcal heat loss, 49.1 kcal of metabolic heat

L.H. Baumgard
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Could the health, reproduction and productive problems that both the early transition cow and heat-stressed cow experience, share a common cause?

Metabolic Adaptation to Heat Stress

Summary
Metabolic Flexibility: Decreased Insulin Sensitivity
Metabolic Inflexibility Remains Insulin Sensitive
Summary

- Reduced feed intake accounts for only ~50% of the decreased milk yield.
- Large metabolic changes that are not associated with energy balance
- Maximizing glucose synthesis will benefit both cow health and production
- Practical solutions and long term effect discussed this afternoon.

Dietary and Management Strategies to Reduce the Negative Effects of Heat Stress

- Clean water tanks daily
  - Heat stressed cows become hyper-hydrated
- Dietary HCO₃
  - Helps prevent rumen acidosis
- Heat stress cows are already prone to rumen acidosis
- Dietary Fat (by-pass)
  - Additional energy without the heat increment of feeding
  - Heat stressed cows are in negative energy balance dietary fat should help maintain milk yield and body condition
- Ionophores
  - Increases propionate and therefore overall liver glucose production
  - Crosses predict to reduce glucose during heat stress
  - Studies indicate Monensin can stabilize rumen pH during periods of stress
- Direct fed microbials
  - A product that increases rumen digestion, stabilizes pH, increases propionate and increases DMI
  - The inconsistencies in the literature regarding these variables is of interest
- rbST
  - Reduces insulin sensitivity and partitions dietary nutrients towards milk production
  - The redirection of glucose towards muscle during heat stress probably limits the glucose supply to the mammary gland
  - BUT the primary strategy to improve production during heat stress is shade and evaporative cooling
  - Typical reaction to one of my lectures…….thanks for your attention!

Typical reaction to one of my lectures……thanks for your attention!

Questions?

- Pair-fed
- Insulin sensitivity?
- Heat stress?