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

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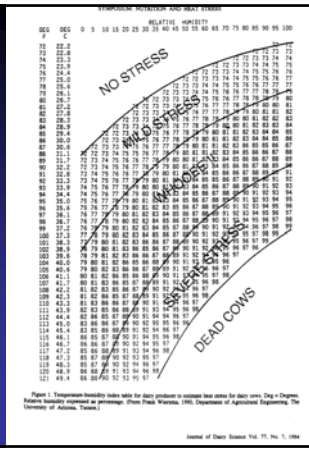
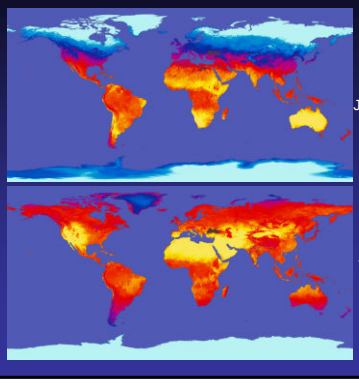
Department of Animal Sciences

Temperature Humidity Index (THI)

Easy way to measure and evaluate heat stress

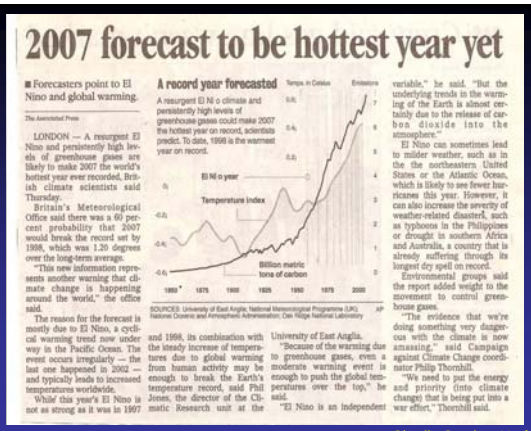


Heat Stress is a Global Problem



January 2003, NASA

July 2003, NASA



2007 forecast to be hottest year yet

Forecasters point to El Nino and global warming.

LONDON — A resurgent El Nino and persistently high levels of greenhouse gases are likely to make 2007 the world's hottest year ever recorded, British climate scientists said Thursday.

Britain's Meteorological Office said there was a 60 percent probability that 2007 would break the record set by 1998, which was 1.20 degrees over the long-term average.

"This new information represents another warning that climate change is happening around the world," the office said.

The reason for the forecast is mostly due to El Nino, a cyclical warming trend now under way in the Pacific Ocean. The event occurs irregularly — the last one happened in 2002 — and typically leads to increased temperatures worldwide.

While this year's El Nino is not as strong as it was in 1997 and 1998, its combination with the steady increase of temperatures due to global warming from human activity may be enough to break the Earth's temperature record, said Phil Jones, the director of the Climatic Research unit at the University of East Anglia.

"Because of the warming due to greenhouse gases, even a moderate warming event is enough to push the global temperatures over the top," he said.

"El Nino is an independent variable," he said. "But the underlying trends in the warming of the Earth is almost certainly due to the release of carbon dioxide into the atmosphere."

El Nino can sometimes lead to milder weather, such as in the the northeastern United States or the Atlantic Ocean, which is likely to see fewer hurricanes this year. However, it can also increase the severity of weather-related disaster, such as typhoons in the Philippines or drought in southern Africa and Australia, a country that is already suffering through its longest dry spell on record.

Environmental groups said the report added weight to the movement to control greenhouse gases.

"The evidence that we're doing something very dangerous with the climate is now amassing," said Campaign against Climate Change coordinator Philip Thornhill.

"We need to put the energy and priority (into climate change) that is being put into a war effort," Thornhill said.

A record year forecasted

A resurgent El Ni o climate and persistently high levels of greenhouse gases could make 2007 the hottest year on record, scientists predict. To date, 1998 is the warmest year on record.

El Ni o year

Temperature Index

Billion metric tons of carbon

SOURCES: University of East Anglia; National Meteorological Programme (UK); National Oceanic and Atmospheric Administration; Oak Ridge National Laboratory

AP

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

Heat Stressed Cows

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 Stressed Cows

Results of Heat Stress

Decrease in milk production

Reduced body condition

Rumen Acidosis:
- Reduced cellulose digestion
- Laminitis
- Milk fat depression
- etc…

Added all up … costly!

High death loss

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

Agricultural Research Complex

Environmental/metabolic Chambers

Heat Stress | **Heat Stress + Solar Radiation**

Heat Stress Questions??

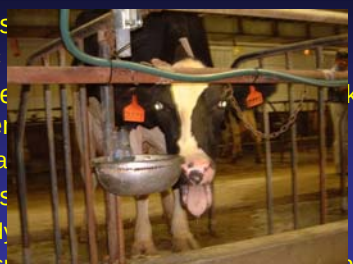
Does the decrease in feed intake explain the reduced milk yield when cows are heat stressed?

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

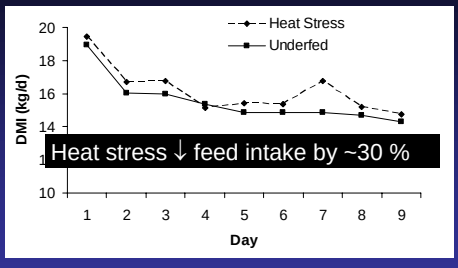
If we have a better understanding of the biological reasons WHY heat stress reduces milk yield, we'll have a better idea of how to alleviate it.

U of Arizona Trials Study 1

- Heat s… July day: cyclic …
- Pair-fe… keep nutrien…
  - 9 da…
- Heat s…
  - Body…
  - Respiration rates went from 44 to 89 breaths/min



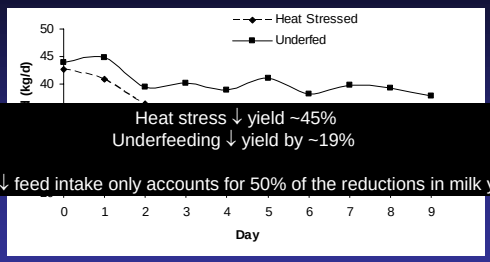
Effects of Heat Stress on Feed Intake



Heat stress ↓ feed intake by ~30 %

Rhoads et al., 2007

Effects of Heat Stress on Milk Yield

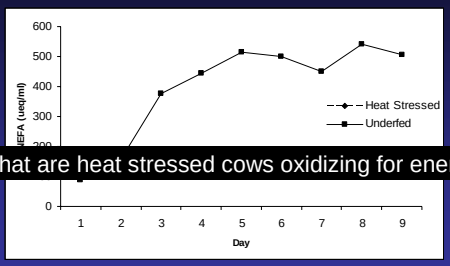


Heat stress ↓ yield ~45%
Underfeeding ↓ yield by ~19%

Thus, ↓ feed intake only accounts for 50% of the reductions in milk yield

Rhoads et al., 2007

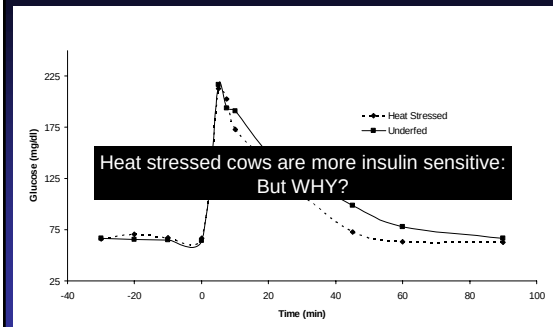
Effects of Heat Stress on Adipose Tissue Mobilization



What are heat stressed cows oxidizing for energy?

Rhoads et al., 2007

Glucose Tolerance Test



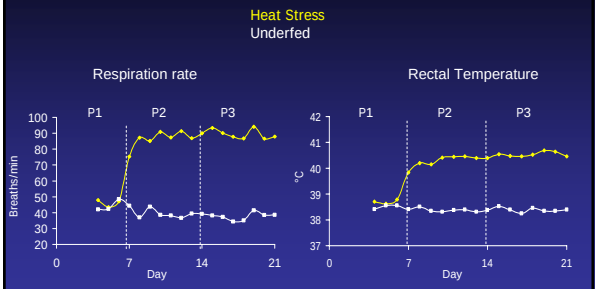
Heat stressed cows are more insulin sensitive: But WHY?

Wheelock et al., 2006

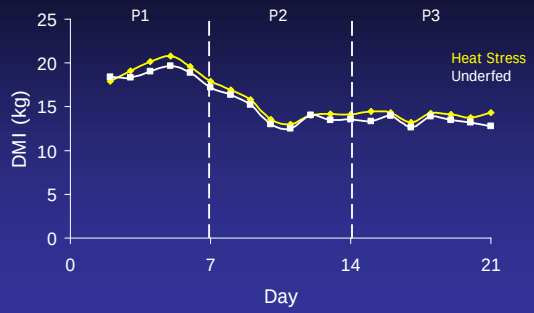
U of Arizona Trials Study 2

- 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

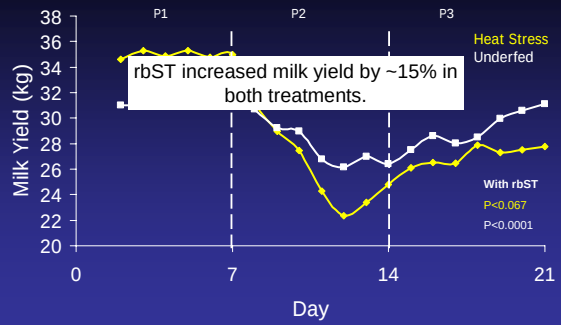
Heat Parameters



Dry Matter Intake

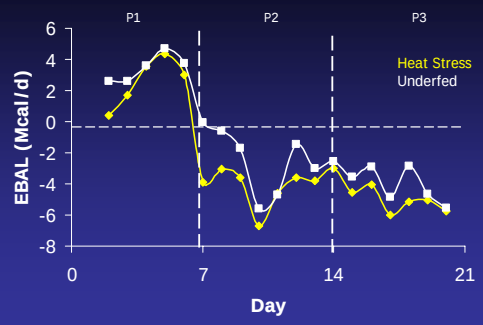


Milk Yield



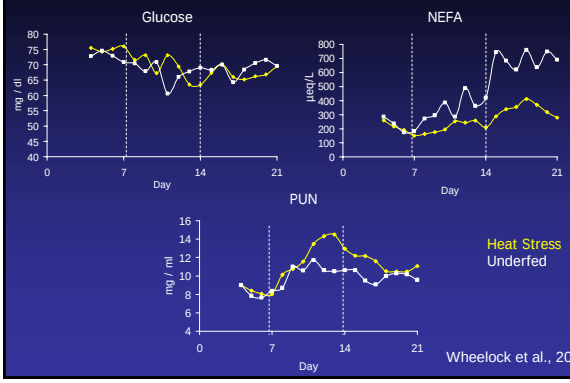
rbST increased milk yield by ~15% in both treatments.

Energy Balance



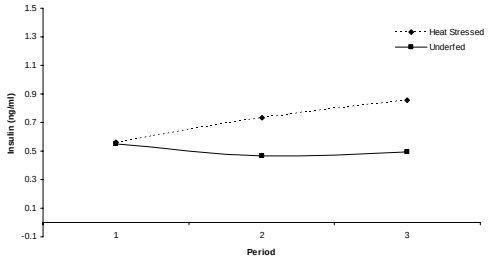
Wheelock et al., 2006

Daily Metabolites

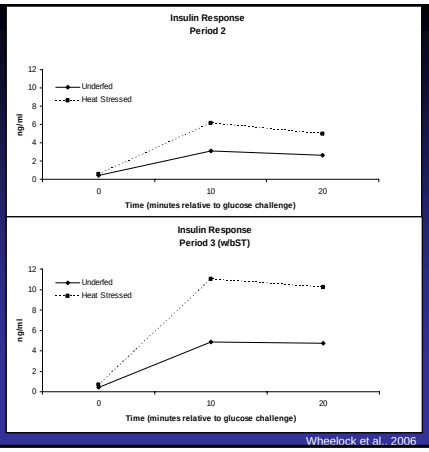


Wheelock et al., 2006

Circulating Insulin



Wheelock et al., 2006



Wheelock et al., 2006

Energetic Summary

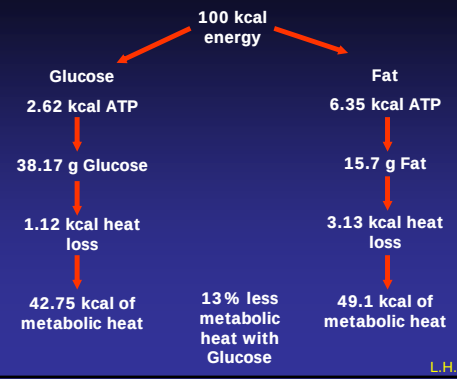
- Heat stress reduces milk yield (~40-50%)
- Decreased feed intake only accounts for ~50% of the reductions in milk yield
- Both underfeeding and heat stressed cows enter similar negative energy balances (~ -3.5 Mcal/d)
  - Ar
  - av

Why increase insulin action?

- Heat stressed cows become hypersensitive to insulin
  - Decreased NEFA
  - Increased glucose disposal

  But why?
- Heat stressed cows require EXTRA ENERGY!
  - Especially glucose
    - Enhanced glucose utilization by the body may limit glucose availability to the mammary gland = ↓ lactose production

Glucose vs. Fat



L.H. Baumgard

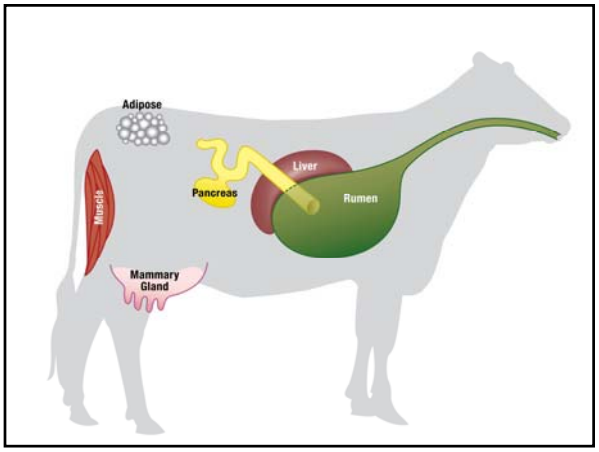
Seminar Outline

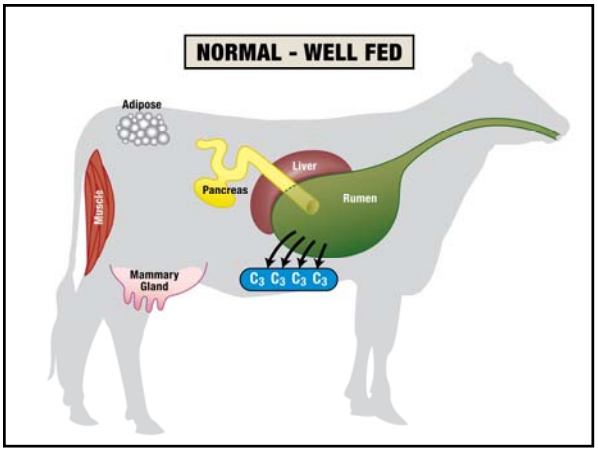
- Heat stress
  - Rumen health
- U of Arizona heat stress trials
- Heat Stress vs. Transition Period
- Metabolic Summary
- Summary
- Conclusions

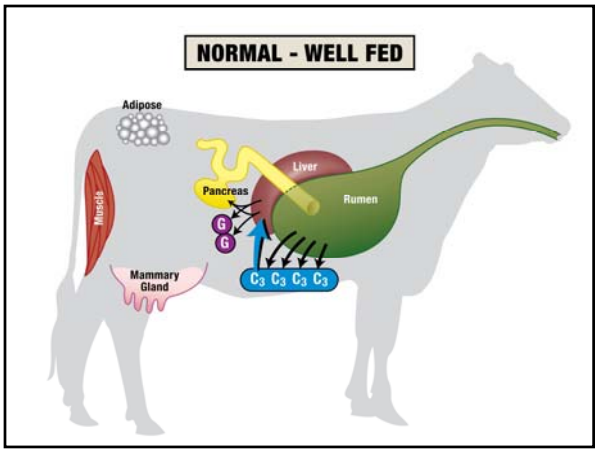
Could the health, reproduction and productive problems that both the early transition cow and heat-stressed cow experience, share a common cause?

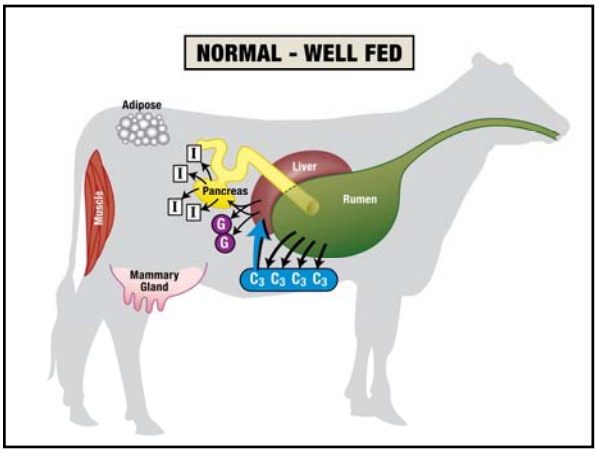
Metabolic Adaptation to Heat Stress

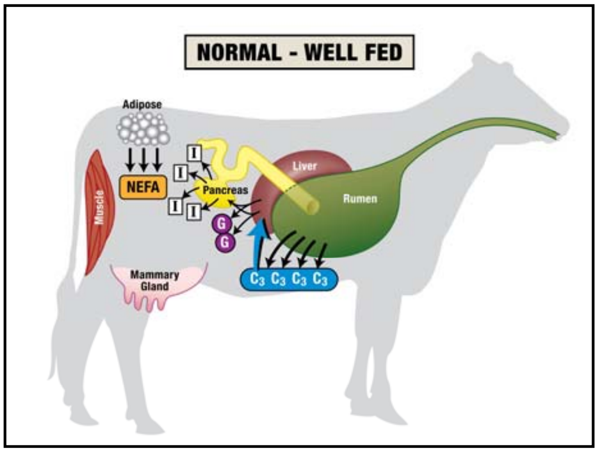
Summary







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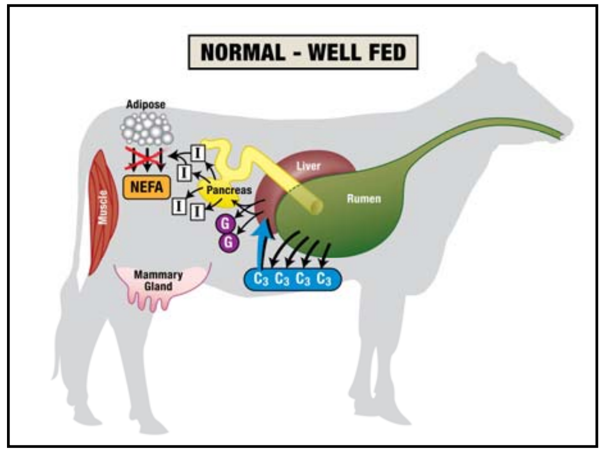
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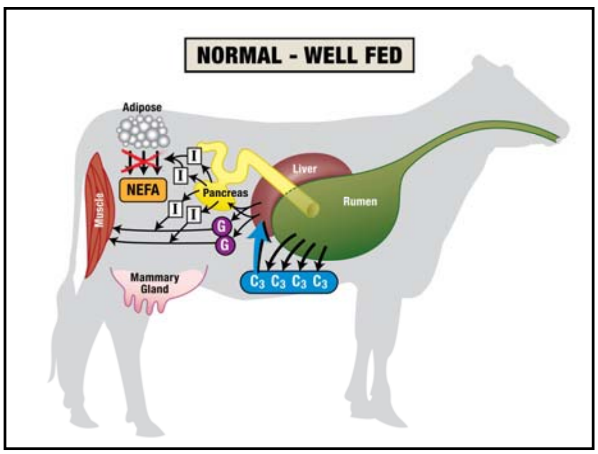
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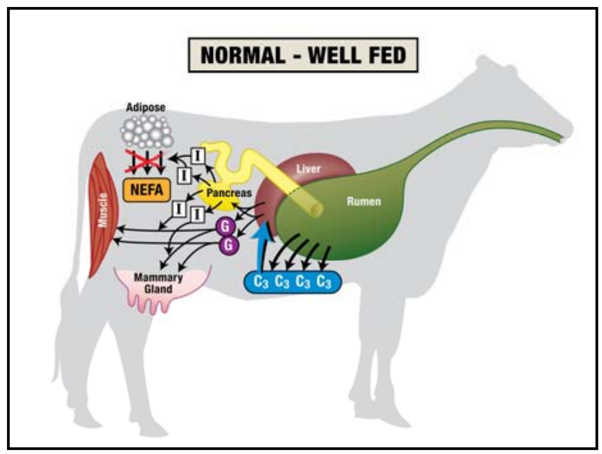
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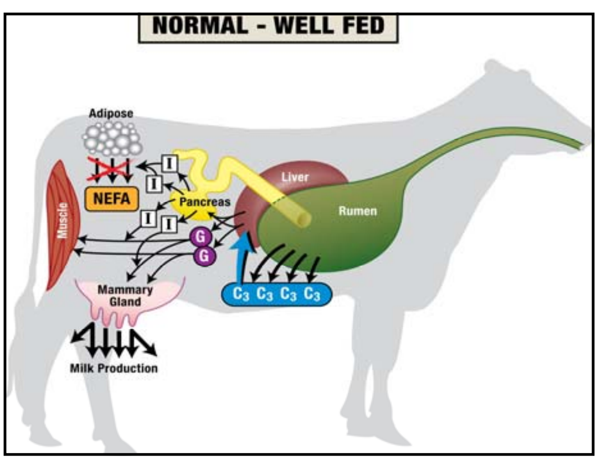
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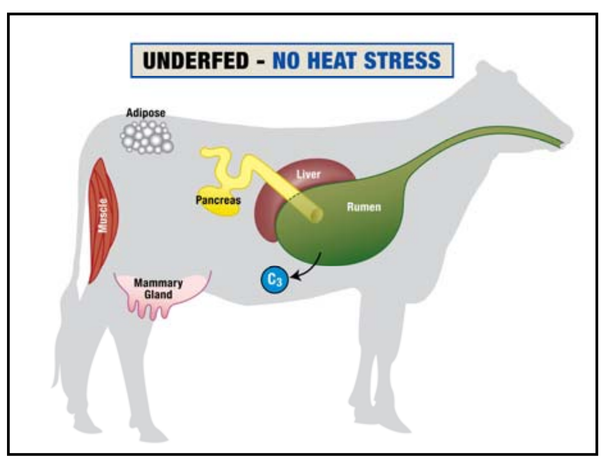
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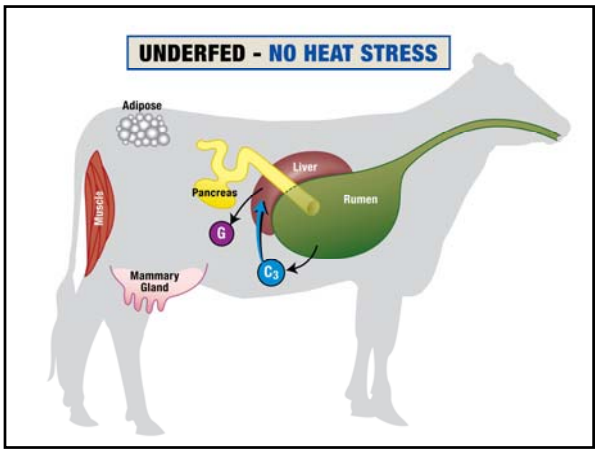
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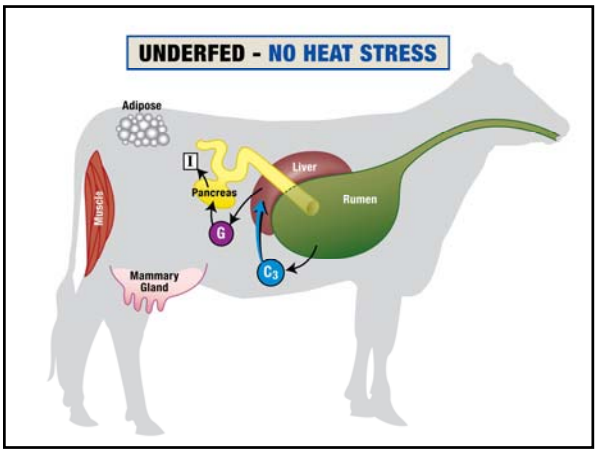
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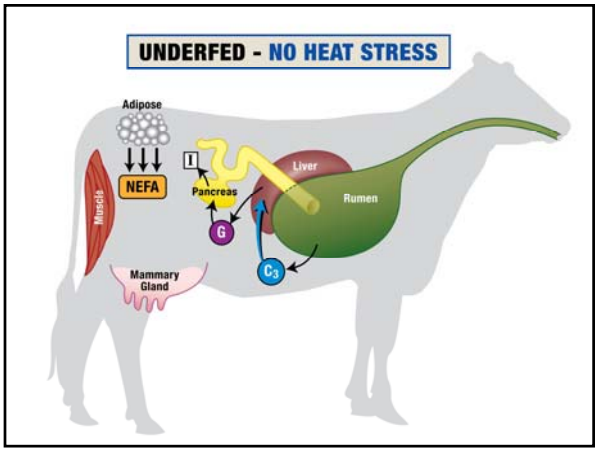
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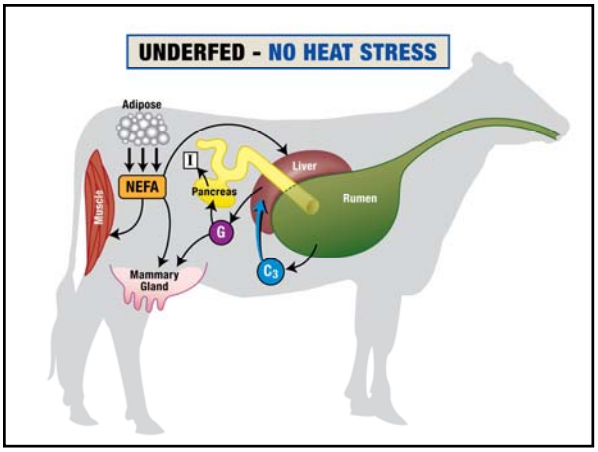
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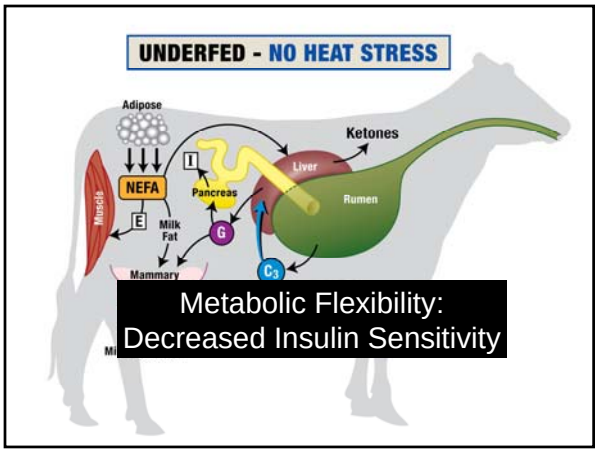
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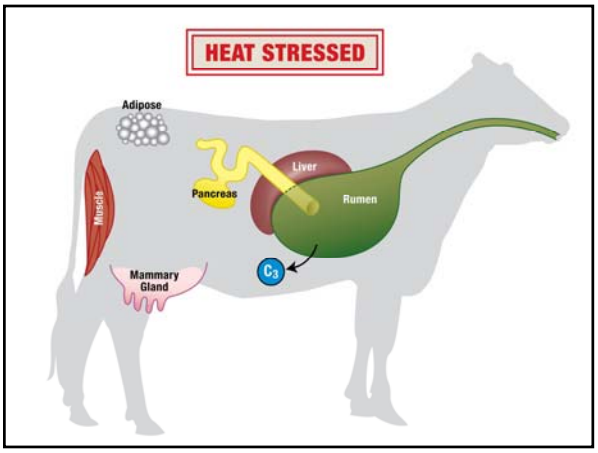
Metabolic Flexibility:
Decreased Insulin Sensitivity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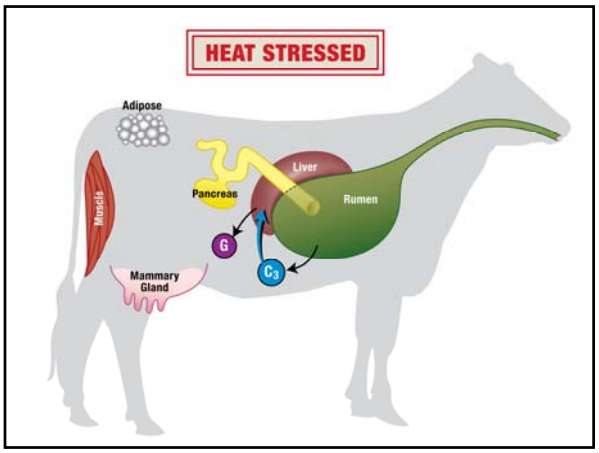
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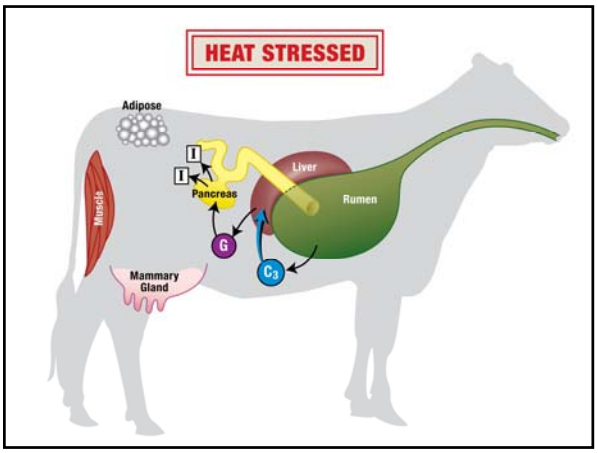
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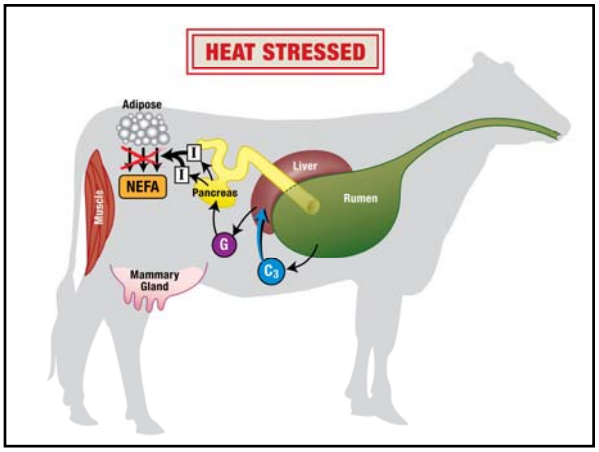
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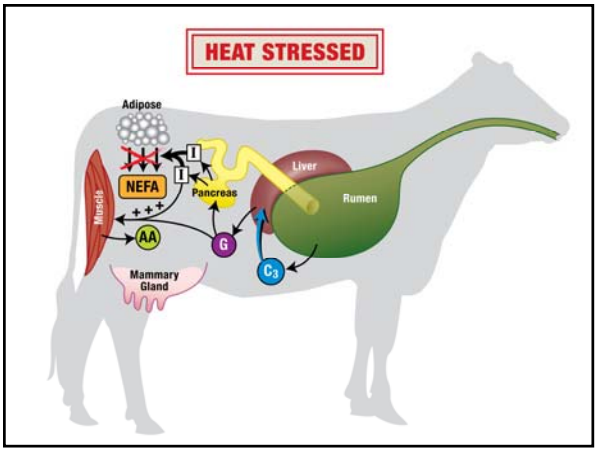
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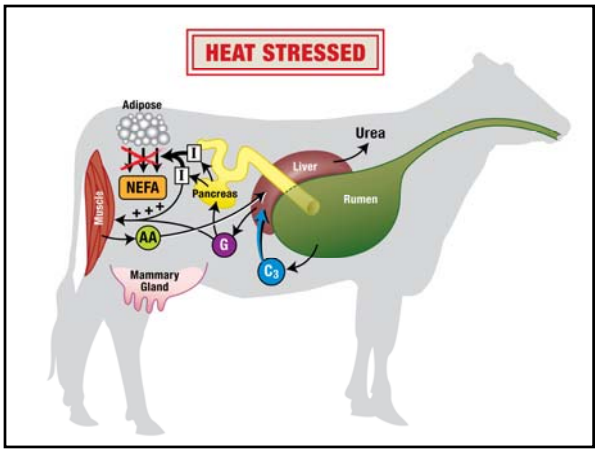
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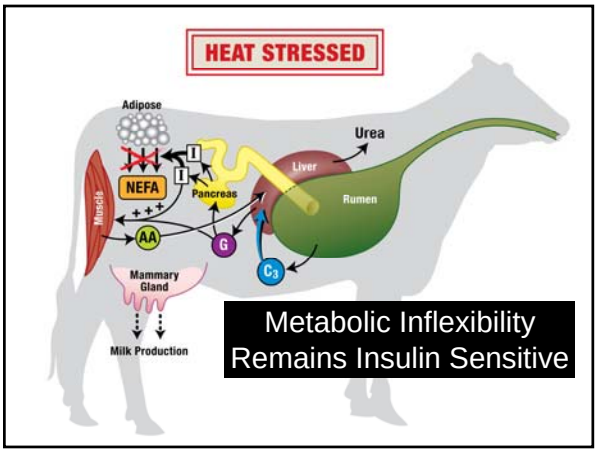
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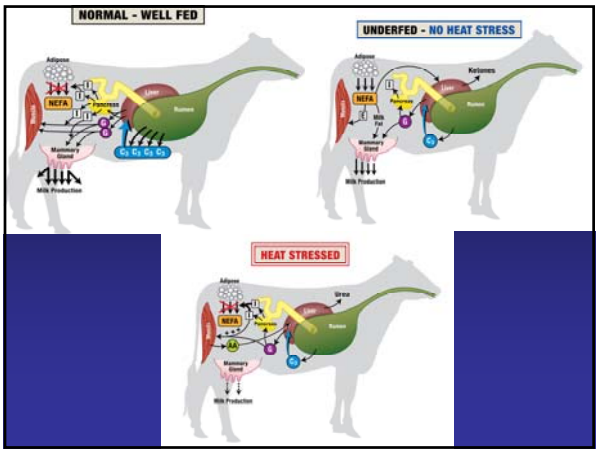
Milk Production
Metabolic Inflexibility
Remains Insulin Sensitive



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 HCO_3
  - Helps prevent rumen acidosis
- BUT the primary strategy to improve production during heat stress is shade and evaporative cooling
  - and body condition
- Ionophores
  - Increases propionate and therefore overall liver glucose production
    - Cows prefer to oxidize 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 should benefit a heat stressed cow
    - The inconsistencies in the literature regarding these variables is of interest
- rbST
  - Reduces insulin sensitivity and partitions dietary nutrients towards milk production
    - The directing of glucose towards muscle during heat stress probably limits the glucose supply to the mammary gland

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

Acknowledgments

- United Dairymen of Arizona
- Dairy Nutrition Services
- Southwest Regional Dairy Center

- Bob Collier
- Matt VanBaale
- Jessica Wheelock
- Morgan O'Brien
- Gilad Shwartz
- Rosemarie Burgos
- Laura Hernandez
- Sara Sanders
- Shannon Baker

Questions?