Metabolism, Nutrition, and Immunity in Transition Cows

Thomas R. Overton, Matthew R. Waldron, and Kelly M. Smith
Department of Animal Science
Cornell University

Introduction

- Transition cow biology and management has become a focal point for research during the past 15 years
  - (Grummer, 1993; Bell, 1995; Grummer, 1995; Horst et al., 1997; Drackley, 1999; Drackley et al., 2001; NRC, 2001; Overton and Waldron, 2004).
- Many dairy producers still struggle to achieve "success" with their transition cow programs

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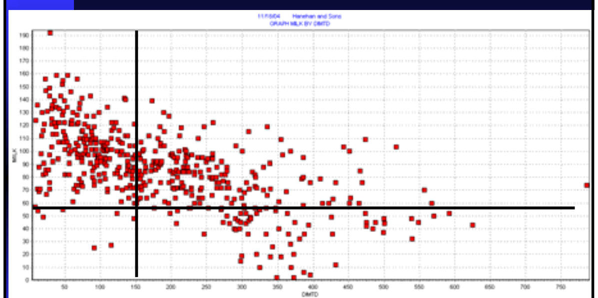
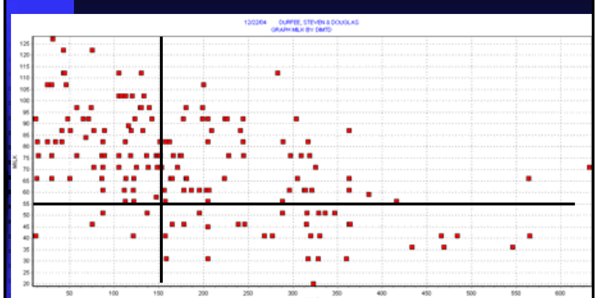
Goals for transition period "success"

- High milk production with low variability
- Minimize occurrence of metabolic disorders
- Minimize susceptibility to infectious disorders (immunocompetence)
- Minimize fresh cow culling (dead cows and sold for nondairy purposes)
- Enable reproductive success



Hanehan, personal communication; From Overton, 2005



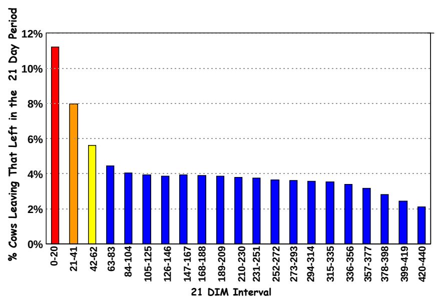
Durfee, personal communication; From Overton, 2005

Achievable goals for metabolic disorders

- Milk fever -- < 5%
- Retained placenta/metritis -- < 9%
- Displaced abomasum -- < 5%
- Clinical ketosis (blood BHBA > 27 mg/dl) -- < 5%
- Subclinical ketosis (blood BHBA > 14.4 mg/dl) -- < 15%

When Cows Leave the Herd

(MN DHIA 10/96 – 10/01) Godden et al., 2003

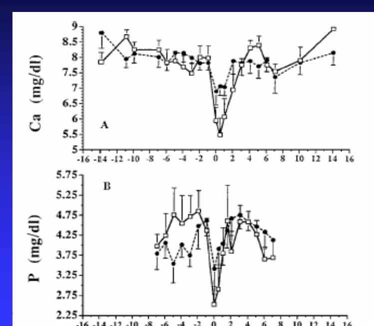


Fresh cow loss (dead and beefed) as a percentage of calvings

- Typical values in "above average" herds in Northeast US are 10 to 12% (unacceptable)
- Best herds consistently average 5 to 6%
- Can be as high as 25% during train wrecks

Metabolic adaptations in the transition cow

Plasma calcium and phosphorus concentrations in periparturient dairy cows



Goff and Horst, 1998

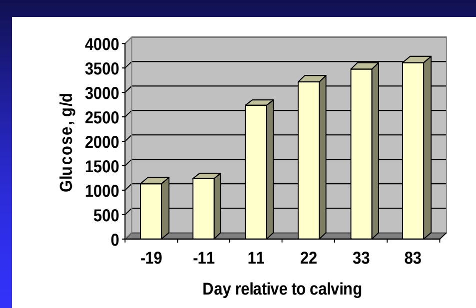
Energy (NE_L) Requirements 2 Days Before Versus 2 Days After Calving

Function	725-kg Cow		575-kg Heifer	
	Pre	Post	Pre	Post
Maintenance	11.2	10.1	9.3	8.5
Pregnancy	3.3	---	2.8	---
Growth	---	---	1.9	1.7
Milk production	---	18.7	---	14.9
Total (Mcal)	14.5	28.8	14.0	25.1

Calculated from NRC (2001). Assumes milk production of 25 kg/d for cow and 20 kg/d for heifer, each containing 4% fat.

Courtesy of J. K. Drackley

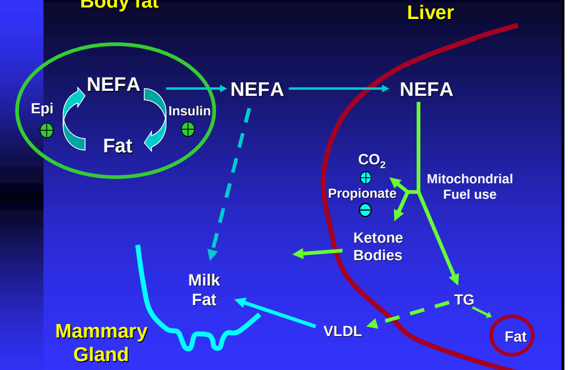
Net release of glucose by splanchnic tissues during the transition period and early lactation (Reynolds et al., 2003)



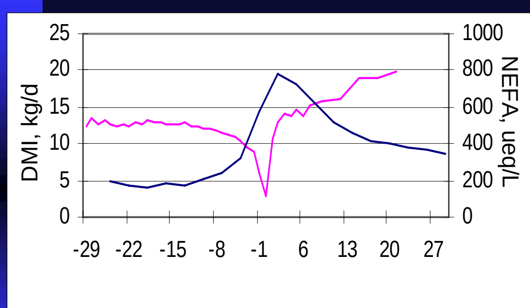
Substrates for liver gluconeogenesis (glucogenic precursors)

- Propionate (maximally 32 to 73%)
- Amino acids (maximally 10 to 30%)
- Lactate (maximally 15%)
- Glycerol (small amounts)

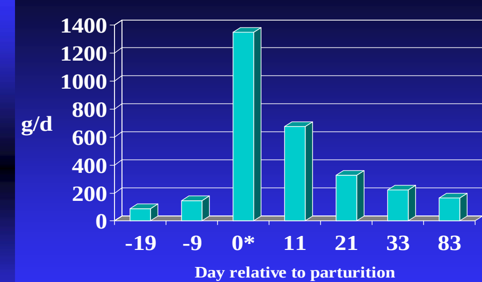
There is NO net synthesis of glucose from fat



Adapted from Drackley, 1999

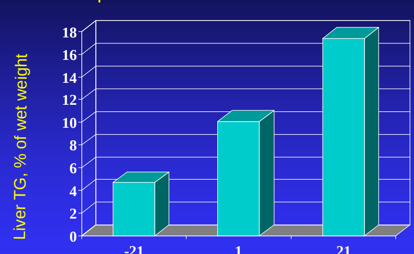


Burhans and Bell, 1998



Calculated NEFA uptake by liver during the transition period. From Reynolds et al., 2003.

Liver triglyceride concentrations (% of wet weight) during the transition period.



Piepenbrink and Overton, 2000

Consequences of increased liver TAG content

- Impaired gluconeogenic capacity from propionate
  - Cadorniga-Valino et al., 1997
  - Piepenbrink et al., 2003
- Impaired ureagenic capacity
  - Strang et al., 1998
  - Zhu et al., 2000
- Impaired capacity to clear bacterial endotoxin
  - (Andersen et al., 1996)
- Impaired reproductive performance

Metabolic status of transition cows and subsequent reproductive function

- Negative association between liver triglyceride accumulation and various indices of reproductive performance (Jorritsma et al., 2003)
- Unclear whether link is direct negative effect of liver triglyceride on liver metabolic processes or coincidental effect of metabolic climate

Marr et al., 2002

- Categorized cows as ovulatory or nonovulatory based upon the fate of the first dominant follicle during early lactation
- Cows that were nonovulatory had
  - Higher plasma NEFA concentrations
  - Higher plasma BHBA concentrations
  - Higher liver TG content
- Cows that were ovulatory had lower ratio of liver TG to plasma NEFA, implying better liver disposal
- Liver TG content more highly correlated with BHBA AUC than NEFA AUC (Piepenbrink and Overton, 2003)

Our charge

- Devise and employ nutritional management strategies and nutritional tools to support metabolic adaptation to lactation
  - *Macromineral metabolism (manage DCAD)*
  - *Glucose metabolism (provide fermentable carbohydrate)*
  - *Fat metabolism (minimize BCS loss)*
- Minimize potential negative effects of nonnutritional factors on metabolic adaptation to lactation
  - *Overcrowding*
  - *Environmental stress (temp., ventilation)*
  - *Infectious challenge/hygiene*
  - *Competition between and among cows/heifers*
  - *Grouping/regrouping*
  - *Comfort*

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Prevention strategies for milk fever and related disorders

- Decrease dietary cation-anion difference (DCAD) of prepartum diet
  - *$(Na^+ + K^+) - (Cl^- + S^{-2})$ -- most commonly used and supported by recent meta analysis (Lean et al., 2006)*
  - *$(Na^+ + K^+) - (Cl^- + 0.6\ S^{-2})$ – supported by other recent meta analysis (Charbonneau et al., 2006); explained more variation in urine pH than in milk fever incidence*
- Two major strategies
  - *Partial adjustment using low potassium forages*
  - *Low potassium forages plus addition of an anionic supplement*

Considerations with anionic supplements

- add anions until urine pH decreases to between 6.0 and 7.0
- Chlorides are more potent than sulfates
- Palatability considerations

NutriChlor	>	$MgCl_2$ >	NH_4Cl
SoyChlor 16		$CaCl_2$	
BioChlor			

- Increase magnesium (0.40 to 0.45% all close-up rations)
- Some concern with low DCAD in prepartum heifer diets (Moore et al., 2000)

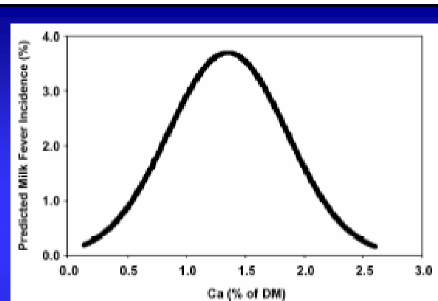


Figure 2. Milk fever incidence in response to varying dietary calcium concentrations as predicted by Model 1.

New meta analysis suggests curvilinear relationship of prepartum dietary Ca concentration and milk fever (Lean et al., 2006)

Calcium content of close-up diet and anionic considerations with heifers (Moore et al., 2000)

- Maintained K concentration at 1.35% of all diets
- Decreased DCAD (+15, 0, -15 mEq/100g) by increasing anions (chloride and sulfur) and also increased Ca concentrations from (0.44, 0.97, 1.50% of diet)
- Determined that simultaneously decreasing DCAD and increasing dietary Ca concentration resulted in improved Ca status
- Low DCAD (-15 mEq/100g) decreased dry matter intake in heifers, suggesting that heifers should not be fed diets with low DCAD
- Best combination in mixed group of cows and heifers is to decrease the DCAD to around 0 and supplement Ca to reach 0.9 to 1.0% of the diet
- Other recent data (Chan et al., 2006) suggest Ca at 0.99 or 1.50% in conjunction with anionic supplement maintained adequate serum Ca

Methods to increase supply energy and glucogenic precursors to meet glucose needs and minimize mobilization of body fat

- Increase Dry Matter Intake /Non Fiber Carbohydrate (NFC) intake
- Grain type and processing – starch fermentability
- Glucogenic supplements – mixed results
- Ionophores

Considerations for NFC content of close-up diet

- In general, increasing NFC content of the close-up diet increases prepartum DMI and plasma insulin, and decreases plasma NEFA and BHBA concentrations
- At comparable energy intake, no difference in performance or metabolism for 34 vs. 40% NFC
  - *(Smith et al., 2005)*
- Increasing NFC content of the closeup diet to 43 to 45% appears to accentuate the decrease in DMI in the days preceding parturition
  - *(Minor et al., 1998; Rabelo et al., 2003)*
- Recommendation: 34 to 36% NFC in close-up diet

Considerations for protein formulation of close-up diet

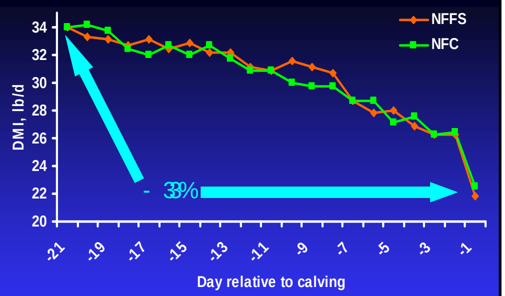
- NRC (2001)
  - Minimum requirement for metabolizable protein of example close-up heifer and cow ~ 900 g/d
    - Does not include mammogenesis
      - *(VandeHaar and Donkin, 1999; Bell et al., 2000)*
- Inclusion of estimate for mammogenesis increases metabolizable protein requirement to ~ 1100 g/d

Protein and AA recommendations

- 1100 to 1200 grams per day of metabolizable protein supplied (based upon 24 to 26 lb/d of DMI closeup)
- If carbohydrates well-formulated, can accomplish with ~ 14.0 to 14.5% CP (avoid > 15% CP)
- Balance Lys at 6.4 to 6.8% of MP and Met at 2.1 to 2.2% of MP using protected soybean meal or blood meal and a synthetic Met source

Which is more important?

- The absolute amount of DMI during the close up period?
- The extent of decrease of DMI during the prepartum period?



Prepartum CHO source did not affect (P > 0.15) prepartum DMI (SEM = 0.4; Smith et al., 2002)

Correlations from Wisconsin data (Mashek and Grummer, 2003)

- Examined relationships of total DMI from d 21 to 1 prepartum or the change in DMI from d 21 to 1 prepartum on postpartum variables
  - Postpartum DMI and milk yield were more strongly correlated (positively) with total prepartum DMI
  - Plasma NEFA and liver TG were more strongly correlated (positively) with the change in DMI from 21 d prepartum to 1 d prepartum

What are our goals and how to we achieve them?

- The Goals
  - Moderately high DMI of well-formulated close-up diets while attempting to minimize extent of DMI decrease during the prepartum period
- How do we achieve them?
  - *Many herds still struggle to get ENOUGH dry matter intake in close-up cows (goal mixed Holstein ~13 kg/d of suggested close-up cow diet)*
  - *In herds where close-up cows are consuming large amounts of DM (> 15 kg/d), limit grain-type forages and other very palatable feeds to control intake within goal and complement with a consistent, low potassium forage source (preferably bulky)*
- The challenge – extent of DMI decrease extremely difficult to characterize in group-fed animals

Big rocks from the nutritional side

- Manage DCAD
  - *Start with low potassium forages for close-up cows*
  - *Feeding management is CRITICALLY important*
- Get enough (but not too much) energy into close-up cows
- Strategically use nutritional tools
- Thinner (within reason) is better
- Don't overfeed during the early dry (or close-up) period
- Trends toward shortened dry periods and one-group nutritional strategies for dry cows
  - *Manage high producing mature cows down to ~ 40 days dry (watch colostrum quantity – quality is OK)*
  - *Cows end of their first lactation maintain ~50-60 days dry*

Far-Off Dry Cows

- Dry off until ~ 3 weeks pre freshening
- Ration considerations
  - –NE_L 0.59 to 0.63 Mcal/lb (1.30 to 1.35 Mcal/kg) for maintenance BCS
  - –Do not want to overfeed (Dann et al., 2003)

General goals for diet formulation for closeup cows and one-group dry cow systems up to 40 days

	Partial anionic	Full anionic
NE_L, Mcal/lb	0.68 to 0.70	
NE_L, Mcal/kg	1.50 to 1.54	
Metabolizable protein, g/d	1100 to 1200	
NFC, %	34 to 36	
Starch, %	19 to 21	
Dietary Ca, g/d	100	140
Dietary Ca, %	0.90	1.2
Dietary P, %	0.30 to 0.35	
Mg, %	0.40 to 0.42	
Cl, %	0.3	0.8 to 1.2
K, %	< 1.3	< 1.3
Na, %	0.10 to 0.15	
S, %	0.20	0.3 to 0.4
Added Se, ppm (organic)	0.3	
Vitamin A (IU/d)	100000	100000
Vitamin D (IU/d)	30000	30000
Vitamin E (IU/d)	1800	1800

Prefer use of organic trace elements, including organic Se

Tools to assist in energy-related metabolic adaptations

Nutritional "tools" potentially used to support energy-related metabolic adaptations

Increase glucose and/or decrease NEFA

- Propylene glycol
- Propionate
- Monensin
- Niacin
- Biotin
- Chromium
- Glycerol

Lipotropic compounds

- Choline
- Methionine and lysine
- Specific fatty acids
  - Specific FA isomers that decrease milk fat
  - Essential FA and HUFA (EPA and DHA)

Immune function and the transition cow

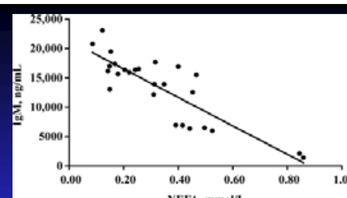
Periparturient Immunosuppression

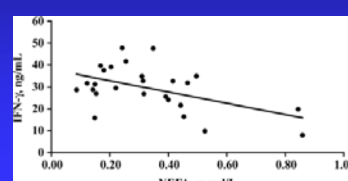
- Decreased responsiveness of immune system makes the cow more susceptible to infection
  - ~3 weeks either side of calving
    - Mallard et al., 1998
  - Increased cytokine secretion
    - Sordillo et al., 1995; Shuster et al., 1996

Immune function in transition cows

- Decreases in immune cell numbers and evidence of impaired function at calving until first 2 weeks of lactation (Kehrli et al., 1989; Kimura et al., 1999).
- Negative energy balance during transition period exacerbates this immunosuppression (Kimura et al., 1999).
- Defects in immune cell function are associated with development of disorders such as retained placenta/metritis and mastitis (Cai et al., 1994).

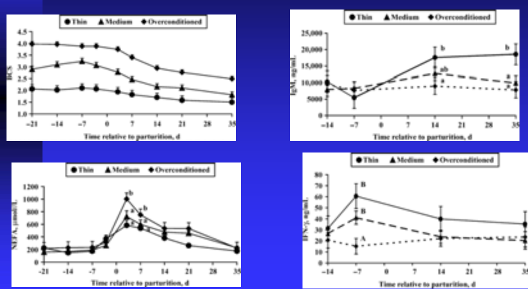
Elevated plasma NEFA exacerbate immunosuppression in transition cows





Lacetera et al., 2005

Cows with BCS>3.5 have decreased immune function and are to be considered at high risk of infection



Lacetera et al., 2005

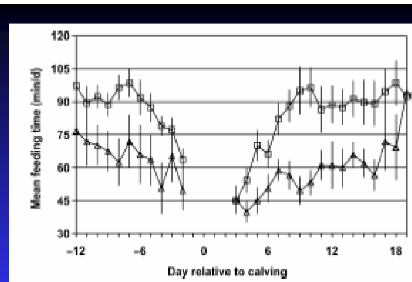


Figure 1. Daily mean feeding time (min/d) of 9 Holstein cows with acute metritis (△) and 17 Holstein cows without acute metritis (□) (±SE) from 12 d before calving until 19 d after calving.

Cows that develop metritis have significantly decreased feeding time beginning prepartum (Urton et al., 2005)

Retained placenta

- Associated with mastitis occurrence (Emanuelson et al., 1993; Peeler et al., 1994).
- Are they linked because they are at least partly caused by immune suppression?

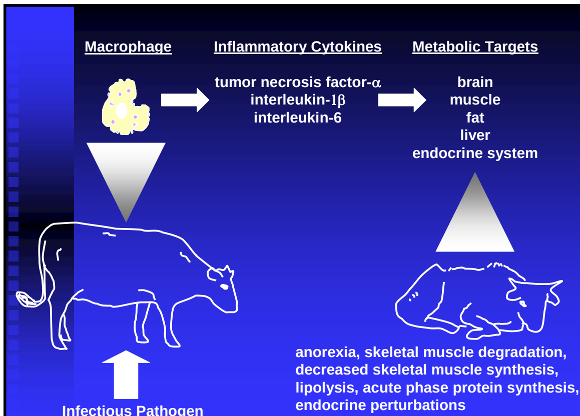
Goff and Kimura, 2002

Gunnink theory for retained placenta

- Fetal placenta must be recognized as “foreign” tissue and rejected by the immune system following parturition (Gunnink, 1984).
- Neutrophils isolated from blood of cows with RP had significantly decreased function before calving that lasted through 1 to 2 wk postcalving (Kimura et al., 2002).
- Production of IL- 8(activates neutrophils) also was depressed (Kimura et al., 2002).

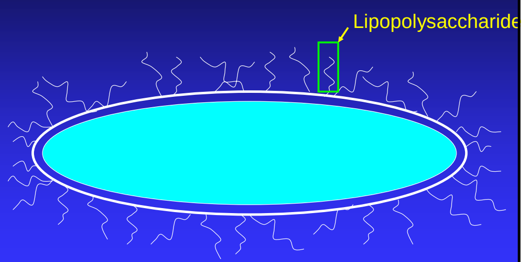
Potential risk factors for retained placenta

- Immunosuppression
  - Increased glucocorticoid levels due to stress or poor hygiene?
  - Nutritional factors for retained placenta
    - Energy and protein
    - Hypocalcemia?
    - Vitamin E and selenium
    - Trace minerals

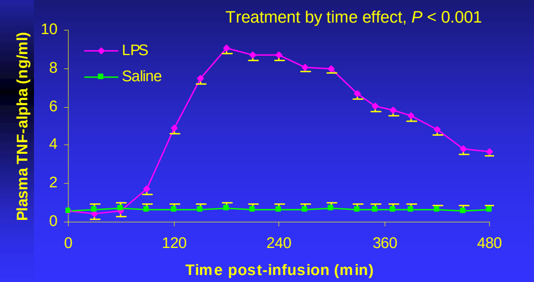


-R. W. Johnson, 2001

Escherichia coli

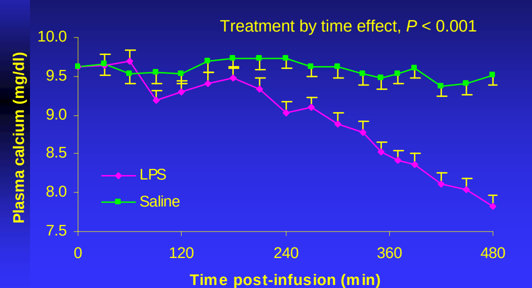


Plasma tumor necrosis factor α concentration after intramammary lipopolysaccharide or saline infusion



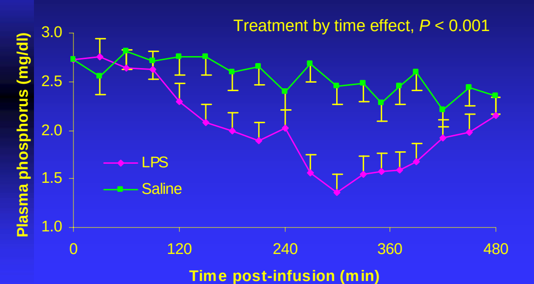
Waldron et al., 2005

Plasma calcium concentration after intramammary lipopolysaccharide or saline infusion



Waldron et al., 2005

Plasma phosphorus concentration after intramammary lipopolysaccharide or saline infusion



Waldron et al., 2005

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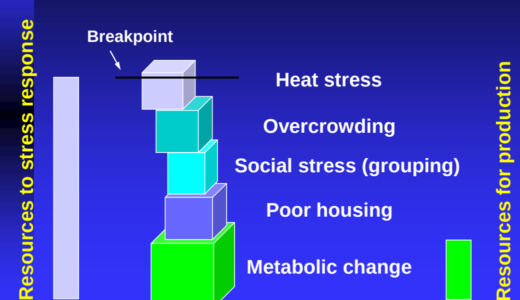
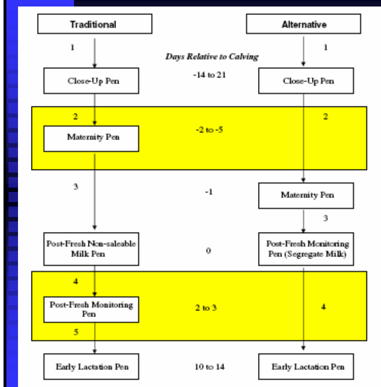
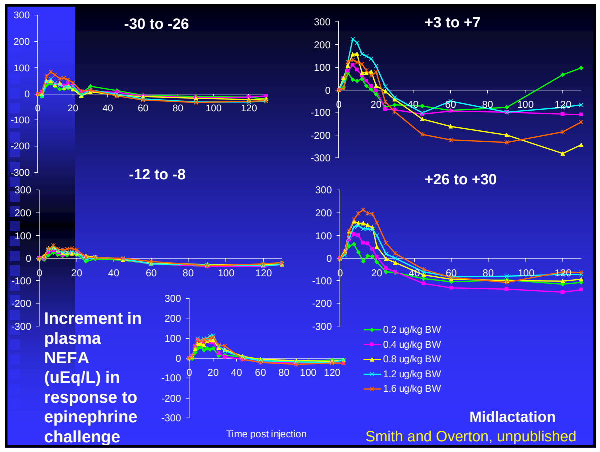
Effects of multiple stressors accumulate...



Adapted from Drackley, 2002



Streamline approaches to grouping management of transition cows (Cook and Nordlund, 2004)



Ongoing field study (160 herds in Northeast US) assessing energy-related blood indicators of transition health (Nydam, Stokol, and Overton)

- Prepartum NEFA
  - Current recommendations (Herdt and Oetzel) are no more than 10% of cows > 425 uM
- Postpartum BHBA and NEFA
  - Current recommendation BHBA no more than 10% (Oetzel) or 15% (Overton and Nydam) of cows > 14 mg/dl
  - No current guideline for NEFA (any cow > 1000 uM mobilizing LOTS of fat)
- Relating outcomes (health, performance, repro) with blood variables to refine guidelines and better define nutritional and management factors that cause variation