Ovarian Dysfunction in Lactating Cows

James D. Ferguson, VMD, MS ACT, ACVN
University of Pennsylvania
School of Veterinary Medicine

Center for Animal Health and Productivity
UNIVERSITY of PENNSYLVANIA

Penn
Veterinary Medicine
New Bolton Center

What do we mean?

- Cows that have failed to ovulate by the voluntary waiting period
    - Typically 40 to 60 days postpartum in the literature
    - The later the VWP the fewer cows will be anovulatory, therefore a VWP of 70 DIM have been proposed for higher producing cows
- Cows that initiate ovulation and then enter a phase of anovulation prior to the breeding period
    - A prolonged CL lifespan – often due to uterine infection
    - Occasionally cows initiate a rise in progesterone but then fail to continue with estrous cycles

Who are the players?

Takes coordination between structures in the brain and the ovary (and the uterus)

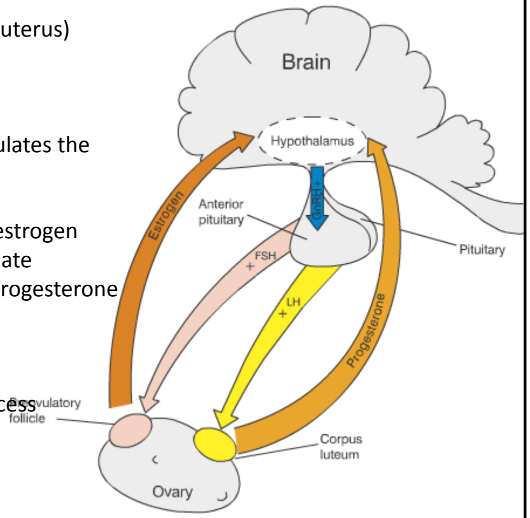
Hypothalamus is the driver: releases pulses of GnRH, which drives the…

Pituitary Gland, which is an amplifier, and releases FSH and LH, which stimulates the

Ovary – produces follicles in waves due to FSH bursts
one follicle becomes dominant and sensitive to LH and produces estrogen
which stimulates an LH surge causing the dominant follicle to ovulate
cells in the collapsed follicle form a Corpus Luteum and produce progesterone

Uterus produces prostaglandin F-2α which induces regression of the CL
based on a timed sequence of 16 days or so; unless an embryo
is present at day 14-17 days and produces a protein to stop the process

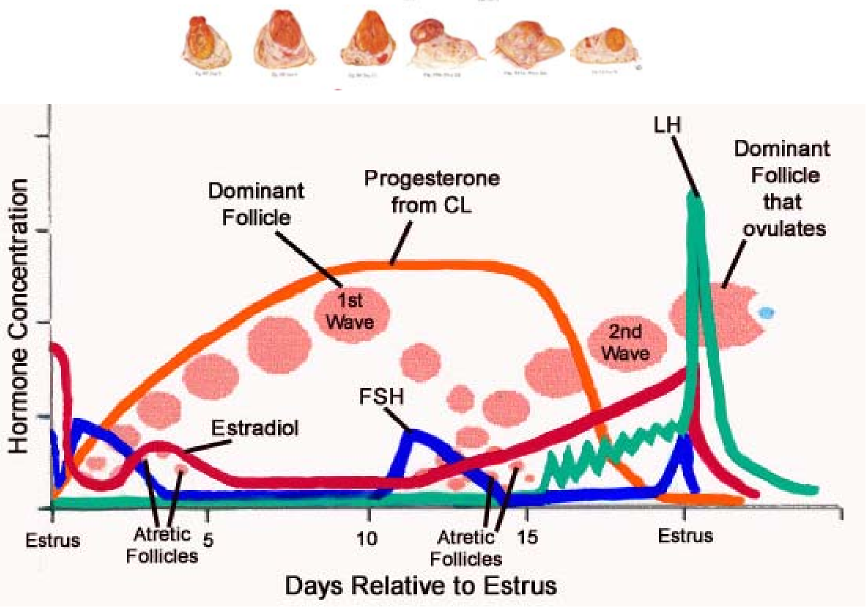
Ovulation occurs every 21 d (18 to 24 days)



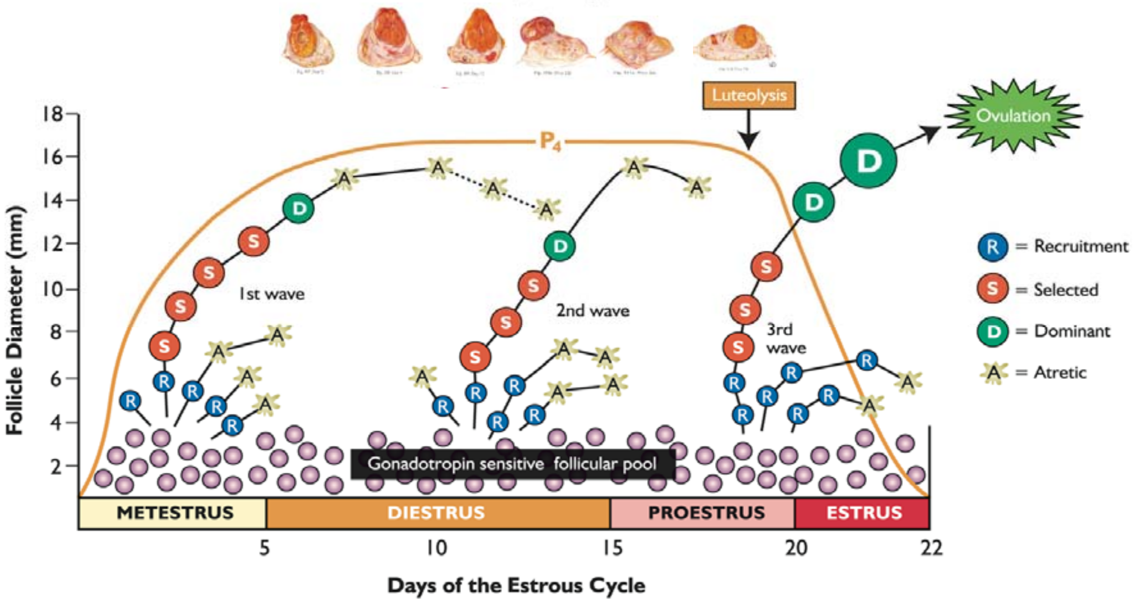
Some definitions

- Follicular waves – emergence of a group of follicles on the ovary > 4mm in diameter
  - FSH bursts initiate follicular waves
  - a cohort of follicles, usually 4 to 6 in a wave or more
  - Occurs every 7 to 10 days
- Divergence – a follicle within the cohort achieves 8.5 mm in size
  - Becomes LH sensitive
  - Produce estrogen and inhibin and causes regression of other follicles
  - Usually develops 2 to 3 days after emergence
- Dominance – a follicle > 10 mm in size and has the potential to ovulate
  - Ovulatory follicles are anywhere from 13 mm to 20 mm in size
  - If no LH surge (Progesterone inhibits LH surge) follicle regresses in 2 to 3 days
- Follicular waves – during an estrous cycle cows have either 2 or 3 waves of follicles which influences estrous cycle length
  - 2 waves: estrous cycle 19 – 20 days (Pring et al. 2012)
  - 3 waves: estrous cycle 21 – 22 days (Pring et al. 2012)
  - Cows tend to be consistent in the follicular waves they have

Two Wave Estrous cycle



Three wave Estrous Cycle



What's the incidence of ovulatory problems?

- Varies by herd and VWP
- Primiparous cows 49 – 71 DIM range 28% to 54.1% four studies
- Multiparous cows 49 - 71 DIM range 15% to 31.5% four studies
  - Greater in first lactation cows than older cows
- Associated with greater body condition loss (>=1 unit) and cows < 2.5 in BCS
- There has not been a strong association with milk production
- For example Roth followed 47 cows to 100 days post calving
  - 30 ovulated by 40 DIM; 17 had not
  - 17 cows
    - 4 ovulated by 50 days
    - 4 ovulated by 60 days
    - 8 were cystic (fluid structure>20 mm) but ovulated by 62 days (6 cows) and 1 cow by 99 days
      - 1 cows failed to ovulate by 100 days

Lamming followed 505 cows with sequential progesterone concentrations every 3 to 5 days

Days	N ovulating	Cumulative percent (%)	Percent Ov. (%)
1-10	13	2.6	2.6
11-20	240	50.4	47.8
21-30	157	81.7	31.3
31-40	54	92.4	10.7
41-50	16	95.6	3.2
51 – 160	22	100.0	4.4

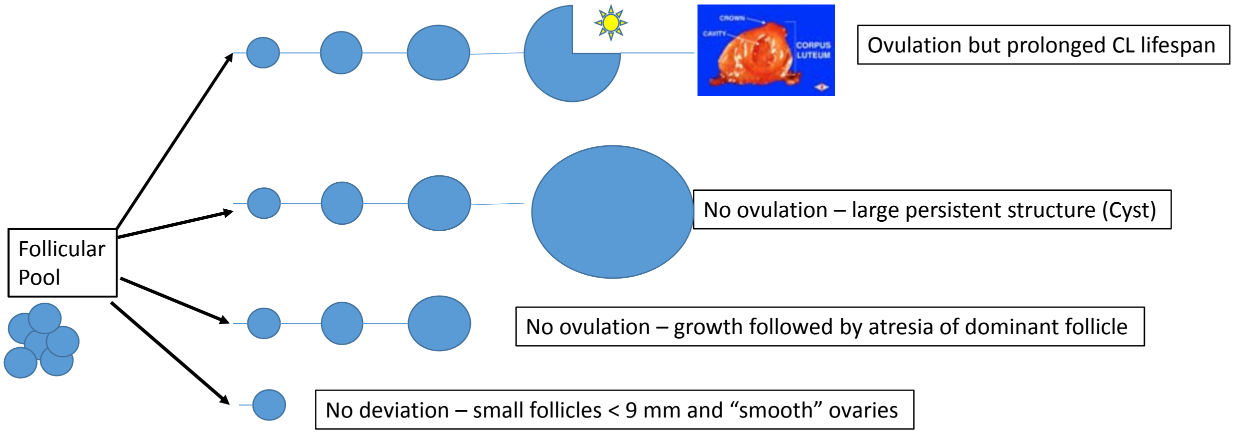
What's the fertility in anovulatory cows on TAI

Typical Literature	CR, %
Ovulatory cows	32, 32, 34, 35, 35, 40
Anovulatory cows	24, 9, 21, 21, 22, 27

Based on low progesterone (<1 ng/ml) prior to insemination

OR of pregnancy is about 2.04 for ovulatory cows versus anovulatory cows
Delays in ovulation are associated with reduced fertility

Anestrous Conditions (AT Peters et al. 2009)



Follicular Pool

Ovulation but prolonged CL lifespan

No ovulation – large persistent structure (Cyst)

No ovulation – growth followed by atresia of dominant follicle

No deviation – small follicles < 9 mm and "smooth" ovaries

What’s the incidence on classification?

- Ovarian Cysts (Follicular and Luteal) – structures >=25 mm
  - Garverick reported 5.6% to 18.8% in the literature in a review paper in 1999
  - 2.7% Argentina in 9,156 cows more recent report
  - Data from Norway 0.8%
  - Personal observation 1.8% (five year period 35 herds, >5,000 cows)
- Anovular ovaries – follicular structures <= 20 mm
  - 10% is typical for most reports but can be up to 20% to 30%
- Other ovarian dysfunctions
  - Prolonged CL: luteal phases longer than 15 - 25 days especially early postpartum –1.6% to 8%
  - Prolonged interluteal interval: longer than 12 days, long follicular period – 13%

What’s the difference between a cyst and failure to ovulate

- Size of the anovulatory structure
  - Classic definition >= 25 mm in size but now >17 to 20 mm are being used
  - Anovulatory follicles <= 20 mm
- Persistence on the ovary
  - cysts fail to ovulate and fail to regress – remain for up to 20 days
    - Cysts classic definition > 10 days; now some are using >6 days
  - Anovulatory follicles fail to ovulate but regress
    - persist less than 10 days – regress normally
- Absence of a CL
  - In both cases there is no CL present on the ovaries
- Presence of other follicles
  - In Cystic cows follicle recruitment is depressed so there are few follicles > 5mm
  - In anovulatory cows follicular waves still occur

Why does a cyst develop?

- It is unknown at this time
- There is a disruption in the hypothalamic-pituitary-ovarian axis
  - there is a failure in estrogen to elicit an LH surge and induce ovulation
- In “normal” cases the dominant follicle will regress, estrogen production decline, FSH will peak and a new follicular wave emerge
  - this repeats until the system “works” and ovulation ensues
- In “cystic” cases there is a disruption in the process of apoptosis and growth so regression of the follicle does not occur, estrogen continues to be produced
  - Sufficient LH is released to stimulate growth of the follicle and production of estrogen and inhibin so FSH is depressed and no new follicular waves emerge
  - the system “freezes” so to speak

Alterations in the system

- Both a disruption in the production of reproductive hormones
  - Gonadotropins and steroid hormones
- Disruption in response in the ovary to gonadotropins and steroid
  - Production of receptor proteins and gene transcription is altered
- Systemic factors and local factors play a role in the condition

Ovulation - what should happen

- Five days post calving FSH should increase and initiate a follicular wave
- Emergence of a dominant follicle at 8.5 mm in size in 2 to 3 days
    - Dominant follicle becomes LH dependent with expression of LH receptors
    - Estrogen, Inhibin, Actin produced by dominant follicle depress FSH and cause atrophy of other follicles in the cohort
    - Increasing estrogen produced by the dominant follicle triggers an LH surge and ovulation (FSH also peaks prior to ovulation)
- Progesterone is produced by granulosa and theca cells of the collapsed follicle
- Ovulation should occur by 21 days post calving

Postpartum – all together this should be the case

- Uterine involution - Complete prior to 50 days
- Ovarian function - First ovulation by 15 to 21 postpartum
    - Second ovulation by 32 to 42 days postpartum
- So by 50 days postpartum the reproductive axis is fully functional
    - Uterus is fully involuted and ovarian activity has been fully established
    - Conception rates can exceed 40% at first breeding

What can go wrong

- Uterus fails to clear infection
  - Primarily a concern with *Trueperella pyogenes*
- Ovarian function is dampened
  - Low production of estradiol and progesterone – low fertility
  - Low LH amplitude and frequency of LH production
- Normal ovarian function is disrupted
  - Failure of resumption of ovulation due to failure to trigger an LH surge
    - Cystic Ovarian Disease
    - Failure of a dominant follicle to ovulate with normal follicular waves
    - Cessation of cycling after it begins
    - Prolonged interestrus interval due to retained CL or delayed follicular recruitment after ovulation

Anovulatory conditions with no CL

Anovulatory conditions (Wiltbank et al. Therio. 57:2002, Lopez et al. 2010, Peters 2009)

1. Cystic Ovarian Disease
2. Follicles 16 to 24 mm in size with no ovulation (not considered cystic by some)
3. Small follicles – maximal size of only 9 to 15 mm and no ovulation
4. A cow with follicular growth only to emergence – small follicles <9 mm

Anovulatory conditions with no CL

Anovulatory conditions (Wiltbank et al. Therio. 57:2002, Lopez et al. 2010, Peters 2009)

1. Cystic Ovarian Disease
   - Classically – a follicular structure on the ovary >=25mm, which persists for at least 10 days in the absence of a Corpus Luteum (>17 mm persists for 6 days; others use 20 mm and 10 days)
   - Follicular cysts often undergo luteinization and become a “luteal cyst”
   - A “cystic CL” is a normal ovarian structure typically formed after ovulation and is an immature CL usually 2 to 7 days old
2. Follicles 16 to 24 mm in size with no ovulation (not considered cystic by some)
   - High circulating estrogen but no LH surge to cause ovulation of a dominant follicle
   - Still have follicular waves on a regular basis
   - Most common anovular condition (Lopez et al.2010)
3. Small follicles – maximal size of only 9 to 15 mm and no ovulation
   - Common in cows early postpartum – 25% may fail to ovulate first dominant follicle
   - Common with more negative energy balance
   - Deficiency of LH pulses frequency and amplitude → inadequate follicular development of dominant follicle
   - Low estrogen production (or high liver clearance) dampens GnRH/LH pulses and leads to failure to ovulate
4. A cow with follicular growth only to emergence – small follicles <9 mm
   - Wiltbank reports that they have observed this only in 3/1000 cases
   - My experience is this is not common – “small” ovaries with no large follicular or luteal structures

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What is the difference: cyst vs anovulation?

- Anovulatory condition – absence of CL over 10 day period
  - Dominant follicles arise but don’t ovulate – persist 6 days or so
  - Follicle waves continue every 7 to 9 days
  - Estrogen is produced but no LH surge
- Cystic follicle – absence of CL over a 10 day period
  - Large follicular structure that persists for 13 to 20 days
    - Wall thickness < 3mm (Luteal cyst wall thickness > 3mm)
  - Follicular waves are depressed and appear to arise only when the cyst stops producing estrogen - every 15 to 21 days – but a new cyst may form
  - Cysts do turnover and are replaced by other cysts
- Both conditions have higher prevalence in first 40 days postpartum

What is the defect leading to anovulation?

- Failure of LH surge to cause ovulation
  - Estrogen fails to induce an LH surge to cause ovulation
  - Hypothalamus is unresponsive to estrogen
- Failure of adequate LH pulse frequency and amplitude to cause maturation of a dominant follicle
  - Low estrogen synthesis so insufficient estrogen to elicit an LH surge
- Increased estrogen clearance by the liver inhibiting LH surge

What might cause lack of LH surge in a Cyst

- Cystic structure
  - Low progesterone (0.1 to 1.0 ng/ml) can block LH surge but not suppress pulsatile LH
    - About 60 to 75% of cystic cows have marginal progesterone concentrations
  - Follicular structure responds to LH and continues to grow and produce estrogen and inhibin delaying follicular wave recruitment by depressing FSH
  - Continues to grow beyond 20 mm in size due to LH stimulation
  - Cysts will turnover and new cyst arise
  - Cysts cause a depression of follicular waves and a long period between recruitment

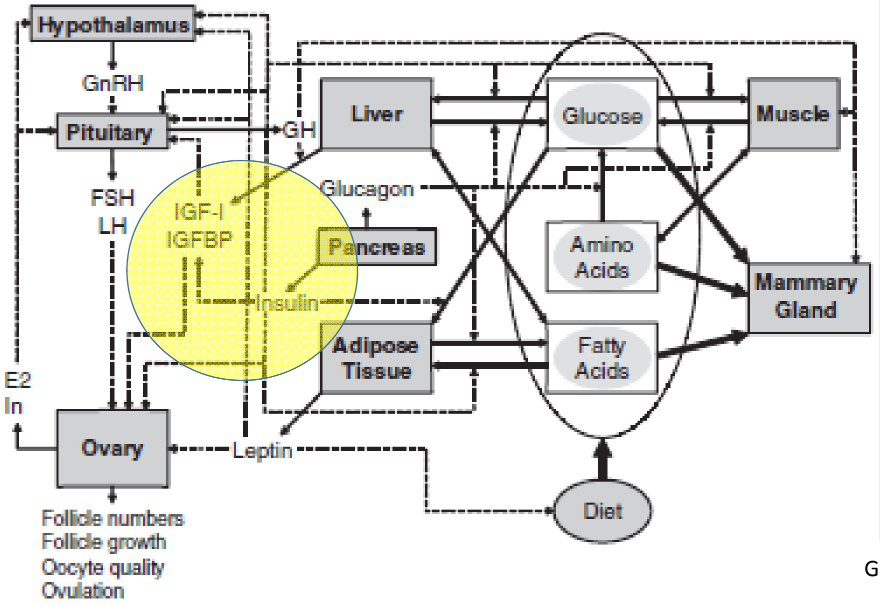
Hypothalamus – cite of the major defect

- Hypothalamus is not responsive to estrogen feedback
- Give estrogen and no GnRH is released to cause LH release from pituitary
  - Hypothalamus seems insensitive to feedback
- May need progesterone concentrations above 2 ng/ml to condition hypothalamus
- If progesterone drops <0.1 ng/ml then spontaneous ovulation
- Or give progesterone to increase blood level >1 ng/ml and hypothalamus regains responsiveness

What modifies the response of the system

- Metabolic
- Uterine infection
- Stress
- Genetic – but very low heritability (Sweden!!)

Reproductive System Metabolic System



Linkage of the reproductive system
And the metabolic system
Critical linkages

Insulin
Insulin like growth factor – I,II
- **IGF-I, II**
- **Binding proteins (IGFBP, 1-6)**

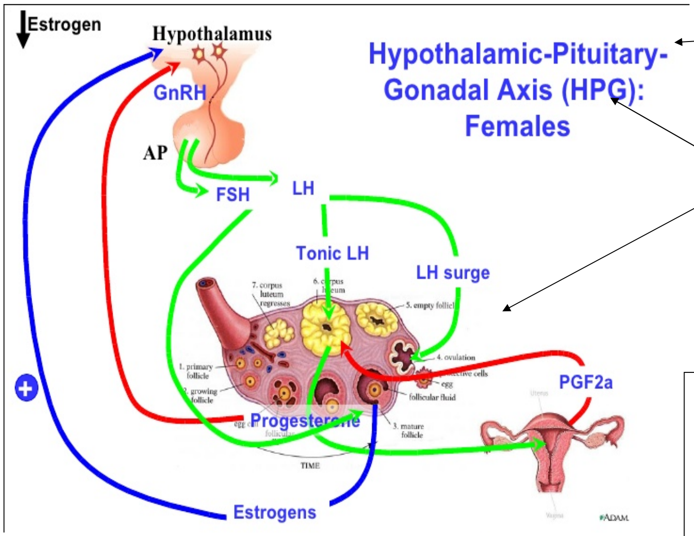
Nutrients
- fatty acids
- amino acids
- glucogenic precursors

Trace minerals

Vitamins

Modify the reproductive organs

Garnsworthy et al. Animal 2008



Hypothalamic-Pituitary-Gonadal Axis (HPG): Females

Metabolism

IGF1
Insulin
Urea/ammonia

Dietary factors

Fatty acids
Trace Minerals
Vitamins

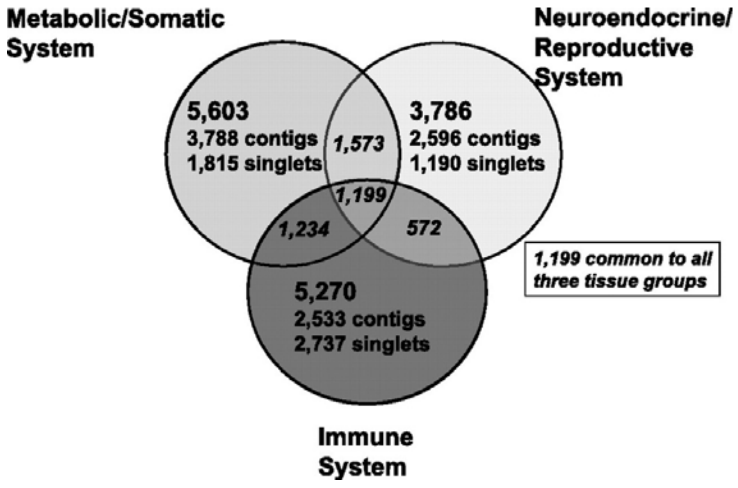
Uterine System

Fertilization

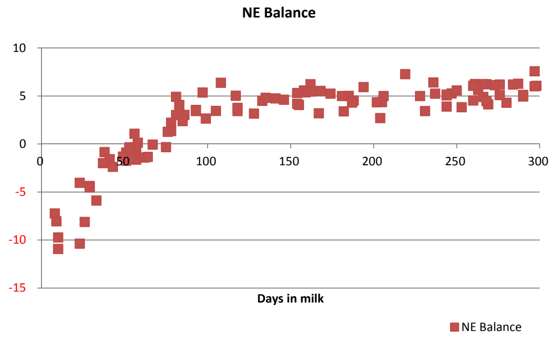
Early embryo

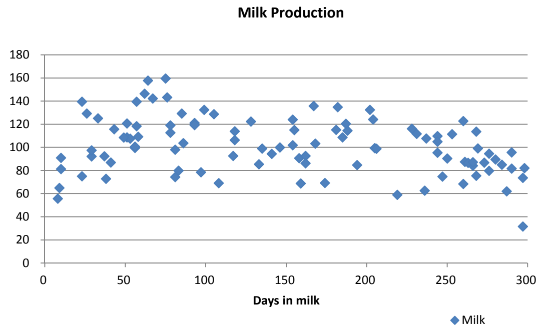
Conceptus

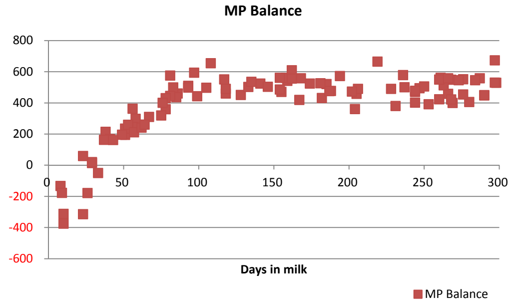
Overlap in genes expressed in immune, reproduction and metabolic systems



1,199 common to all three groups
Influenced by immune and metabolic conditions in the cow





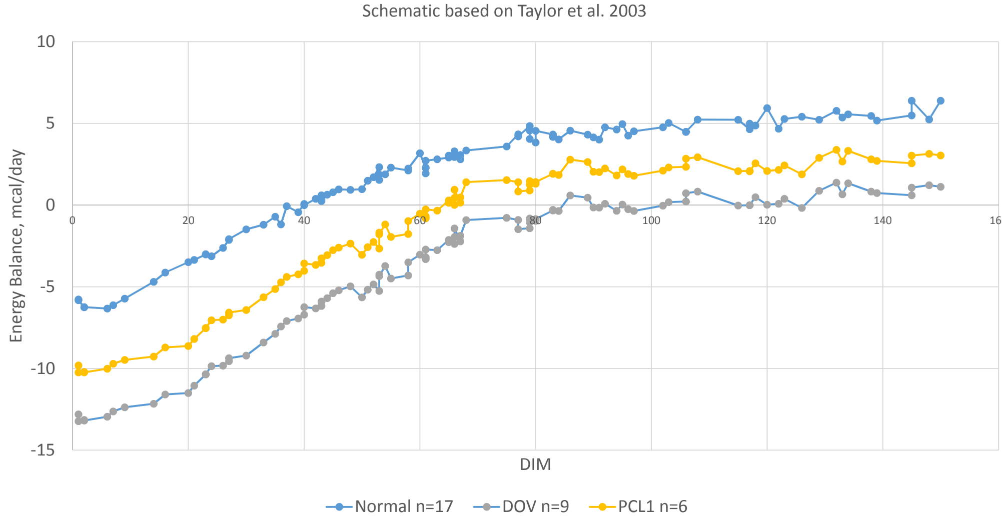


Patterns post-calving in a group of cows

What influences ovulation?

- Metabolic
    - Negative energy balance – small follicles
    - Low serum insulin, low IGF-1
        - Low insulin associated with delayed ovulation and cystic ovarian disease
    - Fewer recruited follicles and sensitivity to gonadotropins is reduced
    - Reduced GnRH output and LH production
- Uterine infection – endotoxin release
    - Delays folliculogenesis – dampens GnRH output
    - High uterine production of PGF-2α suppresses ovarian activity
- Stress
    - Cortisol inhibits LH surge and prevents ovulation
    - Sequential ACTH injections will lead to ovarian cyst formation

Study by Taylor et al. 2003 in first lactation cows and ovulation postpartum
Normal – first progesterone rise by 17 days postpartum
DOV – first progesterone rise by 71 days postpartum
PCL1 – extended first luteal phase – ovulation day 19 with luteal length of 46 days



Additional influences: Acute Dietary Restriction

- Dietary restriction
  - reduced estrogen synthesis, reduced responsiveness to FSH and IGF signaling in granulosa cells
  - LH responsiveness in theca cells is reduced
- Amplitude and frequency of LH pulses is reduced
- The preovulatory surge of LH is reduced
- Cows that ovulate: steroidal hormonal output reduced
  - Decline in hormonal production of estrogen and progesterone influencing sequential follicular development and hypothalamus and pituitary function
- Cows that don't ovulate: reduced steroidal hormonal output and a reduction in transcription of mRNA reducing LH receptors on GC
  - Decline in production and responsiveness of system

Influences: Systemic and Local factors

- Systemic factors – dampening of the hypothalamus-pituitary-ovarian axis
  - Reduction in hormonal outputs and feedback regulation
  - Modified by insulin and IGF system of IGF-I, II and IGF binding proteins (IGFBP1-6) which influence IGF availability
- Local factors in the ovarian follicle
  - IGF-I, II and binding proteins
  - Inhibin, activin, follistatin
  - Receptor levels and gene transcription influences response to hormonal inputs and output of steroidal hormones

Nutritional status modifiers

Item	Nutritional Influence	Possible Signal
Release rate of GnRH	Energy Balance	Neuronal
Release rate of LH	Energy Balance	Insulin, IGF-1
Release rate of FSH	Energy Balance	Insulin, IGF-1
Clearance rate of LH	Dry matter intake	Liver blood flow
Clearance rate of FSH	“	“
Clearance rate of estrogen	“	“
Clearance rate of progesterone	“	“
Follicle sensitivity to FSH	Energy balance	Insulin
Follicle growth to FSH	Energy balance	Insulin
Growth of selected follicles	Energy balance, dietary fat	Insulin, NEFA
Growth of dominant follicle	Energy balance, dietary fat	Insulin, NEFA

Pring et al. 2012

How do you diagnose it?

- Palpation – low sensitivity and specificity on one time examination of structures
  - West Virginia – 28 herds, 10 vets 40 cows with cyst; saline vs GnRH no difference in response
  - Follicular cysts – 70% - 85%; Luteal cysts – 41% - 52% (>=25 mm structure criteria)
  - If no large structures cow may be around estrous making diagnosis of anovulation difficult
- Ultrasound – improves sensitivity and specificity
  - Follicular cysts – 72% to 92%; Luteal cysts – 74% to 88%
  - Cows just post ovulation may be difficult to distinguish from anovulation
- One time exam for each is fraught with errors – need two examinations 7 to 14 days apart
  - Remember – any diagnosis has to lead to a treatment to improve the likelihood of pregnancy sooner than if no diagnosis had been made
- Progesterone profiles
  - Daily up to every 3 days with milk recording systems or kits
  - ELISA or Biometallics Target test kits
- Presynch – OvSynch Protocol progesterone check

Problem with diagnosis on one observation

- What is a cyst? – Definition has varied from >17 mm to >25mm for 6 to 10 days
- Large follicle on the ovary(ies) may be present 45% of the time within a cycle
  - 10 to 20 mm in size; waxing or waning
- Early CL is present for 28% of the days of a cycle (Corpora hemorrhagicum)
  - Poorly formed and globular and "mushy"
- 73% of the time of a cycle the ovary may have a structure that "appears" abnormal – "cystic"
- Spontaneous cure
  - Cysts are observed most frequently 14 d to 40 d postpartum and many cows initiate ovulation with no treatment

For Example

- Hatler et al. Follicular Cyst Criteria - > 17 mm for 6 days no CL
- 32 cows diagnosed
  - 6 cows ovulated 7 days later
- 26 cows
  - 13 of the 26 cows ovulated in an average of 19 days (range 6 to 41)
- 13 cows (13/32 = 40%) from initial observation
- The spontaneous and transient nature of ovarian structures make diagnosis and prospective studies difficult
  - Low frequency condition after 40 days
  - Errors of diagnosis on one examination (very high with a one time exam)
    - 63% cows coming in estrus in Polish study diagnosed with a cyst
  - High spontaneous "cure" rate >60% reported in literature
    - Prior to 30 to 40 days post-calving up to 30% of cows may have a "follicular cyst"
      - Observe luteinization, rise in progesterone, and initiation of ovulation in >90% of cases
  - Prospective studies would require many observations to document longitudinal changes

Using Presynch – Ovsynch to check ovulation Combined with progesterone tests

Typical injection schedule for presynch-ovsynch

PGF ------14 days ----**PGF** ------14 (11) days------**GnRH** ------7 days--------**PGF** ---2 days---**GnRH** –1/2 day TAI

PGF1 PGF2 **PGF3**
If cows are cycling the following should be observed sampling blood or milk:

60% of cows P4>1 ng/ml

80% of cows P4>1 ng/ml

>80% of cows P4> 1ng/ml

The key sample is one taken at the PGF3 - >=80% of cows should have high progesterone by this injection
Sample a group of cows going through the protocol at the time of the PGF3 injection

So what do you do?

- If a cow is cystic versus anovulatory does the type of treatment matter?
  - Probably not
- Options
  - GnRH injection – induce ovulation or luteinization – estrus in 21+ days
    - Cause a rise in LH and ultimately a rise in progesterone to reset the hypothalamus
  - hCG – human chorionic gonadotropin – estrus in 21 days
    - LH like activity does the same as GnRH
  - Progesterone supplement – CIDR/PRID for 7 - 12 days and removal – estrus 4 days
    - Intravaginal device to increase progesterone to reset hypothalamus responsiveness to estrogen
  - GnRH and prostaglandin – either in combination at GnRH injection or followed by PGF 7 to 14 days later
  - GnRH and implant a CIDR followed by CIDR removal and PGF 7 days later
  - Presynch – Ovsynch protocol

Problems you may encounter

- Treatment responses for cysts are reported > 80%
  - Fertility is often lower at first estrus
- Progesterone therapy alone has been variable for initiation of cycles; fertility is low at first ovulation following treatment
- Marginal progesterone concentrations at time of treatment with GnRH
  - May blunt response of LH release although most studies show LH increases
  - Give PGF with GnRH to regress any residue luteinized structure
  - Use a CIDR to increase progesterone above 1 to 2 ng/ml to reset hypothalamus
  - PGF combined with GnRH at treatment has had variable improvement in response
- GnRH + 2 CIDRs in a timed TAI protocol in anovulatory cows has shown an improvement in CR versus GnRH alone
  - 2 CIDRs to increase blood progesterone above 1 ng/ml (closer to 2 ng/ml) to reset the hypothalamus

Observed Data Responses

Presynch - OvSynch

	0 d	+14	+28	+35			
Injection	PG1	PG2	GnRH	**PG3**	N	FSTCR	% .
Progesterone <>1 ng/ml							
Anov.	Low	Low		Low	19	4/19	21.1
No GnRH resp	Low	High		Low	9	5/9	55.6
No GnRH resp	High	Low		Low	15	5/15	33.3
No GnRH resp	High	High		Low	20	6/20	30.0
“Out of synch”					**63**	**20/63**	**31.7**
Late Ov./	Low	Low		High	13	4/13	30.8
Early Ov./cycle	High	Low		High	24	8/24	33.3
Delay Ov.	Low	High		High	50	21/50	42.0
Early Ov.	High	High		High	55	24/55	43.6
“In Synch”					**142**	**57/142**	**40.1**
All					**205**	**77/205**	**37.6**

Florida Protocol (Bisinotto et al. 2015)

U/S at GnRH(1)	38 - 44 DIM **U/S** **U/S**
No CL@GnRH	PGF1 –14 d --- PGF2 --- 11 d --- **GnRH** ---- 7 d --- **PGF3** ---- 21/2 d – GnRH –1/2 d – TAI
No CL@ GnRH	PGF1 –14 d --- PGF2 --- 11 d --- **GnRH** ---- 7 d --- **PGF3** ---- 21/2 d – GnRH –1/2 d – TAI **2 CIDR+** **2CIDR out**
CL at@GnRH	PGF1 –14 d --- PGF2 --- 11 d --- **GnRH** ---- 7 d --- **PGF3** ---- 21/2 d – GnRH –1/2 d – TAI

	No CL control (649)	No CL 2CIDR (633)	CL (640)
CR%, 32 d	31.3%	42.2	38.4
Preg, 60 d	28.9	37.2	33.9
Preg loss	8.5%	11.4	8.8
New CL at PGF3	42.6 (371)	46.8 (354)	48.0 (229)
No New CL@PGF3	**18.6 (149)**	**35.0 (176)**	38.3 (274)
	anovular cows----------------------------------		ovular cows

Cows with no CL at GrRH(1) was 27.0% across five herds
Cows with low P4 with no CIDR – CR 18.6%, typical for the literature for anovulatory cows on TAI
Cows with no CL but with CIDR (2) – CR 35.0%, similar to cycling cows

Prevention

- Control uterine infection
- Minimize transition problems
- Feed diets to increase insulin post calving
  - Garnsworthy et al. observed earlier ovulation when diets with 22% starch were fed versus 16% starch but…
  - These are still low levels of starch (22%)
- Adequate metabolizable protein prior to and post calving
- Injection of GnRH at 30 days postclaving – but increased pyometra

Conclusion

- Anovulatory cows by the VWP may be 20% to 30% of cows
- Diagnosis involves sequential observations or a protocol to create a high prevalence of cows with a CL (Presynch-Ovsynch Protocol at PGF3)
    - Use progesterone or US exam at this time to determine if CL/Progesterone is present
- Treatments utilize GnRH to elicit an LH surge and ovulation of a dominant follicle or luteinization of a cyst
- GnRH combined with prostaglandin or progesterone vaginal inserts may enhance fertility
- The most effective approach is to incorporate cows in a TAI program

Feeding for Milk Protein

Mark D. Hanigan
Juan Castro Marquez

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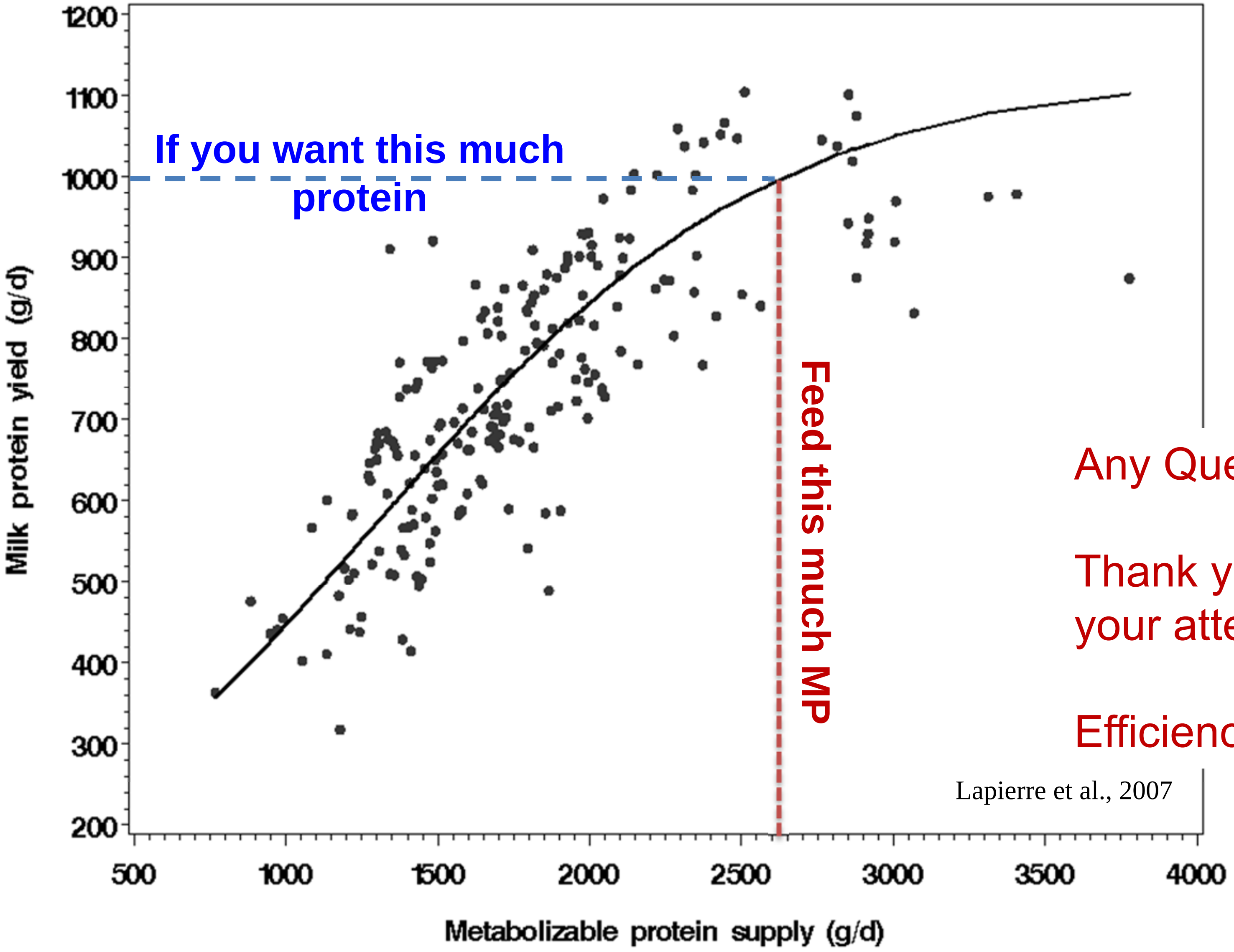
Milk Protein vs Metabolizable Protein



If you want this much protein

Feed this much MP

Lapierre et al., 2007

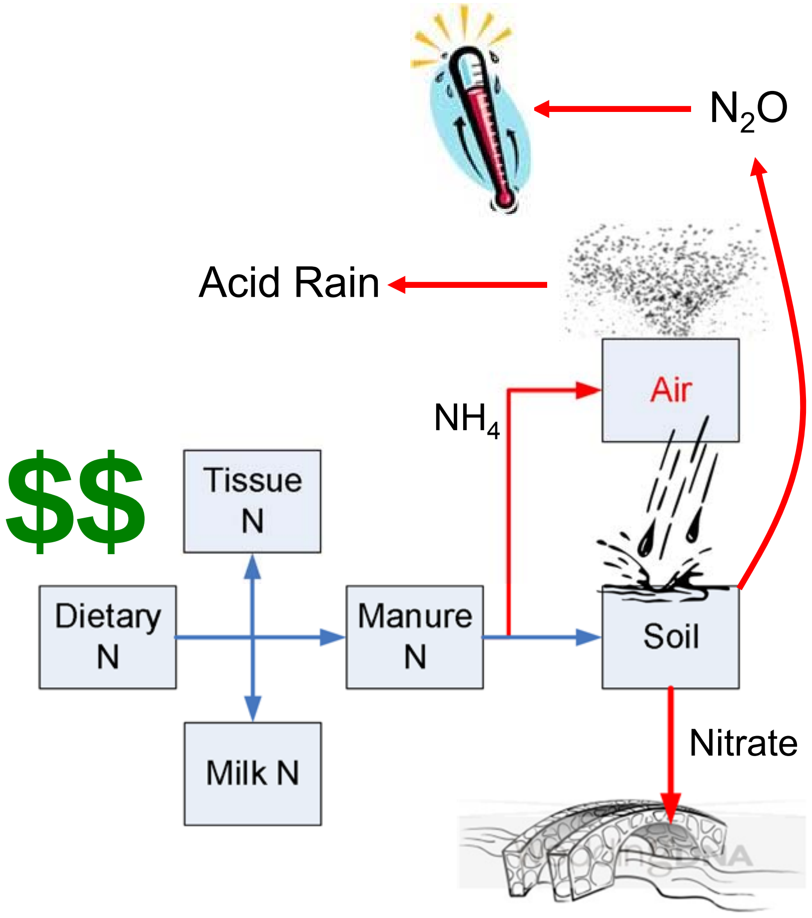
Any Questions?

Thank you for your attention!

Efficiency???

N Conversion Efficiencies are Relatively Poor for the Ruminant

↑ efficiency = ↑ food/ac and ↓ environmental loading!


N_2O

Acid Rain

Air

NH_4

$$

Tissue N

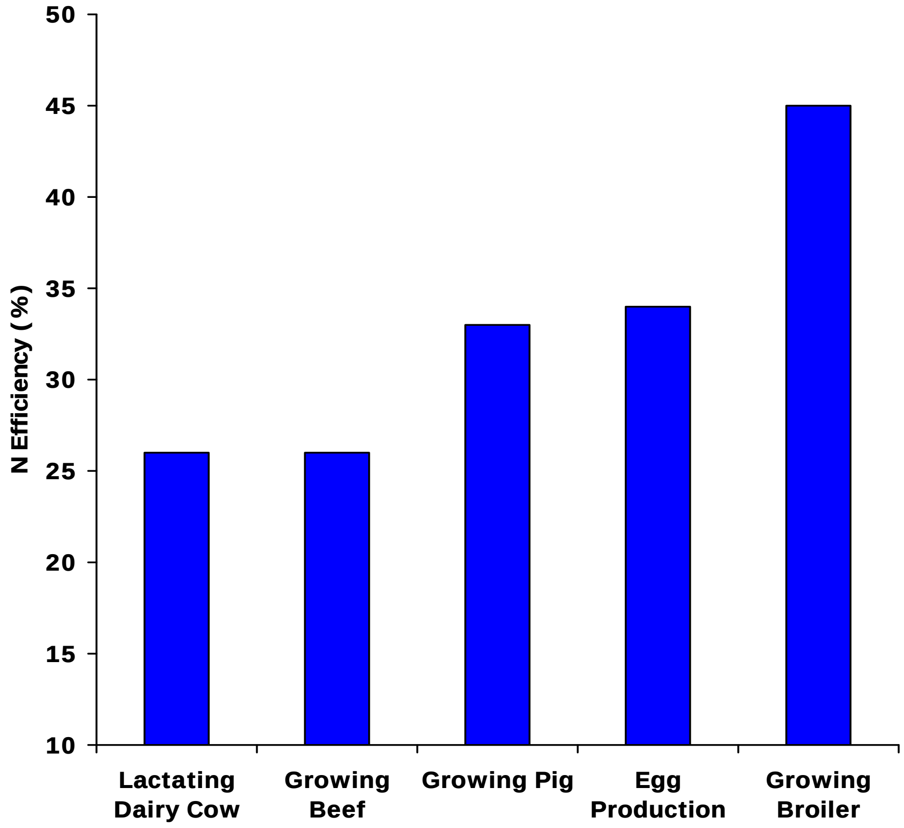
Dietary N

Manure N

Soil

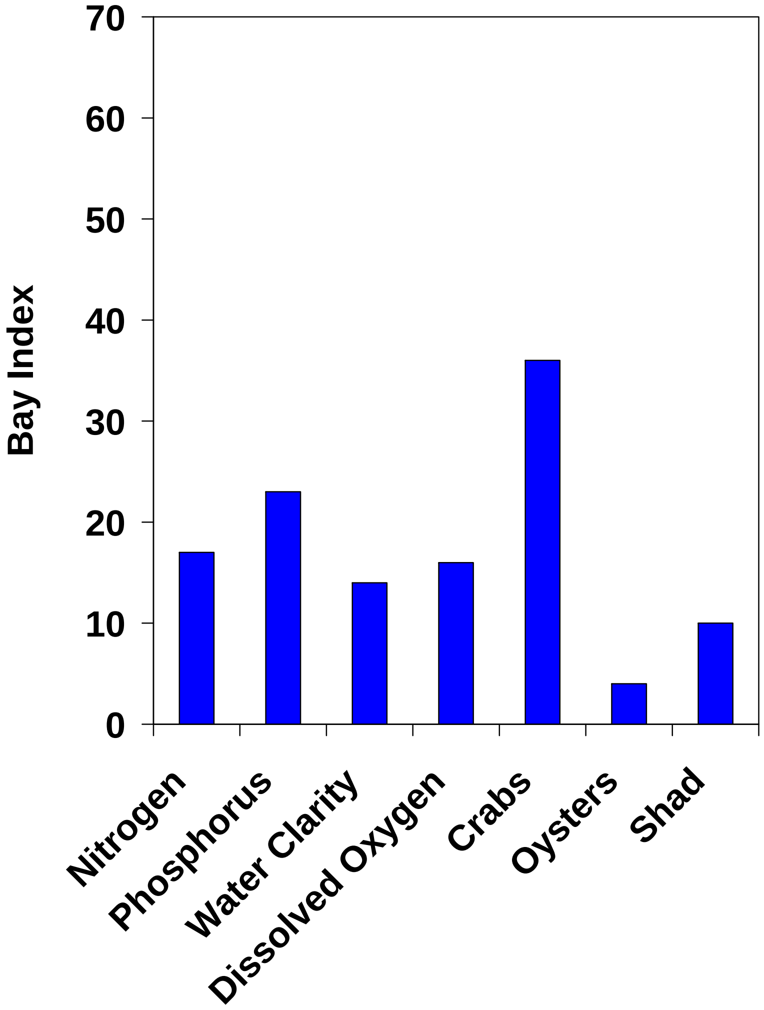
Milk N

Nitrate



Bequette et al., 2003

Chesapeake Bay Index

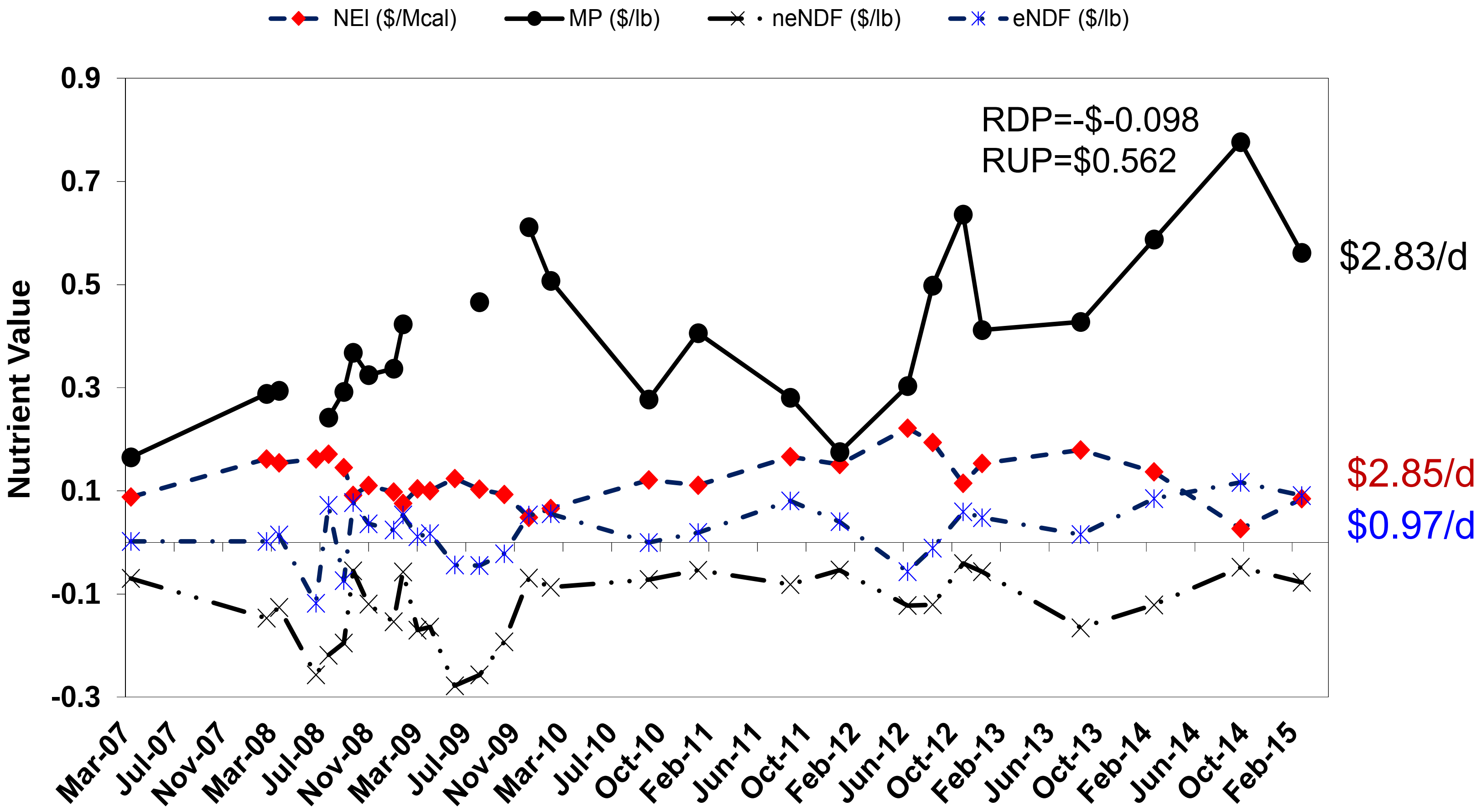


- 100 = Bay Index in 1600
- >70 is viewed as goal
- Current overall = 32
- Was 23 in 1983 (the low)
- Current Dairy Goals:
  - 20% reduction in manure nutrients in one-half the cows by 2015 using feed management.
- **2010 CBF lawsuit settlement**
  - By June 27, 2015, EPA will assess each jurisdiction’s AFO and CAFO programs
  - Will enforce compliance
  - If full compliance does not resolve the problem by 2018, corrective regulations are mandated
-

Chesapeake Bay Foundation, 2007 State of the Bay Report

Dietary Protein Cost

Nutrient Values for Ohio

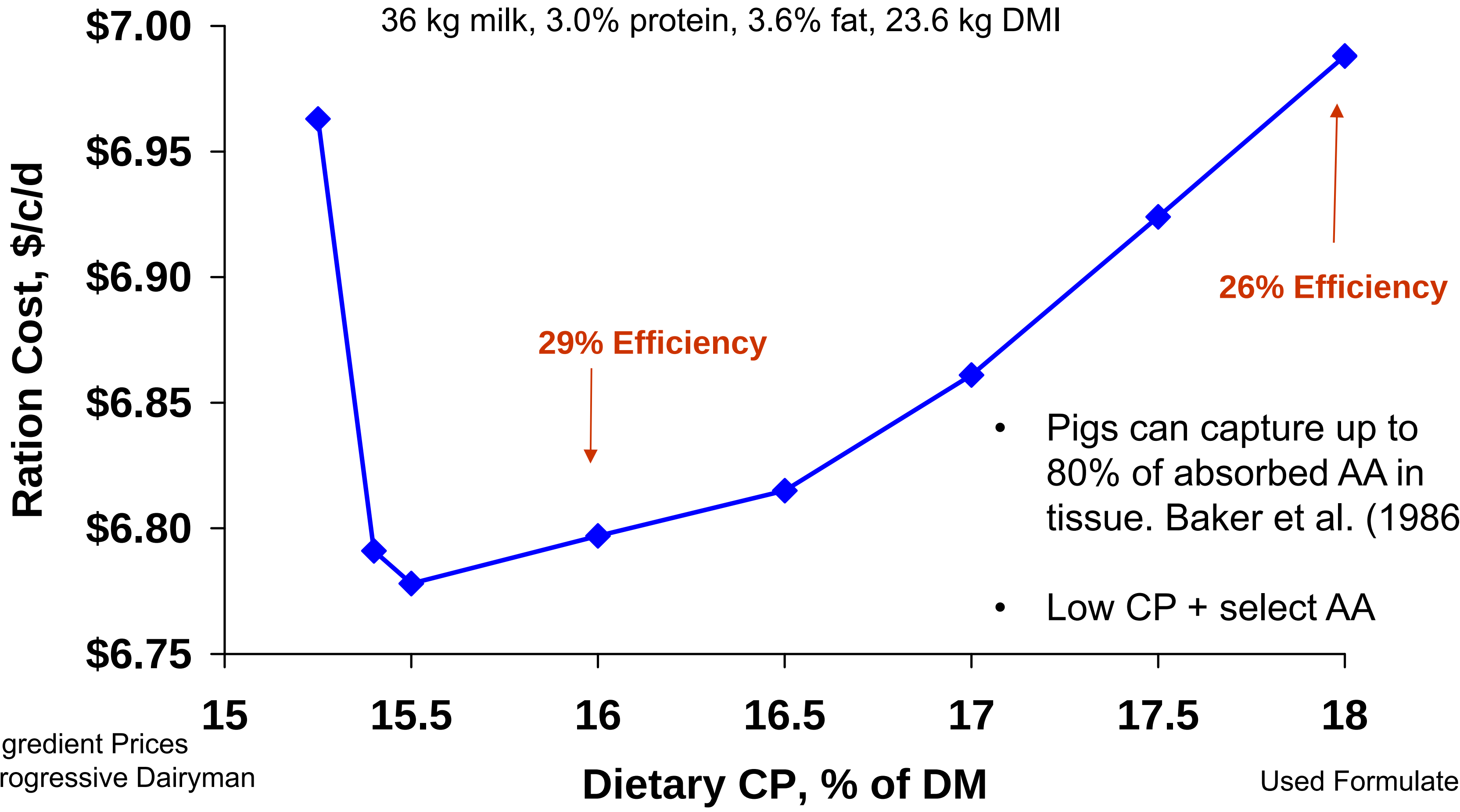


Aggregated from the Buckeye Dairy News: http://dairy.osu.edu/bdnews/bdnews.html

St-Pierre and Knapp

NRC 2001 Least Cost Rations

Balanced to NRC 2001 Requirements (MP & RDP)



36 kg milk, 3.0% protein, 3.6% fat, 23.6 kg DMI

29% Efficiency

26% Efficiency

- Pigs can capture up to 80% of absorbed AA in tissue. Baker et al. (1986)
- Low CP + select AA

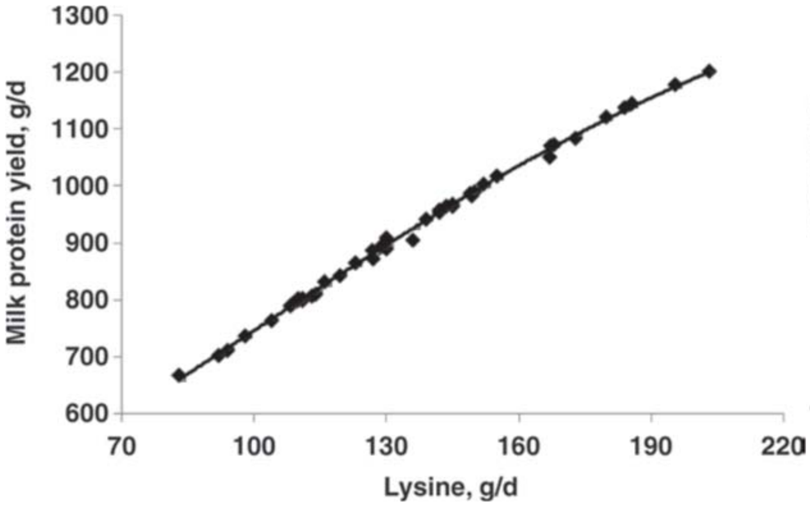
Mar, 2013 Ingredient Prices
ST-Pierre, Progressive Dairyman

Used Formulate2©

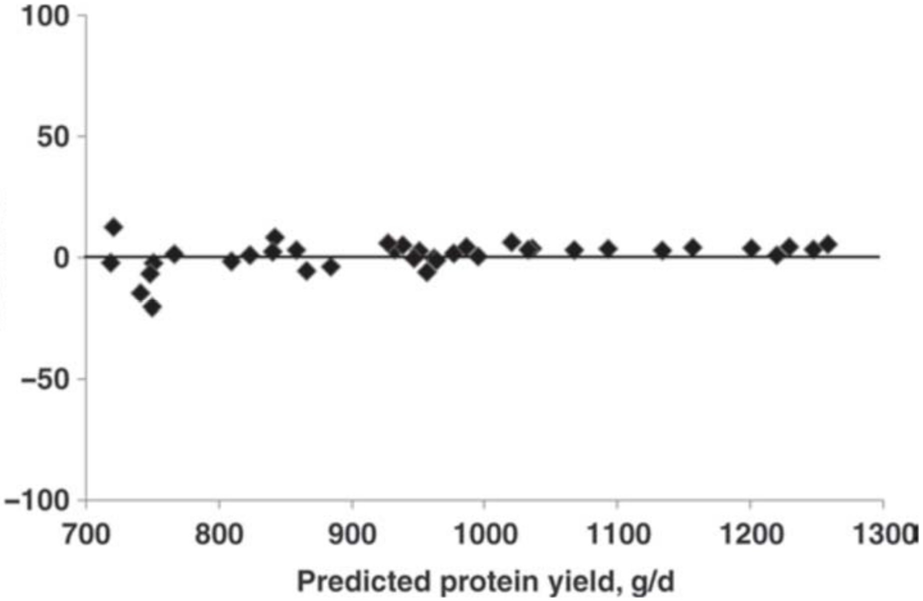
AA Requirements in Lactating Cows

- Do cows also have AA requirements??
  - Of course they do!
- Can we deliver AA via supplementation?
  - YES!
    - RP-Met – Commercially available
    - RP-Lys
    - RP-His – Research products
    - RP-Leu
    - RP-Ile
    - RP-Thr
  - Efficiency of delivery vs price
  - Gold standard for efficacy is blood appearance!
- Can we predict requirements and responses?

Milk Protein Responses to Lysine



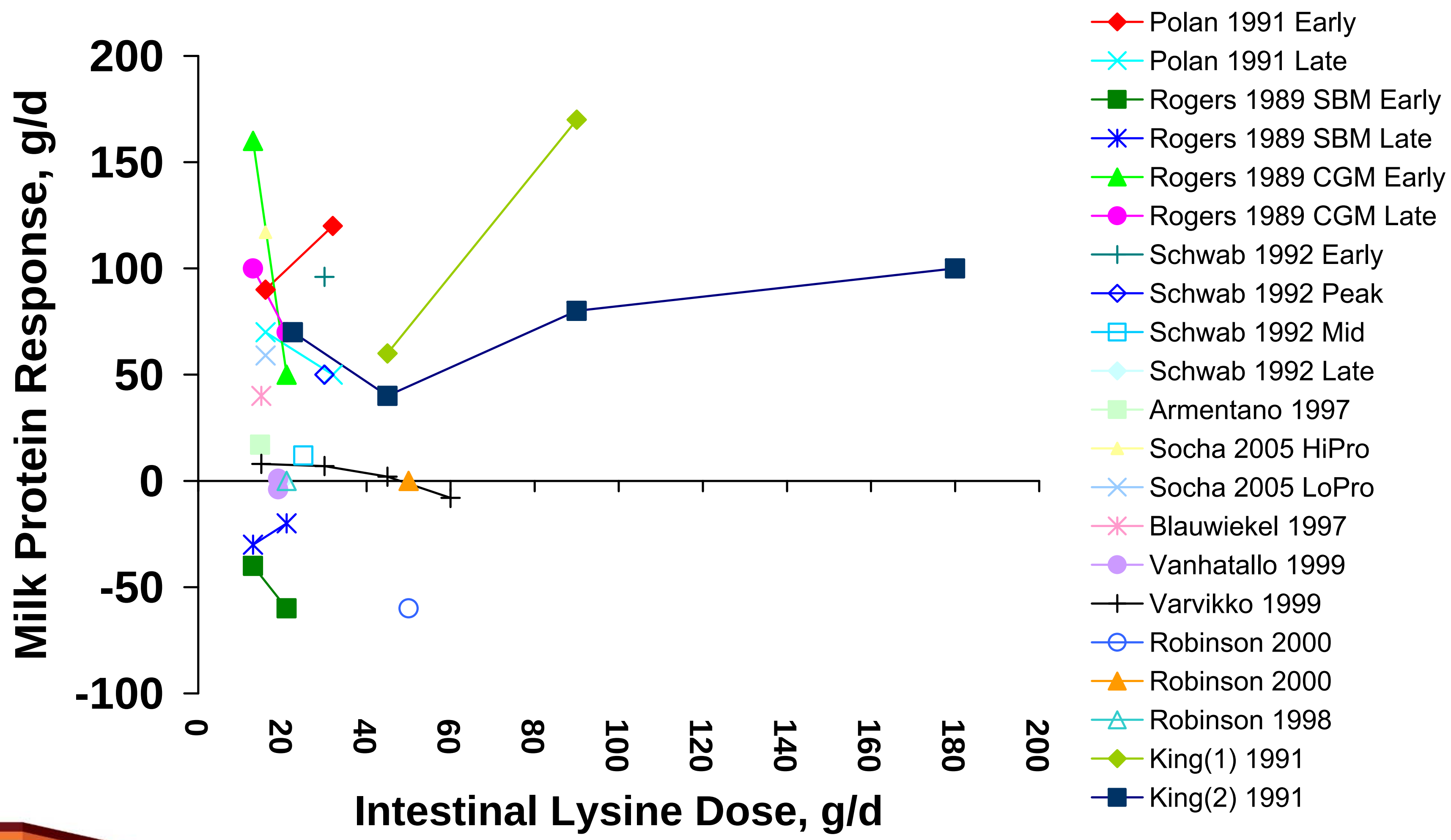
Experiment adjusted milk protein yield (g/d) versus model-predicted milk protein yield (solid line) in response to Lys intake (g/d).



Residuals vs predicted milk protein yield in response to Lys supplementation. There was no mean or linear bias (*P* > 0.05).

Vyas and Erdman, 2009

Milk Protein Responses to Supplemental Post-ruminal Lysine



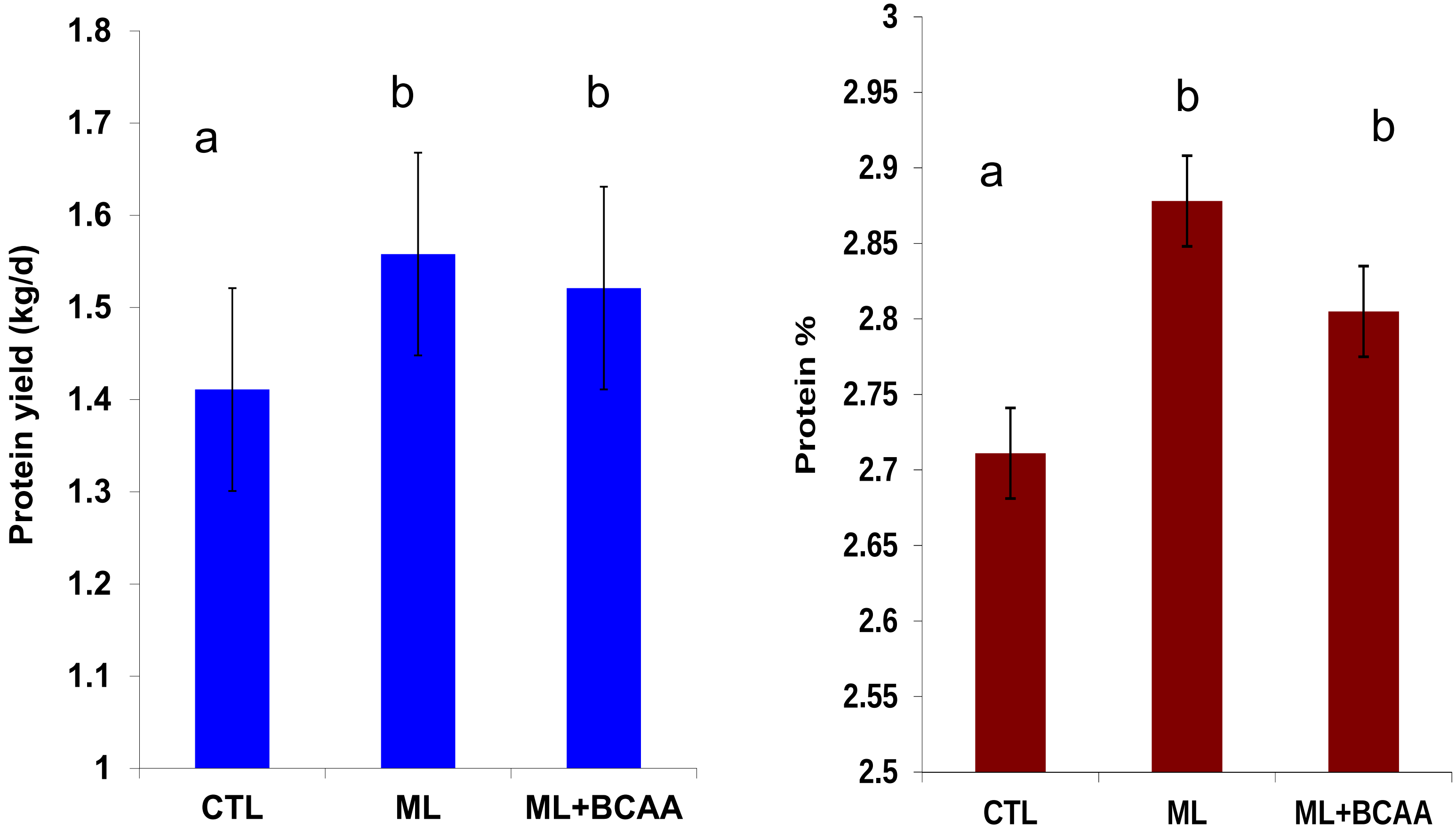
Meta analysis of responses to RP-Met in cows predicted to have varying AA deficiencies

Model Predicted Deficiency	N	Milk Protein Response kg/d	Variance	Minimum	Maximum	Q^2	Heterogeneity Probability
None	22	0.027	0.001	−0.030	0.186	0.16	NS
Met	18	0.017	0.001	−0.028	0.074	0.04	NS
Met+Lys	11	0.007	0.001	−0.023	1.36	0.05	NS
Met+Lys+1 Other AA	26	0.019	0.001	−0.073	0.078	0.09	NS

Q = chi-squared value for homogeneity.

Patton, 2010

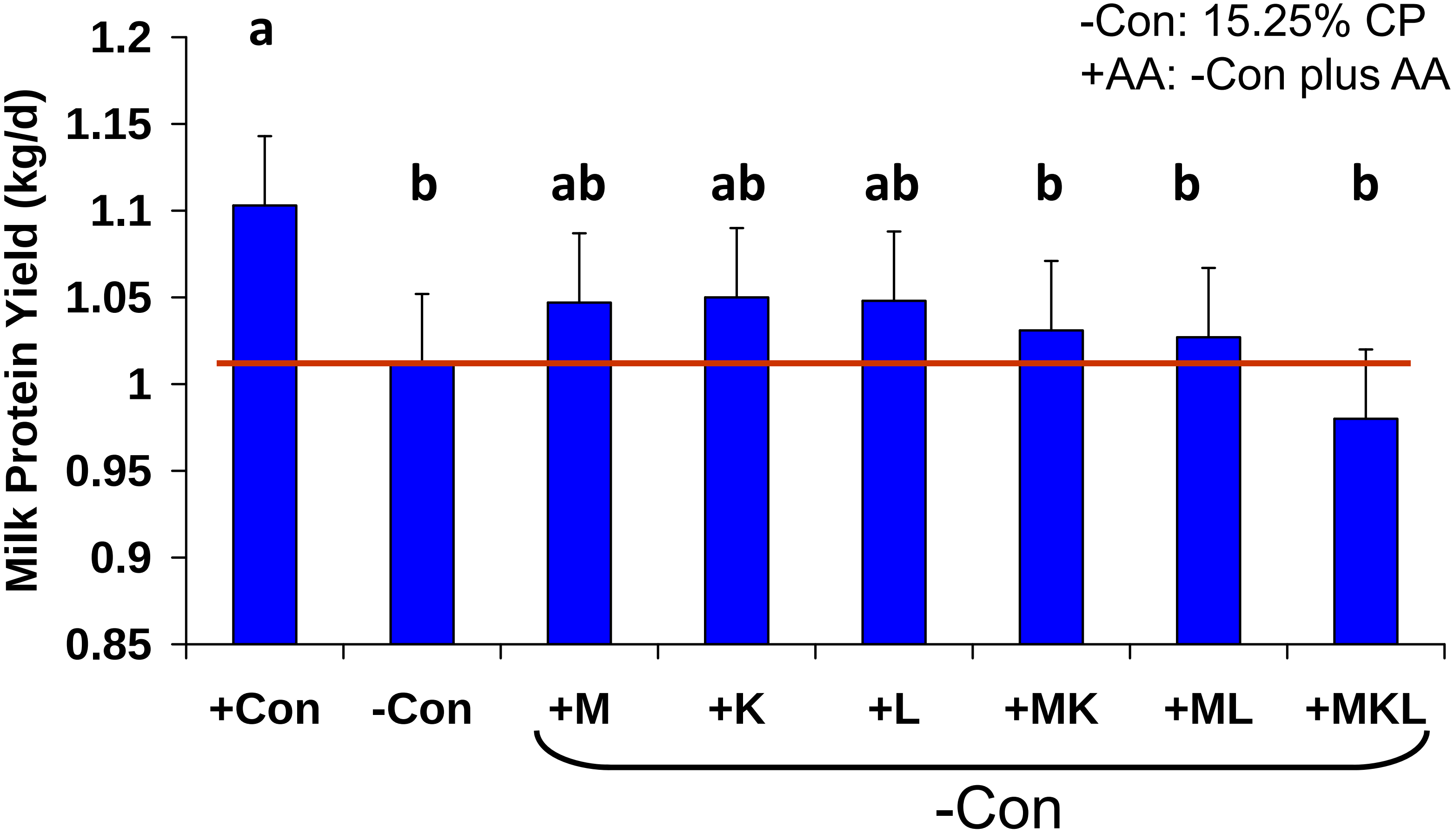
Effects of Methionine + Lysine and Branched-Chain Amino Acids on Milk Protein Yield



Appuhamy et al., 2009

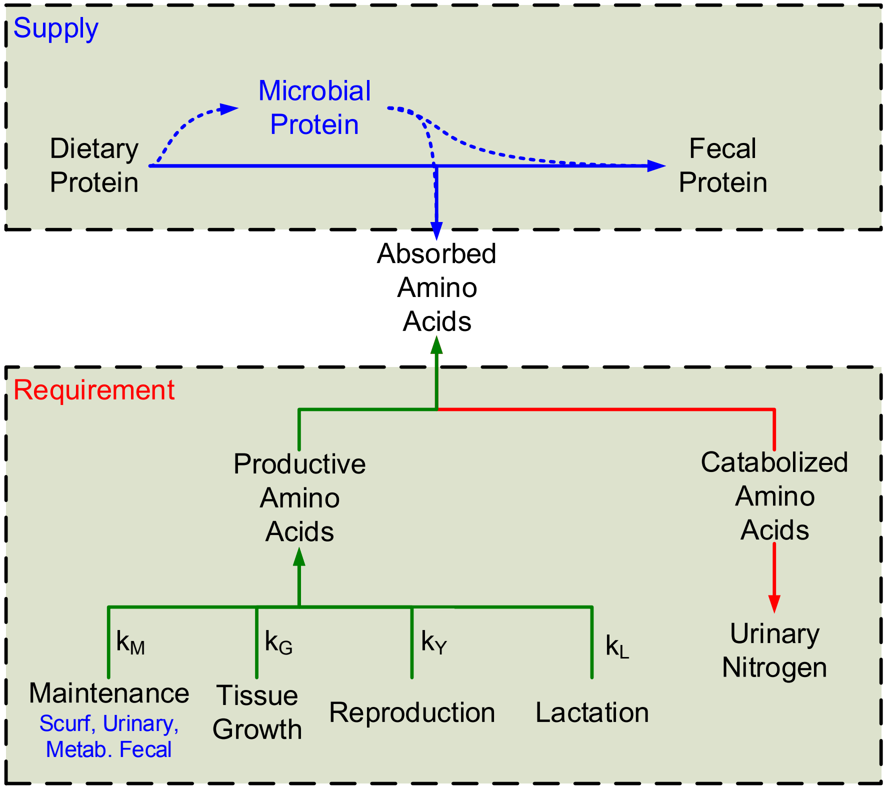
Effects of Protein and Ruminally Protected Met, Lys, and Leu on Milk Protein Yield

+Con: 17% CP
-Con: 15.25% CP
+AA: -Con plus AA



Arriola et al, 2014

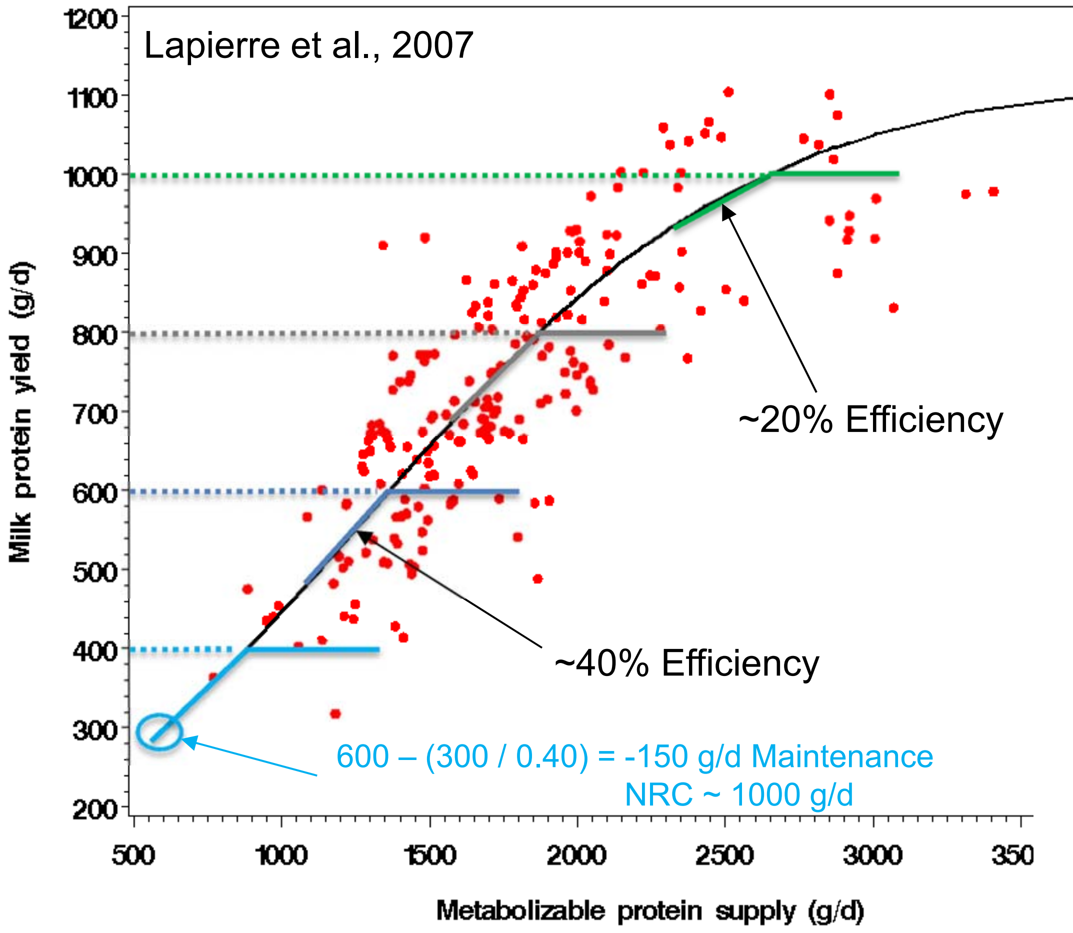
Current Requirement Model Representation



67% **25%** **33%** **67%**

- Variable ruminal output
- Static postabsorptive conversion factors
- Factorial requirements
- Single limiting nutrient

MP Requirements


Lapierre et al., 2007

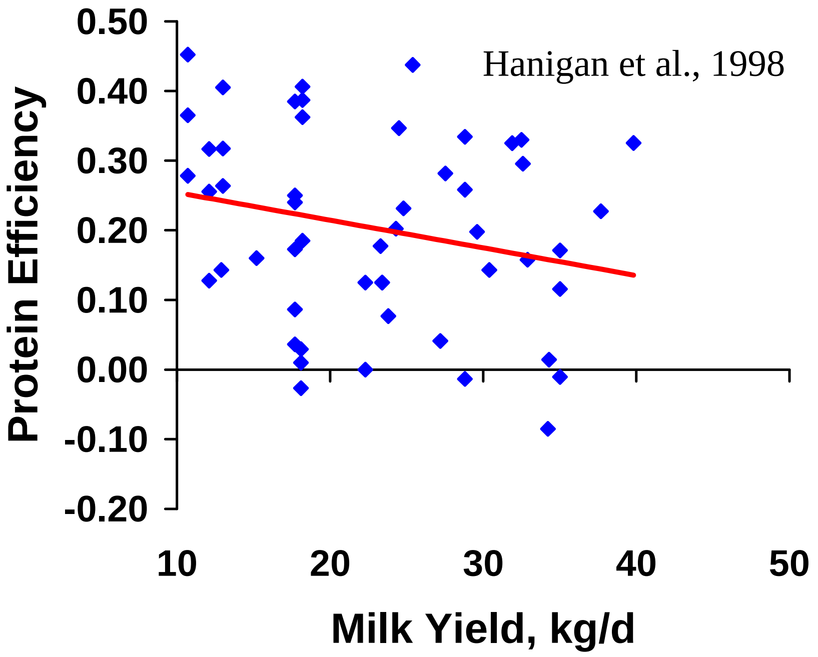
~20% Efficiency

~40% Efficiency

600 – (300 / 0.40) = -150 g/d Maintenance

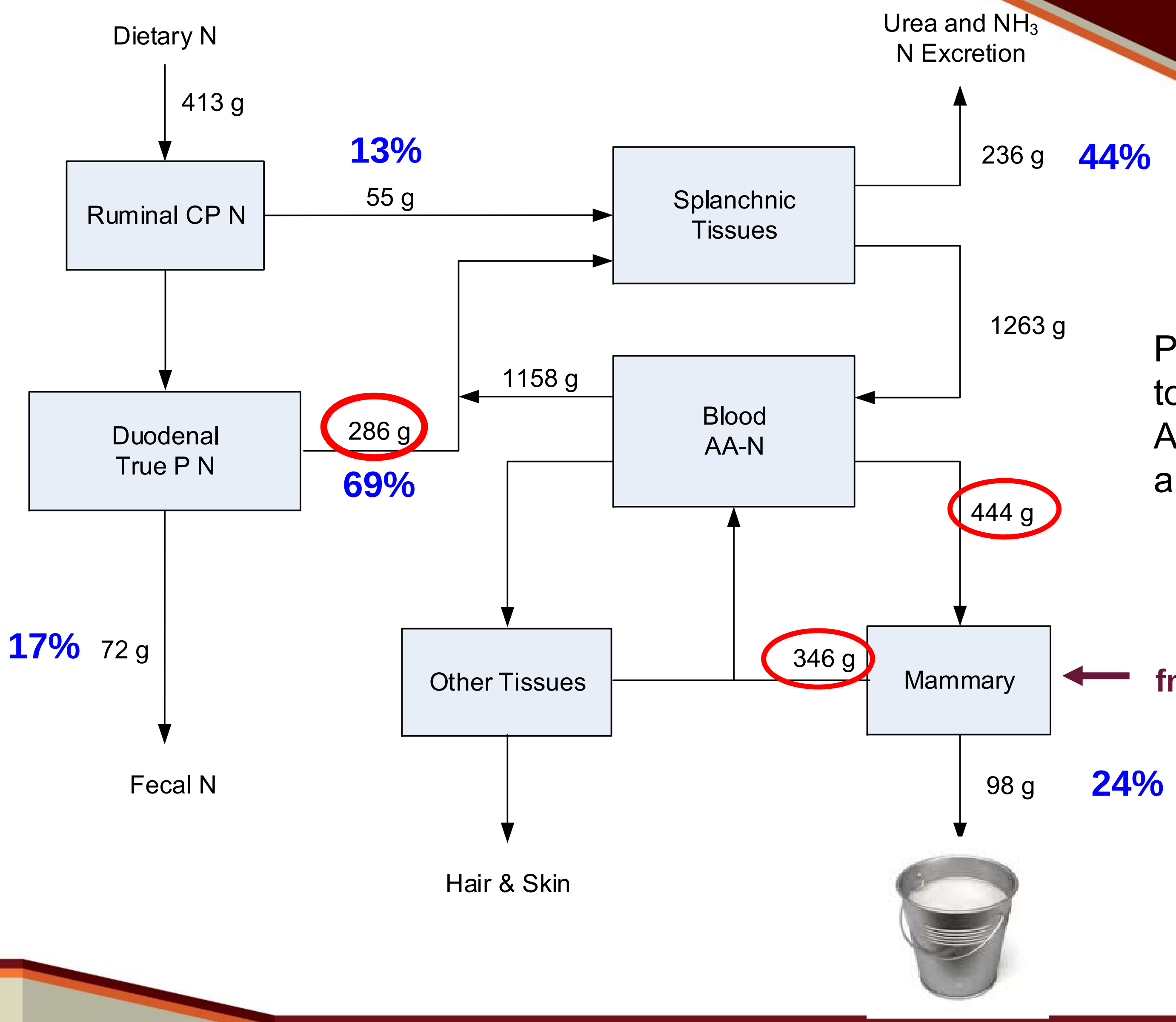
NRC ~ 1000 g/d

Marginal Responses to Infused Casein


Hanigan et al., 1998


KINO LUCERNA
PŘÍŠTÍ PROGRAM
KINO LUCERNA
DNEŠNÍ PROGRAM

N Metabolism in Dairy Cows



Dietary N

413 g

Ruminal CP N

13%

55 g

Splanchnic Tissues

Urea and NH_3 N Excretion

236 g

44%

1263 g

Duodenal True P N

286 g

69%

1158 g

Blood AA-N

444 g

17%

72 g

Fecal N

Other Tissues

346 g

Mammary

98 g

24%

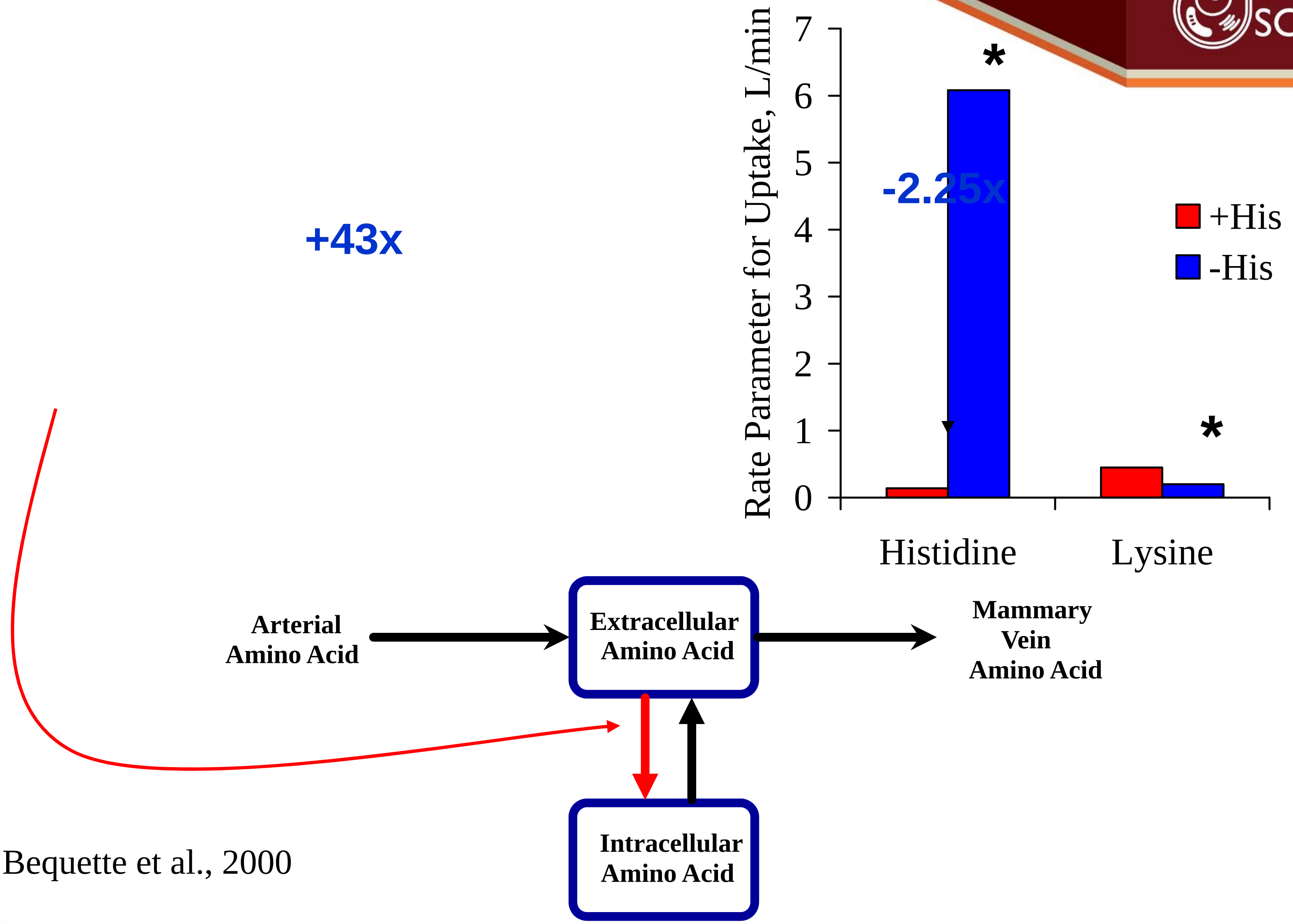
Hair & Skin

fn([Art], Affinity, BF)

Pigs can capture up to 80% of absorbed AA in tissue. Baker et al. (1986)

Arriola et al., 2014. JDS.

Amino Acid Transport Activity



Arterial Amino Acid

Extracellular Amino Acid

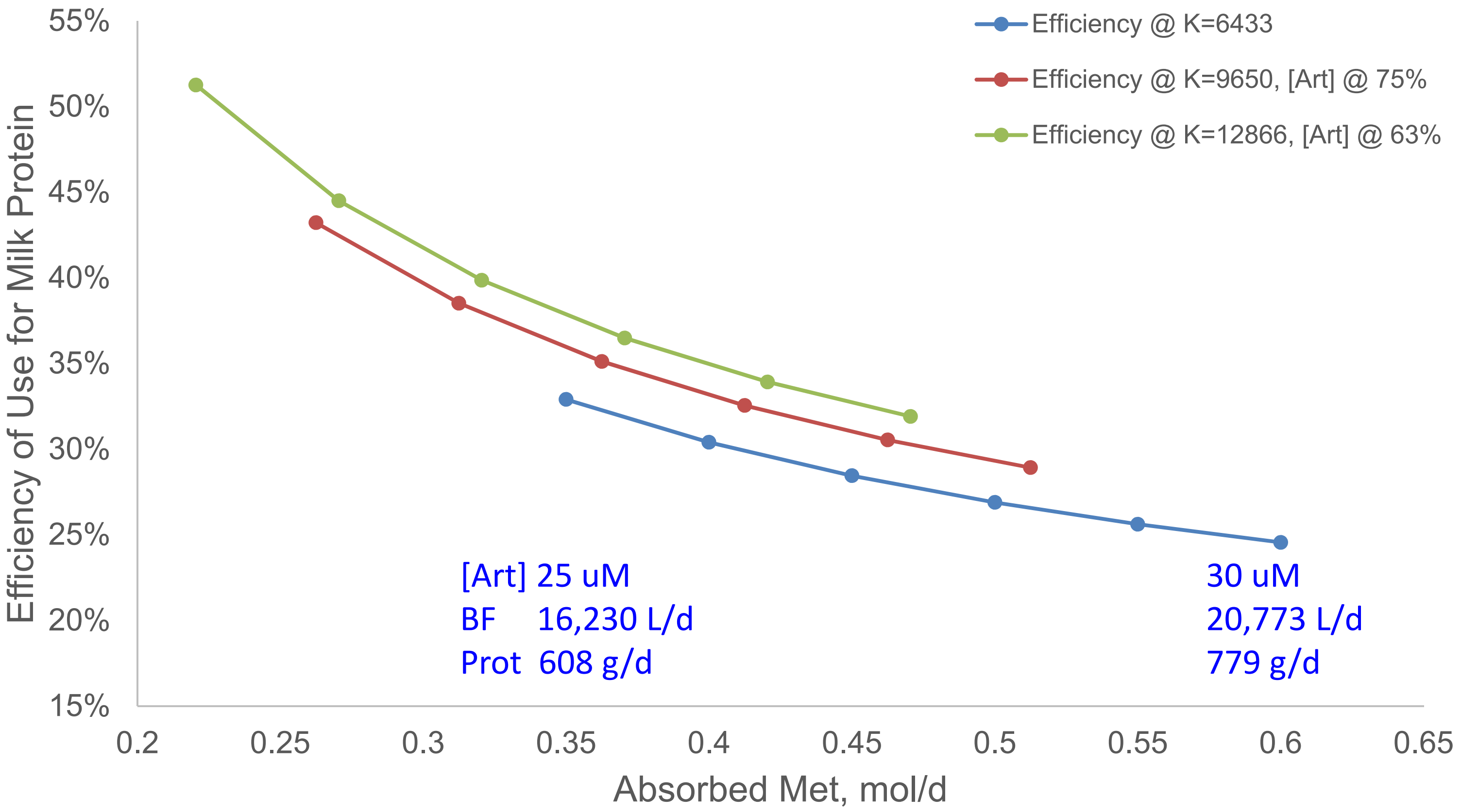
Mammary Vein Amino Acid

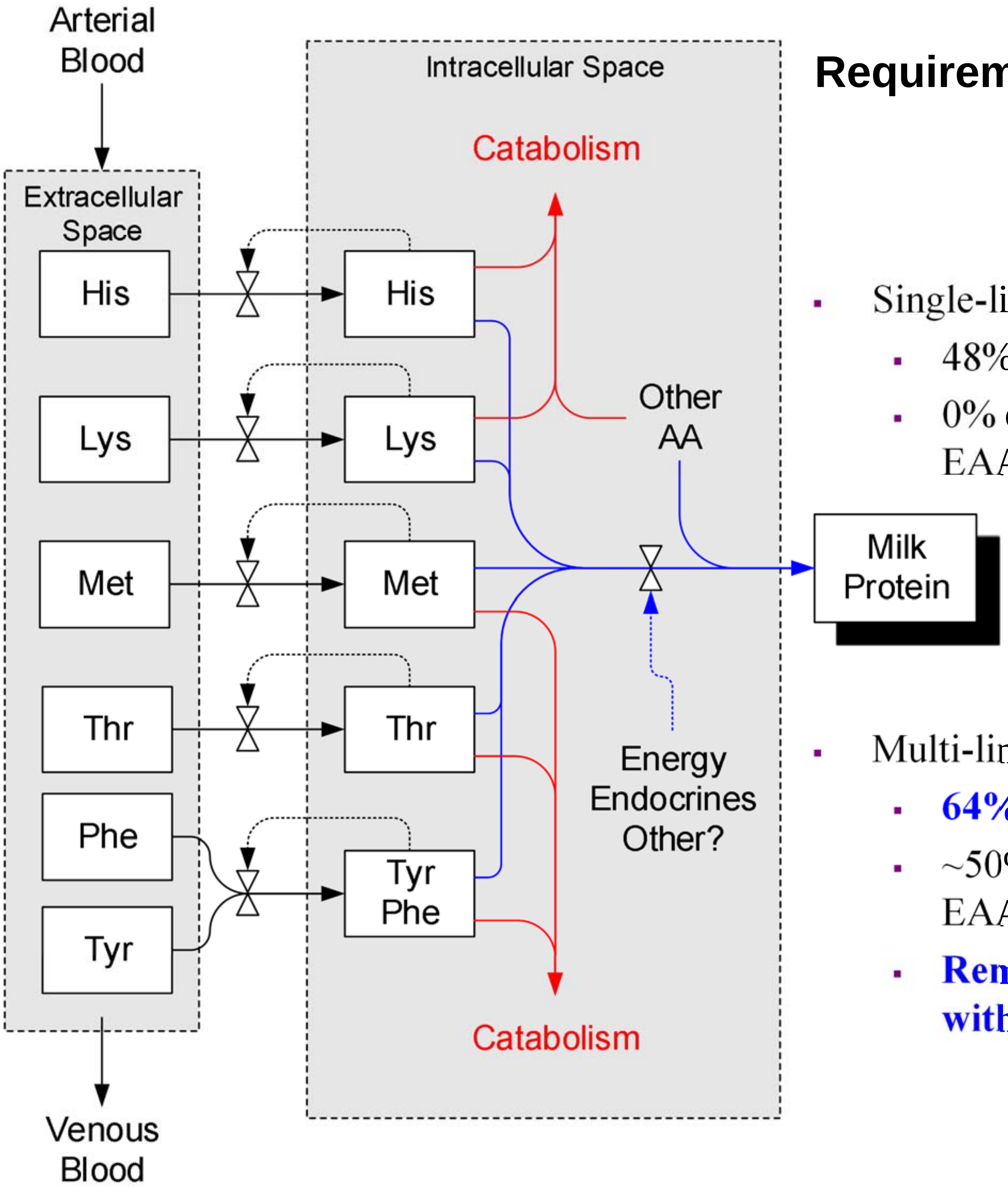
Intracellular Amino Acid

Bequette et al., 2000

Methionine Efficiency Example

Based on Hanigan et al. 1998 model
[Ven] = [Art] * BF / (K_{cl} + BF)
Uptake = BF * [Art – Ven]



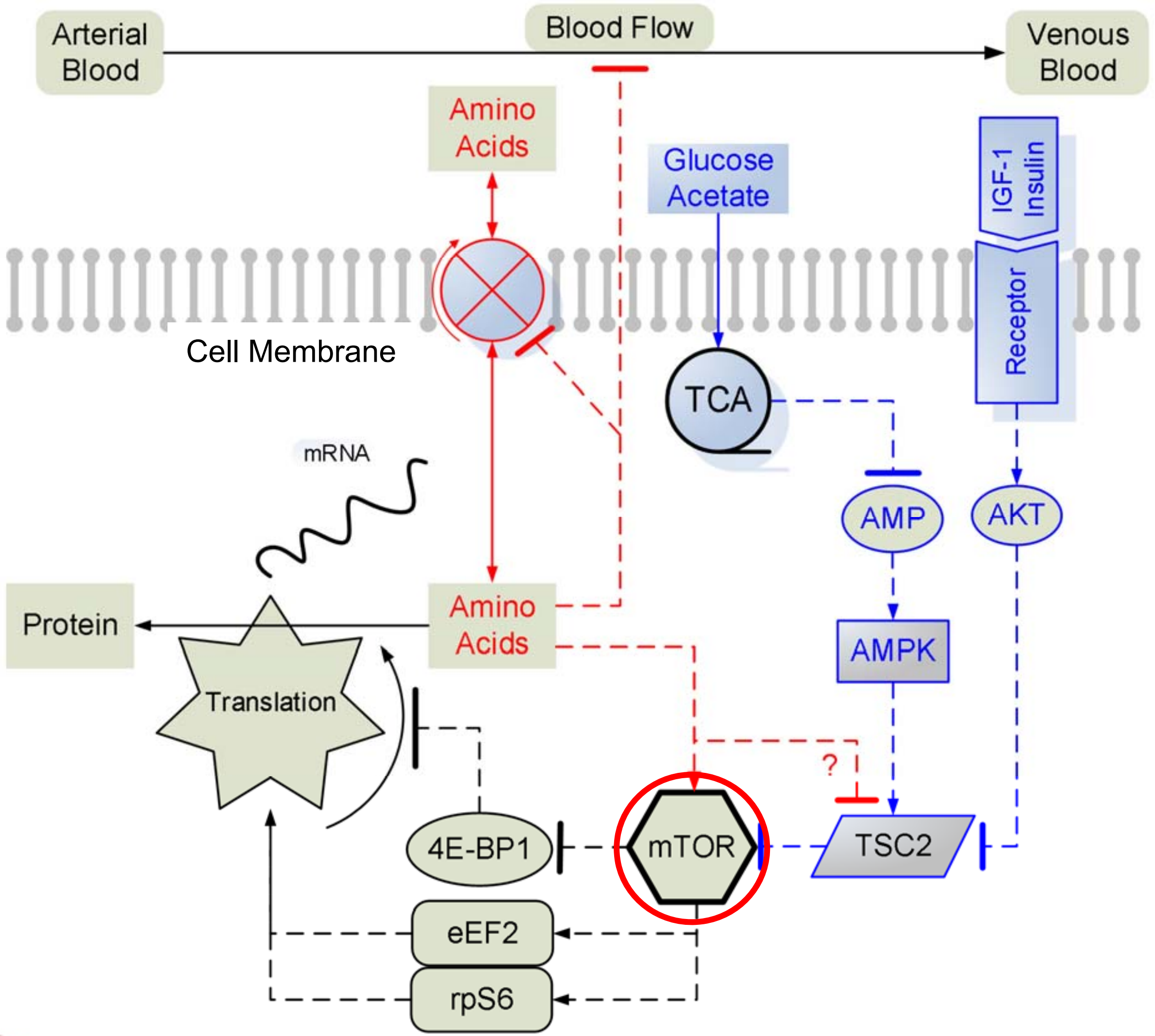


Requirement Accuracy:

- Single-limiting AA
  - 48% of Lit variation
  - 0% of variation when single EAA infused
- Multi-limiting AA
  - **64%** of Lit variation
  - ~50% of variation when single EAA infused
  - **Remaining error correlated with energy supply**

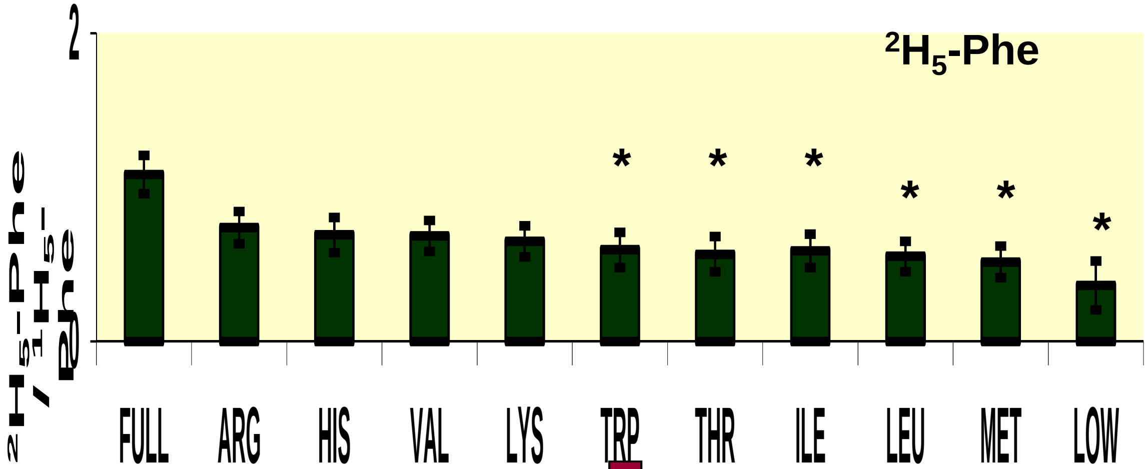
Hanigan et al., 2000

Cell Signaling and mRNA Translation



AA Deficiencies in Mammary Tissue Slices

^{2}H-Phe Incorporation into casein



Deficiencies of multiple AA affect casein synthesis

r=0.80 (*P = 0.002*)

mTOR-P

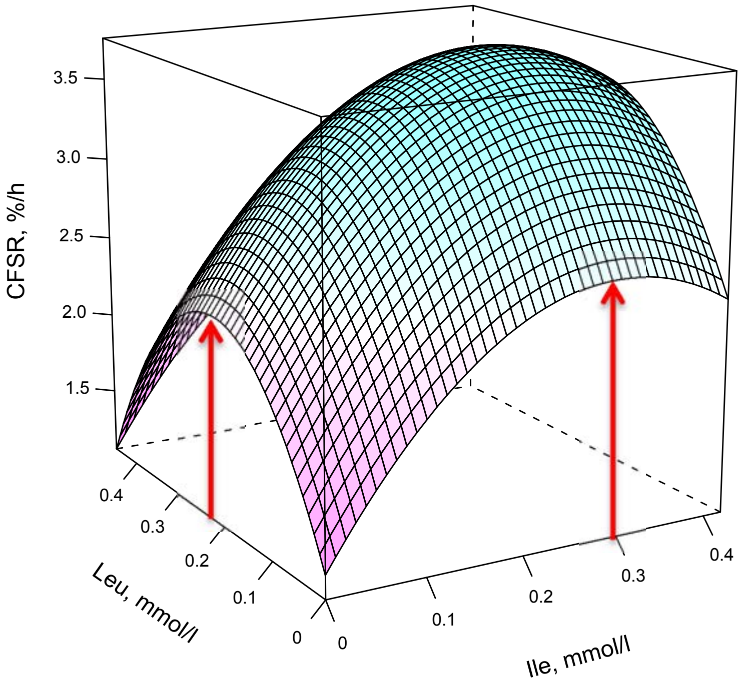
*

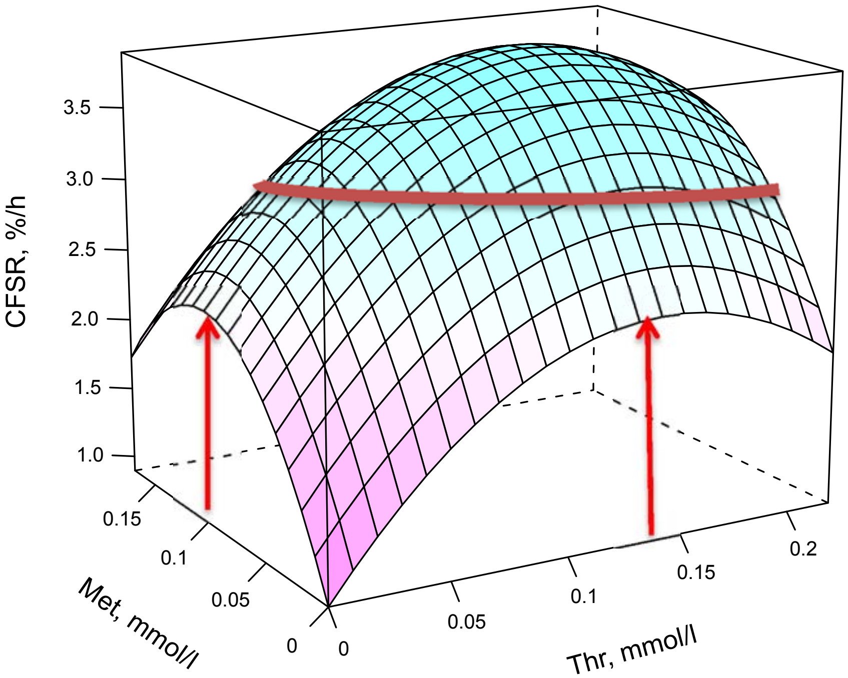
Positive correlation between $^2H_5$-Phe and phospho-mTOR

* Differs (P<0.05) from +EAA

Appuhamy et al., 2009

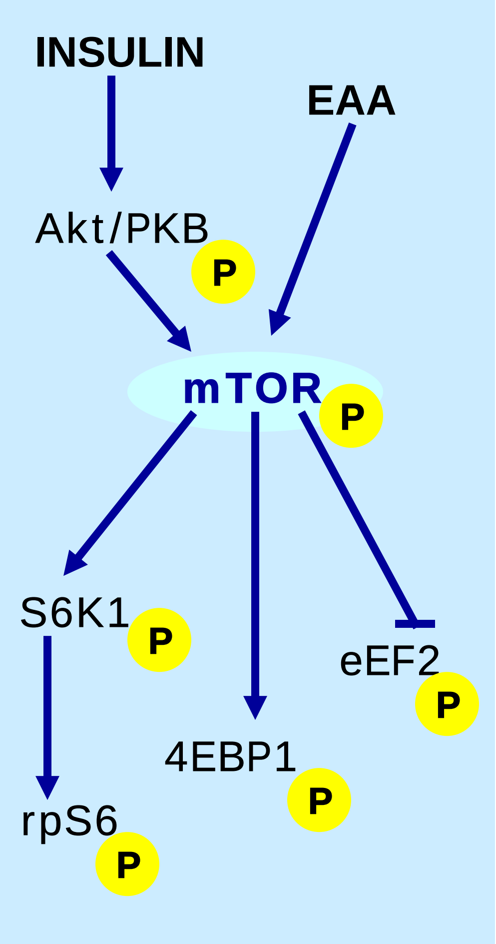
AA Effects on αS1-Casein Synthesis

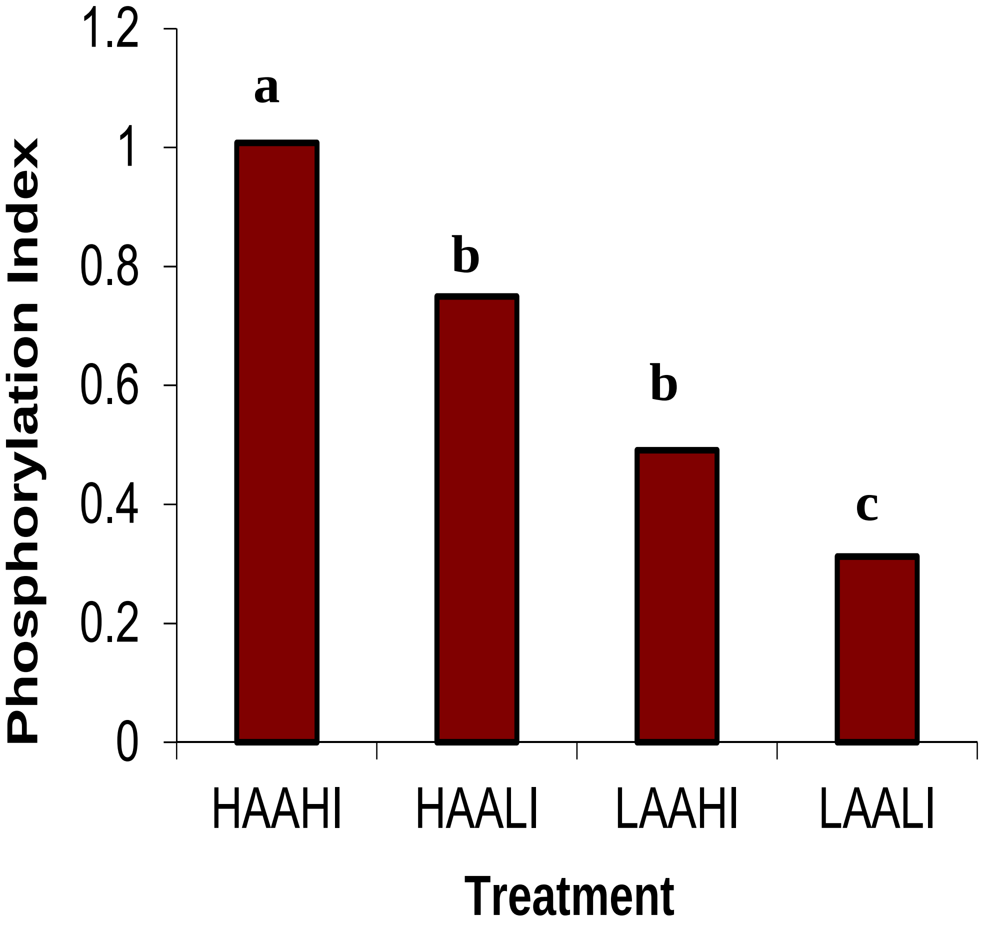




Arriola, 2014

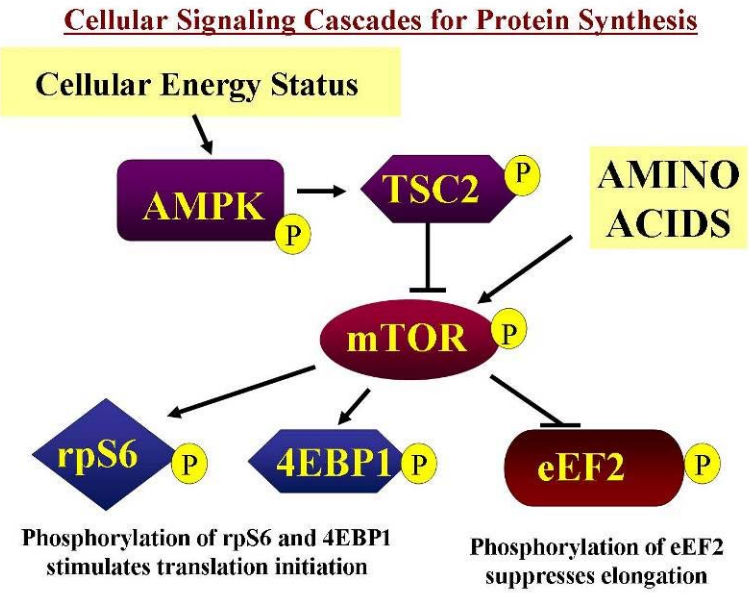
Insulin and EAA on mTOR in Mammary Cells

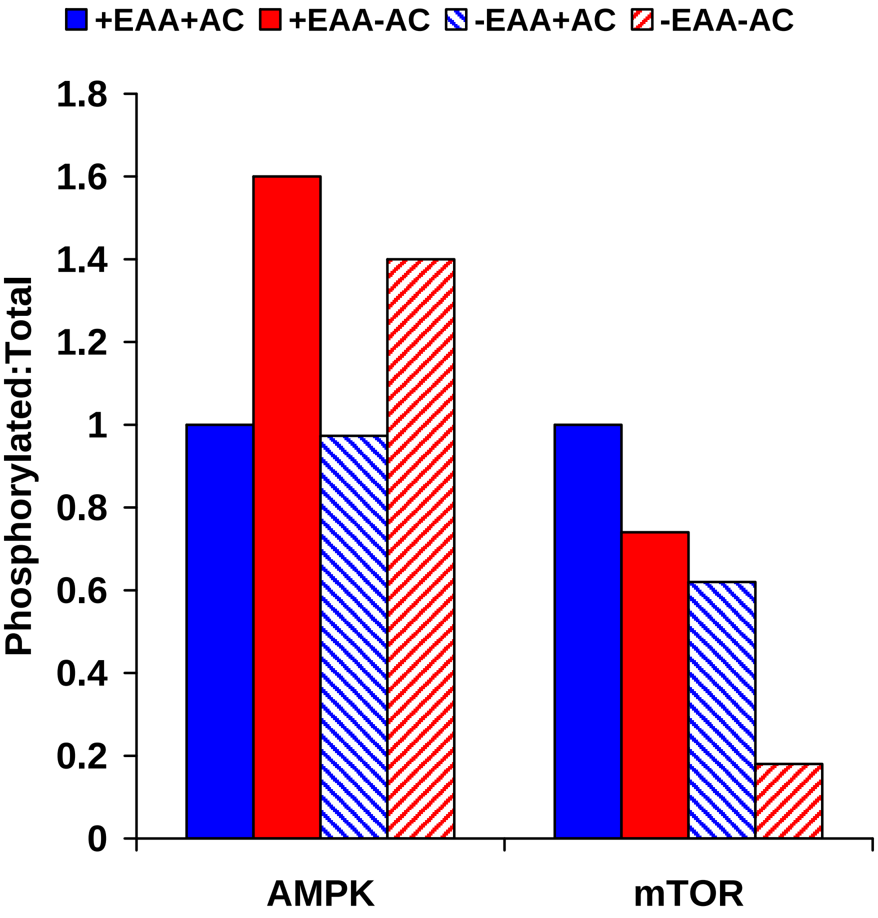




Appuhamy et al., 2011

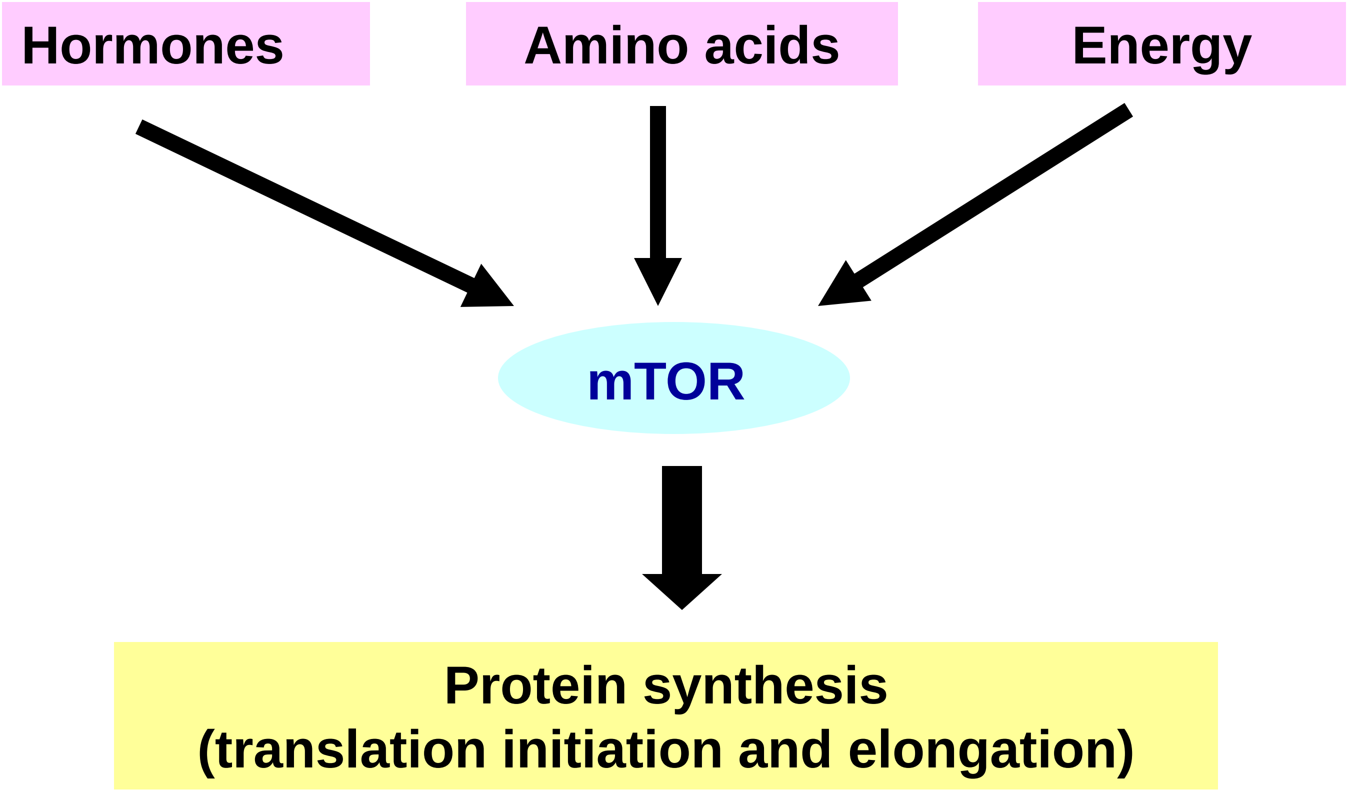
Acetate and EAA on Mammary Cell Signaling





Appuhamy et al., 2009

Protein Synthesis Regulation



Hormones

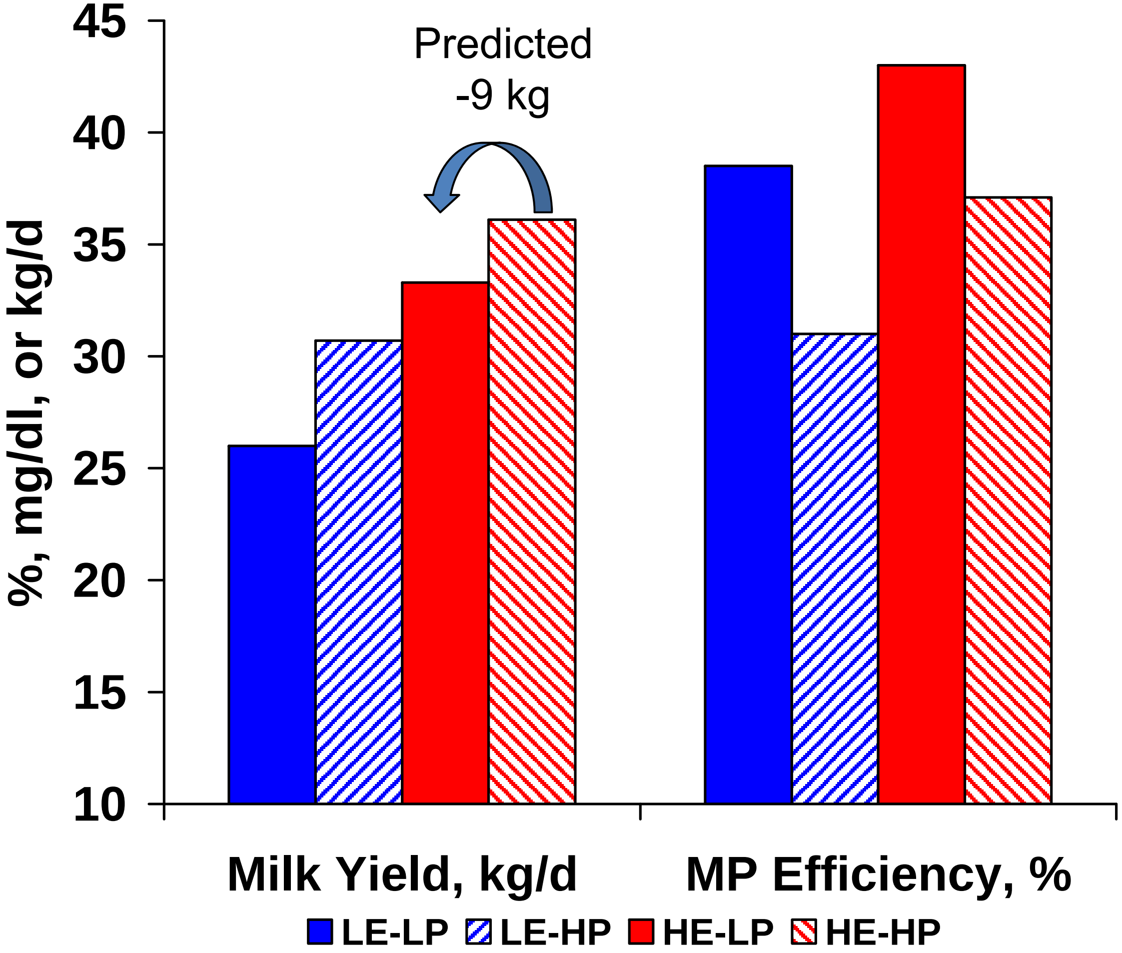
Amino acids

Energy

mTOR

Protein synthesis
(translation initiation and elongation)

Effects of Energy and MP Supply on Production and Nitrogen Efficiency



Milk

Protein *P*<.08
Energy *P*<.01
E x P *P*=.64

Efficiency

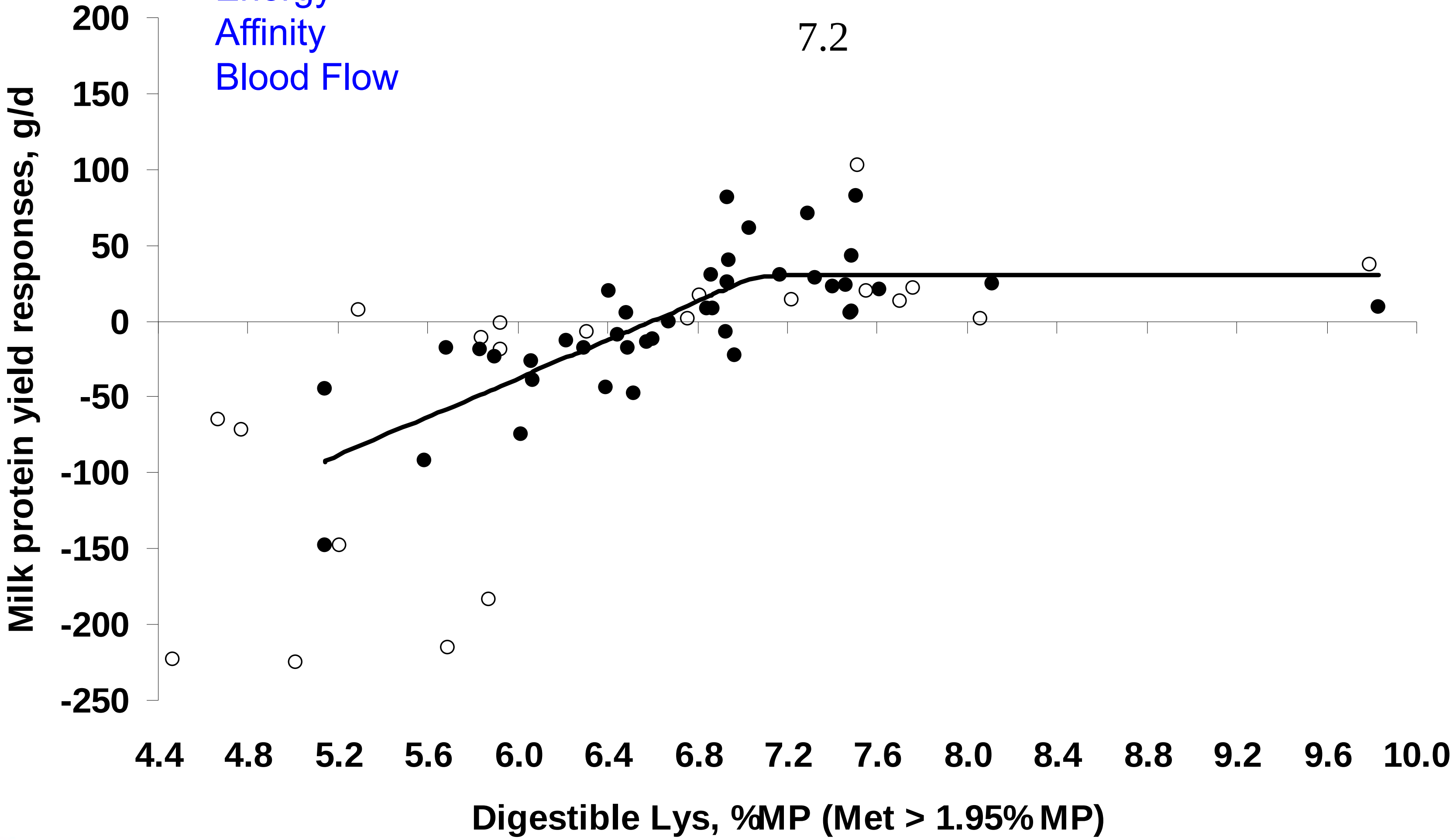
Energy *P*<.001
Protein *P*<.001
E x P *P*=.53

HEHP = 1.54 MCal/kg, 11.8% MP
HELP = 1.54 MCal/kg, 9.5% MP
LEHP = 1.45 MCal/kg, 11.8% MP
LELP = 1.45 MCal/kg, 9.5% MP

Rius et al., 2010, JDS

Milk Protein Responses to Digestible Lysine

Individual AA
Hormones
Energy
Affinity
Blood Flow

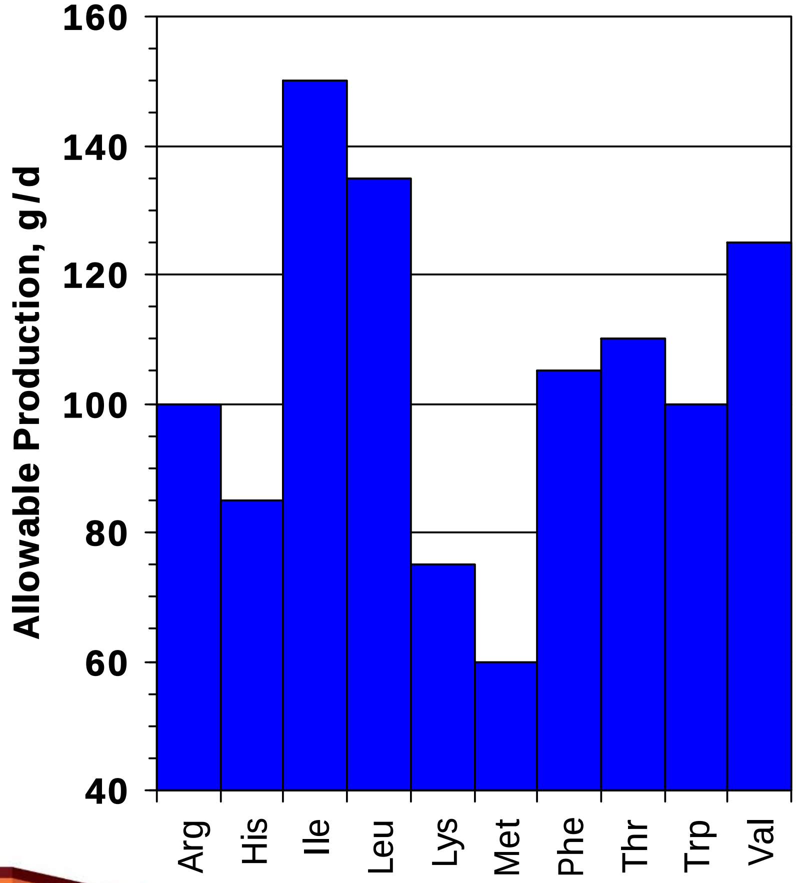


NRC, 2001

AA Metabolism Knowledge

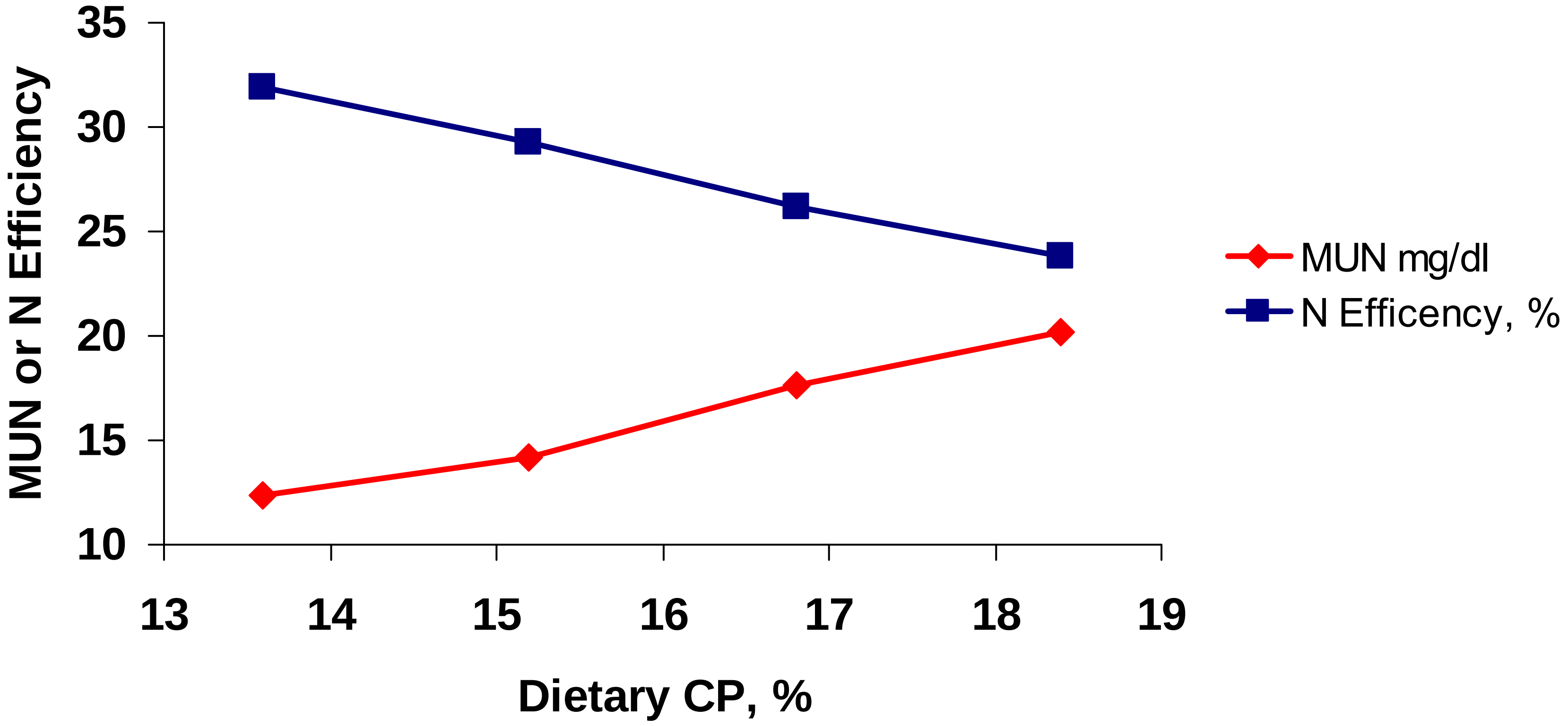
Single Limiting Nutrient Theory

Water Barrel Analogy



- Lowest Stave determines the water level in the barrel
- **Sprengel, 1828**
  - A soil nutrient can limit plant growth
  - When limiting, growth will be proportional to supply
- **von Liebeg, 1862**
  - If a nutrient is limiting, then growth can't respond to another nutrient
  - "Law of the Minimum"
- **Mitchell and Block, 1946**
  - Order of limitation
  - Barrel with staves

Effects of Dietary Protein (RDP) on MUN and N Efficiency



Cyriac et al., 2006

Monitor MUN to Achieve Optimum Return

1. Establish a baseline for your herd
   - Some genetic variation
   - Dietary salt also affects
   - Balance ration to NRC 2001 or equivalent
   - Feed ration for 2 weeks and Measure MUN (~11 mg/dl)

2. Systematically reduce RUP (0.25% units at a time)
   - For example, CP from 16.5% to 16.25% via RUP
   - Keep RDP and energy constant
   - Feed for 3 weeks; Monitor MUN and milk yield
   - MUN should ↓ by ~0.5 mg/dl
   - Any milk loss will be half of NRC predicted loss
   - Calculate Income/Feed Cost (IOFC)
   - If greater, retain reduction and lower another 0.25%

3. Reduce RDP by 0.5% of Diet DM while holding RUP constant
   - Same approach as for RUP

4. MUN at maximal IOFC is target for the herd

Bottom Line at the Animal Level

System responses

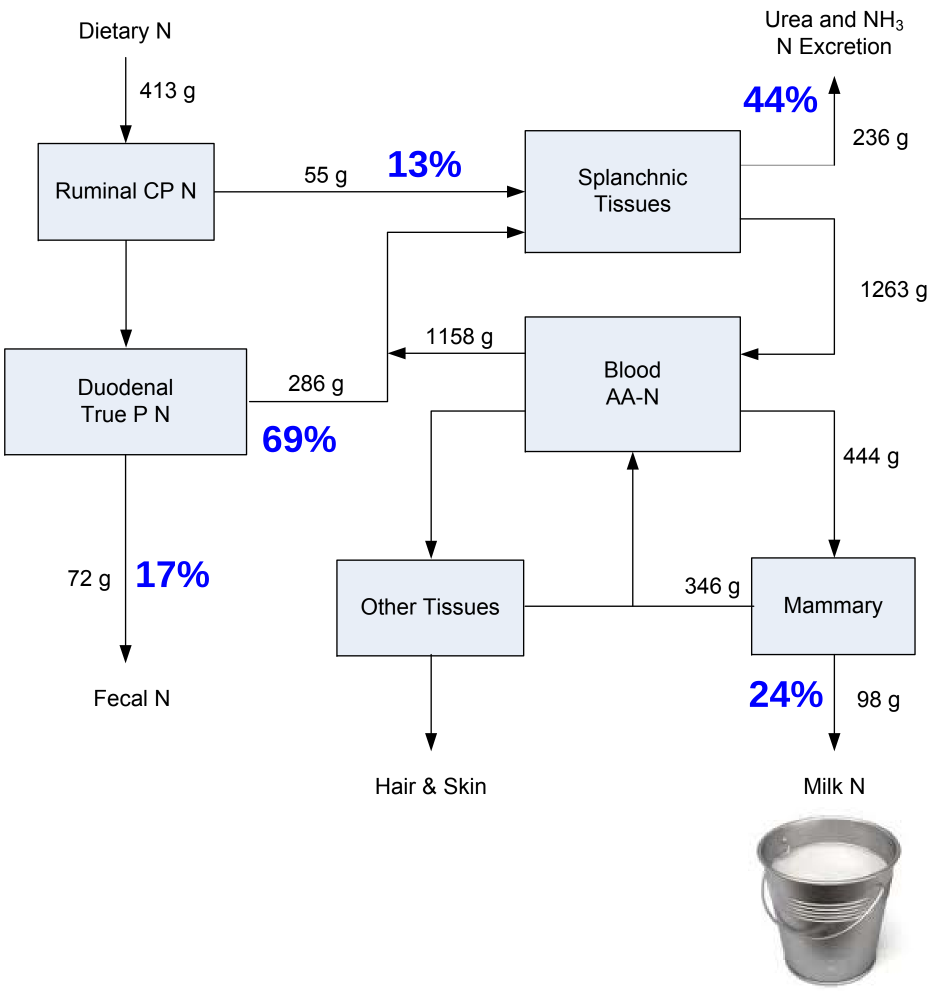
- Large excess of AA
- Complex, satureable response surface
- Variable EAA efficiencies
- “Cost” of doing business

“Single” limiting nutrient

- mTOR Phos is saturated???
  - ↑ EAA ⇒ ~ milk
  - ↓ EAA ⇒ ↓ milk
- mTOR Phos is not saturated???
  - ↑ EAA ⇒ ↑ milk
  - ↓ EAA ⇒ ↓ milk
  - No single limiter ⇒ no single responder
- Law of the Minimum …… eventually

Feed High Energy, Low Protein diets

- Best AA mix depends on cost



What We Have Learned About Circadian Rhythms of Dairy Cows?

Dr. Kevin J. Harvatine
Associate Professor of Nutritional Physiology
Department of Animal Science
Penn State University

2015 Penn State Nutrition Workshop

Collaborator:
Dr. Paul Bartell

PennState
College of Agricultural Sciences

Circadian Rhythms in the Dairy Cow

- Are 24 hour repeating cycles

- Many biological functions follow a 24 cycle

- Activity and Alertness
- Nutrient Metabolism
- **Milk Synthesis**
- **Intake**

Why??

Allows the animal to anticipate changes and adapt before they occur

Key Principles

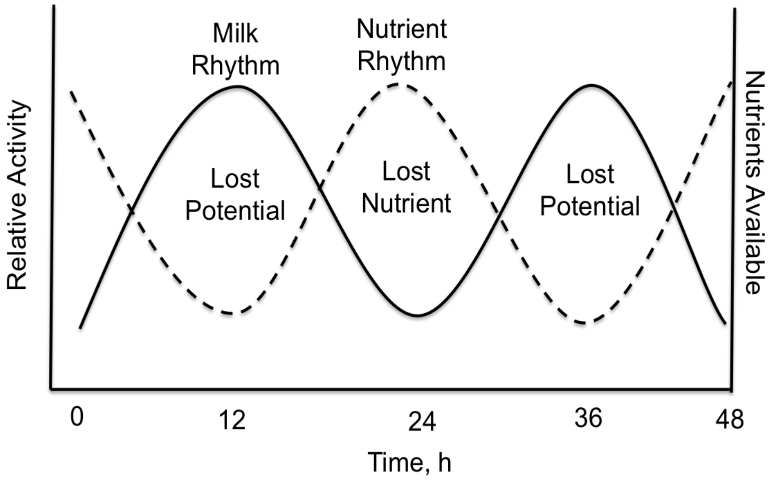
There is a daily (circadian) pattern of intake that has a major impact on the rumen

There is a daily pattern to milk synthesis

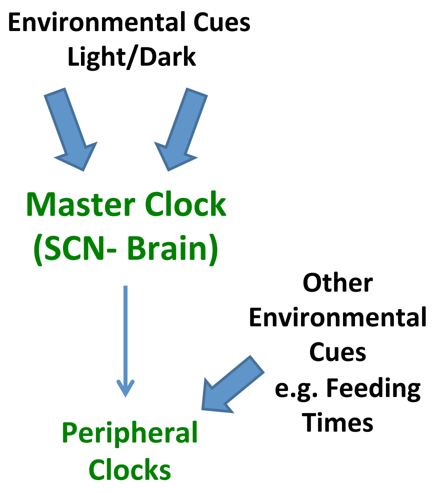
Maximizing efficiency requires synchronizing nutrient absorption and mammary needs

Considering daily patterns provide additional avenues to optimize milk production

Are the Daily Patterns of Nutrient Absorption and Milk Synthesis Synchronized?



How Does the Cow Know What Time of Day it is?


Environmental Cues
Light/Dark

Master Clock
(SCN- Brain)

Other
Environmental
Cues
e.g. Feeding
Times

Peripheral
Clocks

- **Main environmental cues:**
  - Light/Dark
  - Feeding Times
  - Milking Time?
- **A disconnect between environmental cues can cause metabolic issues in humans and rodents**

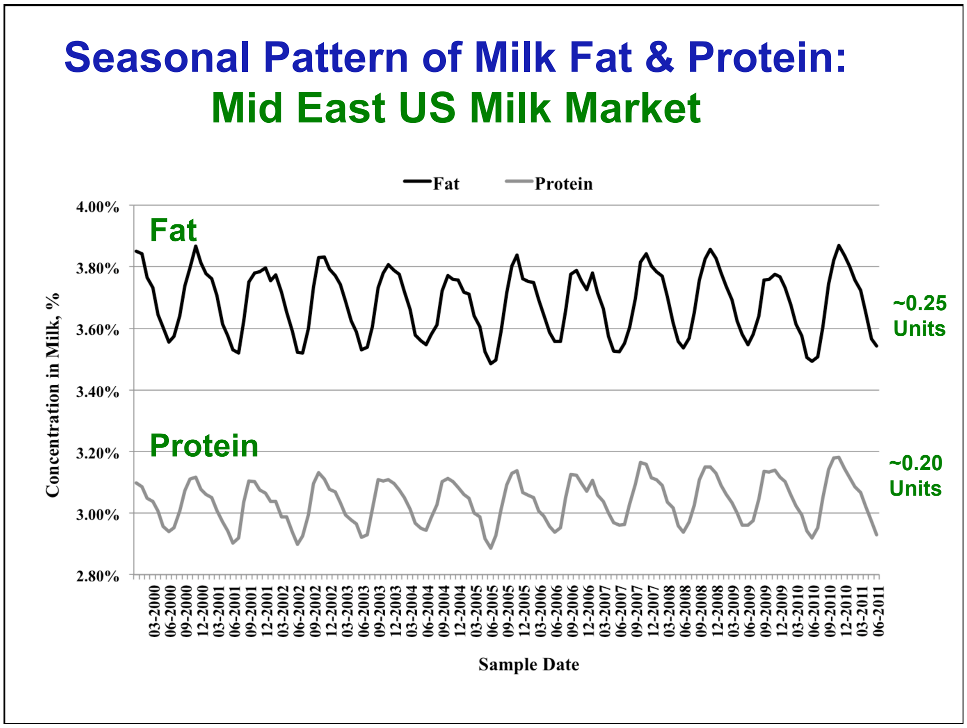
- This occurs in restricting feed to the day in nocturnal animals and night shift work in humans

Asher, Schibler 2011

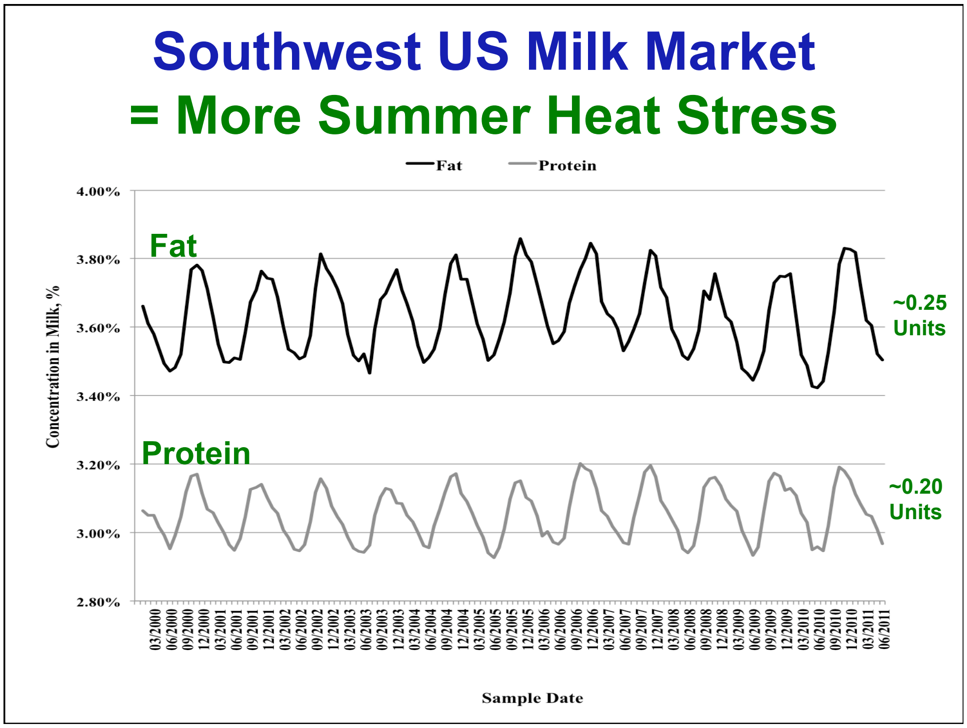
Seasonal Rhythms are also Common in Biology

- **Patterns that repeat every year**
- **Mostly driven by day length and/or changes in day length**
- **Regulated through the same molecular system as circadian rhythms**

Some Amazing Examples in Biology



Seasonal Pattern of Milk Fat & Protein: Mid East US Milk Market



Southwest US Milk Market = More Summer Heat Stress

Day Length = Photoperiod

- Milk, milk protein, and milk fat yield are increased by long days

- Milk yield is maximized by short days during the dry period

- The effect of long days is eliminated by constant light which disrupts the circadian rhythm

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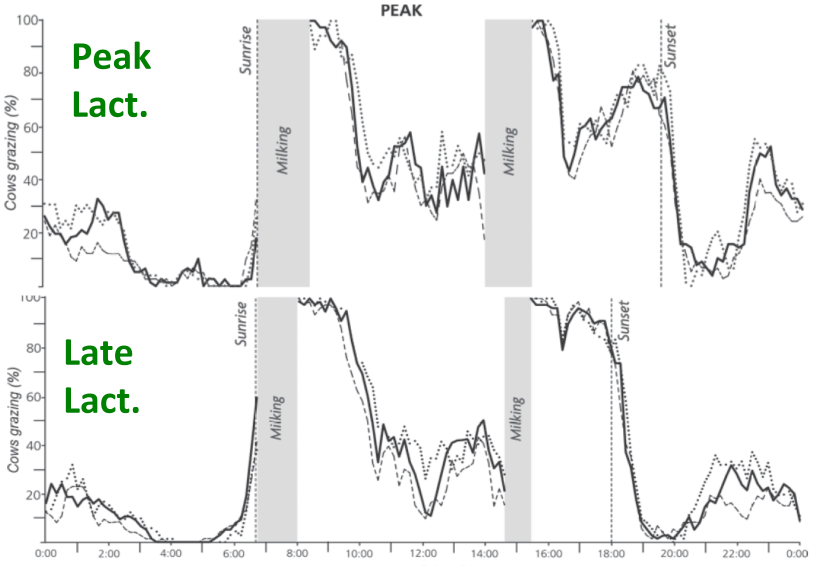
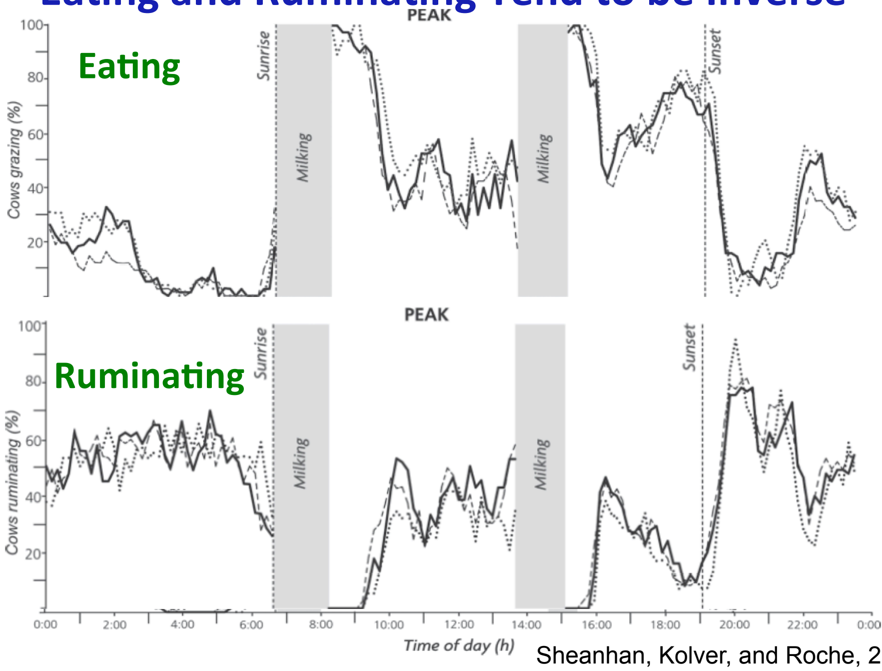
Is there a Circadian Pattern of Intake?

Pasture Fed Cows



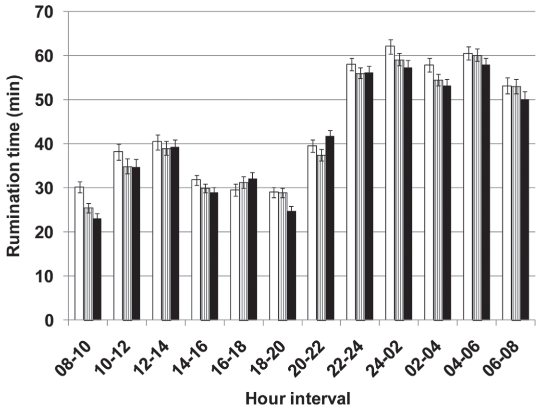
Sheanhan, Kolver, and Roche, 2011

Eating and Ruminating Tend to be Inverse



Sheanhan, Kolver, and Roche, 2011

Rumination Pattern



Low, Medium, and high Temperature-Humidity Index

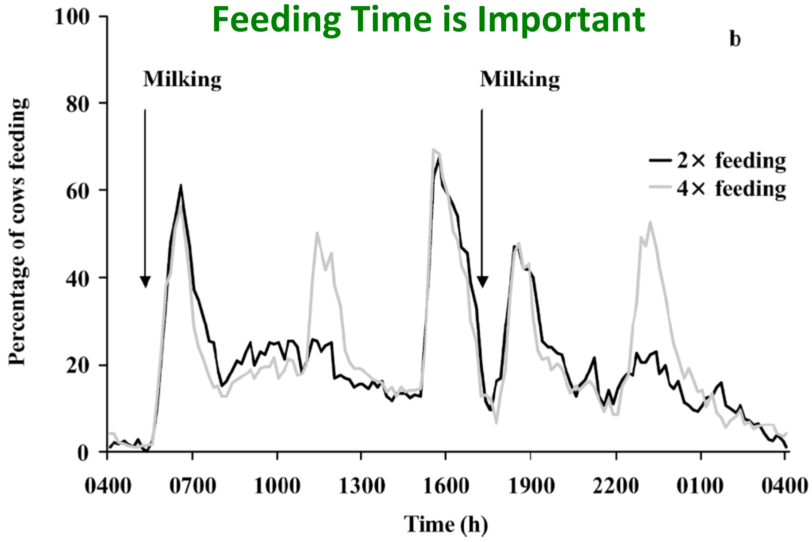
Daily pattern of rumination time expressed in minutes per 2 h in 3 levels of daily maximum temperature-humidity index (THI).
White bars = THI <80; bars with vertical lines = THI from 80 to 85; black bars = THI >85.

Soriani et al. JDS 2014

TMR Fed Cows

Feeding and Milking commonly both near Dawn & Dusk

Feeding Time is Important

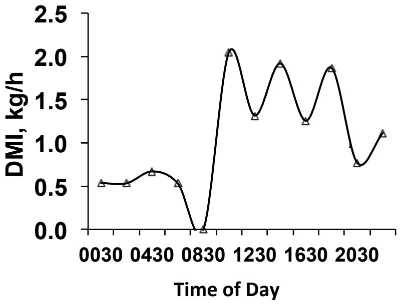


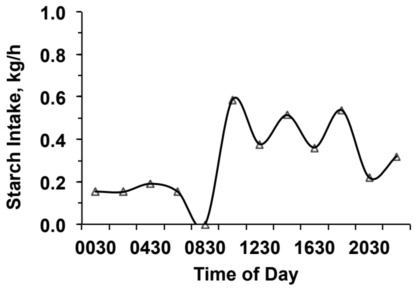
DeVries et al. 2005

PSU Feeding Behavior System

MooMonitor+
Dairymaster
(Image Dairymaster.ie)

Rate of Feed Intake is Variable over the Day





Ying et al. 2015

What is the Impact of the Daily Pattern of Intake

Intake =

Entrance of fermentable organic matter into the rumen

Fermentable organic matter =

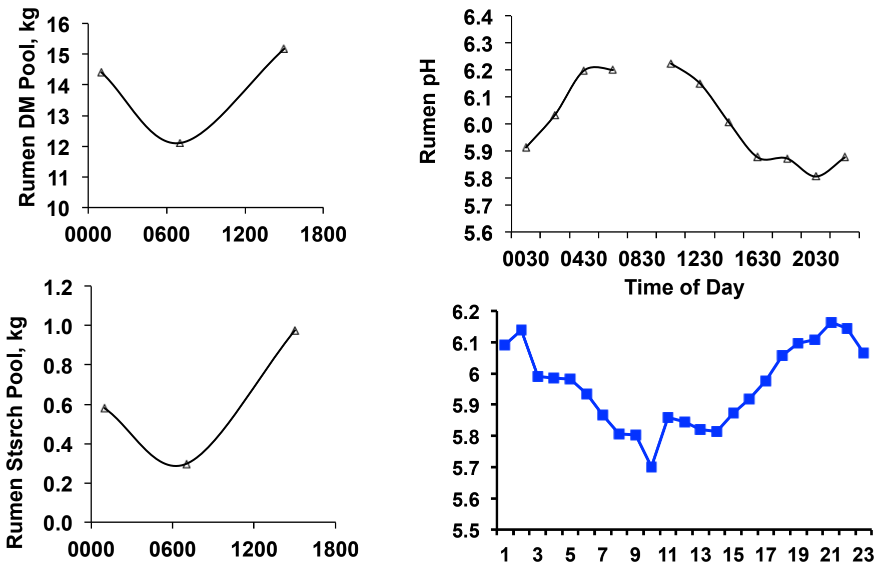
Synthesis of VFA’s & microbial protein

VFA’s =

Acid Load

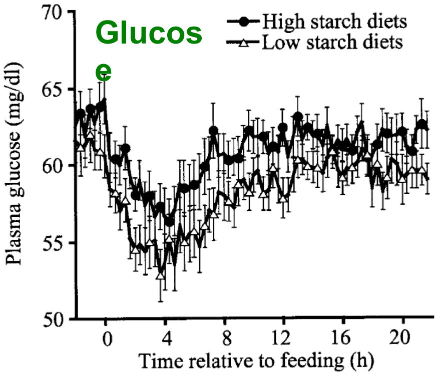
Nutrient supply for cow

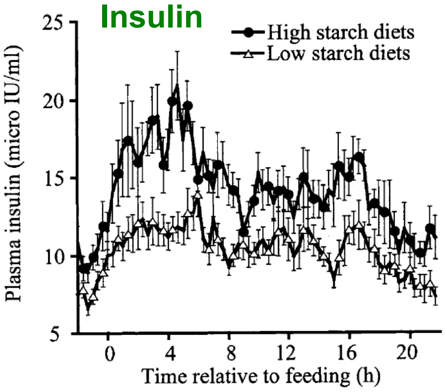
Rumen Pool Size Changes Relative to Feeding



Ying et al. 2015

Intake Creates a Circadian Pattern of Plasma Metabolites and Hormones





Oba and Allen, 2003

How Flexible is the Daily Pattern of Feed Intake?

- Feeding stimulates intake, but what is the impact of feeding time

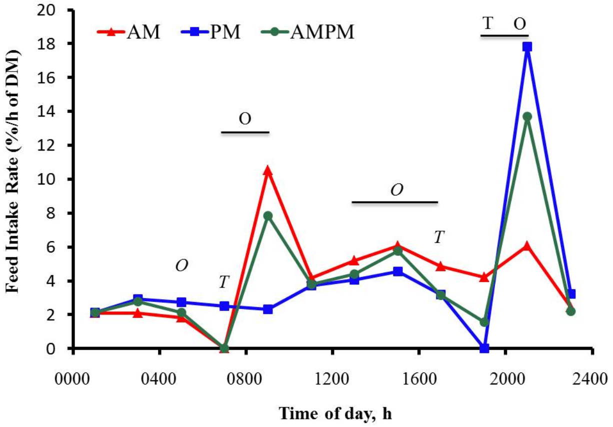
- **Tested the effect of feeding a TMR:**
  - 1x/d at 0830 h (AM)
  - 1x/d at 2030h (PM)
  - 2x/d at 0830 and 2030 h (AMPM)

Daily DMI, Milk Production, and Composition

	Treatment LS-Means				*P*-value		
						-----Contrasts-----	
Item	AM	PM	AMPM	SE	Trt	AM vs. PM	AM vs. AMPM
Yield, kg/d							
Milk	50.0	50.5	50.8	2.6	0.69	0.59	0.40
Milk fat	1.72	1.72	1.75	0.04	0.84	0.99	0.62
Milk protein	1.48	1.49	1.50	0.06	0.77	0.78	0.48
Milk composition, %							
Fat	3.51	3.49	3.48	0.15	0.90	0.83	0.66
Protein	2.97	2.95	2.96	0.07	0.80	0.52	0.69
DMI, kg/d	32.6	31.4	31.9	0.9	0.40	0.18	0.44
Feed Efficiency	1.54	1.58	1.57	0.05	0.43	0.21	0.37

❖ **Also no difference in milk FA profile**

Circadian Pattern of Feed Intake at 2-h Intervals



- ANOVA

Effect	*P*-value
Treatment	0.78
Time	<0.01
Treatment x Time	<0.01

- Circadian Parameters

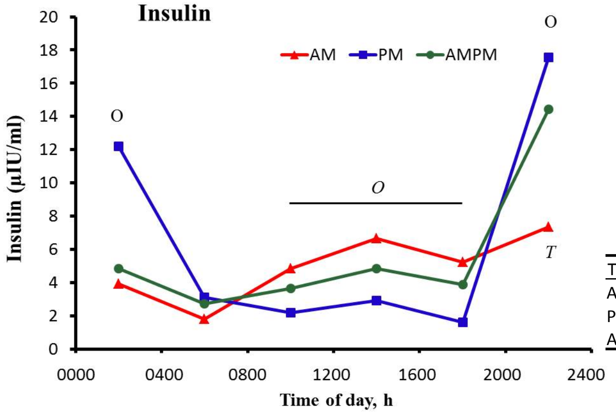
Treatment	Phase/h	Amplitude	*P*-value
AM	1654	2.0	<0.01
PM	1638*	0.6*	<0.01
AMPM	1448*	1.1*	<0.01

*Significantly ($P < 0.05$) different from AM

❖AM vs.PM (^{O} = $P < 0.01$, and ^{O} = $P < 0.05$); AM vs. AMPM (^{T} $P < 0.01$, and ^{T} $P < 0.05$)

- Conditional meals were larger at the evening feeding
- Modestly higher intake rate in the early afternoon for **AM**

Circadian Rhythm of Plasma Insulin



- ANOVA

Effect	*P*-value
Treatment	0.76
Time	<0.01
Treatment x Time	<0.01

- Circadian Parameters

Treatment	Phase/h	Amplitude	*P*-value
AM	1844	1.8	0.07
PM	0031*	8.3*	<0.01
AMPM	2220*	4.8*	<0.01

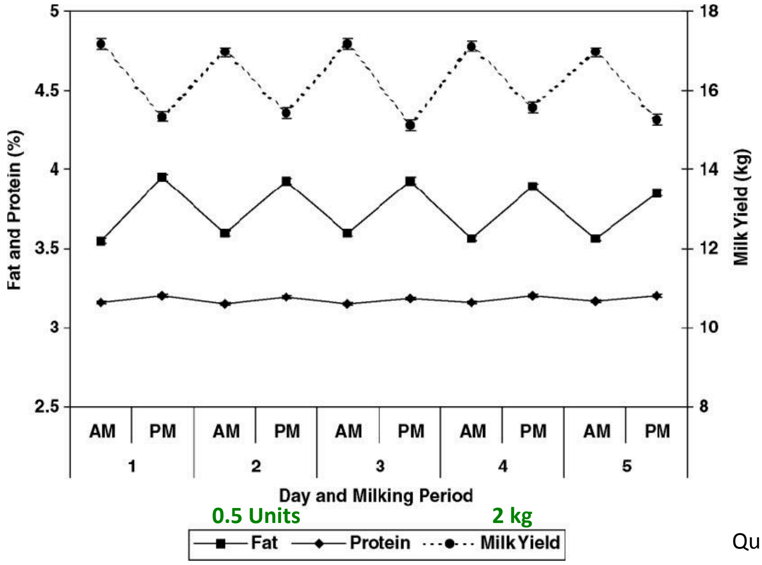
*Significantly ($P < 0.05$) different from AM

❖AM vs.PM (^{O} = $P < 0.01$, and ^{O} = $P < 0.05$); AM vs. AMPM (^{T} $P < 0.01$, and ^{T} $P < 0.05$)

- Fresh feed delivery at night resulted in greater insulin secretion
- Morning feeding moderately increased insulin in the early afternoon

Milk Synthesis is Variable over the Day

Within-Day Variation: 2x Milked Herds



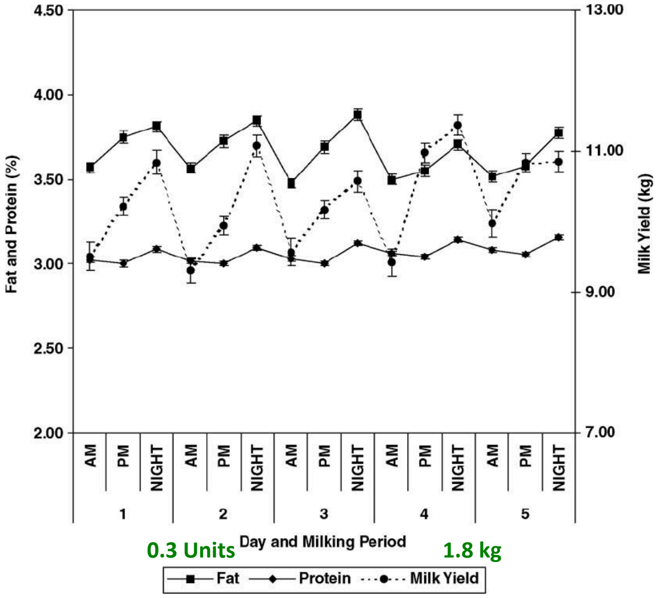
0.5 Units

2 kg

Quist et al. 2008

Milk Yield is Variable over the Day

Within-Day Variation: 3x Milked Herds

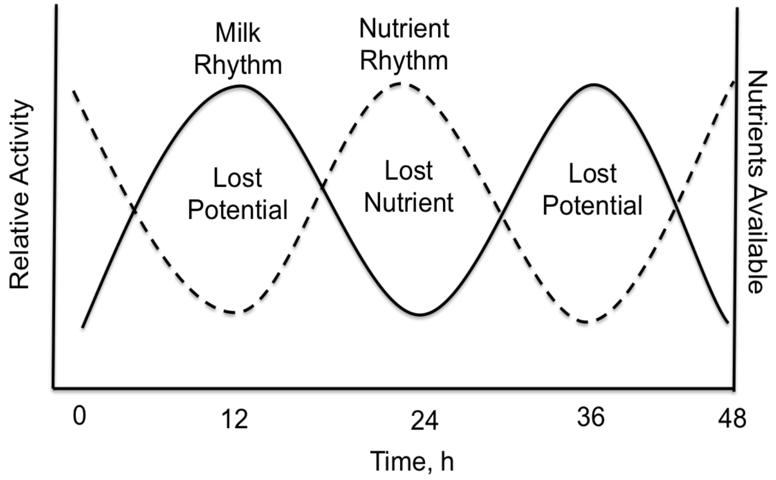


0.3 Units

1.8 kg

Quist et al. 2008

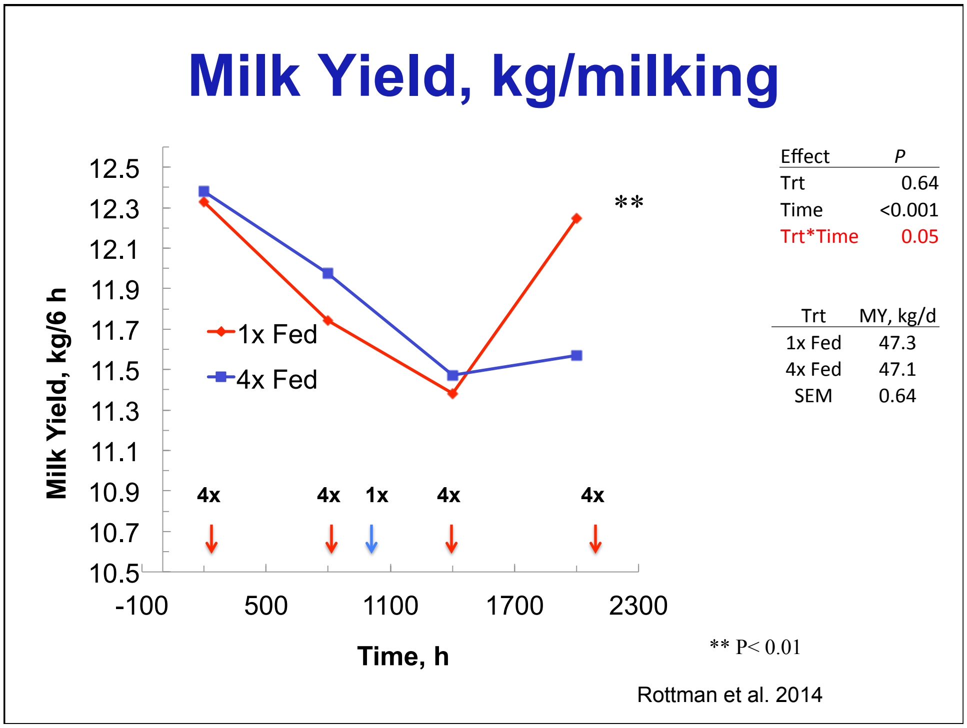
Theoretical de-synchronization of intake and mammary metabolism



Interaction of Intake and Milk Synthesis

- **Hypothesis**
  - The dairy cow has a circadian rhythm of milk synthesis that is dependent on the timing of nutrient absorption

- **Fed cows 1 x/d or 4 x/d in equal meals**
- **Milked 4 x/d**



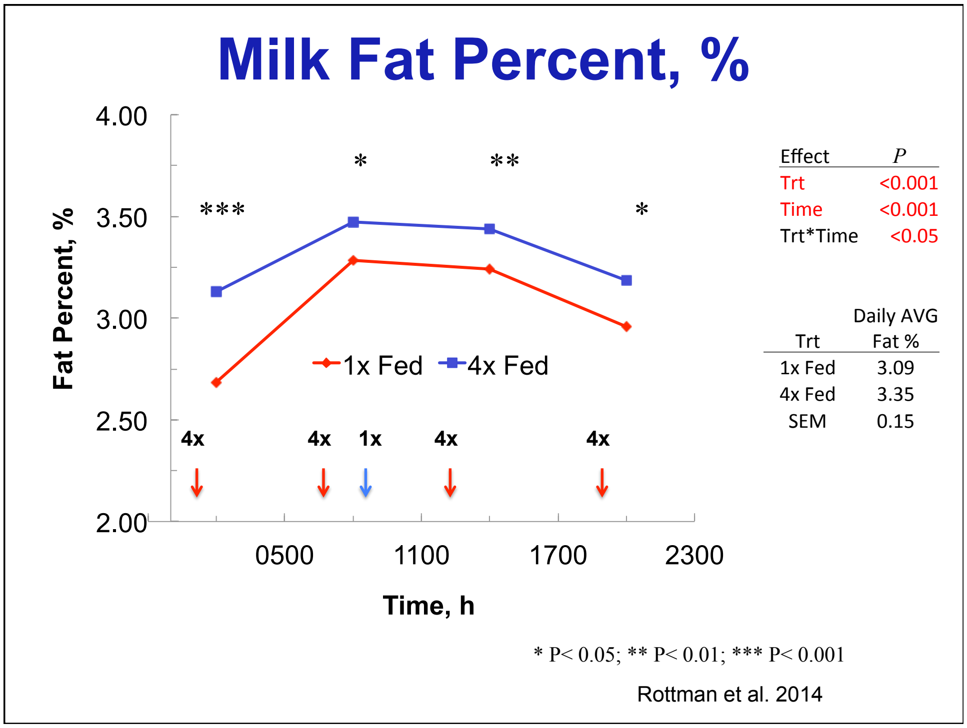
Milk Yield, kg/milking

Effect	*P*
Trt	0.64
Time	<0.001
Trt*Time	0.05

Trt	MY, kg/d
1x Fed	47.3
4x Fed	47.1
SEM	0.64

** P< 0.01

Rottman et al. 2014



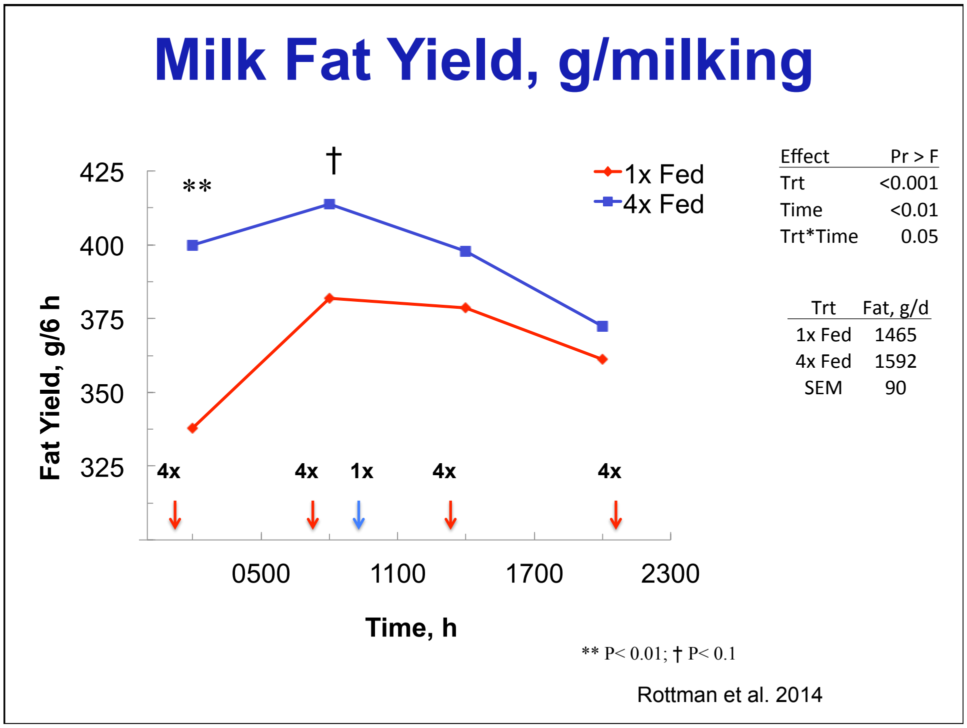
Milk Fat Percent, %

Effect	*P*
Trt	<0.001
Time	<0.001
Trt*Time	<0.05

Trt	Daily AVG Fat %
1x Fed	3.09
4x Fed	3.35
SEM	0.15

* P< 0.05; ** P< 0.01; *** P< 0.001

Rottman et al. 2014



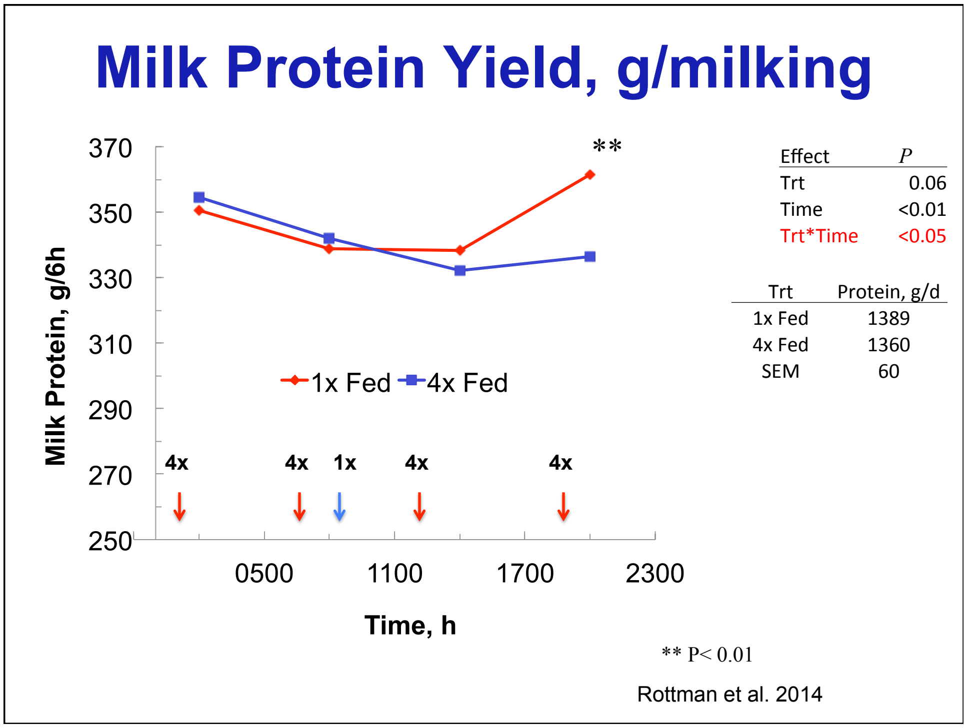
Milk Fat Yield, g/milking

Effect	Pr > F
Trt	<0.001
Time	<0.01
Trt*Time	0.05

Trt	Fat, g/d
1x Fed	1465
4x Fed	1592
SEM	90

** P< 0.01; † P< 0.1

Rottman et al. 2014



Milk Protein Yield, g/milking

Effect	*P*
Trt	0.06
Time	<0.01
Trt*Time	<0.05

Trt	Protein, g/d
1x Fed	1389
4x Fed	1360
SEM	60

** P< 0.01

Rottman et al. 2014

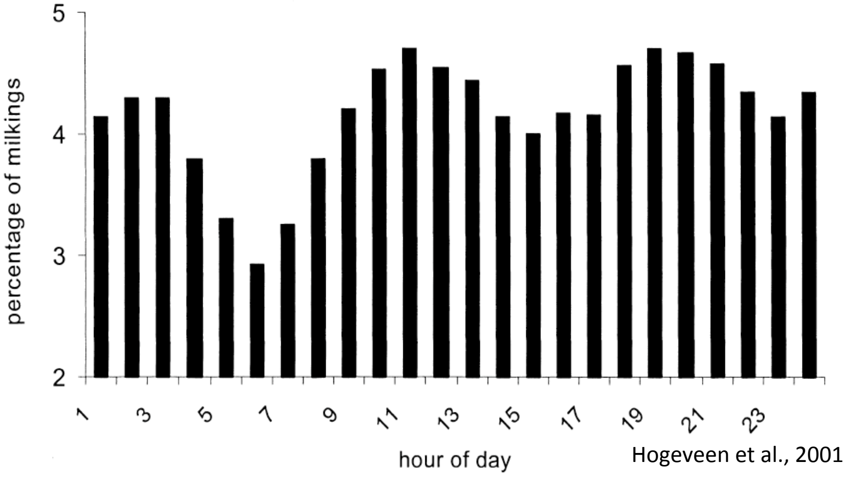
Summary

- Milk and milk components were altered by changing only the feeding regimen.
- Feeding 4x increased milk fat, but did not eliminate the circadian pattern.

Therefore- milk and milk component synthesis follows a circadian pattern that is dependent on the timing of nutrient intake.

When do cows prefer to be milked??

Automated Milking System

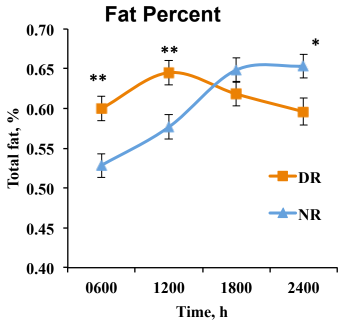


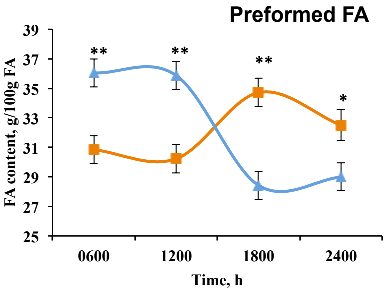
Hogeveen et al., 2001

Regulation of the Biological Clock in the Mammary Gland

- Wild-type female FVB mice from d 7 to 13 of lactation
- Modified timing of feed availability
    - Feed restriction during the day (1100 to 1800 h; **DR**)
    - Feed restriction during the night (2300 to 0600 h; **NR**)
- Mice euthanized at 0600, 1200, 1800, or 2400 h

Pup Stomach Milk Clots



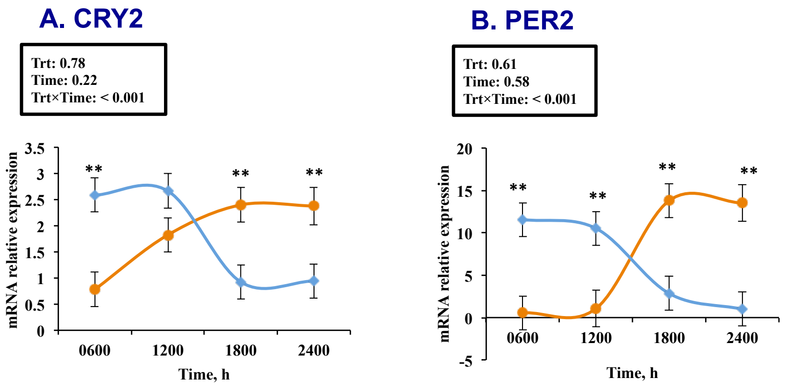


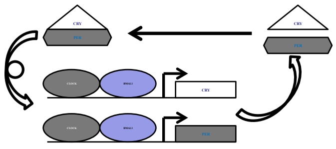
Trt: 0.24
Time: < 0.001
Trt×Time: < 0.001

- Phase shifted between DR and NR
    - Higher fat and more de novo synthesized FA after food intake occurred

Ma et al. Unpublished

Negative arm of the core clock





- **Negative arm**
  - – Phase inverted
  - – ↑ when food available
- **Positive arm**
  - – BMAL1 also phase shifted

Ma et al. Unpublished

How Can We Use This Information??

“Circadian Feeding Strategies”

Match the timing of delivery and diet composition to the temporal requirements of the rumen and the cow

1st… Think of the rumen

- Can we stabilize the amount of fermentable organic matter entering the rumen over the day?
- Feeding a single TMR does not provide this since there is high and low periods of intake over the day

Feeding Multiple TMRs over the Day

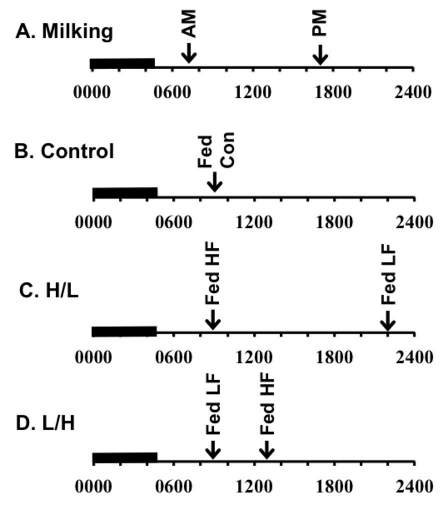
- **Three diets were used**
  - Control (Con): 30.1% NDF
  - High fiber (H): 31.8% NDF
  - Low fiber (L): 26.9% NDF

70% of H & 30% of L = Control

- **Three Treatments**
  - **Fed control TMR once per day at 0900**
  - **High-Low Treatment (HL)**
    - 70% of feed fed as High Fiber Diet at 0900 h
    - 30% of feed fed as Low Fiber Diet at 2200 h
  - **Low-High Treatment (LH)**
    - 30% of feed fed as Low Fiber Diet at 0900 h
    - 70% of feed fed as High Fiber Diet at 1300 h

Rottman et al. 2015; Ying et al. 2015

Treatments Plan



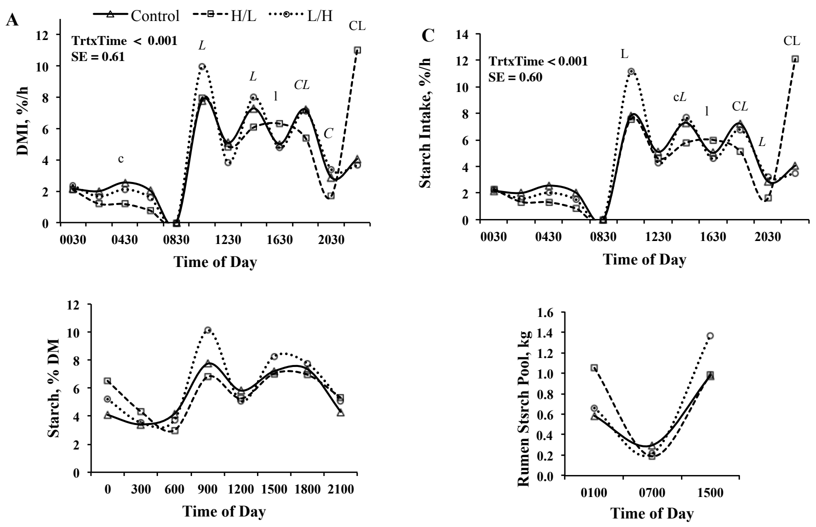
Intakes and Energy Balance

Parameter	Treatment Con	 HL	 LH	 SEM	*P*-Value *Trt*
DMI, kg	26.3	**24.4**^{C}	25.3	1.1	0.01
Dig. DMI, kg/d	16.2	**15.3**^{C}	15.8	0.6	0.12
EBW Gain, kg/d	11.4	19.5	10.0	1.7	0.30

Milk Yield and Composition

	Treatment				P-value
	CON	HL	LH	SEM	Trt
Milk, kg/d	39.7	38.6	41.0	2.4	0.14
Milk Fat					
Percent	3.44	3.39	3.45	0.25	0.73
Yield, kg/d	1.36	**1.28**^{LH}	1.41	0.05	0.07
Milk Protein					
Percent	3.08	3.10	3.10	0.09	0.86
Yield, kg/d	1.22	1.20	1.27	0.07	0.19

Pattern of Intake



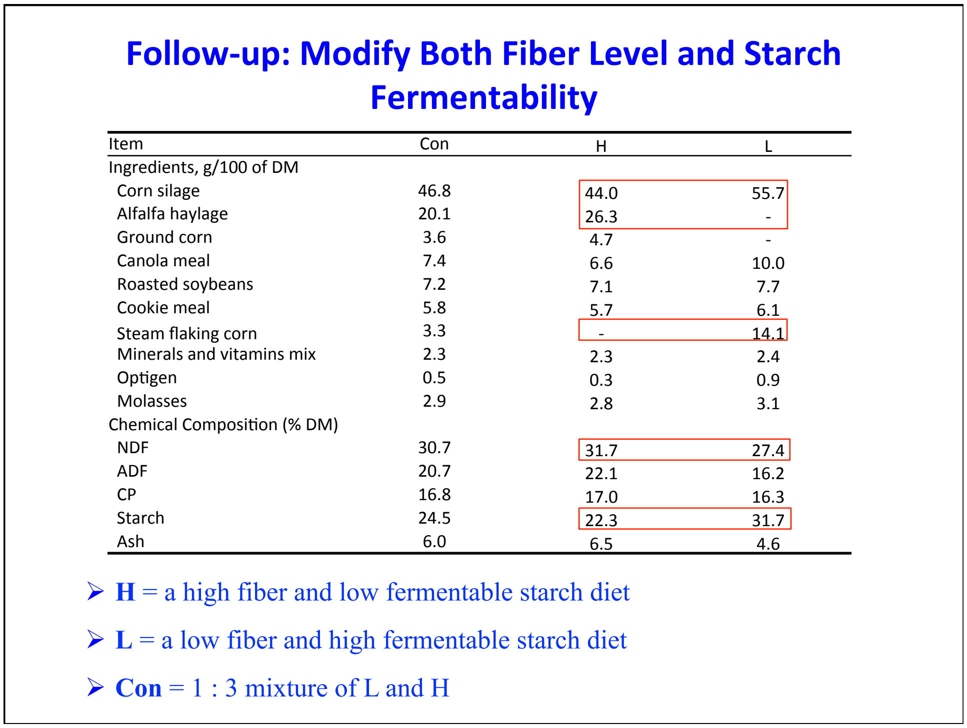
Rumen Observations

- No Change in
  - Average pH or time under pH 5.8 or 5.6
  - No change in daily average rumen VFA's
  - No change in DM or OM digestibility

Summary of Experiment

- Feeding a high forage diet first decreased intake without changing milk yield and body weight gain.
- Feeding a low forage diet first increased milk fat yield compared to feeding a high forage diet first.

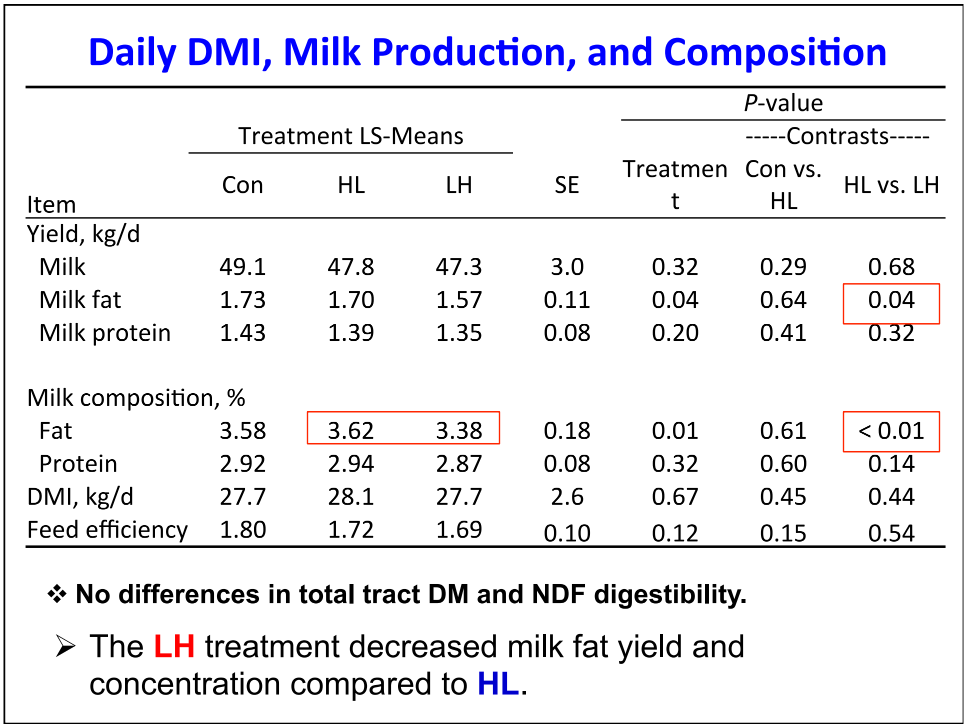
- Clear that timing of offering of feed and the impact on feeding behavior are key components



Follow-up: Modify Both Fiber Level and Starch Fermentability

Item	Con	H	L
Ingredients, g/100 of DM			
Corn silage	46.8	44.0	55.7
Alfalfa haylage	20.1	26.3	-
Ground corn	3.6	4.7	-
Canola meal	7.4	6.6	10.0
Roasted soybeans	7.2	7.1	7.7
Cookie meal	5.8	5.7	6.1
Steam flaking corn	3.3	-	14.1
Minerals and vitamins mix	2.3	2.3	2.4
Optigen	0.5	0.3	0.9
Molasses	2.9	2.8	3.1
Chemical Composition (% DM)			
NDF	30.7	31.7	27.4
ADF	20.7	22.1	16.2
CP	16.8	17.0	16.3
Starch	24.5	22.3	31.7
Ash	6.0	6.5	4.6

- **H** = a high fiber and low fermentable starch diet
- **L** = a low fiber and high fermentable starch diet
- **Con** = 1 : 3 mixture of L and H

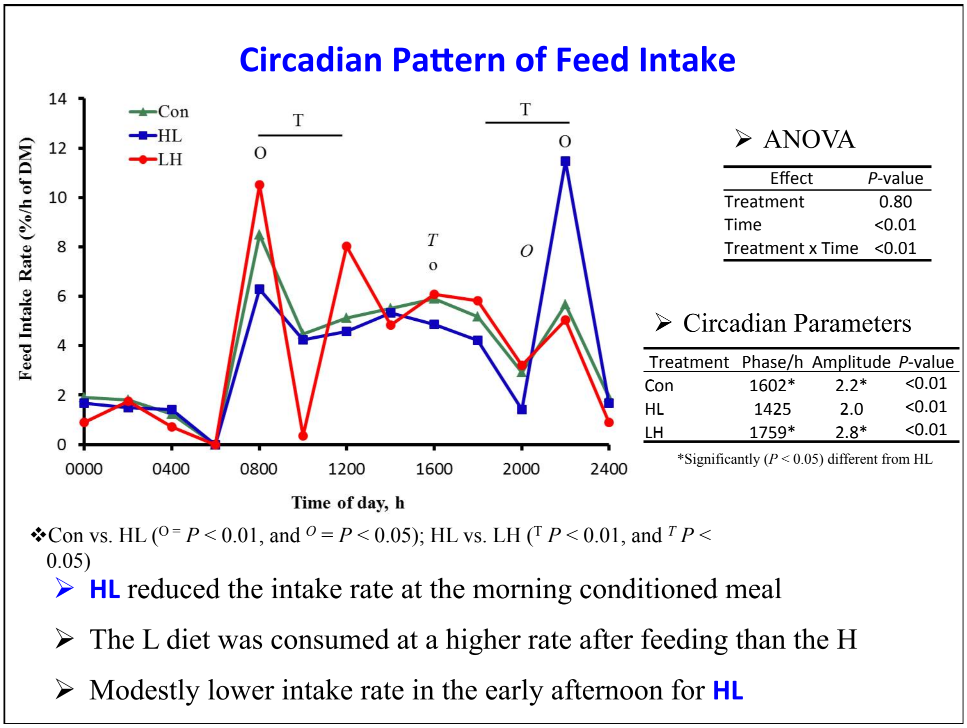


Daily DMI, Milk Production, and Composition

					P-value		
	Treatment LS-Means					-----Contrasts-----	
Item	Con	HL	LH	SE	Treatment	Con vs. HL	HL vs. LH
Yield, kg/d							
Milk	49.1	47.8	47.3	3.0	0.32	0.29	0.68
Milk fat	1.73	1.70	1.57	0.11	0.04	0.64	0.04
Milk protein	1.43	1.39	1.35	0.08	0.20	0.41	0.32
Milk composition, %							
Fat	3.58	3.62	3.38	0.18	0.01	0.61	< 0.01
Protein	2.92	2.94	2.87	0.08	0.32	0.60	0.14
DMI, kg/d	27.7	28.1	27.7	2.6	0.67	0.45	0.44
Feed efficiency	1.80	1.72	1.69	0.10	0.12	0.15	0.54

❖ **No differences in total tract DM and NDF digestibility.**

- The **LH** treatment decreased milk fat yield and concentration compared to **HL**.



Circadian Pattern of Feed Intake

- ANOVA

Effect	*P*-value
Treatment	0.80
Time	<0.01
Treatment x Time	<0.01

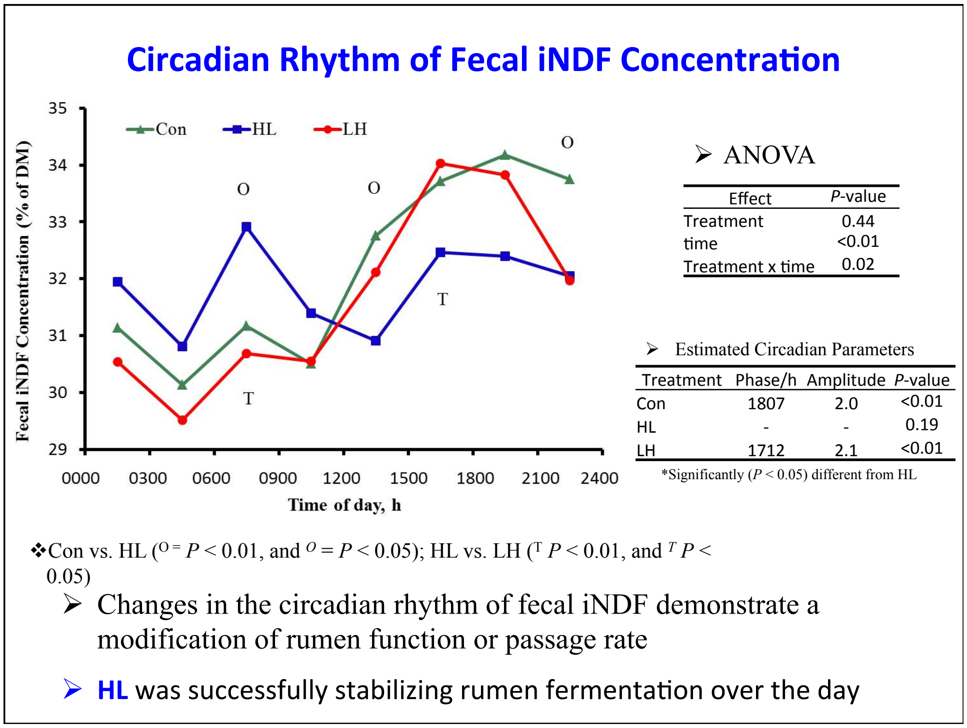
- Circadian Parameters

Treatment	Phase/h	Amplitude	*P*-value
Con	1602*	2.2*	<0.01
HL	1425	2.0	<0.01
LH	1759*	2.8*	<0.01

*Significantly ($P < 0.05$) different from HL

❖Con vs. HL ($^{\mathrm{O}} = P < 0.01$, and $^{O} = P < 0.05$); HL vs. LH ($^{\mathrm{T}}\ P < 0.01$, and $^{T}\ P < 0.05$)

- **HL** reduced the intake rate at the morning conditioned meal
- The L diet was consumed at a higher rate after feeding than the H
- Modestly lower intake rate in the early afternoon for **HL**



Circadian Rhythm of Fecal iNDF Concentration

- ANOVA

Effect	*P*-value
Treatment	0.44
time	<0.01
Treatment x time	0.02

- Estimated Circadian Parameters

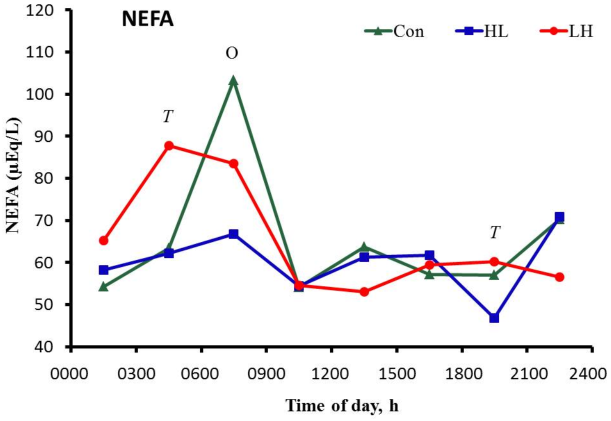
Treatment	Phase/h	Amplitude	*P*-value
Con	1807	2.0	<0.01
HL	-	-	0.19
LH	1712	2.1	<0.01

*Significantly ($P < 0.05$) different from HL

❖Con vs. HL ($^{\mathrm{O}} = P < 0.01$, and $^{O} = P < 0.05$); HL vs. LH ($^{\mathrm{T}}\ P < 0.01$, and $^{T}\ P < 0.05$)

- Changes in the circadian rhythm of fecal iNDF demonstrate a modification of rumen function or passage rate
- **HL** was successfully stabilizing rumen fermentation over the day

Circadian Rhythm of Plasma NEFA



- ANOVA

Effect	*P*-value
Treatment	0.33
time	<0.01
Treatment x time	0.01

- Estimated Circadian Parameters

Treatment	Phase/h	Amplitude	*P*-value
Con	0622	10.2	<0.01
HL	-	-	0.41
LH	0421	13.1	<0.01

*Significantly ($P < 0.05$) different from HL

❖Con vs. HL (^{O} = $P < 0.01$, and ^{O} = $P < 0.05$); HL vs. LH (^{T} $P < 0.01$, and ^{T} $P < 0.05$)

- Feeding L diet at night decreased NEFA during the overnight period
- A daily rhythm was not detected for **HL** cows

Summary of Circadian Feeding Strategies

- Feed delivery is a strong signal for feeding which can be used to increase intake during low intake periods of the day
- Make sure feed is available when return from parlor………, but
  - Delivery of feed 2-3 h before or after milking may spread intake more across the day??

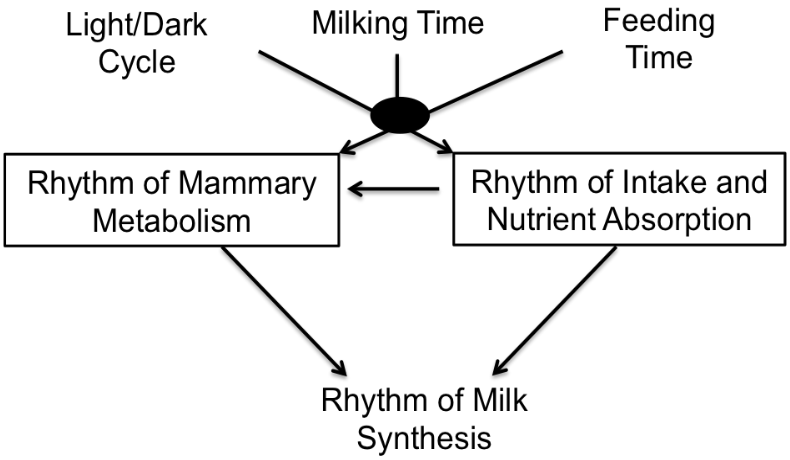
Is he crazy or can "Circadian Feeding" concepts be applied in the field?

- **Some products may be most effective during a certain time of day (Both ruminally and post-ruminally)**
- **Multiple rations may not be that more complex**
  - **Feed same ration to entire herd in morning**
  - **Return to "top-off" high groups**

Interesting Call From the Field

- One pen of cows on a large farm consistently 0.3 to 0.5 units lower in milk fat than peer pen in another barn fed same diet
- Moved fifteen cows from the pen to another pen and they increased milk fat
- Normal MFD troubleshooting turned up no clues
- Cows being fed later in the day (11:30 AM)
- Switched milking and feeding order so feed delivered earlier and before milking.
- Milk fat increased equal to peer pen

Must Consider Multiple Factors That Have an Impact on Behavior



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Thank You!

Questions For You!!

- Have you ran into situations where changing the timing of feeding or management had an impact?

- What variables do you think are most important?

Heat Stress
What's New and What Can We Do About It?

Penn State Nutrition Conference
November 12, 2015

Andrew Holloway, DVM, PAS
Dairy Technical Service Director
Elanco Animal Health

Outline

- Heat stress basics
  - THI
  - Cow impacts
  - Cooling basics
- What's new?
  - Dry cows
  - Calves
- What can we do about it?
  - Prioritize by watching the cows
  - Drinking water and shade
  - Active cooling
  - Dry cows

At what environmental temperature do cows start to experience the effects of heat stress?

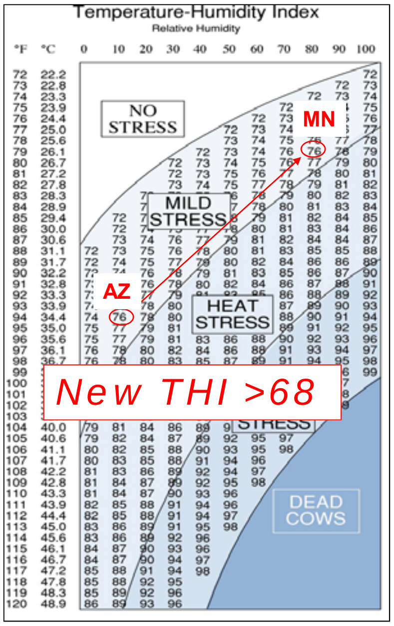
"Pleistocene Mega fauna"

– Born or evolved during the last Ice Age

From Wikipedia, the free encyclopedia

Temperature Humidity Index (THI)[1]

- Combination of ambient temperature and relative humidity
- Better predictor of cow stress than temperature alone
- THI > 72 is the point that dairy cattle start to decrease productivity
- THI > 72 can be achieved at moderate temperatures if humidity is high (AZ vs. MN)
- Cattle standards developed from data collected in 1950 and 1960s[2]
- Standards based data from 56 cows[2]
- Average milk production 35 lbs/day (Range 6.0-70 lbs)[2]



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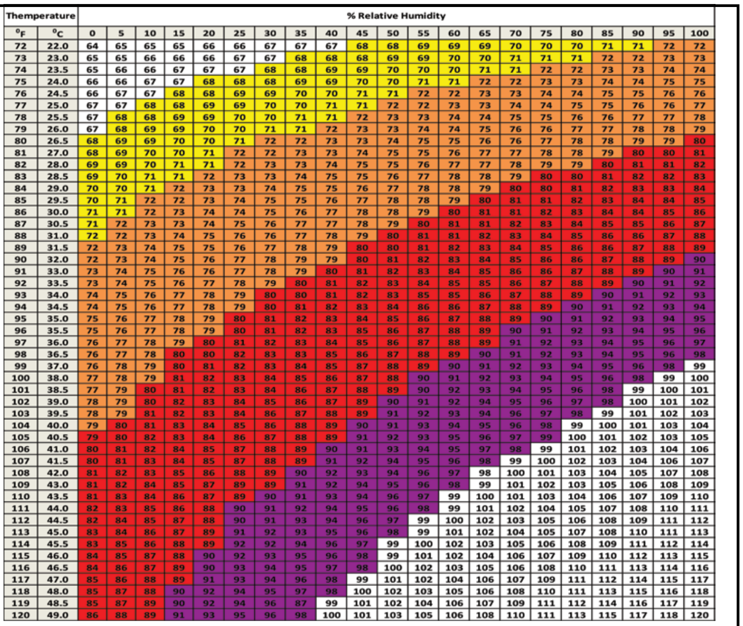
[1] Armstrong DV. 1994. J Dairy Sci 77:2044-2050.
[2] Collier RJ et al. Western Dairy Management Conf. March 9-11, 2011. Reno, NV 113-126.

STRESS

- 🟨 Mild (68)
- 🟧 Moderate (72)
- 🟥 Severe (80)
- 🟪 Danger (90)



Themperature		% Relative Humidity																				
°F	°C	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
72	22.0	64	65	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72	72
73	23.0	65	65	66	66	66	67	67	68	68	68	69	69	70	70	71	71	71	72	72	73	73
74	23.5	65	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74
75	24.0	66	66	67	67	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
76	24.5	66	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76
77	25.0	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	77
78	25.5	67	68	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	76	77	77	78
79	26.0	67	68	69	69	70	70	71	71	72	73	73	74	74	75	76	76	77	77	78	78	79
80	26.5	68	69	69	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78	79	79	80
81	27.0	68	69	70	70	71	72	72	73	73	74	75	75	76	77	77	78	78	79	80	80	81
82	28.0	69	69	70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82
83	28.5	69	70	71	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	82	83
84	29.0	70	70	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84
85	29.5	70	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85
86	30.0	71	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
87	30.5	71	72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	85	85	86	87
88	31.0	72	72	73	74	75	76	76	77	78	79	80	81	81	82	83	84	85	86	86	87	88
89	31.5	72	73	74	75	75	76	77	78	79	80	80	81	82	83	84	85	86	86	87	88	89
90	32.0	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
91	33.0	73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89	90	91
92	33.5	73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90	91	92
93	34.0	74	75	76	77	78	79	80	80	81	82	83	85	85	86	87	88	89	90	91	92	93
94	34.5	74	75	76	77	78	79	80	81	82	83	84	86	86	87	88	89	90	91	92	93	94
95	35.0	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
96	35.5	75	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94	95	96
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100	38.0	77	78	79	81	82	83	84	85	86	87	88	90	91	92	93	94	95	96	98	99	100
101	38.5	77	79	80	81	82	83	84	86	87	88	89	90	92	93	94	95	96	98	99	100	101
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103	39.5	78	79	81	82	83	84	86	87	88	89	91	92	93	94	96	97	98	99	101	102	103
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115	46.0	84	85	87	88	90	92	93	95	96	98	99	101	102	104	106	107	109	110	112	113	115
116	46.5	84	86	87	89	90	93	94	95	97	98	100	102	103	105	106	108	110	111	113	114	116
117	47.0	85	86	88	89	91	93	94	96	98	99	101	102	104	106	107	109	111	112	114	115	117
118	48.0	85	87	88	90	92	94	95	97	98	100	102	103	105	106	108	110	111	113	115	116	118
119	48.5	85	87	89	90	92	94	96	87	99	101	102	104	106	107	109	111	112	114	116	117	119
120	49.0	86	88	89	91	93	95	96	98	100	101	103	105	106	108	110	111	113	115	117	118	120

Collier R.J., R.B. Zimbelman, R.P. Rhoads, M.L. Rhoads, and L.H. Baumgard. Department of Animal Sciences, The University of Arizona. 2011.
A Re-evaluation of the Impact of Temperature Humidity Index (THI) and Black Globe Humidity Index (BGHI) on Milk Production in High Producing Dairy Cows.

Temperature Humidity Index Impact on Milk Production in High Producing Dairy Cows

- Heat production of cows producing 41 lb and 70 lbs milk/day is 27.3 and 48.5% higher, respectively, compared to non lactating cows[1]
- When milk production increases from 77 to 99 lb/day the threshold temperature for heat stress is reduced 9° F[1]

New THI >68

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[1] Collier et al. Proceedings of the 10th Western Dairy Management Conf. Reno, NV, March 9-11, 2011. PP113-126.

Heat Stress and Performance

- Decreased feed intake > 35%[1,2]
  - 10 to 15% on well cooled dairies
- Decreased milk yield > 50%[1,2]
  - 10 to 15% on well cooled dairies
- Milk fat depression
- Increased risk of rumen acidosis[3]
- Increased risk of lameness
- Decrease in body condition
- Depressed immune function
  - Increased mastitis
  - Increased transition diseases
- Negative effects on reproduction[4,5]
  - Short term
  - Long term

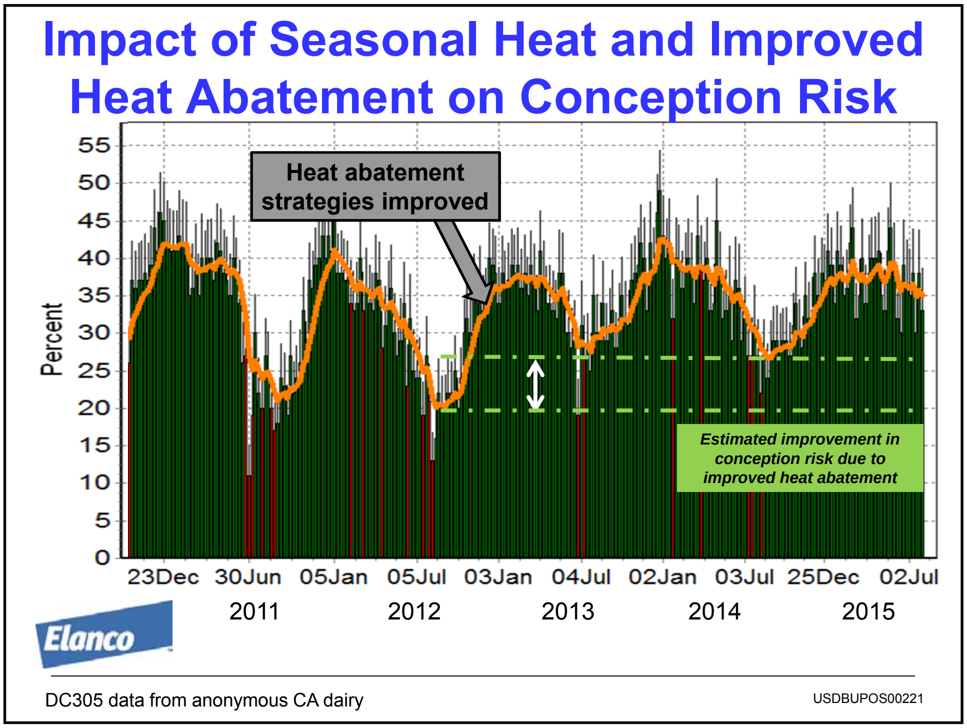
[1] Collier R J Dairy Sci 65:2213-2227

[2] West J. 2003. J Dairy Sci 86:2131-2144

[3] Shearer J. 2005. Proc 4th AZ Dairy Prod Conf 25-31

[4] Fuquay 1981. J Anim Sci 52:164-174

[5] Roth J 2004. Thermal Biol. 29:681-685



Impact of Seasonal Heat and Improved Heat Abatement on Conception Risk

Heat abatement strategies improved

Estimated improvement in conception risk due to improved heat abatement

DC305 data from anonymous CA dairy

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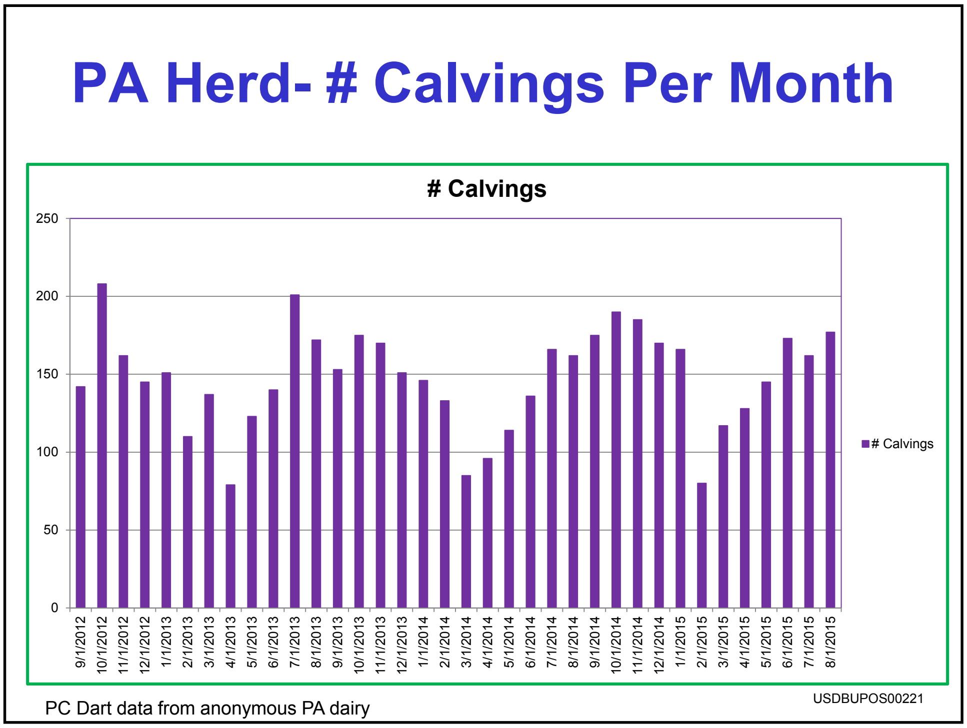

PA Herd- # Calvings Per Month

PC Dart data from anonymous PA dairy

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Basics: How do Cows Cool Themselves?

1. Non-evaporative
   - Convection
   - Conduction
   - Radiation
2. Evaporative
   - Panting
   - Sweating

Temperature Gradient Required

Once ambient temperature exceeds 90F, >85% of the heat dissipated is through evaporative cooling.[1]

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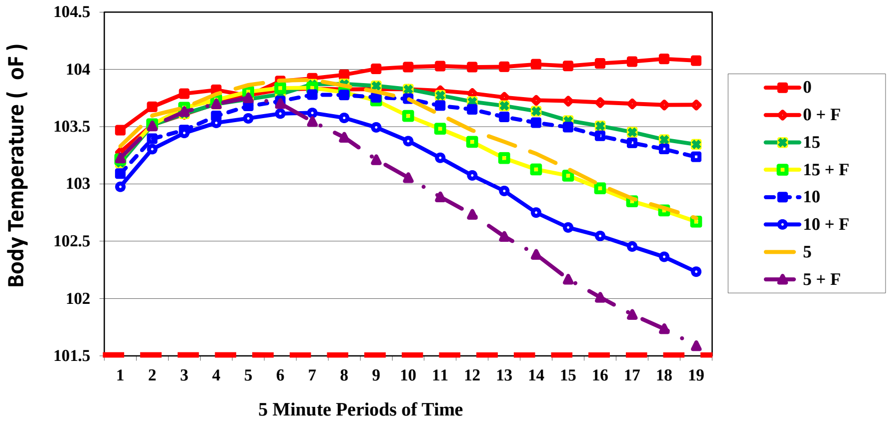
[1] Brouk, M.J., J.F. Smith and J.P.Harner. 2003. Effectiveness of cow cooling strategies under different environmental conditions. Proc. of the 6th Western Dairy Mgt. Conference. Reno, NV. pp. 141-154.

Effects of Cooling Treatments on Body Temperature over 95 Minute Period



Brouk, M.J, et al. 2003. Proceedings from the Western Dairy Management Conference. pp 141-154

High Humidity Limits Our Ability to Take Advantage of Using Evaporative Cooling to Cool the Air

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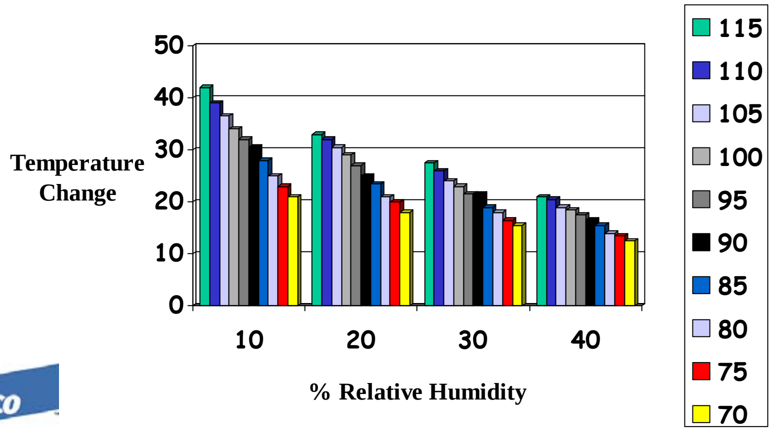
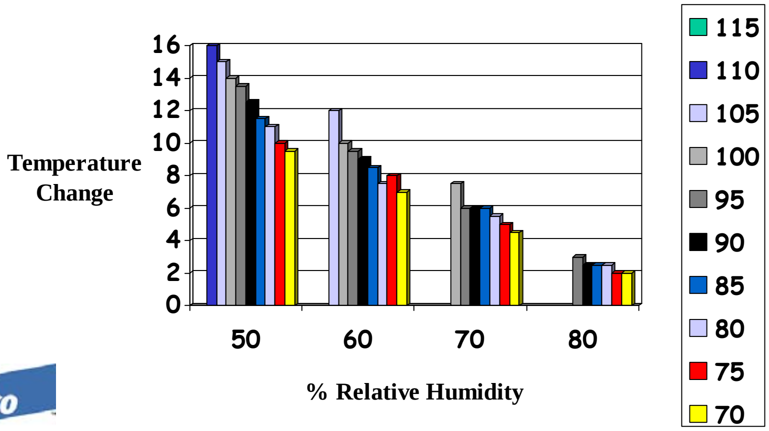
Potential Temperature Change Due to Water Evaporation in a Low Relative Humidity Environment



KSU Cow Comfort Consortium (Brouk, M.J., J.F. Smith and J.P. Harner, III)

Potential Temperature Change Due to Water Evaporation in a High Relative Humidity Environment



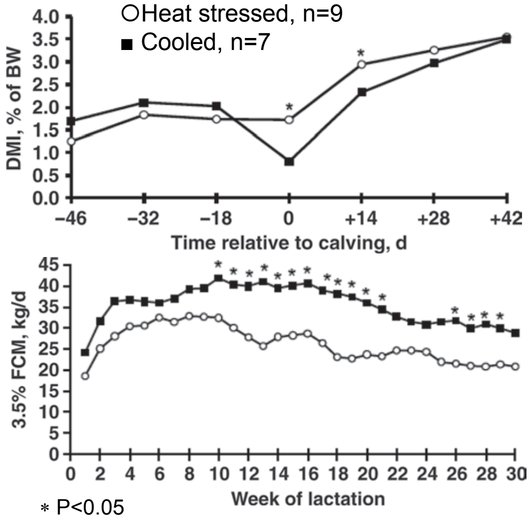
KSU Cow Comfort Consortium (Brouk, M.J., J.F. Smith and J.P. Harner, III)

Outline

- Heat stress basics
  - THI
  - Cow impacts
  - Cooling basics
- **What's new?**
  - **Dry cows**
  - **Calves**
- What can we do about it?
  - Prioritize by watching the cows
  - Drinking water and shade
  - Active cooling
  - Dry cows

Effects of Heat Abatement during the Prepartum Period on Heat Stress, DMI and Milk Yield

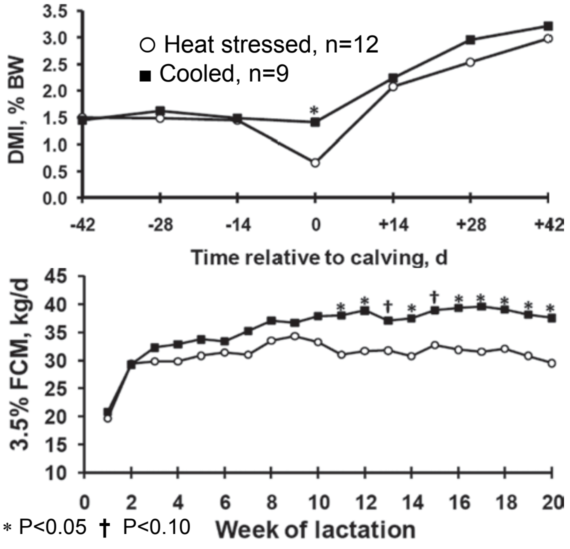
- ↓ DMI at calving less severe in cooled vs. non-cooled cows
- ↑ FCM yield for cooled vs. non cooled cows starting on week 10 of lactation
- Overall +9.3 kg/d (19.8 lb/d) FCM yield (*P*=0.01)



do Amaral BC et al. 2009. J. Dairy Sci. 92 :5988-5999

Effects of Heat Abatement during the Prepartum Period on Heat Stress, DMI and Milk Yield

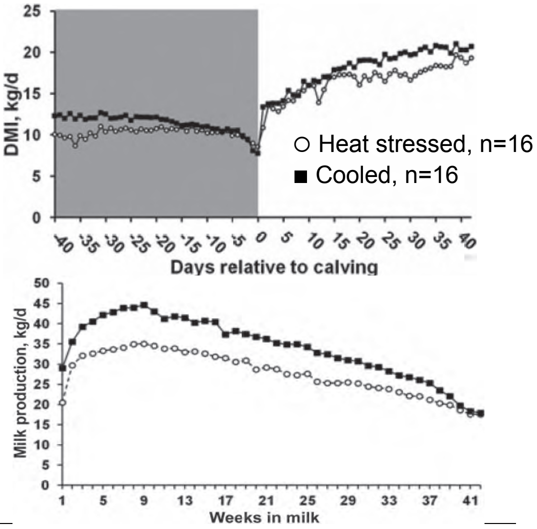
- ↓ DMI at calving less severe in cooled vs. non-cooled cows
- ↑ FCM yield for cooled vs. non cooled cows starting on week 11 of lactation
- Overall +4.7 kg/d (10.3 lb/d) 3.5% FCM yield (*P*=0.07)



do Amaral BC et al. 2011 J. Dairy Sci. 94 :86–96

Effects of Heat Abatement during the Prepartum Period on Heat Stress, DMI and Milk Yield

- Tendency for ↑DMI pre & post calving (*P*=0.10)
- ↑DMI after 2 weeks post calving (*P*=0.04)
- ↑ Milk yield for cooled vs. non cooled cows through 42 weeks + 6.3 kg/d (13.9 lb/d) (*P*<0.01)



Tao S.et al. 2012. J. Dairy Sci. 95:5035-5046

Effect of heat stress during the dry period on mammary gland development

- Experimental design
  - 29 multiparous Holstein cows with average dry off 46 days prior to calving
  - Two treatments – 1) Heat stressed; 2) Cooled
  - In cooled cows sprinklers and fans came with ambient temperature = 70^{o} F
  - Dry period measures
    - Body temperature
    - Respiration rate
    - DMI
  - Lactation period measures
    - Milk production through 280 days
    - Milk protein
    - SCC

Tao S et al. 2011. J. Dairy Sci. 94:5976–5986

Effect of heat stress during the dry period on mammary gland development

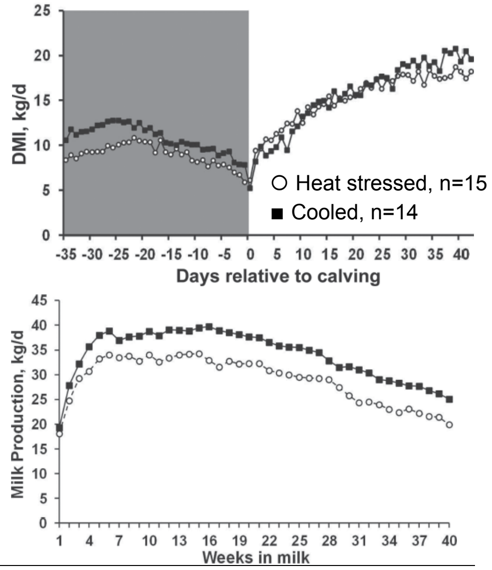
Mean THI = 76.6

Item	Heat Stressed	Cooled
Number	15	14
Rectal Temperature AM/PM	101.8/102.9	101.5/102.2
Respirations (Breaths/min.)	78.4	45.6
Dry Period DMI (lb)	19.6	23.3
Mean Milk Production (280 DIM)	63.6	74.6
Milk Protein (%)	3.01	2.87
SCC (linear score)	3.35	2.94

Tao S et al. 2011. J. Dairy Sci. 94 :5976–5986

Effects of Heat Abatement during the Prepartum Period on Heat Stress, DMI and Milk Yield

- ↑DMI pre calving (*P*=0.02)
- No difference DMI post calving (*P*=0.70)
- ↑ Milk yield for cooled vs. non cooled cows through 40 weeks lactation + 5.0 kg/d (11 lb/d) (*P*<0.03)



Tao S et al. 2011. J. Dairy Sci. 94 :5976–5986

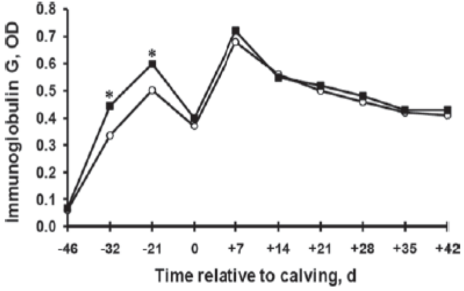
Effect of heat stress during the dry period on mammary gland development

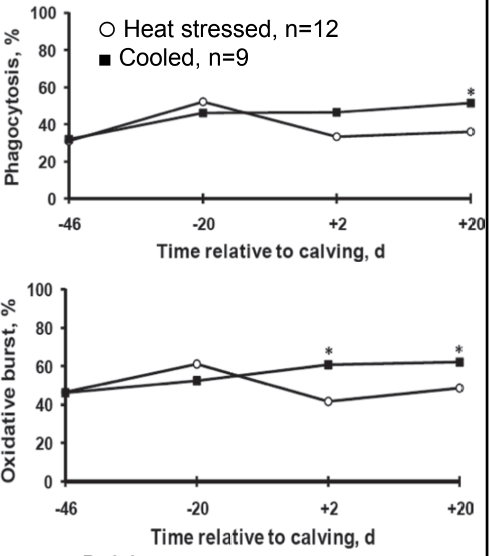
Summary

- Heat stress cows had lower mammary epithelial cell proliferation during the transition period.
- Heat stress during the dry period negatively affects hepatic metabolism and cellular immune function during the transition period, and milk production in the subsequent lactation.

Tao S, J. Dairy Sci. 2011. 94 :5976–5986

Heat Abatement Improved Humoral Immunity Prepartum and Innate Immunity Postpartum

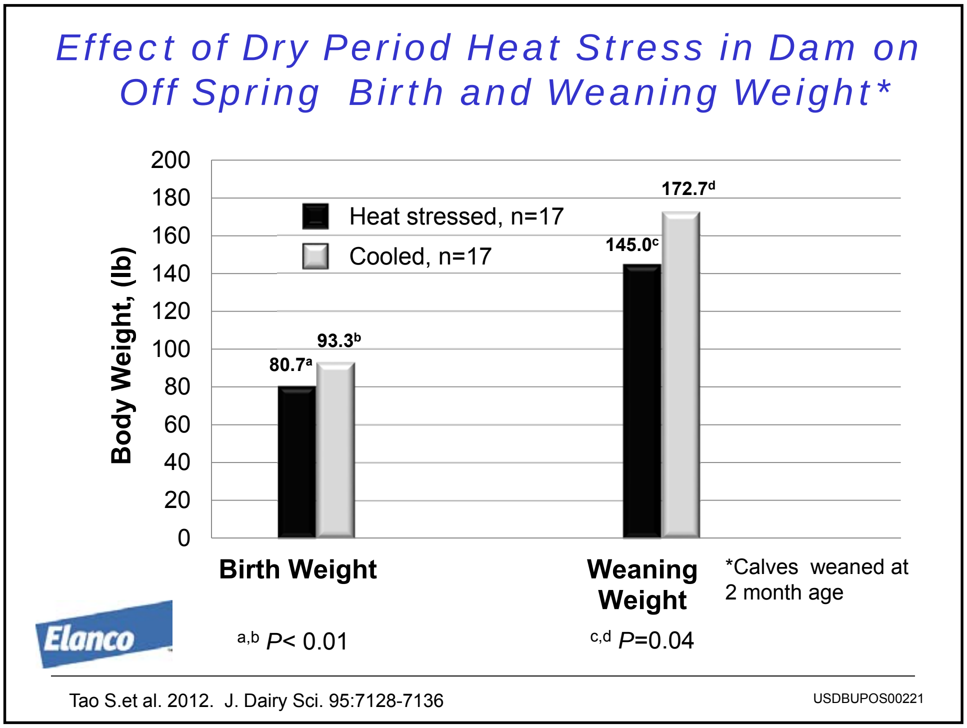




- ↑ IgG concentration prepartum in response to ovalbumin challenge
- ↑ PMNL activity in the postpartum

∗ P<0.05

do Amaral BC et al. 2011. J. Dairy Sci. 94 :86–96



Effect of Dry Period Heat Stress in Dam on Off Spring Birth and Weaning Weight*

*Calves weaned at 2 month age

^{a,b} $P< 0.01$

^{c,d} $P=0.04$

Tao S.et al. 2012. J. Dairy Sci. 95:7128-7136

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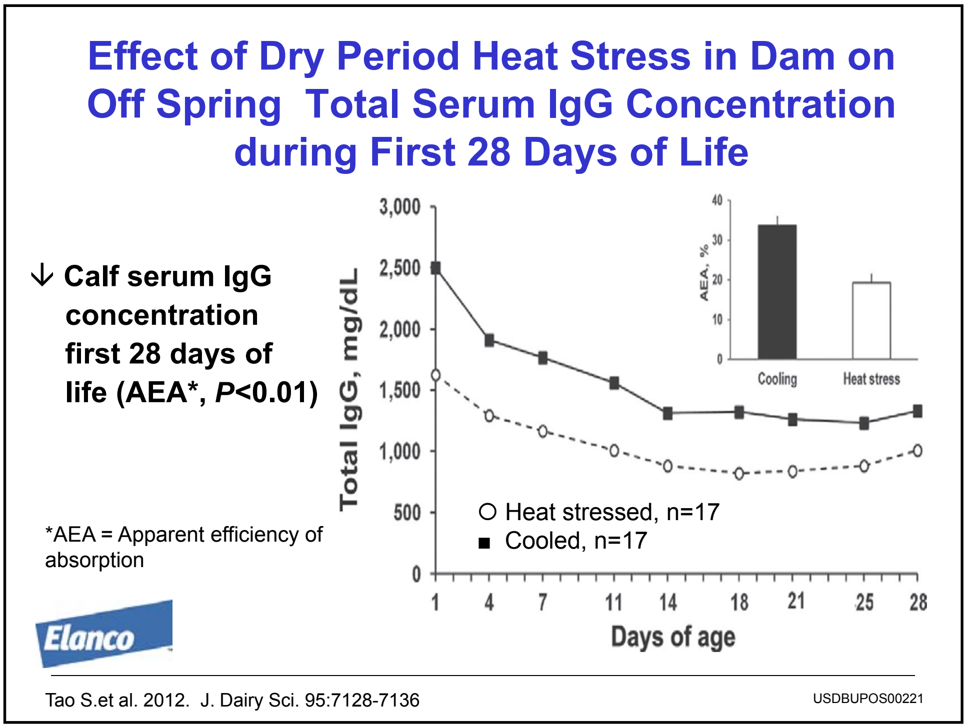


Effect of Dry Period Heat Stress in Dam on Off Spring Total Serum IgG Concentration during First 28 Days of Life

↓ Calf serum IgG concentration first 28 days of life (AEA*, *P*<0.01)

*AEA = Apparent efficiency of absorption

Tao S.et al. 2012. J. Dairy Sci. 95:7128-7136

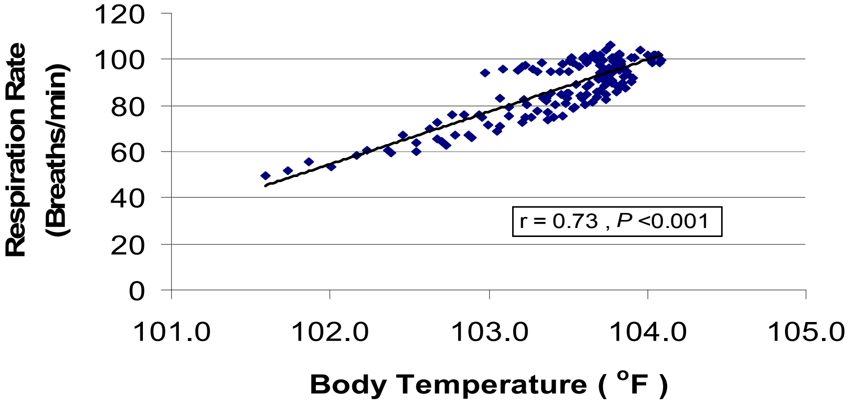
USDBUPOS00221

Outline

- Heat stress basics
  - THI
  - Cow impacts
  - Cooling basics
- What's new?
  - Dry cows
  - Calves
- **What can we do about it?**
  - **Prioritize by watching the cows**
  - **Drinking water and shade**
  - **Active cooling**
  - **Dry cows**

Describe the Heat Stressed Cow

Relationship between Respiration Rate and Body Temperature of Cattle[1]



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[1] Smith J & Brouk M. 2003. Proceedings Four State Dairy Nutrition & Management Conf. pp 99-108

Strategies and Priorities

- First, cool cows where heat stress is the worst
- Then, where you want them to spend the most time
- And finally, where they already spend the most time

Holding Pen Heat Stress

Video by Bailey - Elanco Dairy Business

Holding Pen Heat Abatement

- Cow body temp can increase 3 degrees F in 20 min[1]
- Each cow generates >4500 BTU heat per hr when ambient temperature exceeds 80 degrees F[1]

- Low setting
  - Actuation temp- 68F
  - Shower time 1-1.3 min
  - Interval time- 10 min
- High setting
  - Actuation temp- 78F
  - Shower time 1-1.3 min
  - Interval time- 5 min

---

[1] Smith et al., Reducing Heat Stress in Dairy Holding Pens technical bulletin MF2468. Kansas State University. Sept. 2000.

Strategies and Priorities

1. Drinking water availability
2. Provide shade in the housing areas and holding pen
3. Reduce walking distance to the parlor
4. Reduce time in the holding pen
5. Improve holding pen and housing ventilation
6. Active cooling in:
    1. Holding pen
    2. Prepartum cows
    3. Postpartum cows
    4. High production cows
    5. Low production cows

Changes in maintenance requirements, dry matter intake, milk production and water intake with increasing environmental temperatures[1]

Ambient Temperature, ° F	Maintenance, % of required at 50° F	DMI for maint. + 60 lb milk		Water intake gallons/day
		Needed (lb/day)	Expected	
- 4	151	47	45	14
32	110	41	41	17
68	100	40	40	18
86	111	42	37	21
95	120	43	37	32
104	132	45	23	28

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[1] National Research Council. 1981. Effect of Environment on Nutrient Requirements of Domestic Animals. National Academy Press, Washington http://www.nap.edu/openbook.php?record_id=4963&page=79 Accessed 3/20/2013


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Photo by Dr. Mark Armfelt Ohio Farm – Elanco Dairy Business

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Photo by Dr. Mark Armfelt Ohio Farm – Elanco Dairy Business

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Photo by Bailey - NC Farm – Elanco Dairy Business

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Photo by Holloway– Elanco Dairy Business

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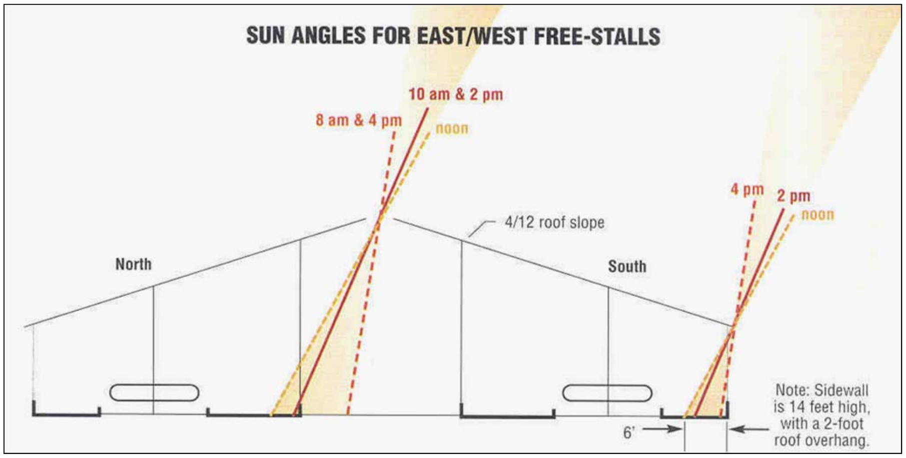
Freestall Barn

East-West Orientation



Source: Joe Harner, KSU

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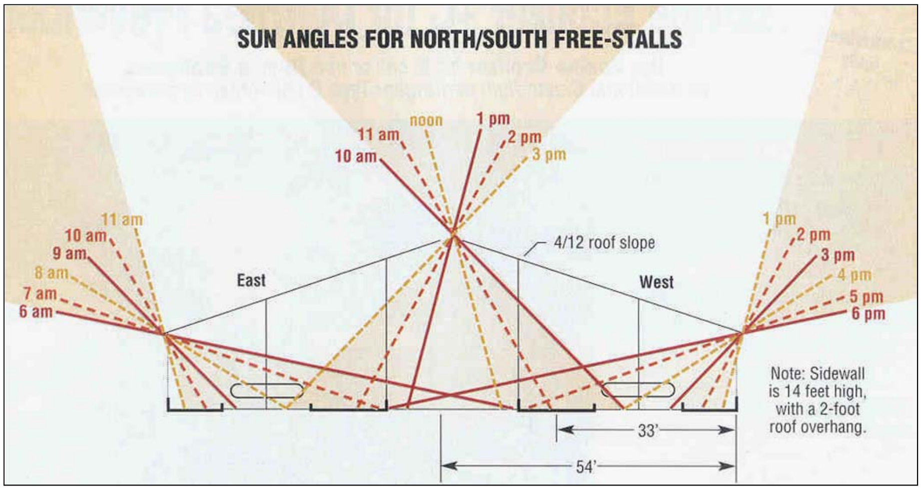
Freestall Barn

North-South Orientation

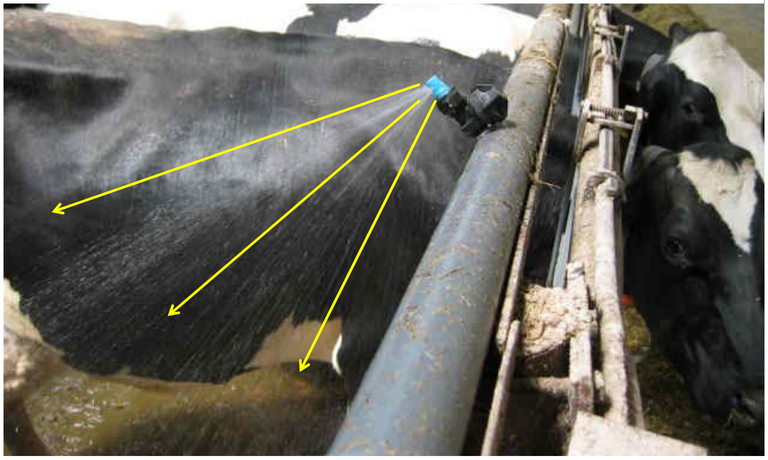


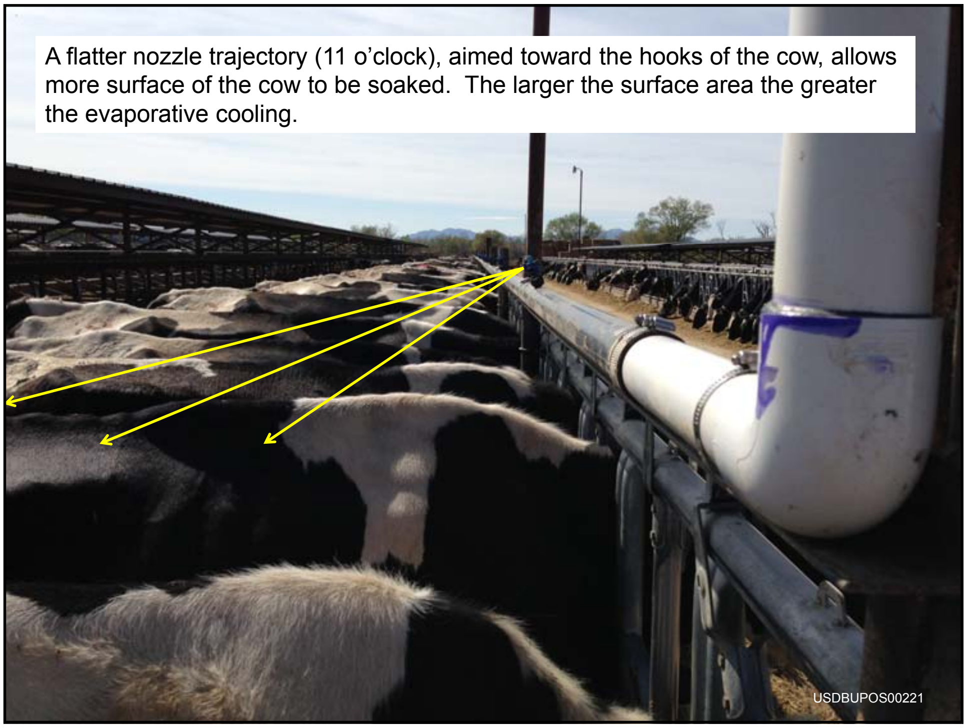
Source: Joe Harner, KSU

Enough Water On Cows and Frequency?

- Low setting
  - Actuation temp- 68F
  - Shower time 1-1.3 min
  - Interval time
    - Depends on # zones
    - 10 min if 4 zones
- High setting
  - Actuation temp- 82F
  - Shower time 1-1.3 min
  - Interval time
    - 3-4 min if 4 zones

Nozzles should be adjusted to soak as much surface area of the cow as possible. A flatter trajectory with a low soaker line allows more water spray to soak a larger surface area of the cow.



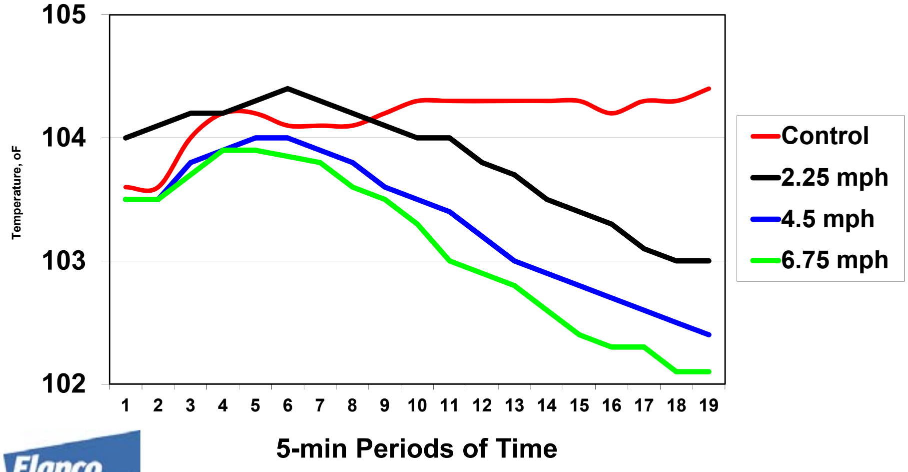


A flatter nozzle trajectory (11 o’clock), aimed toward the hooks of the cow, allows more surface of the cow to be soaked. The larger the surface area the greater the evaporative cooling.

Enough Water on Cows?

Elanco

Vaginal Temperatures of Cattle Cooled by Soaking and Differing Levels of Air Velocity



Brouk, et al., 2004 ADSA

5 mph Air Velocity at Cow?

Heat Abatement in Dry Cows Effect on Milk Yield - Summary Six Studies

Study Site	Cooling Method	Lactation Period (d)	Milk Yield (lb) No cooling	Milk Yield (lb) Cooling	Cooling Adv (lb)	P value
Mexico[1]	Fans/misters	**56**	**44.5**	**49.0**	**+ 4.5**	**0.17**
California[2]	Fans/shades/ sprinklers over feed bunk	**60**	**85.1**	**88.2**	**+ 3.1**	**0.04**
Florida[3]	Fans/sprinklers	**210**	**57.6**	**74.1**	**16.6***	**0.04**
Florida[4]	Fans/sprinklers	**140**	**70.8**	**75.9**	**+ 5.1****	**0.09**
Florida[5]	Fans/sprinklers	**280**	**63.6**	**74.6**	**+ 11.0**	**0.03**
Florida[6]	Fans/sprinklers	**294**	**60.9**	**74.8**	**+ 13.9**	**0.01**

[1] Avendaño-Reyes et al., 2006 Livest Sci 105:198-206
[2] Urdaz et al., 2006. J Dairy Sci 89:2000-2006
[3] do Amaral et al., 2009 J Dairy Sci 92:5988-5998
[4] do Amaral et al. 2011 J Dairy Sci 94:86-96
[5] Tao et al., 2011. J Dairy Sci 94:5976-5986
[6] Tao et al., 2012. J Dairy Sci 95:5035-5046

* +19.8 lb/d 3.5% FCM difference, *P=0.01* ** +10.3 lb/d 3.5% FCM yield difference, *P=0.07*

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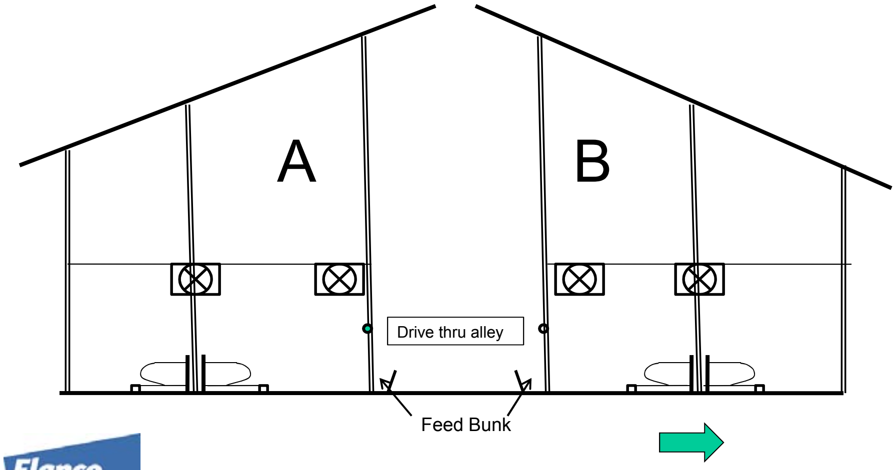
Which side is experiencing greatest heat stress?

Minnesota Dairy Mid Summer 2012 + 90° F for 3 days



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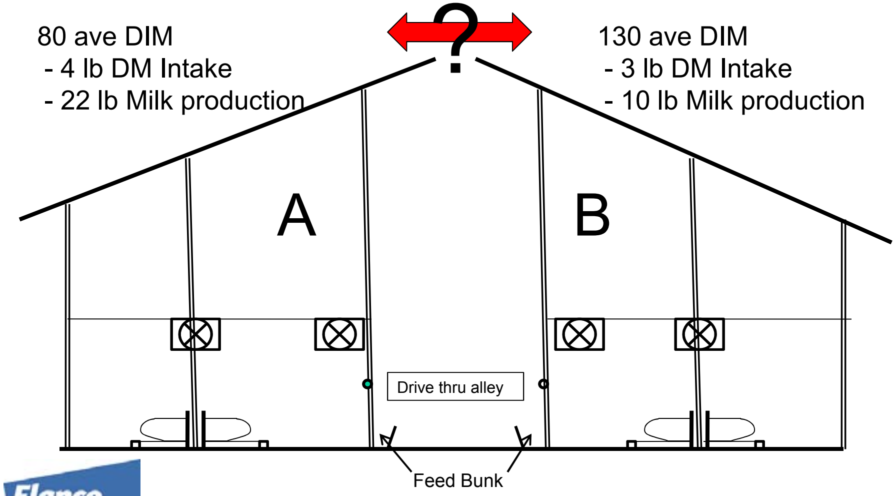
Which side is experiencing greatest heat stress?

Minnesota Dairy Mid Summer 2012 + 90° F for 3 days

80 ave DIM
- 4 lb DM Intake
- 22 lb Milk production

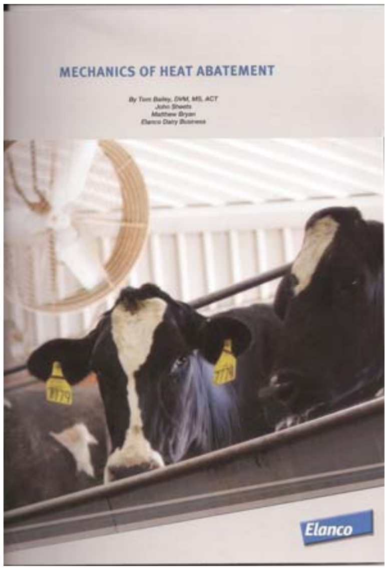
130 ave DIM
- 3 lb DM Intake
- 10 lb Milk production



Mechanics of Heat Abatement

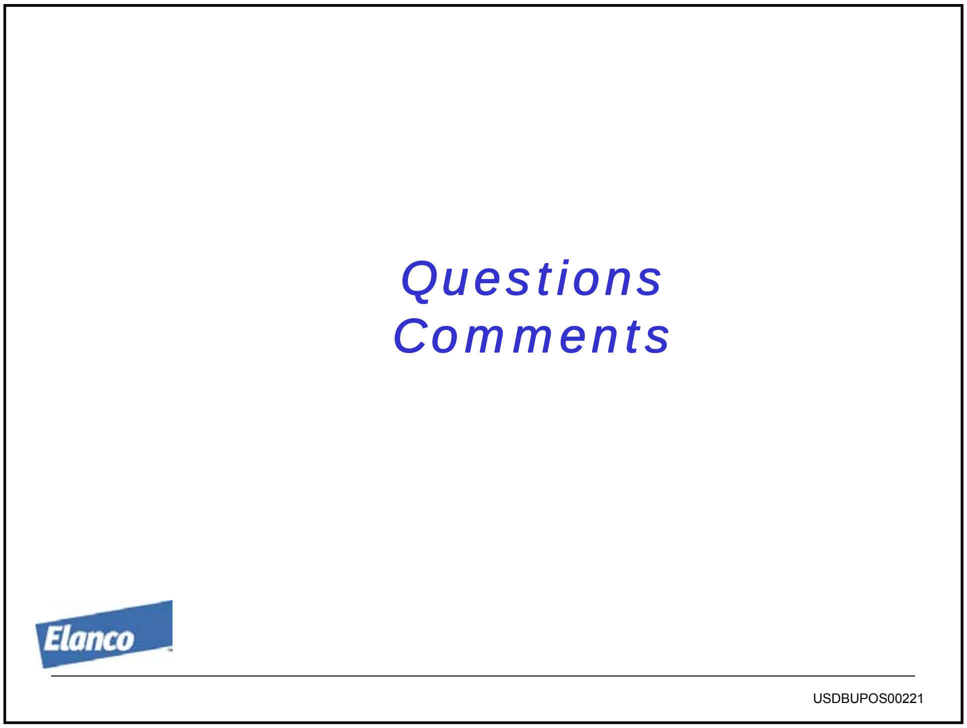
- To Access
  - **www.elanco.us**

> Products/services (drop down menu)
> Dairy
> Posilac®
> Heat Abatement Manual in PDF file



MECHANICS OF HEAT ABATEMENT

By Tom Bailey, DVM, MS, ACT
John Sheets
Matthew Bryan
Elanco Dairy Business



Questions
Comments

Elanco

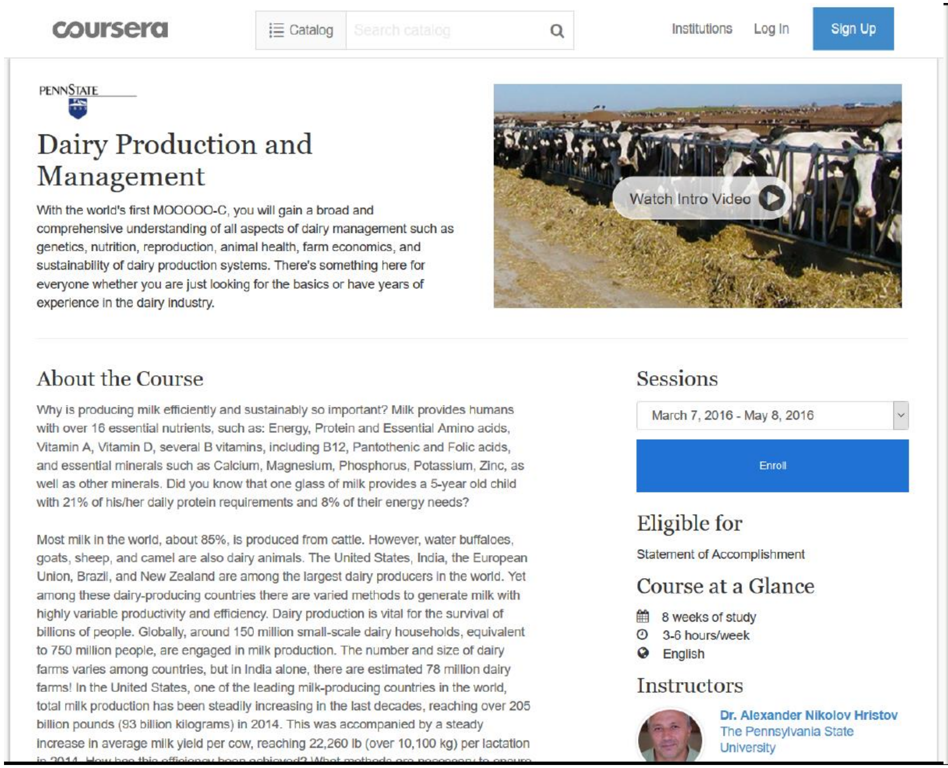
Considerations for Feeding Low Protein Diets to Dairy Cows

Alex N. Hristov and Fabio Giallongo
Department of Animal Science
The Pennsylvania State University

PENNSTATE
College of Agricultural Sciences
ANIMAL SCIENCE

World's first dairy MOOC (Massive Open Online Course)

https://www.coursera.org/course/dairy



Dairy Production and Management

With the world's first MOOOOO-C, you will gain a broad and comprehensive understanding of all aspects of dairy management such as genetics, nutrition, reproduction, animal health, farm economics, and sustainability of dairy production systems. There's something here for everyone whether you are just looking for the basics or have years of experience in the dairy industry.

About the Course

Why is producing milk efficiently and sustainably so important? Milk provides humans with over 16 essential nutrients, such as: Energy, Protein and Essential Amino acids, Vitamin A, Vitamin D, several B vitamins, including B12, Pantothenic and Folic acids, and essential minerals such as Calcium, Magnesium, Phosphorus, Potassium, Zinc, as well as other minerals. Did you know that one glass of milk provides a 5-year old child with 21% of his/her daily protein requirements and 8% of their energy needs?

Most milk in the world, about 85%, is produced from cattle. However, water buffaloes, goats, sheep, and camel are also dairy animals. The United States, India, the European Union, Brazil, and New Zealand are among the largest dairy producers in the world. Yet among these dairy-producing countries there are varied methods to generate milk with highly variable productivity and efficiency. Dairy production is vital for the survival of billions of people. Globally, around 150 million small-scale dairy households, equivalent to 750 million people, are engaged in milk production. The number and size of dairy farms varies among countries, but in India alone, there are estimated 78 million dairy farms! In the United States, one of the leading milk-producing countries in the world, total milk production has been steadily increasing in the last decades, reaching over 205 billion pounds (93 billion kilograms) in 2014. This was accompanied by a steady increase in average milk yield per cow, reaching 22,260 lb (over 10,100 kg) per lactation

Sessions

March 7, 2016 - May 8, 2016

Eligible for

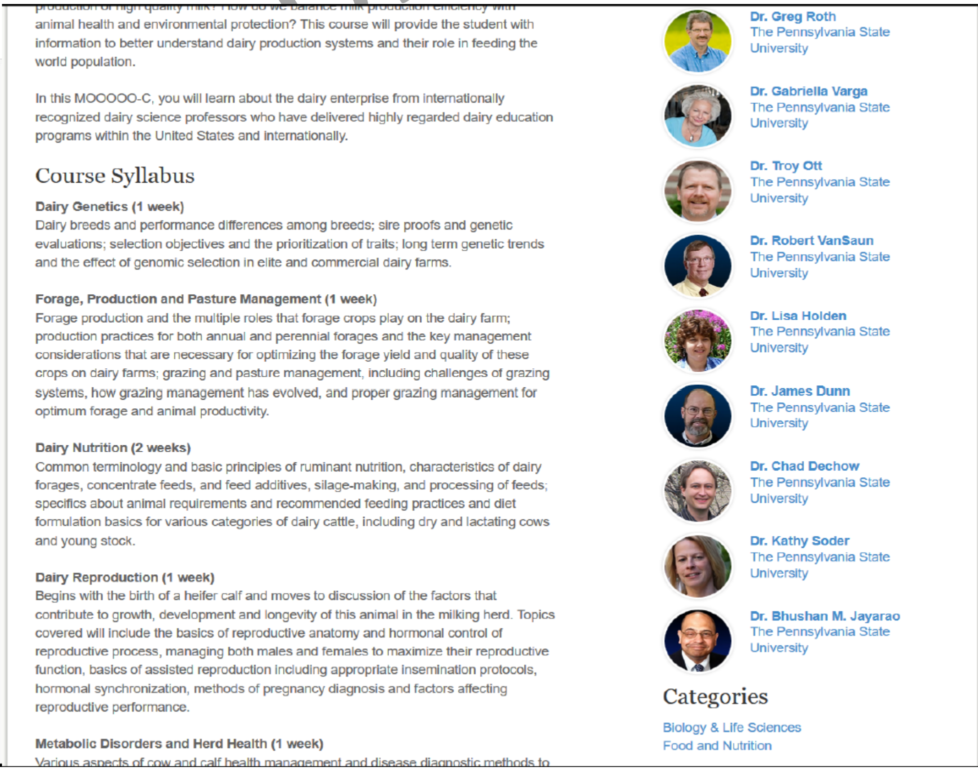
Statement of Accomplishment

Course at a Glance

8 weeks of study
3-6 hours/week
English

Instructors

Dr. Alexander Nikolov Hristov
The Pennsylvania State University



animal health and environmental protection? This course will provide the student with information to better understand dairy production systems and their role in feeding the world population.

In this MOOOOO-C, you will learn about the dairy enterprise from internationally recognized dairy science professors who have delivered highly regarded dairy education programs within the United States and internationally.

Course Syllabus

Dairy Genetics (1 week)
Dairy breeds and performance differences among breeds; sire proofs and genetic evaluations; selection objectives and the prioritization of traits; long term genetic trends and the effect of genomic selection in elite and commercial dairy farms.

Forage, Production and Pasture Management (1 week)
Forage production and the multiple roles that forage crops play on the dairy farm; production practices for both annual and perennial forages and the key management considerations that are necessary for optimizing the forage yield and quality of these crops on dairy farms; grazing and pasture management, including challenges of grazing systems, how grazing management has evolved, and proper grazing management for optimum forage and animal productivity.

Dairy Nutrition (2 weeks)
Common terminology and basic principles of ruminant nutrition, characteristics of dairy forages, concentrate feeds, and feed additives, silage-making, and processing of feeds; specifics about animal requirements and recommended feeding practices and diet formulation basics for various categories of dairy cattle, including dry and lactating cows and young stock.

Dairy Reproduction (1 week)
Begins with the birth of a heifer calf and moves to discussion of the factors that contribute to growth, development and longevity of this animal in the milking herd. Topics covered will include the basics of reproductive anatomy and hormonal control of reproductive process, managing both males and females to maximize their reproductive function, basics of assisted reproduction including appropriate insemination protocols, hormonal synchronization, methods of pregnancy diagnosis and factors affecting reproductive performance.

Metabolic Disorders and Herd Health (1 week)

Dr. Greg Roth
The Pennsylvania State University

Dr. Gabriella Varga
The Pennsylvania State University

Dr. Troy Ott
The Pennsylvania State University

Dr. Robert VanSaun
The Pennsylvania State University

Dr. Lisa Holden
The Pennsylvania State University

Dr. James Dunn
The Pennsylvania State University

Dr. Chad Dechow
The Pennsylvania State University

Dr. Kathy Soder
The Pennsylvania State University

Dr. Bhushan M. Jayarao
The Pennsylvania State University

Categories

Biology & Life Sciences
Food and Nutrition

PENNSTATE
College of Agricultural Sciences
ANIMAL SCIENCE

Importance of balancing dietary protein

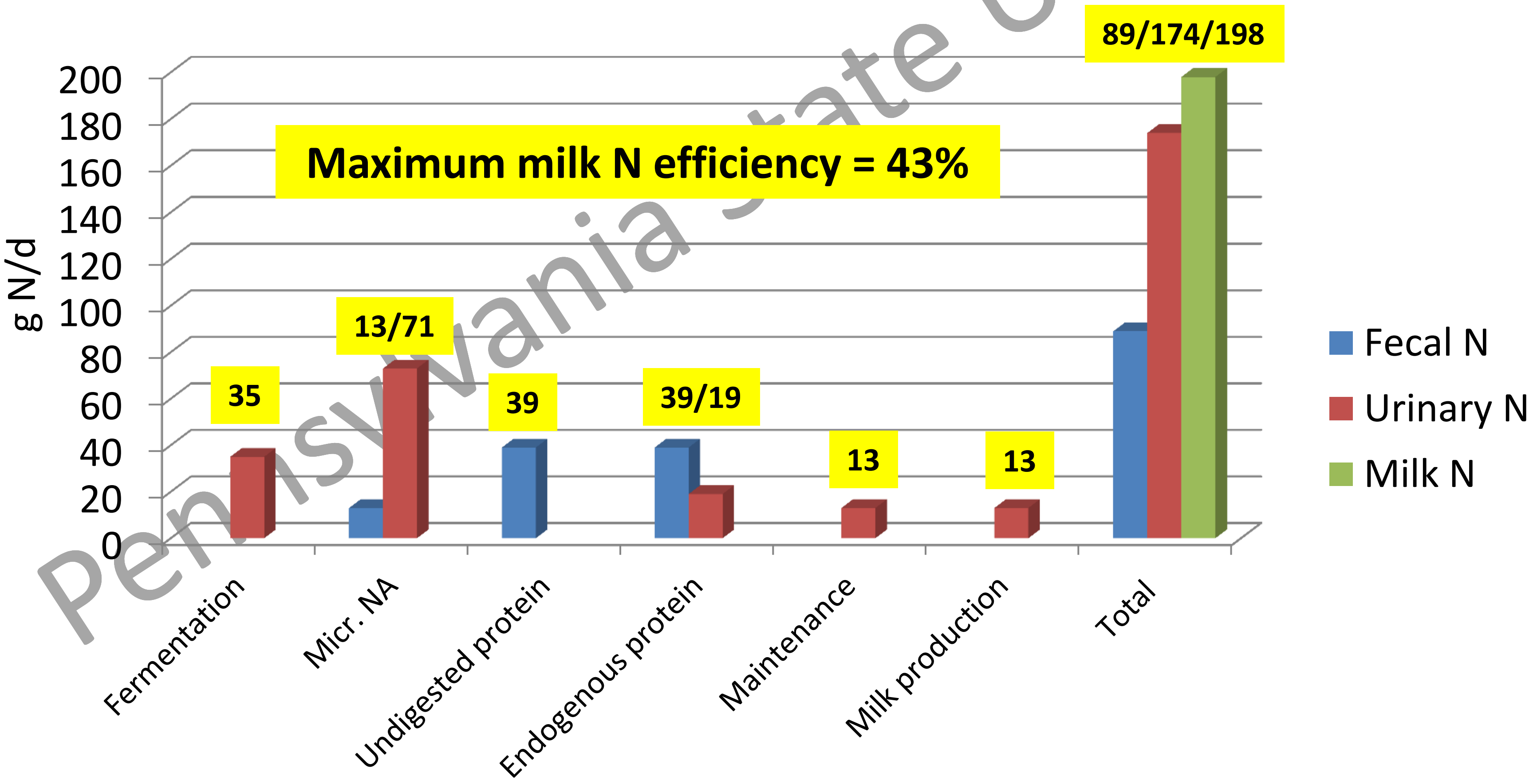
- Direct effect on N efficiency, DMI, production, milk composition
- Direct effect on feed cost
- Environmental issues
- Reproduction?

What is a low-protein diet?

- Diets supplying MP below requirements?
- Diets with CP below "industry standards"?
  - Several surveys showed average CP in dairy diets being around **17%**
  - **Now many diets tend to be closer to 16%**
  - **I would say, < 15% CP**

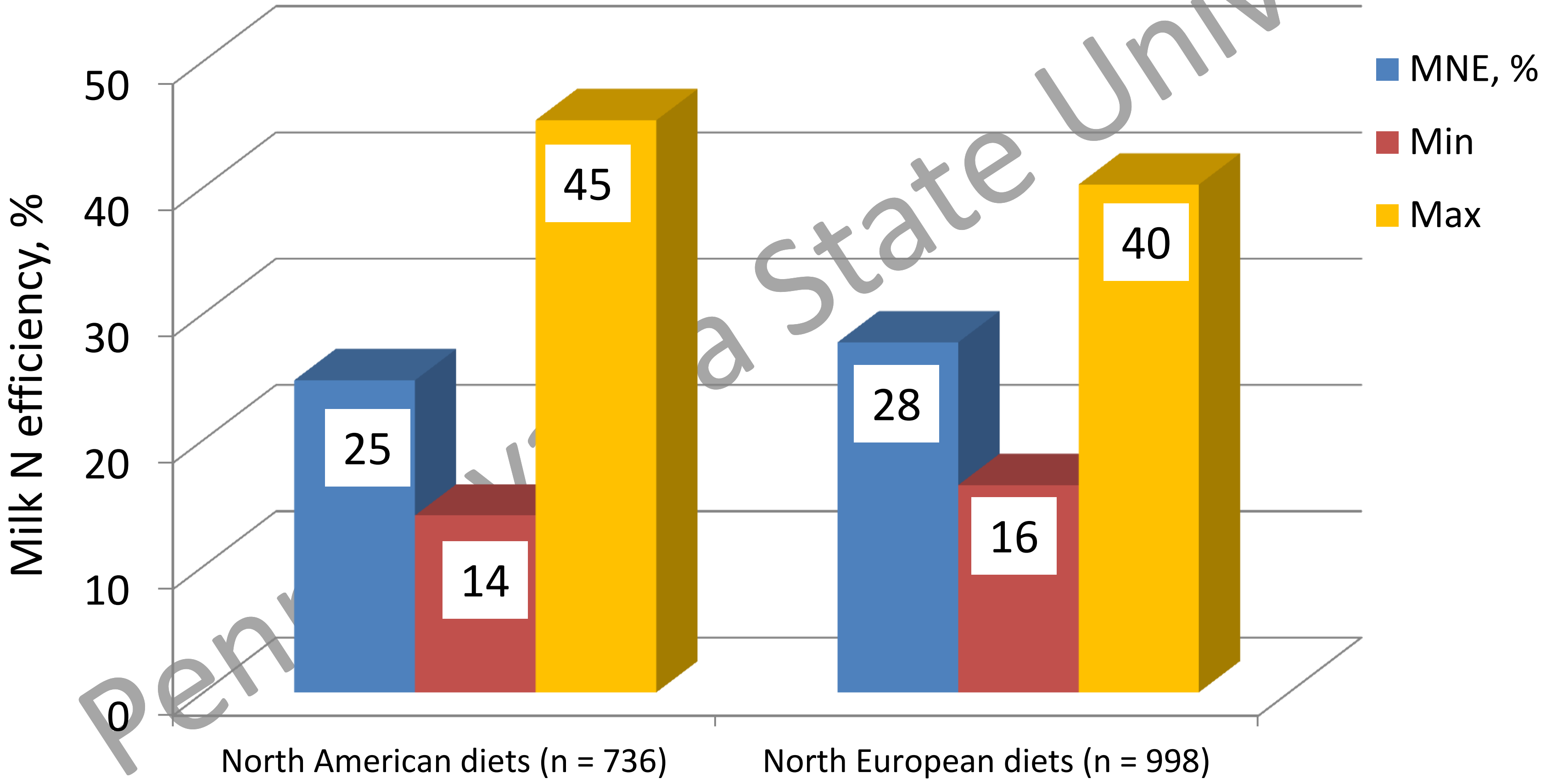
Dijkstra et al. (2013)

Milk N efficiency: flow of N through a dairy cow (40 kg/d milk; 3.15% true protein)



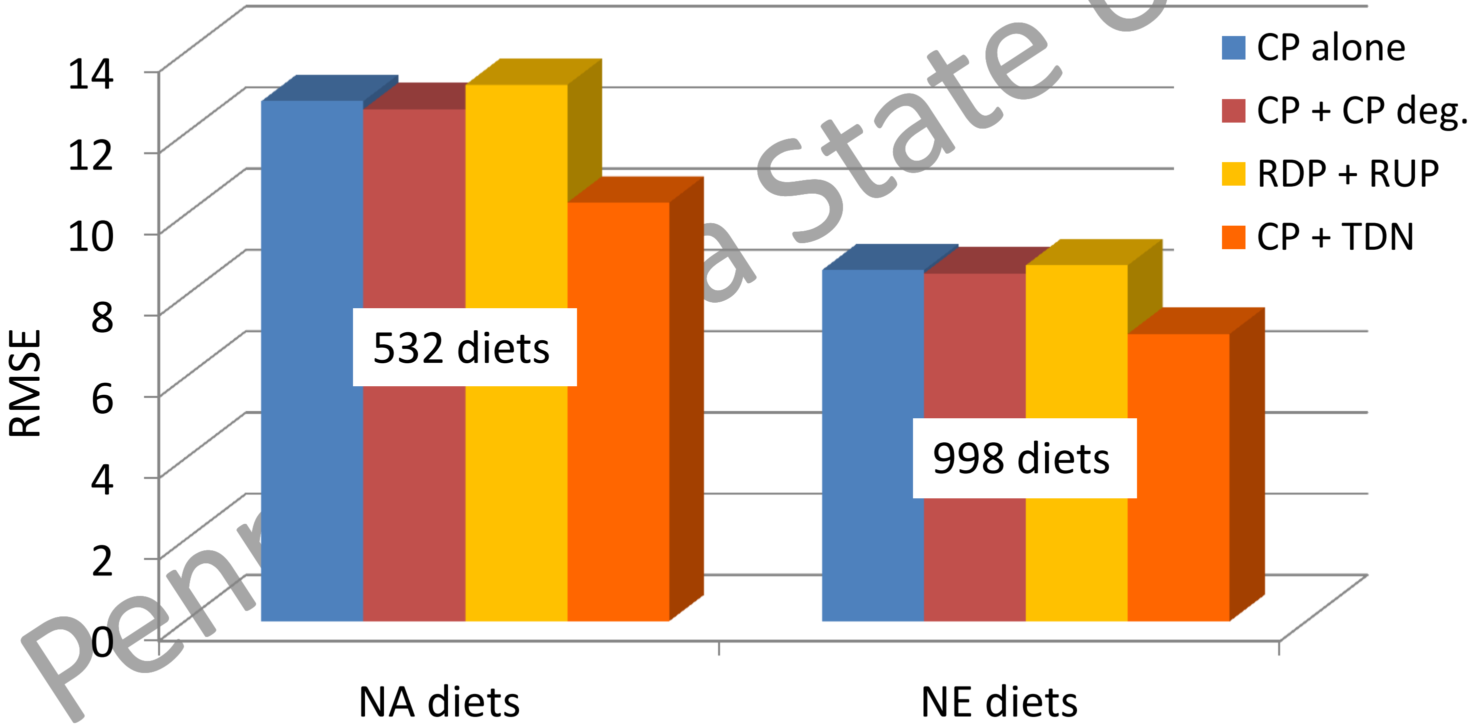
Huhtanen & Hristov, 2009

Milk N efficiency in dairy cows



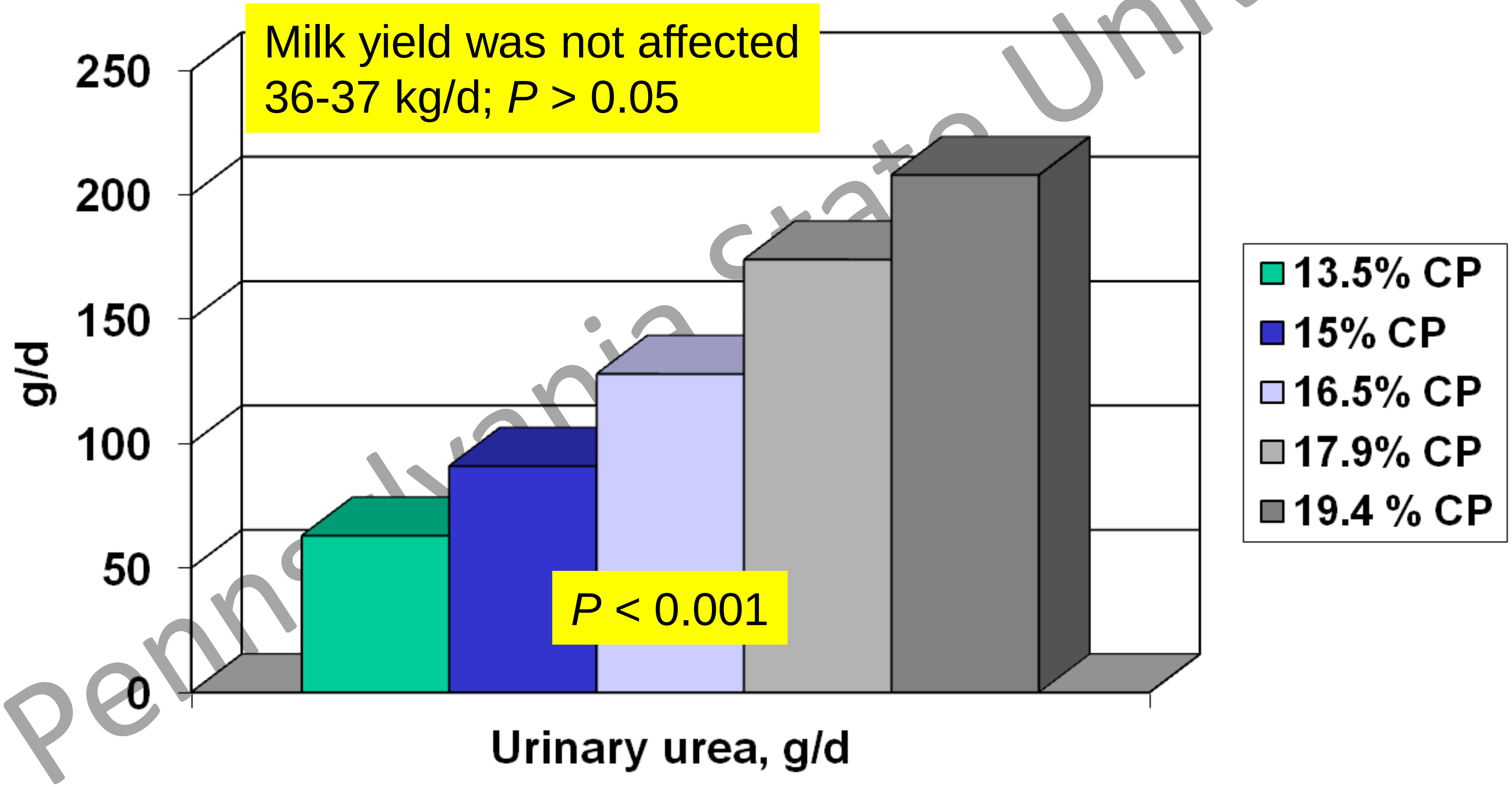
Huhtanen & Hristov, 2009

Crude protein (% or intake) sufficiently explains the variability in MNE



Colmenero and Broderick, 2006

Excess N is lost with urine

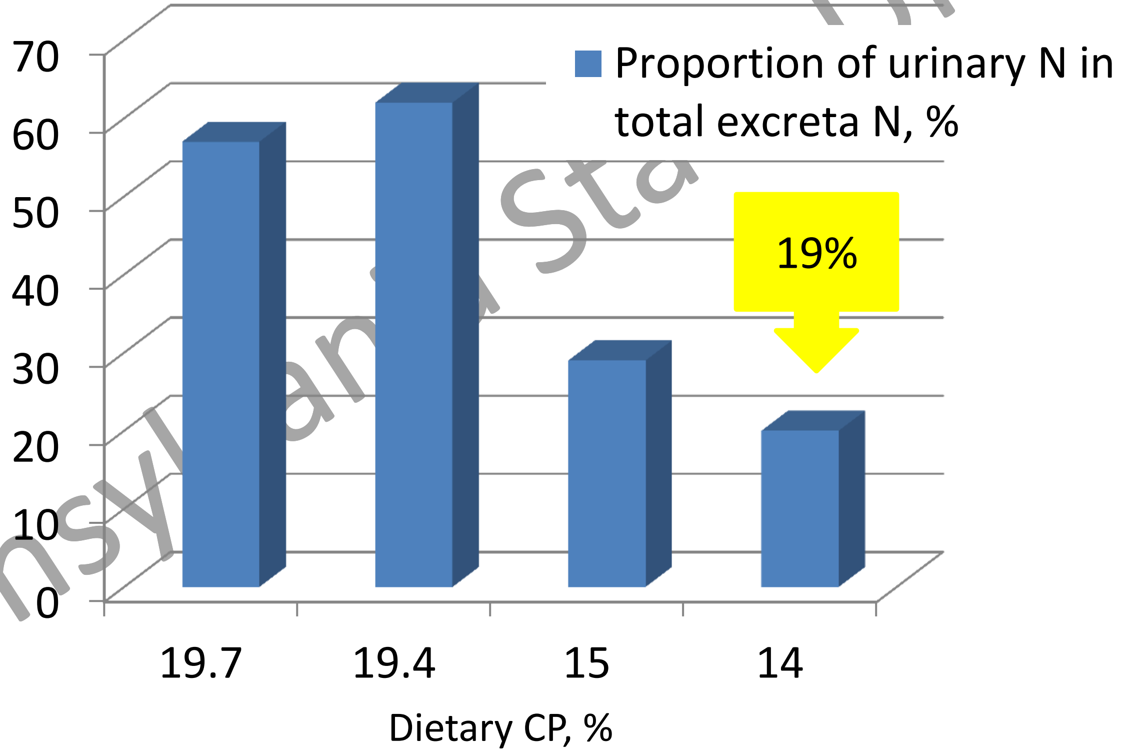


Milk yield was not affected
36-37 kg/d; $P > 0.05$

$P < 0.001$

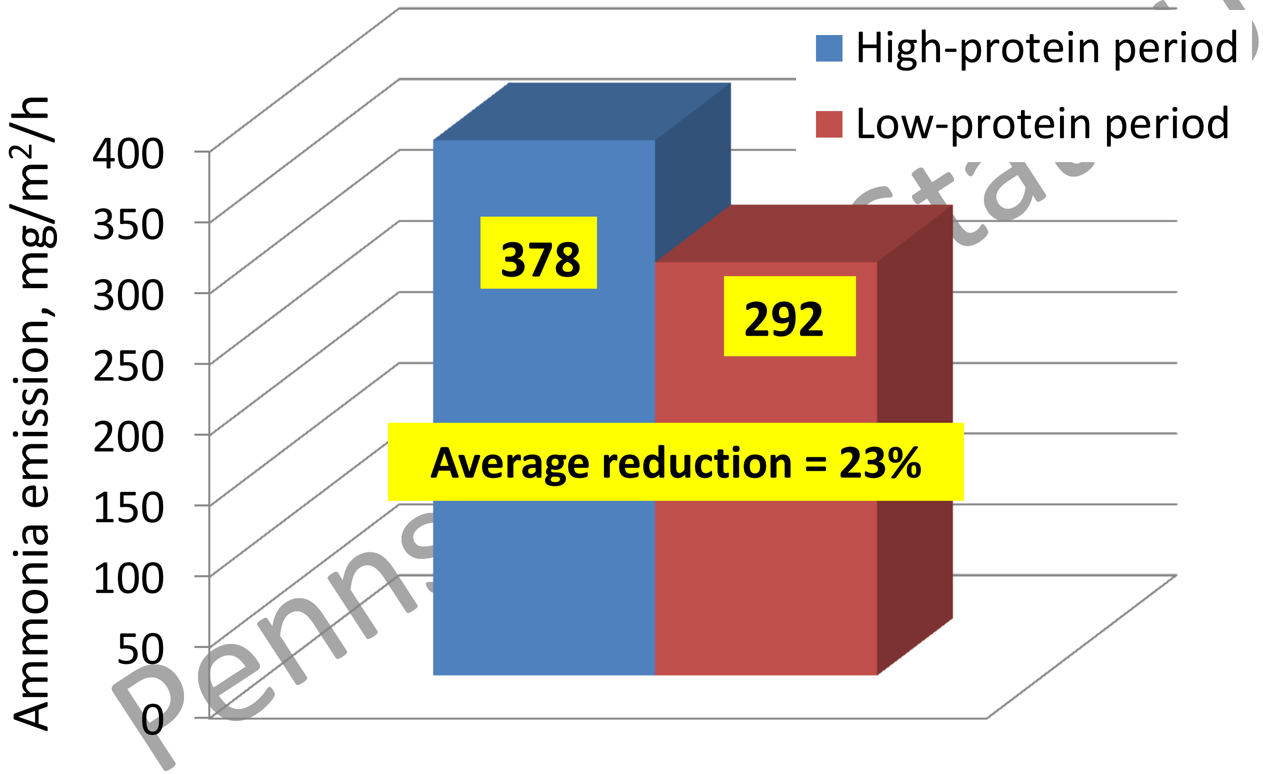
Penn State and Idaho data

Dietary protein reduction decreases urinary N losses



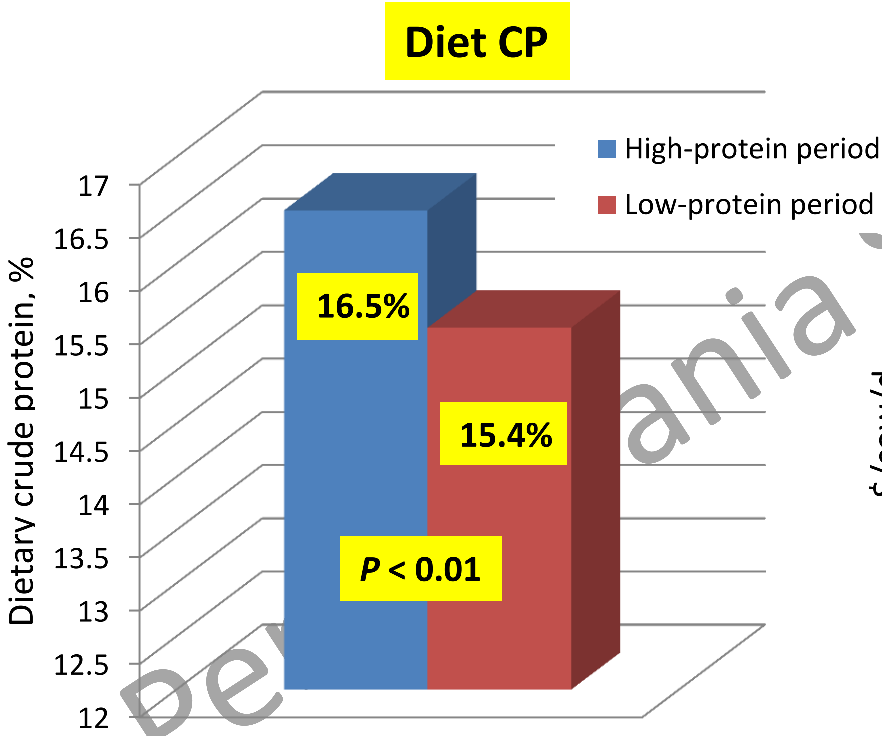
Hristov et al., 2015

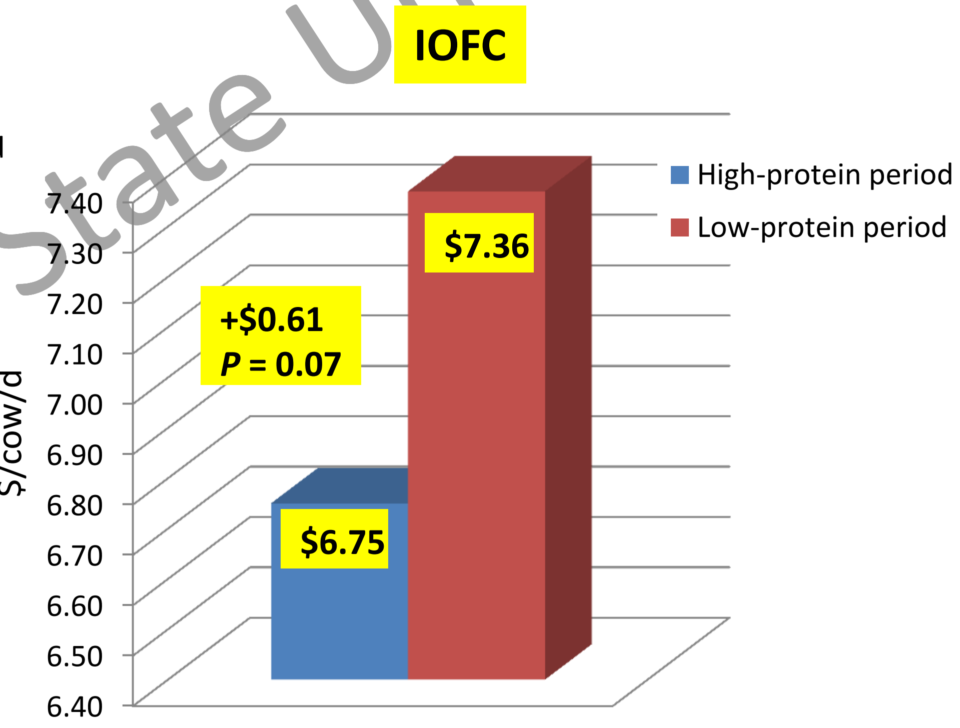
On-farm ammonia emissions from manure – CP 16.5 vs. 15.4%



Hristov et al., 2015

Usually, reduction in CP will decrease feed cost

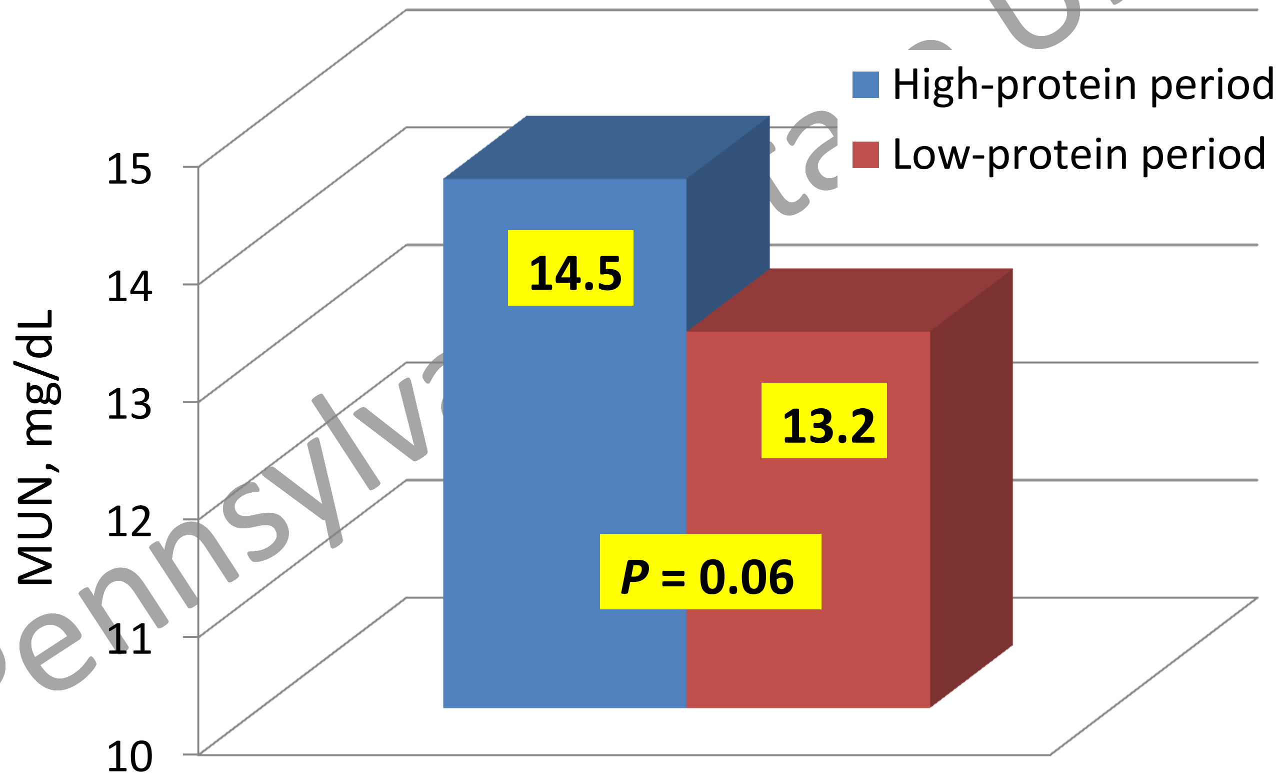




No effect on milk production or components

Hristov et al., 2012

MUN: a reasonably good indicator of protein status



Bulk-tank milk MUN data

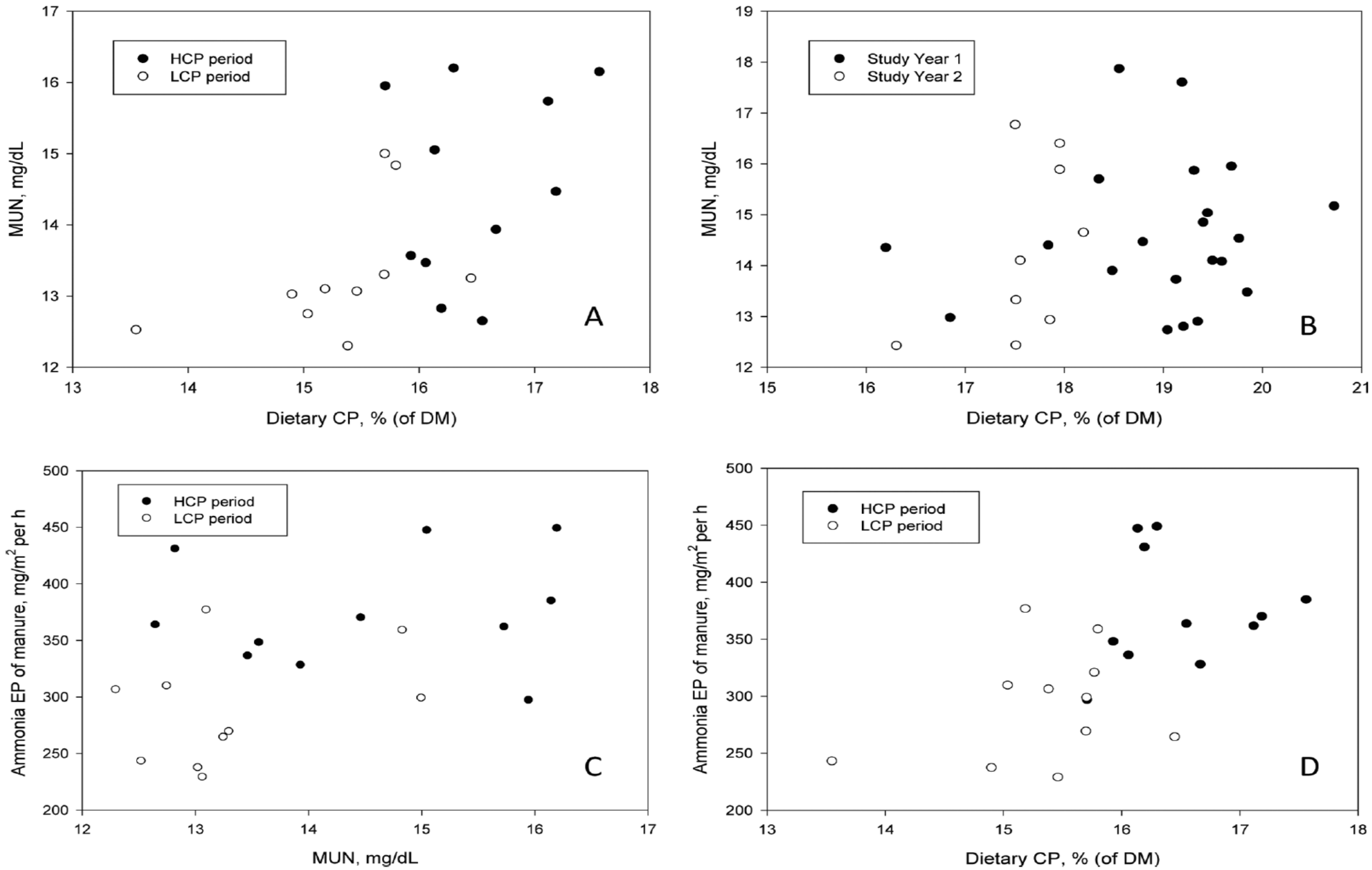


Figure 2. Scatter plots of bulk-tank milk urea N (MUN), dietary CP concentration, and ammonia emitting potential (EP) of reconstituted manure from commercial dairy farms. (A) Analyzed dietary CP and bulk-tank MUN (current study). (B) Analyzed dietary CP and bulk-tank MUN (unpublished data from Hristov et al., 2006). (C) Bulk-tank MUN and ammonia EP of manure (current study). (D) Analyzed dietary CP and ammonia EP of manure (current study). HCP and LCP = high-CP and low-CP periods of the study, respectively. Symbols represent averages of individual farm data.

Low-protein diets

NRC (2001) protein recommendations for Holsteins

Category	Production	MP, g/d	CP, %	RDP, %	RUP, %
Lactating cows	90 DIM, 45 kg/d MY, 3% TP, 27 kg/d DMI	2,950 (about 11% of DMI)	16.0	9.8 (61%)	6.2 (39%)
Fresh cows	11 DIM, 35 kg/d MY, 3% TP, 15.6 kg/d DMI	2,160	19.5	10.5	9.0
1st lactation heifers	270 d pregnant, 10.6 kg/d DMI, 960 g/d ADG	1,030	15.0 (13.5-15.0)	10.2	4.9
Dry cows: far-off	240 d pregnant, 14.4 kg/d DMI	870	9.9	7.7	2.2
Dry cows: close-up	270-279 d pregnant, 13.7-10.1 kg/d DMI	900-810	10.8-12.4	8.7-9.6	2.1-2.8

Both of these diets meet MP requirements

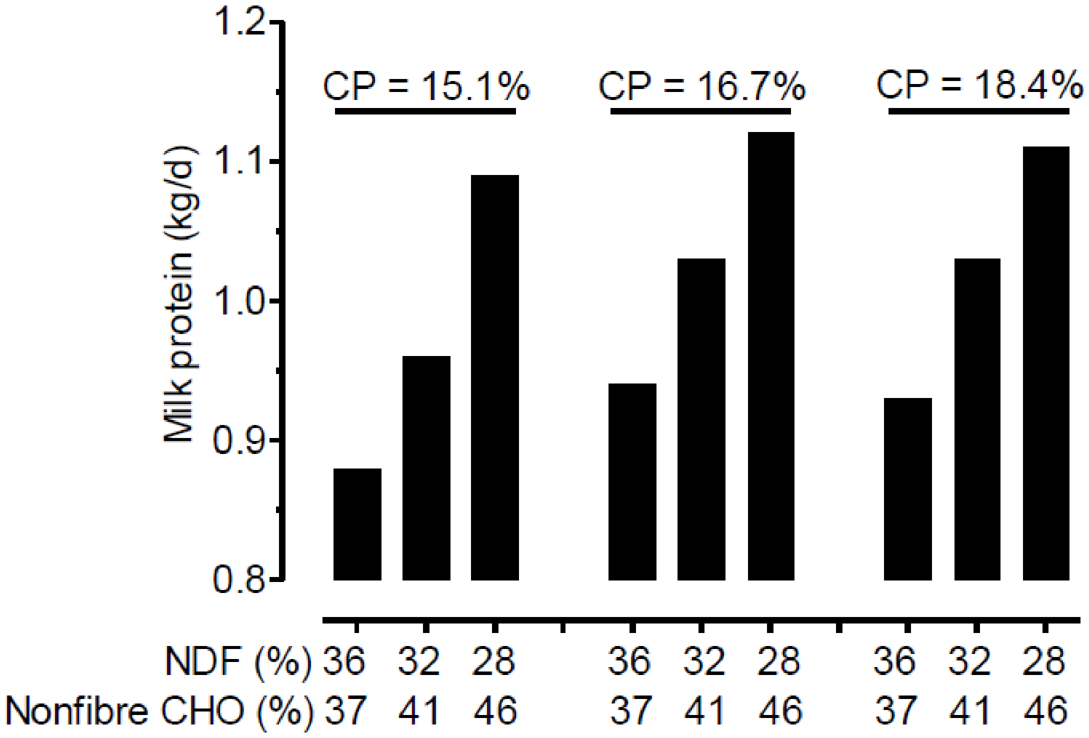
Table 1. Example diets formulated using NRC (2001) to meet the metabolizable protein requirements of a 680-kg/90-days-in-milk cow with milk production of around 40 kg/day, 3% milk true protein, and 25 kg/day DMI

Item	Diet formulated at 16% CP	Diet formulated at 17% CP
Crude protein, %	16.0	17.0
Rumen-degraded protein, % CP	10.0	11.0
Rumen-undegraded protein, % CP	6.0	6.0
Rumen-degraded protein supply, g/day	2,490	2,780
Rumen-degraded protein balance, g/day	10	296
Rumen-undegraded protein supply, g/day	1,500	1,540
Rumen-undegraded protein balance, g/day	37	30
MP supply, g/day	2,700	2,700
MP balance, g/day	30	25
NE_L balance, Mcal/day	1.3	1.6

MP = Metabolizable protein; NE_L = Net energy for lactation.

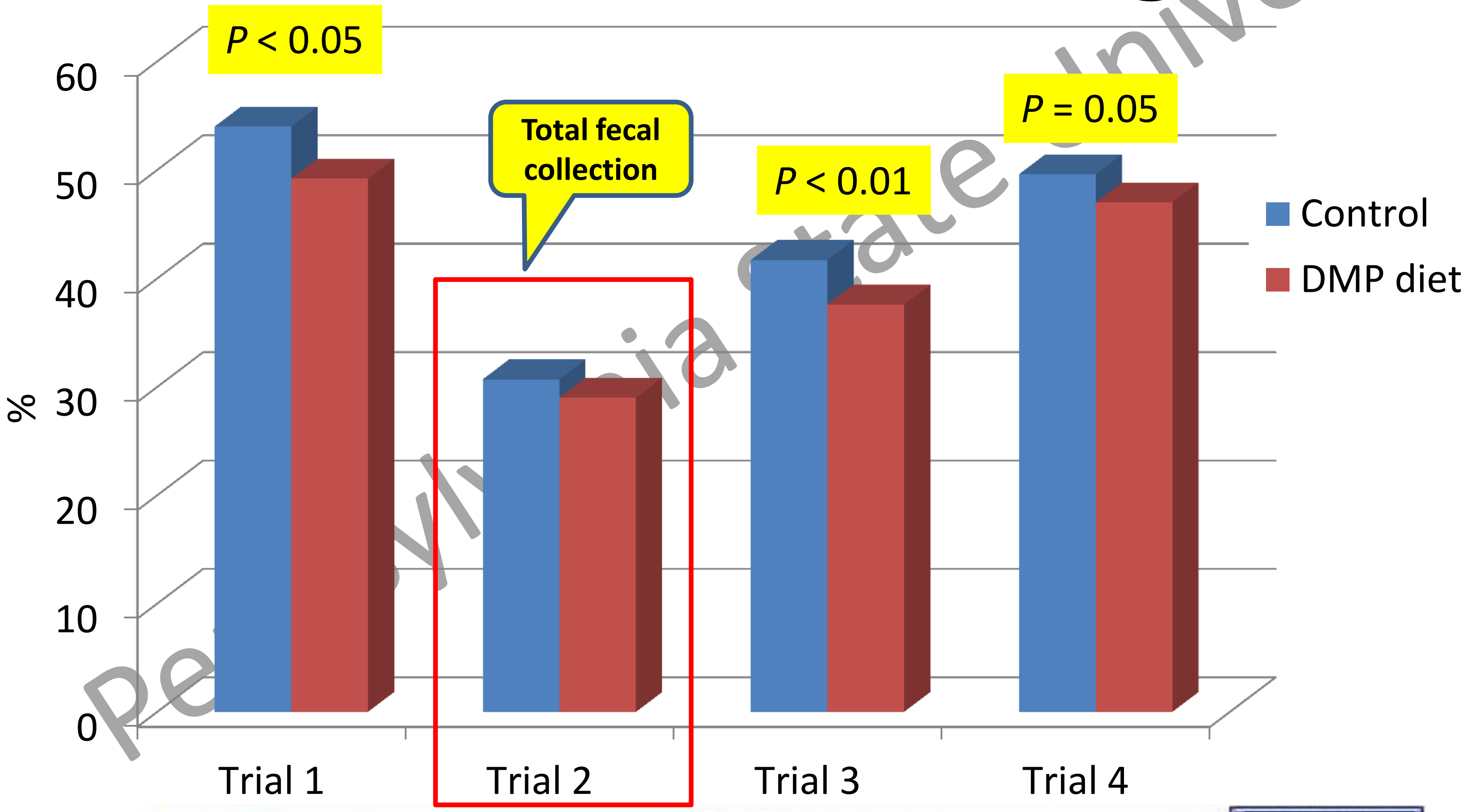
Sinclair et al. (2013); data from Broderick (2003)

Fermentable energy is the first limiting nutrient in the rumen



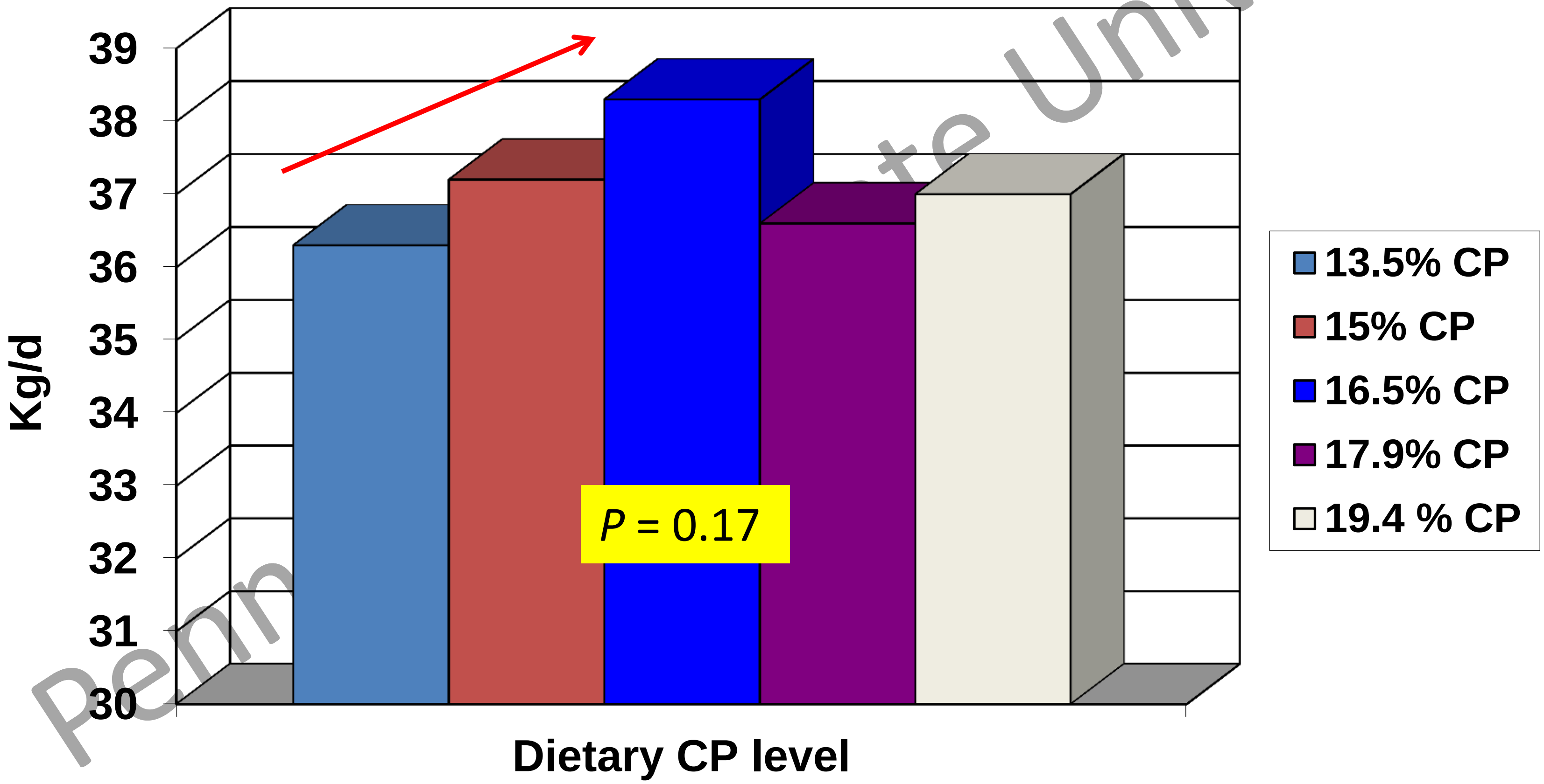
Penn State data

But, low-CP/RDP diets may decrease NDFdig



Colmenero and Broderick, 2006

More long-term experiments are needed



Wu & Satter (2000)

Results from long-term studies

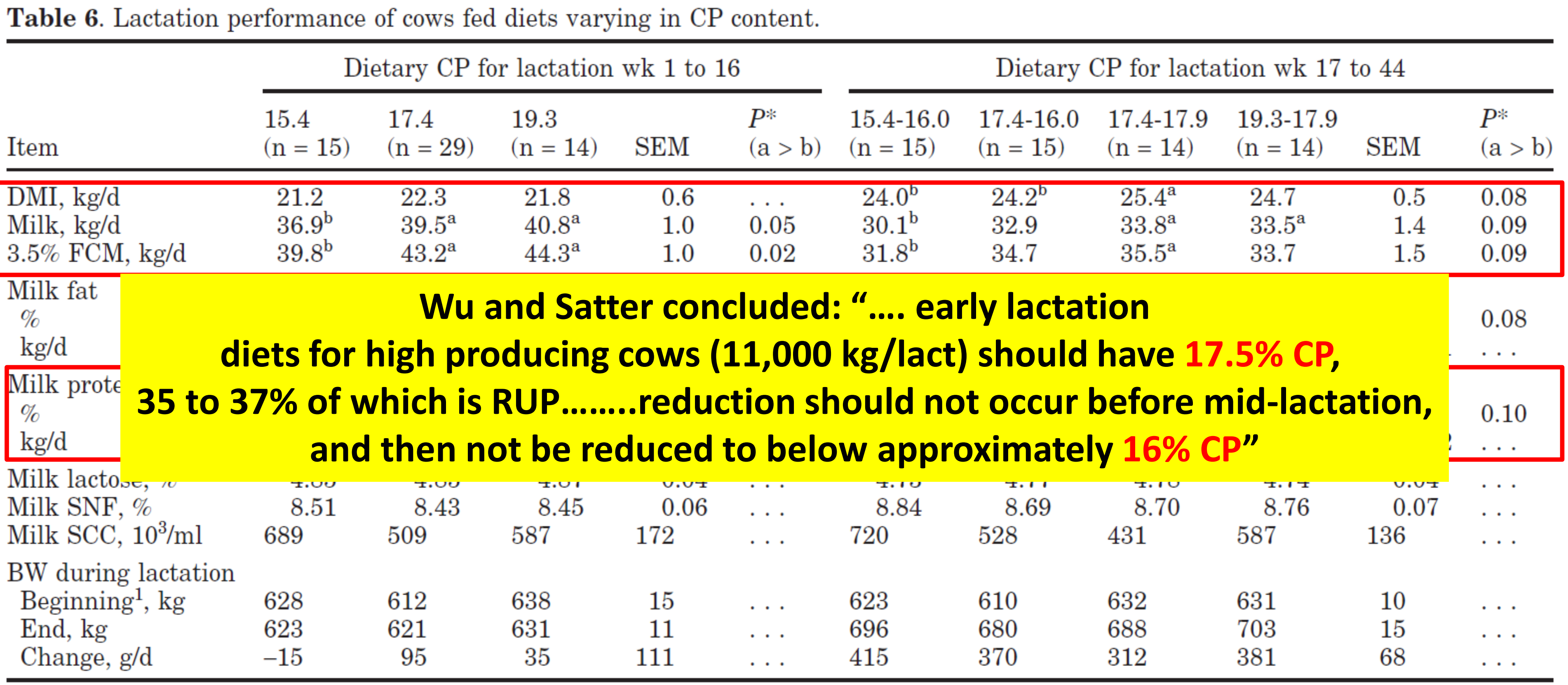


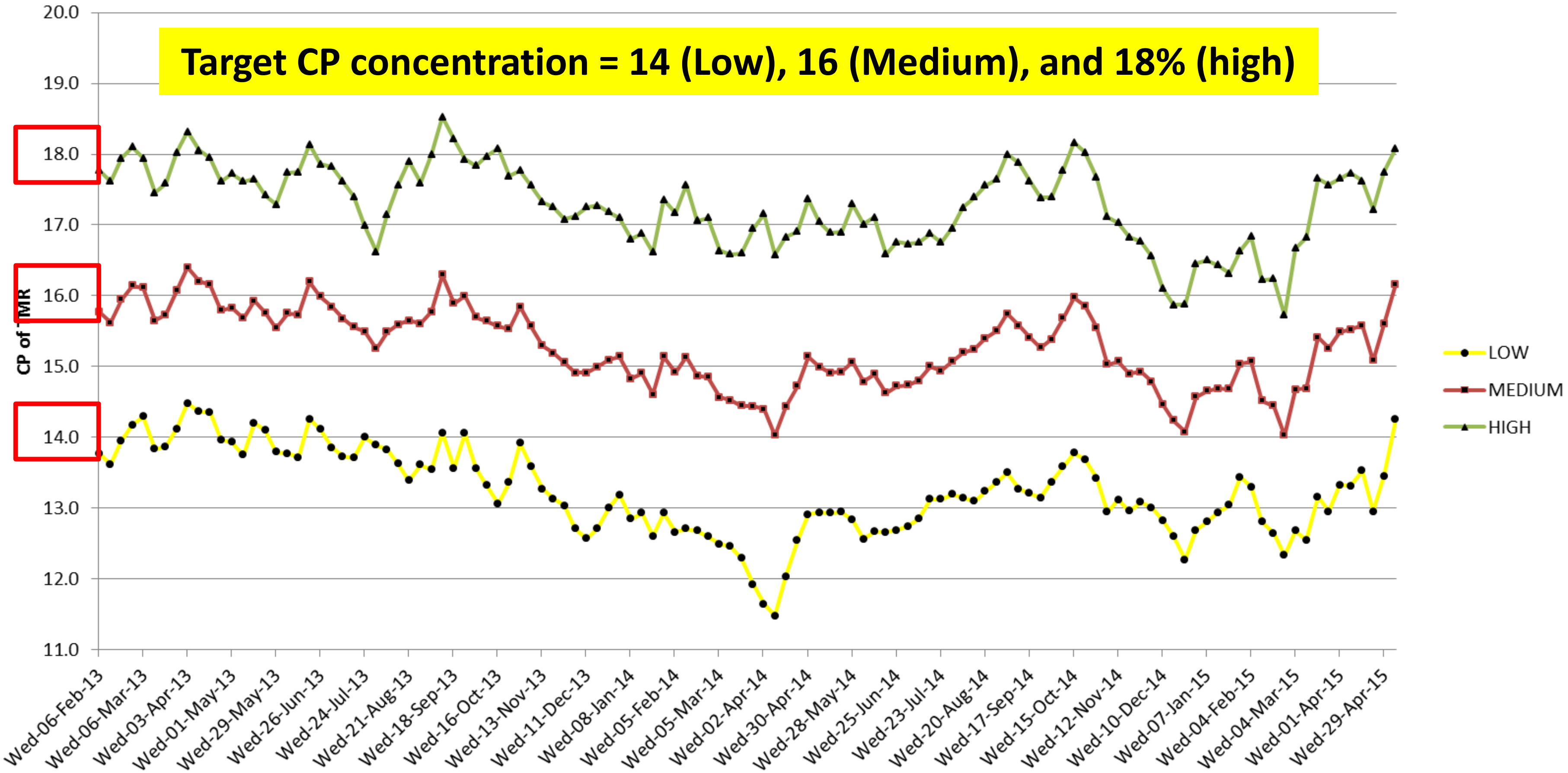
Table 6. Lactation performance of cows fed diets varying in CP content.

Item	Dietary CP for lactation wk 1 to 16 15.4 (n = 15)	 17.4 (n = 29)	 19.3 (n = 14)	 SEM	 *P** (a > b)	Dietary CP for lactation wk 17 to 44 15.4-16.0 (n = 15)	 17.4-16.0 (n = 15)	 17.4-17.9 (n = 14)	 19.3-17.9 (n = 14)	 SEM	 *P** (a > b)
DMI, kg/d	21.2	22.3	21.8	0.6	. . .	24.0^b	24.2^b	25.4^a	24.7	0.5	0.08
Milk, kg/d	36.9^b	39.5^a	40.8^a	1.0	0.05	30.1^b	32.9	33.8^a	33.5^a	1.4	0.09
3.5% FCM, kg/d	39.8^b	43.2^a	44.3^a	1.0	0.02	31.8^b	34.7	35.5^a	33.7	1.5	0.09
Milk fat											
%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.08
kg/d	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	. . .
Milk prote											
%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.10
kg/d	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	. . .
Milk lactose, %	[illegible]	[illegible]	[illegible]	[illegible]	. . .	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	. . .
Milk SNF, %	8.51	8.43	8.45	0.06	. . .	8.84	8.69	8.70	8.76	0.07	. . .
Milk SCC, 10^3/ml	689	509	587	172	. . .	720	528	431	587	136	. . .
BW during lactation											
Beginning[1], kg	628	612	638	15	. . .	623	610	632	631	10	. . .
End, kg	623	621	631	11	. . .	696	680	688	703	15	. . .
Change, g/d	–15	95	35	111	. . .	415	370	312	381	68	. . .

Wu and Satter concluded: "…. early lactation diets for high producing cows (11,000 kg/lact) should have 17.5% CP, 35 to 37% of which is RUP……..reduction should not occur before mid-lactation, and then not be reduced to below approximately 16% CP"

Reynolds et al. (2015)

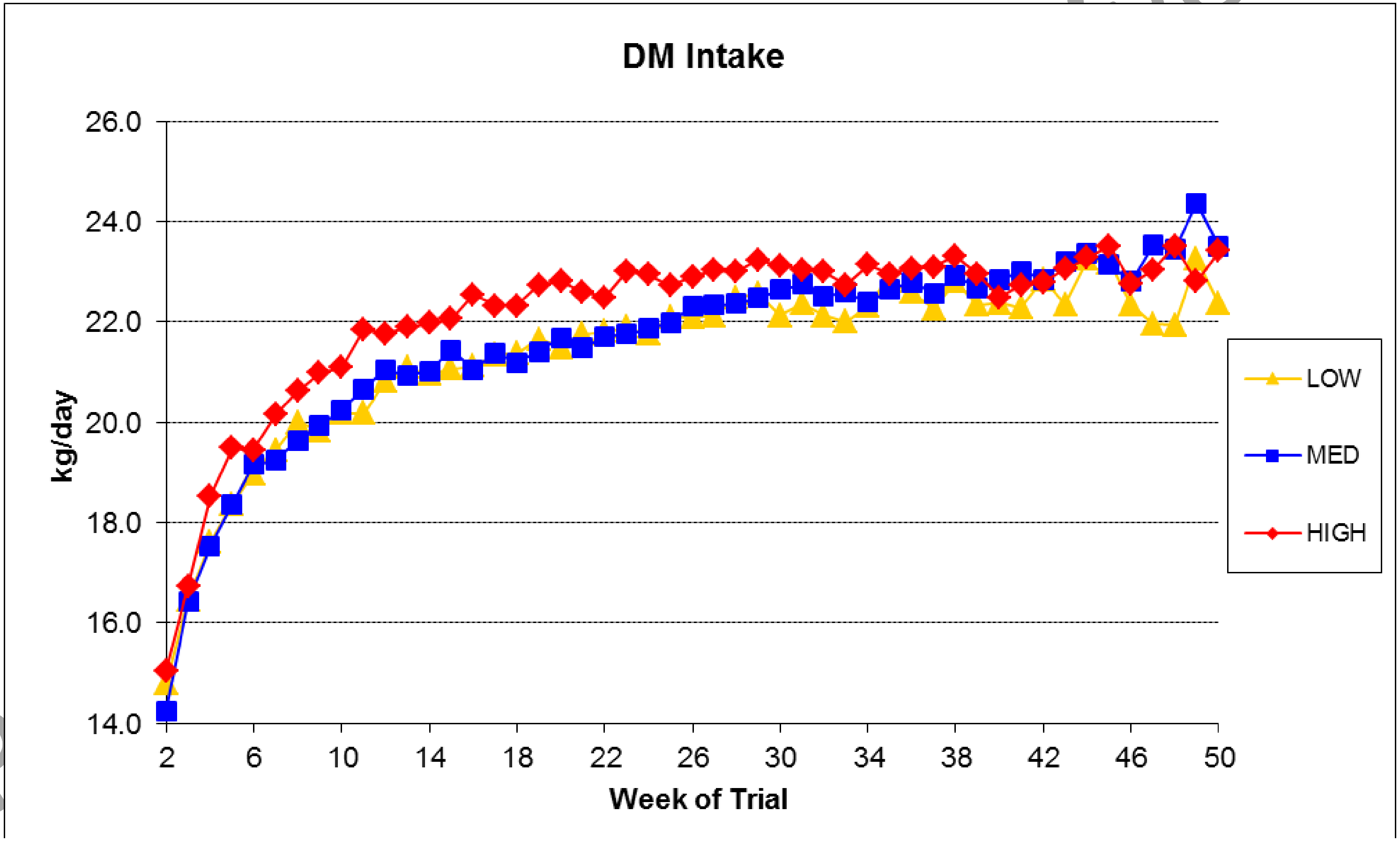
DEFRA (UK) long-term study



Target CP concentration = 14 (Low), 16 (Medium), and 18% (high)

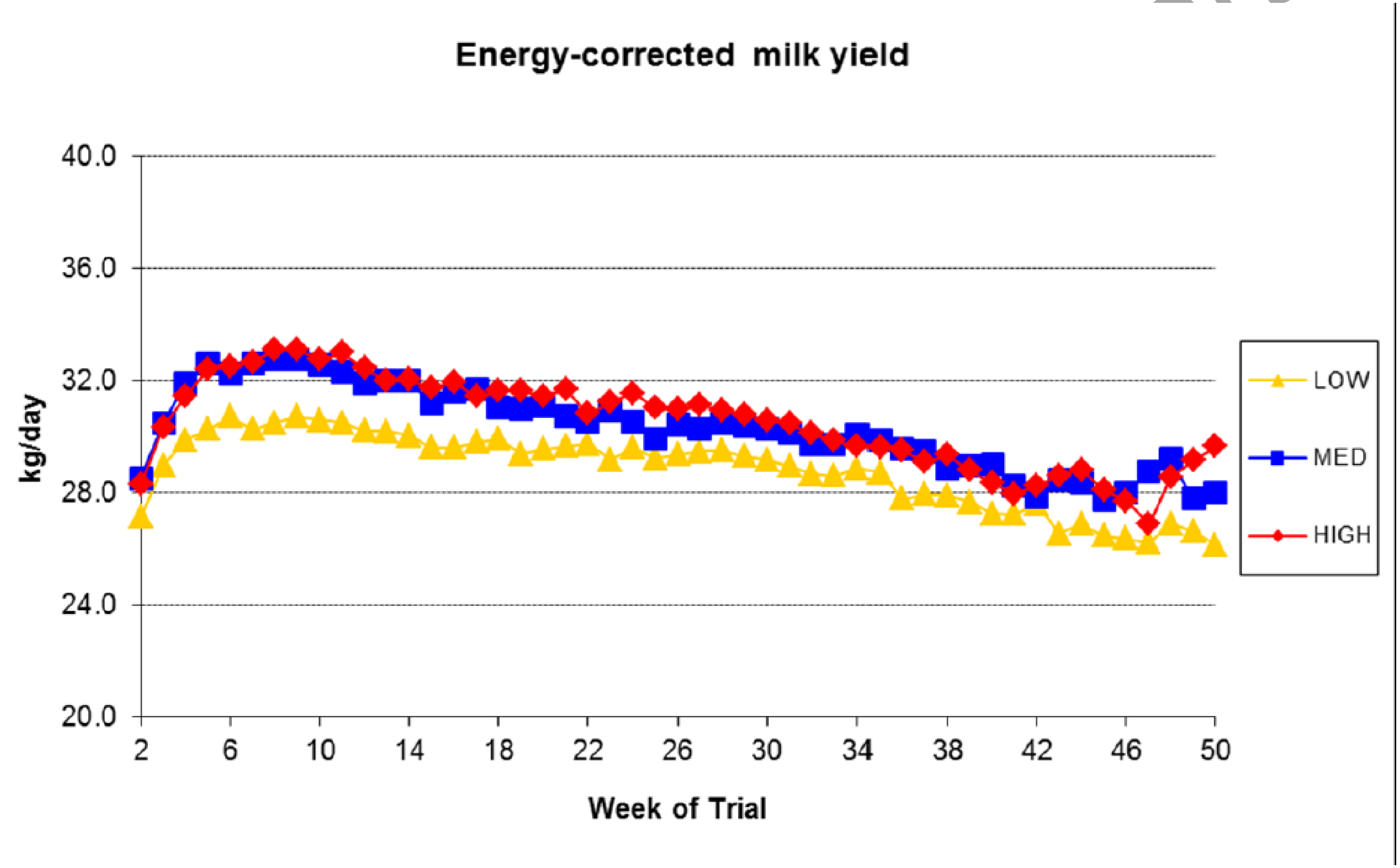
Reynolds et al. (2015)

DEFRA (UK) long-term study



Reynolds et al. (2015)

DEFRA (UK) long-term study



Reynolds et al. (2015)

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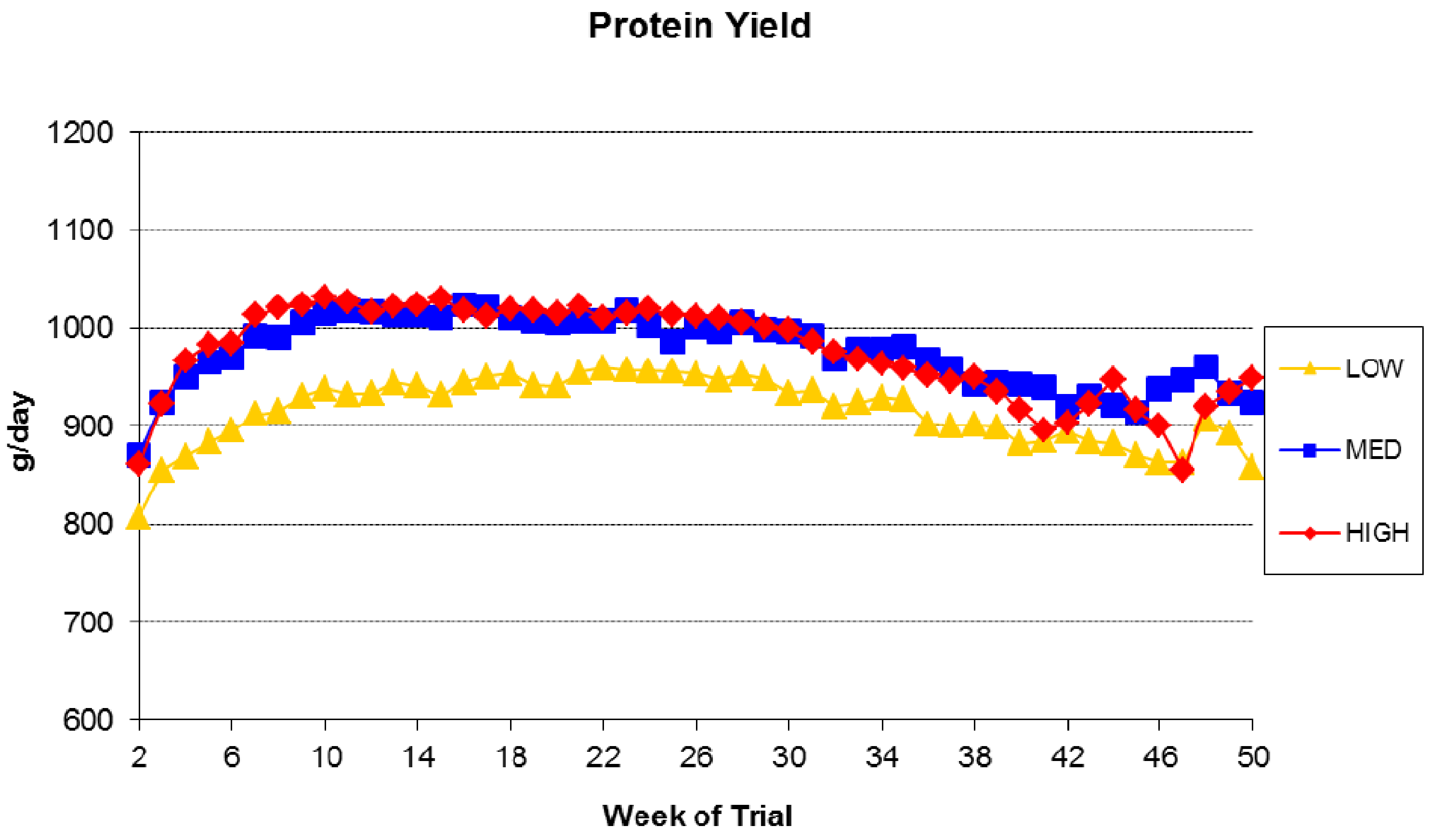

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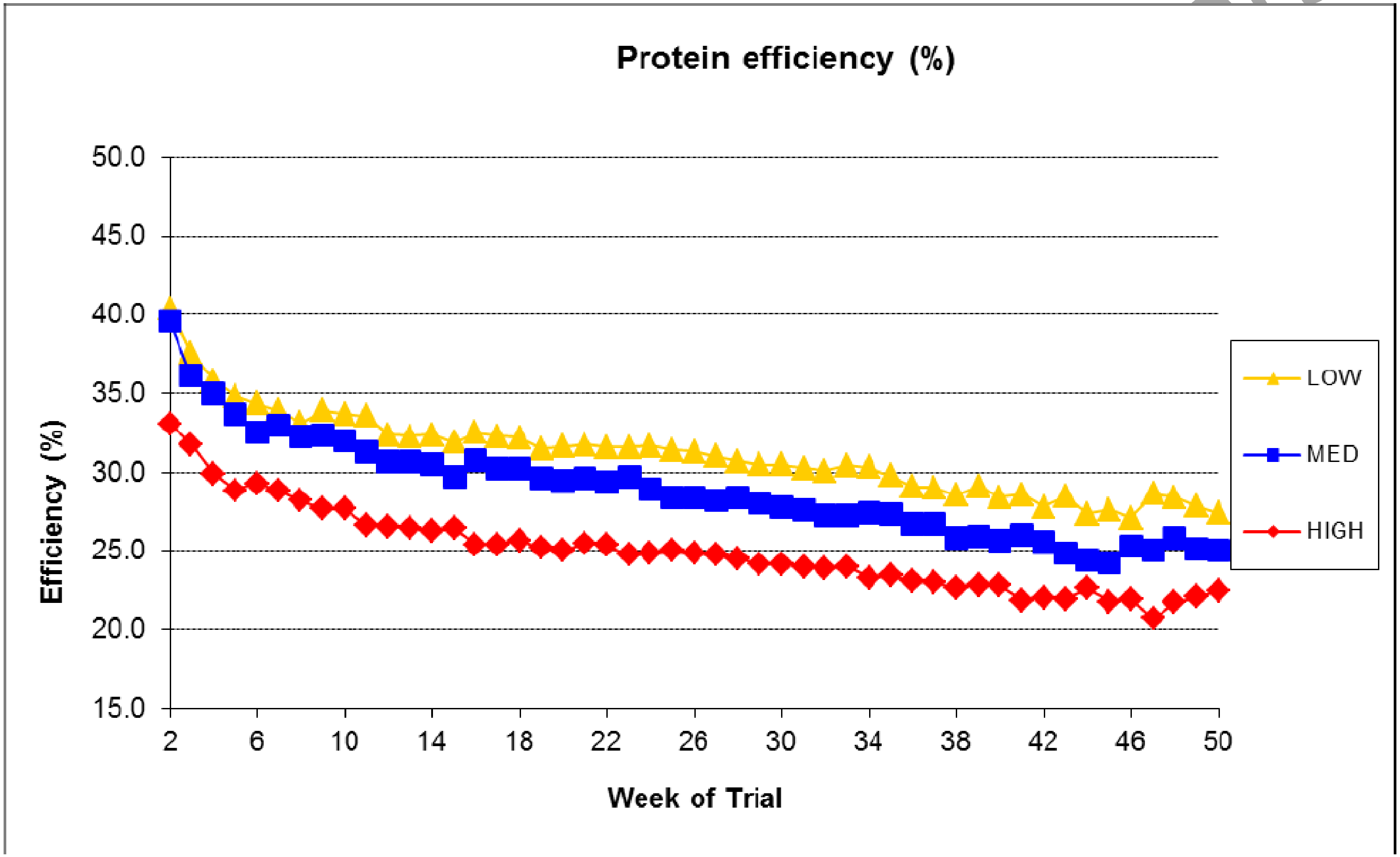
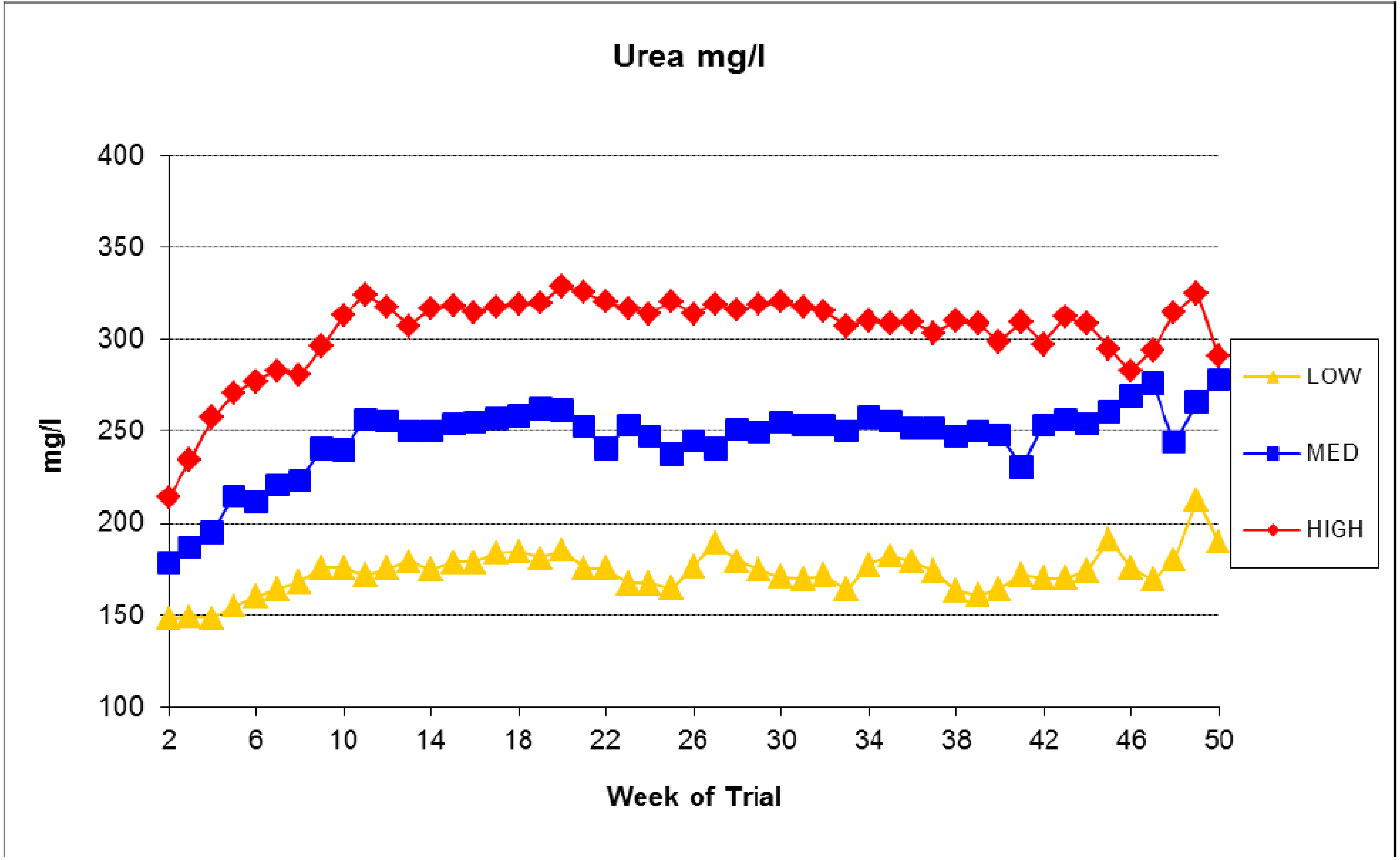


Reynolds et al. (2015)

DEFRA (UK) long-term study



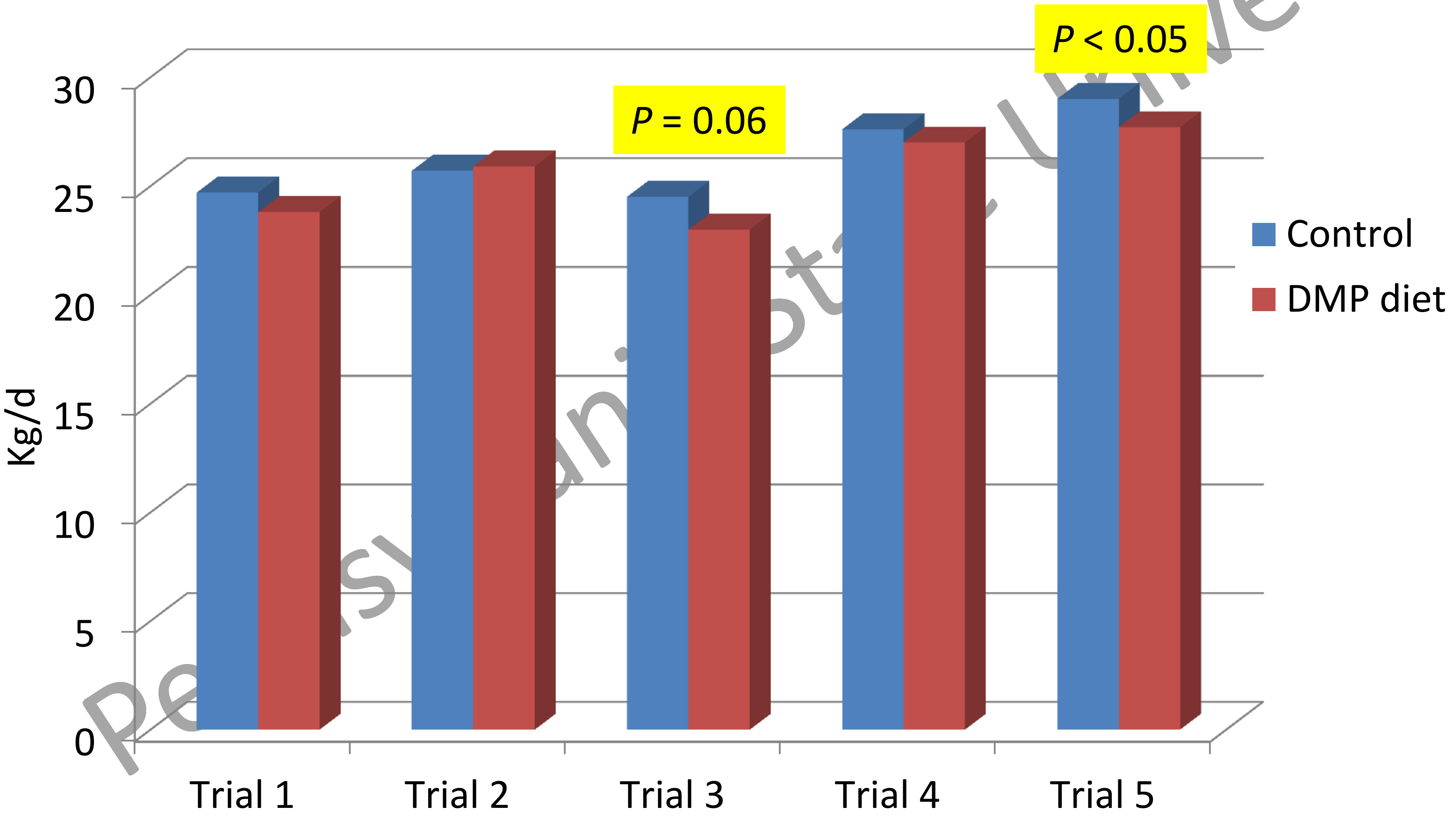
Reynolds et al. (2015)

DEFRA (UK) long-term study

- Reductions in milk yield less than expected
  - Heifers vs multi-parous cows
- DMI reduced for lowest protein diet
- Improvements in N use efficiency apparent, but with large animal variation
- Responses in second and third lactation may (will) differ
- Variation in composition of feeds a challenge

Penn State data

Low-protein diets (around 14%) effect on DMI

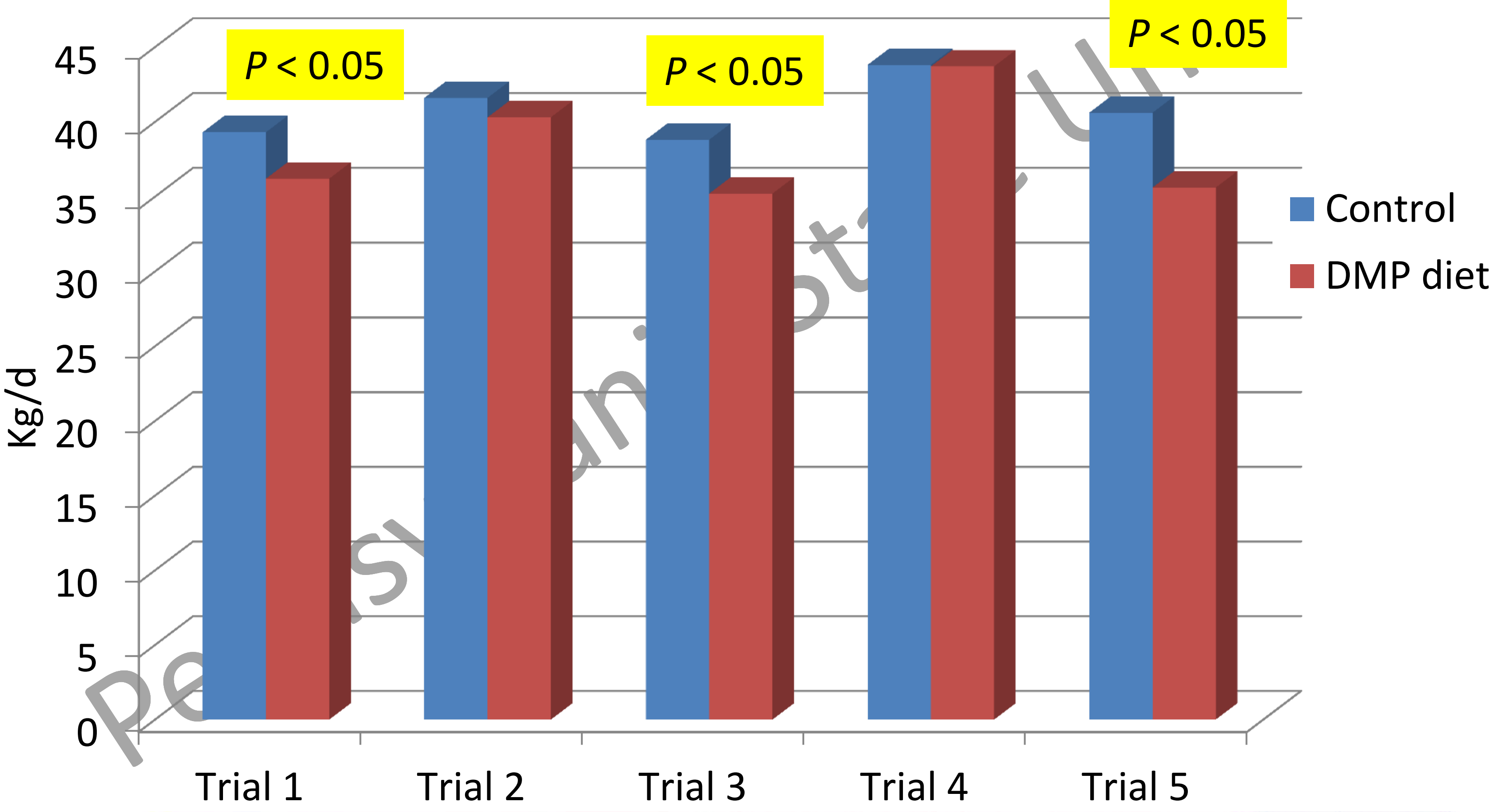


P = 0.06

P < 0.05

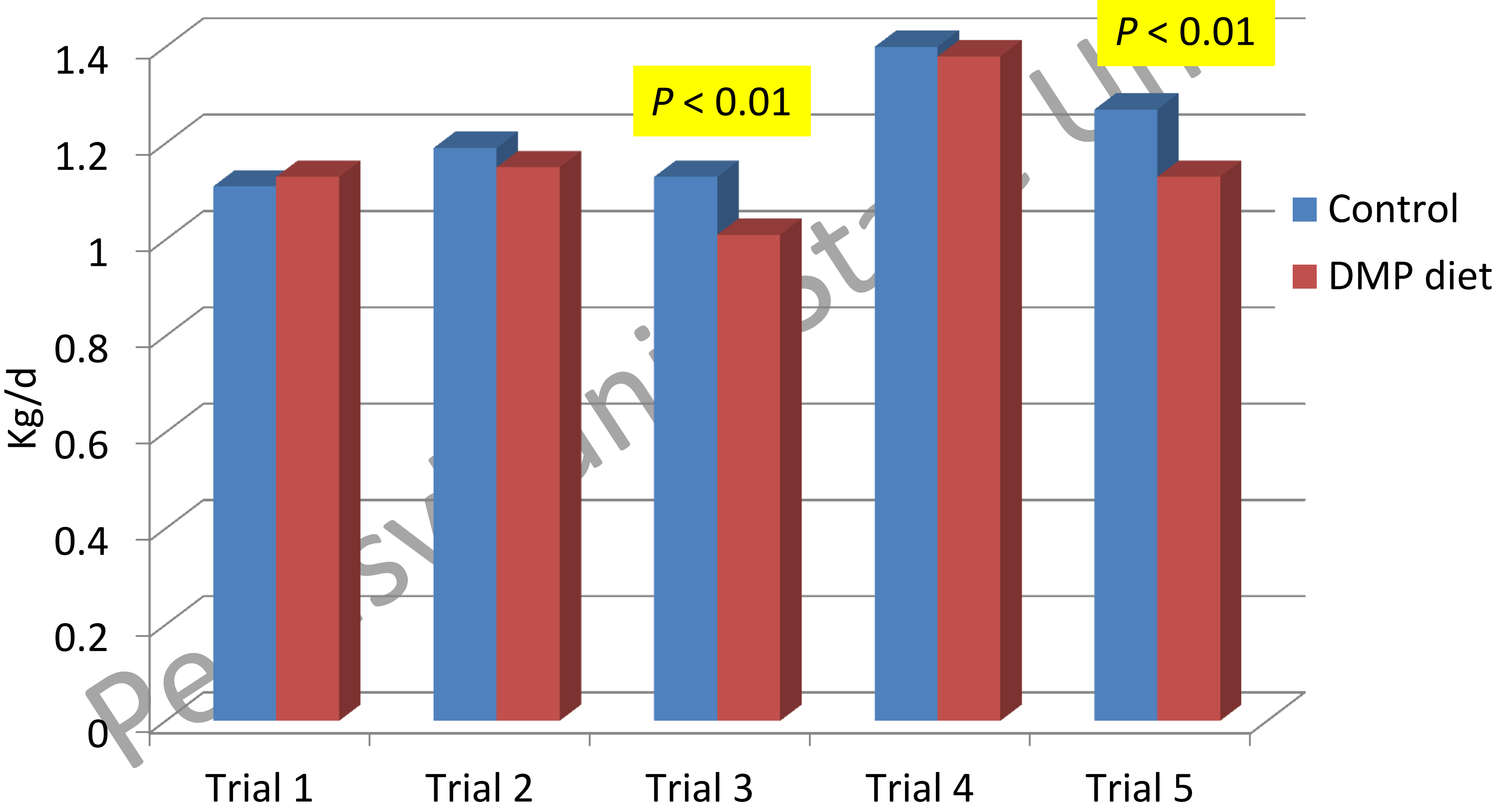
Penn State data

Low-protein diets effect on MY



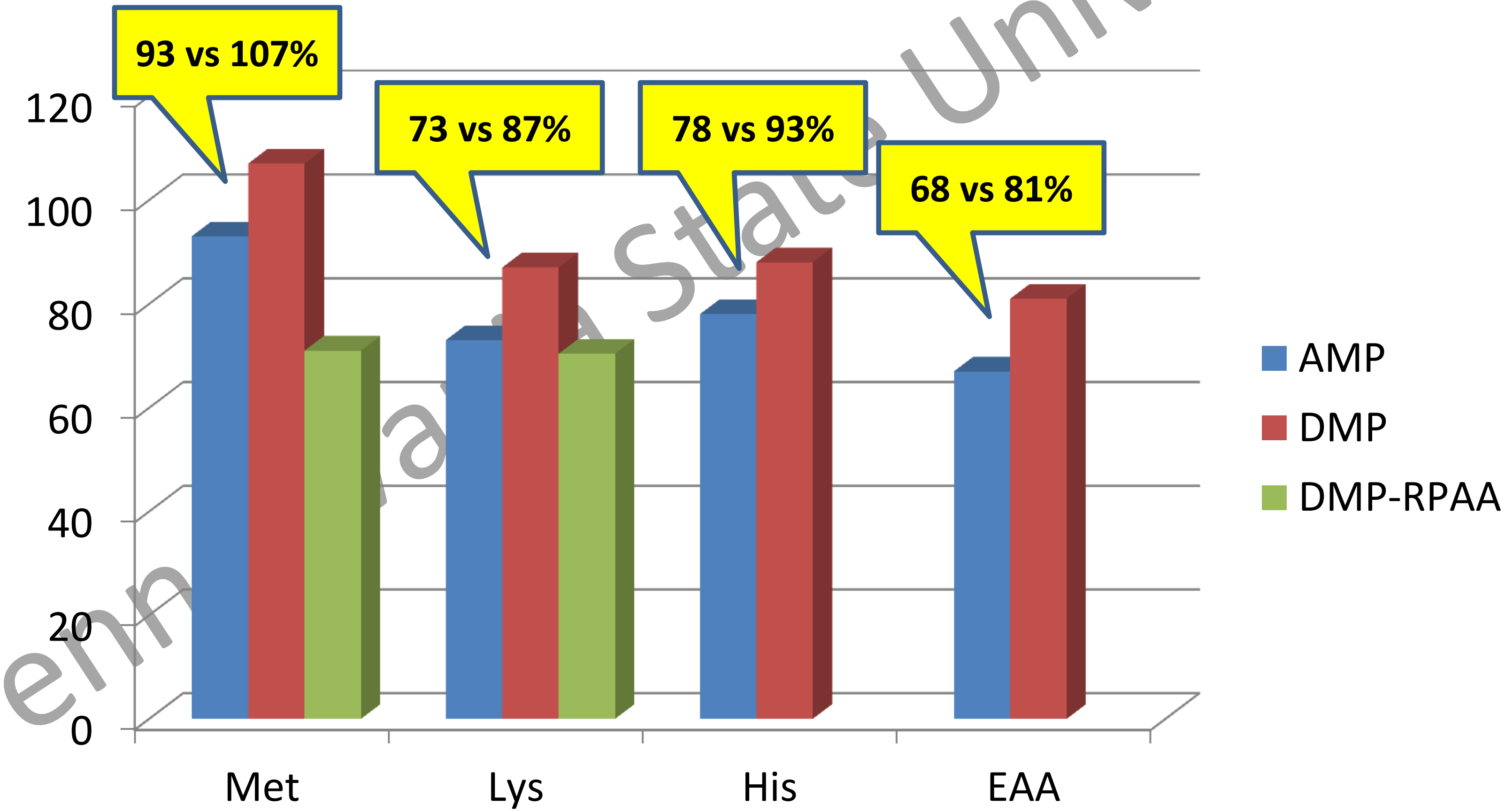
Penn State data

Low-protein diets effect on MPY



Lee et al., 2011

Efficiency of utilization of digestible EAA for milk protein synthesis



93 vs 107%

73 vs 87%

78 vs 93%

68 vs 81%

DairyCo (2013)

Dietary protein and reproduction

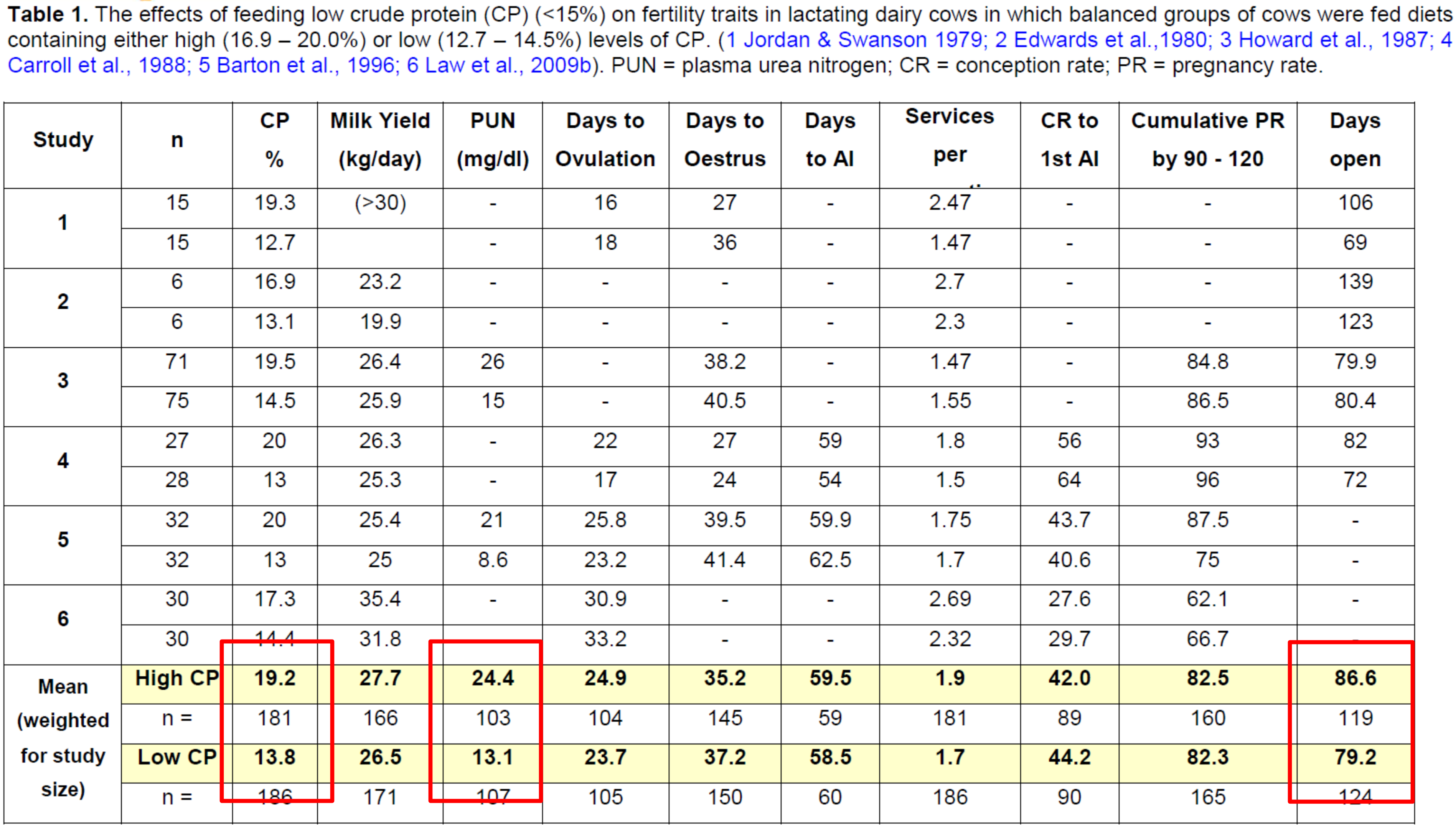


Table 1. The effects of feeding low crude protein (CP) (<15%) on fertility traits in lactating dairy cows in which balanced groups of cows were fed diets containing either high (16.9 – 20.0%) or low (12.7 – 14.5%) levels of CP. (1 Jordan & Swanson 1979; 2 Edwards et al.,1980; 3 Howard et al., 1987; 4 Carroll et al., 1988; 5 Barton et al., 1996; 6 Law et al., 2009b). PUN = plasma urea nitrogen; CR = conception rate; PR = pregnancy rate.

Study	n	CP %	Milk Yield (kg/day)	PUN (mg/dl)	Days to Ovulation	Days to Oestrus	Days to AI	Services per	CR to 1st AI	Cumulative PR by 90 - 120	Days open
1	15	19.3	(>30)	-	16	27	-	2.47	-	-	106
	15	12.7		-	18	36	-	1.47	-	-	69
2	6	16.9	23.2	-	-	-	-	2.7	-	-	139
	6	13.1	19.9	-	-	-	-	2.3	-	-	123
3	71	19.5	26.4	26	-	38.2	-	1.47	-	84.8	79.9
	75	14.5	25.9	15	-	40.5	-	1.55	-	86.5	80.4
4	27	20	26.3	-	22	27	59	1.8	56	93	82
	28	13	25.3	-	17	24	54	1.5	64	96	72
5	32	20	25.4	21	25.8	39.5	59.9	1.75	43.7	87.5	-
	32	13	25	8.6	23.2	41.4	62.5	1.7	40.6	75	-
6	30	17.3	35.4	-	30.9	-	-	2.69	27.6	62.1	-
	30	14.4	31.8		33.2	-	-	2.32	29.7	66.7	-
Mean (weighted for study size)	**High CP**	**19.2**	**27.7**	**24.4**	**24.9**	**35.2**	**59.5**	**1.9**	**42.0**	**82.5**	**86.6**
	n =	181	166	103	104	145	59	181	89	160	119
	Low CP	**13.8**	**26.5**	**13.1**	**23.7**	**37.2**	**58.5**	**1.7**	**44.2**	**82.3**	**79.2**
	n =	186	171	107	105	150	60	186	90	165	124

Lean et al. (2012)

Dietary protein and reproduction

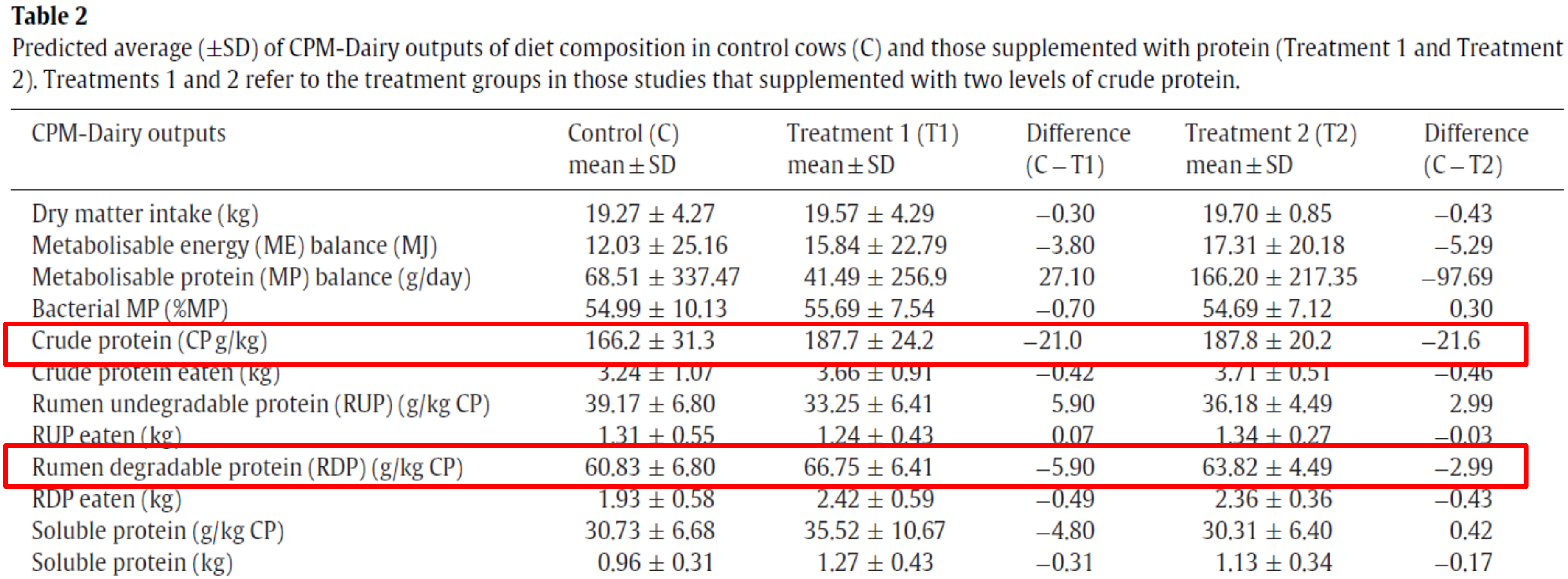


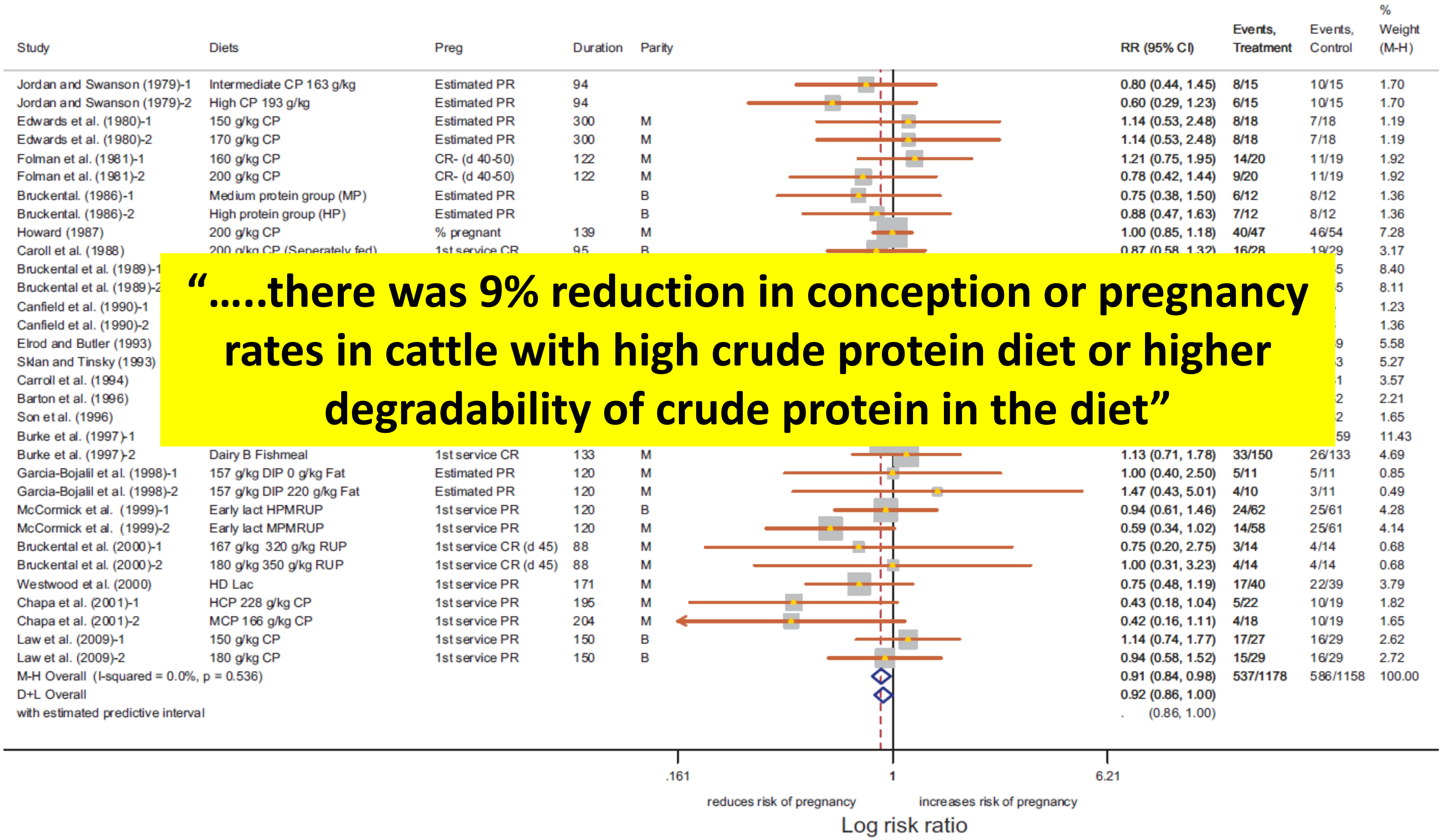
Table 2

Predicted average (±SD) of CPM-Dairy outputs of diet composition in control cows (C) and those supplemented with protein (Treatment 1 and Treatment 2). Treatments 1 and 2 refer to the treatment groups in those studies that supplemented with two levels of crude protein.

CPM-Dairy outputs	Control (C) mean ± SD	Treatment 1 (T1) mean ± SD	Difference (C – T1)	Treatment 2 (T2) mean ± SD	Difference (C – T2)
Dry matter intake (kg)	19.27 ± 4.27	19.57 ± 4.29	–0.30	19.70 ± 0.85	–0.43
Metabolisable energy (ME) balance (MJ)	12.03 ± 25.16	15.84 ± 22.79	–3.80	17.31 ± 20.18	–5.29
Metabolisable protein (MP) balance (g/day)	68.51 ± 337.47	41.49 ± 256.9	27.10	166.20 ± 217.35	–97.69
Bacterial MP (%MP)	54.99 ± 10.13	55.69 ± 7.54	–0.70	54.69 ± 7.12	0.30
Crude protein (CP g/kg)	166.2 ± 31.3	187.7 ± 24.2	–21.0	187.8 ± 20.2	–21.6
Crude protein eaten (kg)	3.24 ± 1.07	3.66 ± 0.91	–0.42	3.71 ± 0.51	–0.46
Rumen undegradable protein (RUP) (g/kg CP)	39.17 ± 6.80	33.25 ± 6.41	5.90	36.18 ± 4.49	2.99
RUP eaten (kg)	1.31 ± 0.55	1.24 ± 0.43	0.07	1.34 ± 0.27	–0.03
Rumen degradable protein (RDP) (g/kg CP)	60.83 ± 6.80	66.75 ± 6.41	–5.90	63.82 ± 4.49	–2.99
RDP eaten (kg)	1.93 ± 0.58	2.42 ± 0.59	–0.49	2.36 ± 0.36	–0.43
Soluble protein (g/kg CP)	30.73 ± 6.68	35.52 ± 10.67	–4.80	30.31 ± 6.40	0.42
Soluble protein (kg)	0.96 ± 0.31	1.27 ± 0.43	–0.31	1.13 ± 0.34	–0.17

Lean et al. (2012)

Dietary protein and reproduction

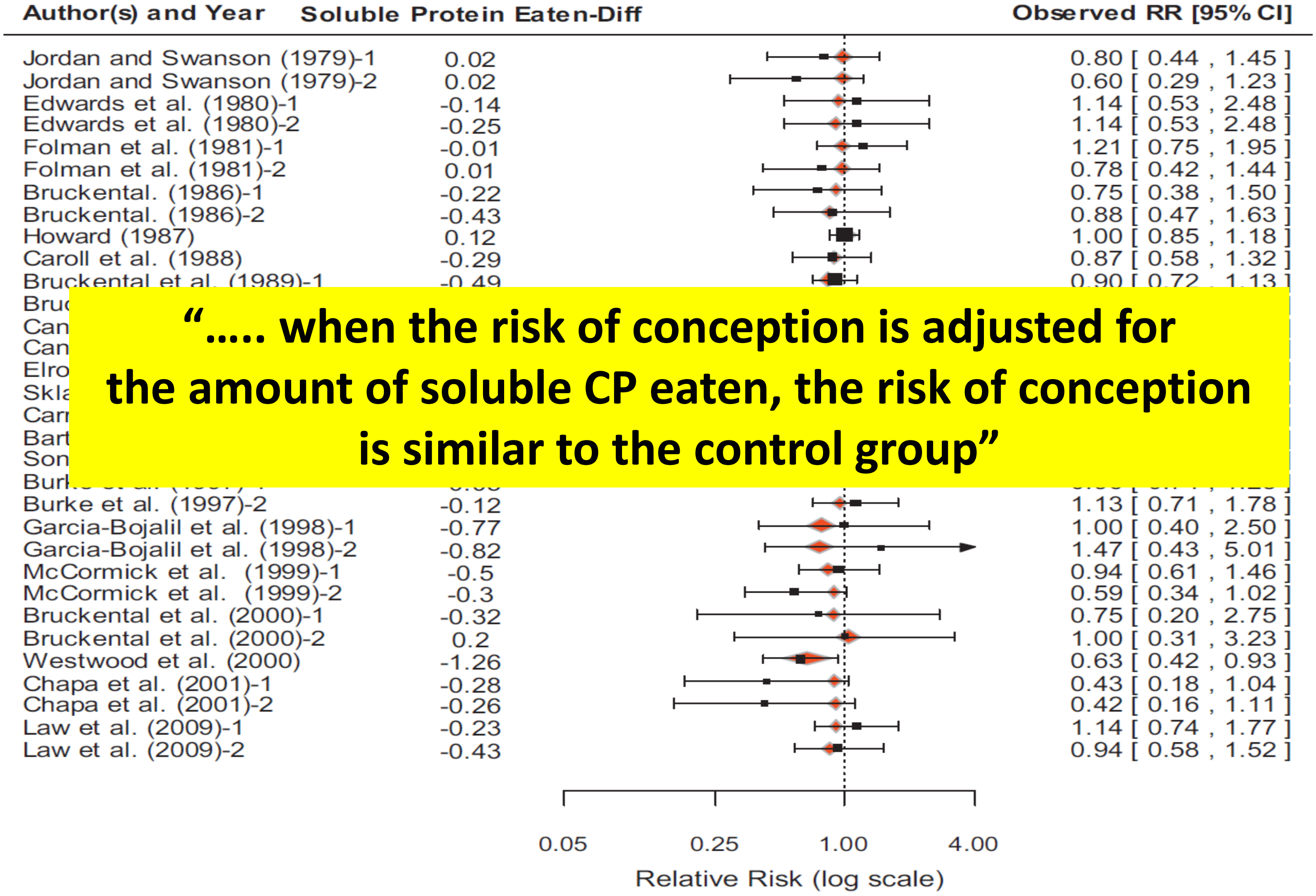


Study	Diets	Preg	Duration	Parity	RR (95% CI)	Events, Treatment	Events, Control	% Weight (M-H)
Jordan and Swanson (1979)-1	Intermediate CP 163 g/kg	Estimated PR	94		0.80 (0.44, 1.45)	8/15	10/15	1.70
Jordan and Swanson (1979)-2	High CP 193 g/kg	Estimated PR	94		0.60 (0.29, 1.23)	6/15	10/15	1.70
Edwards et al. (1980)-1	150 g/kg CP	Estimated PR	300	M	1.14 (0.53, 2.48)	8/18	7/18	1.19
Edwards et al. (1980)-2	170 g/kg CP	Estimated PR	300	M	1.14 (0.53, 2.48)	8/18	7/18	1.19
Folman et al. (1981)-1	160 g/kg CP	CR- (d 40-50)	122	M	1.21 (0.75, 1.95)	14/20	11/19	1.92
Folman et al. (1981)-2	200 g/kg CP	CR- (d 40-50)	122	M	0.78 (0.42, 1.44)	9/20	11/19	1.92
Bruckental. (1986)-1	Medium protein group (MP)	Estimated PR		B	0.75 (0.38, 1.50)	6/12	8/12	1.36
Bruckental. (1986)-2	High protein group (HP)	Estimated PR		B	0.88 (0.47, 1.63)	7/12	8/12	1.36
Howard (1987)	200 g/kg CP	% pregnant	139	M	1.00 (0.85, 1.18)	40/47	46/54	7.28
Caroll et al. (1988)	200 g/kg CP (Seperately fed)	1st service CR	95	B	0.87 (0.58, 1.32)	16/28	19/29	3.17
Bruckental et al. (1989)-1								8.40
Bruckental et al. (1989)-2								8.11
Canfield et al. (1990)-1								1.23
Canfield et al. (1990)-2								1.36
Elrod and Butler (1993)								5.58
Sklan and Tinsky (1993)								5.27
Carroll et al. (1994)								3.57
Barton et al. (1996)								2.21
Son et al. (1996)								1.65
Burke et al. (1997)-1								11.43
Burke et al. (1997)-2	Dairy B Fishmeal	1st service CR	133	M	1.13 (0.71, 1.78)	33/150	26/133	4.69
Garcia-Bojalil et al. (1998)-1	157 g/kg DIP 0 g/kg Fat	Estimated PR	120	M	1.00 (0.40, 2.50)	5/11	5/11	0.85
Garcia-Bojalil et al. (1998)-2	157 g/kg DIP 220 g/kg Fat	Estimated PR	120	M	1.47 (0.43, 5.01)	4/10	3/11	0.49
McCormick et al. (1999)-1	Early lact HPMRUP	1st service PR	120	B	0.94 (0.61, 1.46)	24/62	25/61	4.28
McCormick et al. (1999)-2	Early lact MPMRUP	1st service PR	120	M	0.59 (0.34, 1.02)	14/58	25/61	4.14
Bruckental et al. (2000)-1	167 g/kg 320 g/kg RUP	1st service CR (d 45)	88	M	0.75 (0.20, 2.75)	3/14	4/14	0.68
Bruckental et al. (2000)-2	180 g/kg 350 g/kg RUP	1st service CR (d 45)	88	M	1.00 (0.31, 3.23)	4/14	4/14	0.68
Westwood et al. (2000)	HD Lac	1st service PR	171	M	0.75 (0.48, 1.19)	17/40	22/39	3.79
Chapa et al. (2001)-1	HCP 228 g/kg CP	1st service PR	195	M	0.43 (0.18, 1.04)	5/22	10/19	1.82
Chapa et al. (2001)-2	MCP 166 g/kg CP	1st service PR	204	M	0.42 (0.16, 1.11)	4/18	10/19	1.65
Law et al. (2009)-1	150 g/kg CP	1st service PR	150	B	1.14 (0.74, 1.77)	17/27	16/29	2.62
Law et al. (2009)-2	180 g/kg CP	1st service PR	150	B	0.94 (0.58, 1.52)	15/29	16/29	2.72
M-H Overall (I-squared = 0.0%, p = 0.536)					0.91 (0.84, 0.98)	537/1178	586/1158	100.00
D+L Overall					0.92 (0.86, 1.00)			
with estimated predictive interval					. (0.86, 1.00)			

“…..there was 9% reduction in conception or pregnancy rates in cattle with high crude protein diet or higher degradability of crude protein in the diet”

Lean et al. (2012)

Dietary protein and reproduction



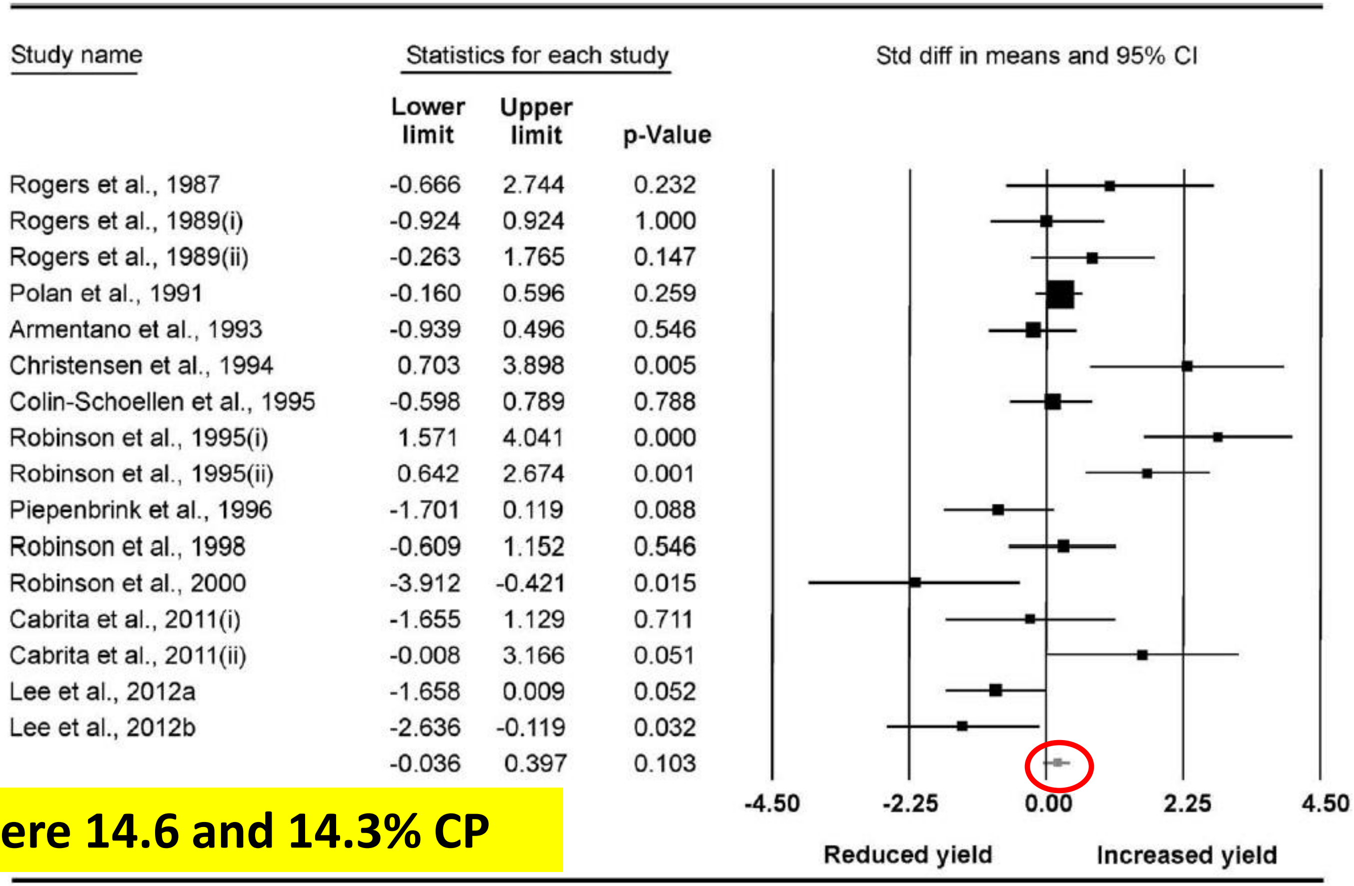
Author(s) and Year	Soluble Protein Eaten-Diff	Observed RR [95% CI]
Jordan and Swanson (1979)-1	0.02	0.80 [0.44 , 1.45]
Jordan and Swanson (1979)-2	0.02	0.60 [0.29 , 1.23]
Edwards et al. (1980)-1	-0.14	1.14 [0.53 , 2.48]
Edwards et al. (1980)-2	-0.25	1.14 [0.53 , 2.48]
Folman et al. (1981)-1	-0.01	1.21 [0.75 , 1.95]
Folman et al. (1981)-2	0.01	0.78 [0.42 , 1.44]
Bruckental. (1986)-1	-0.22	0.75 [0.38 , 1.50]
Bruckental. (1986)-2	-0.43	0.88 [0.47 , 1.63]
Howard (1987)	0.12	1.00 [0.85 , 1.18]
Caroll et al. (1988)	-0.29	0.87 [0.58 , 1.32]
Bruckental et al. (1989)-1	-0.49	0.90 [0.72 , 1.13]
Bruc		
Can		
Can		
Elro		
Skla		
Carr		
Bart		
Son		
Burk		
Burke et al. (1997)-2	-0.12	1.13 [0.71 , 1.78]
Garcia-Bojalil et al. (1998)-1	-0.77	1.00 [0.40 , 2.50]
Garcia-Bojalil et al. (1998)-2	-0.82	1.47 [0.43 , 5.01]
McCormick et al. (1999)-1	-0.5	0.94 [0.61 , 1.46]
McCormick et al. (1999)-2	-0.3	0.59 [0.34 , 1.02]
Bruckental et al. (2000)-1	-0.32	0.75 [0.20 , 2.75]
Bruckental et al. (2000)-2	0.2	1.00 [0.31 , 3.23]
Westwood et al. (2000)	-1.26	0.63 [0.42 , 0.93]
Chapa et al. (2001)-1	-0.28	0.43 [0.18 , 1.04]
Chapa et al. (2001)-2	-0.26	0.42 [0.16 , 1.11]
Law et al. (2009)-1	-0.23	1.14 [0.74 , 1.77]
Law et al. (2009)-2	-0.43	0.94 [0.58 , 1.52]

“….. when the risk of conception is adjusted for the amount of soluble CP eaten, the risk of conception is similar to the control group”

Amino acids

Sinclair et al. (2013)

FCM responses to RPMet and RPLys supplemented to low-protein diets

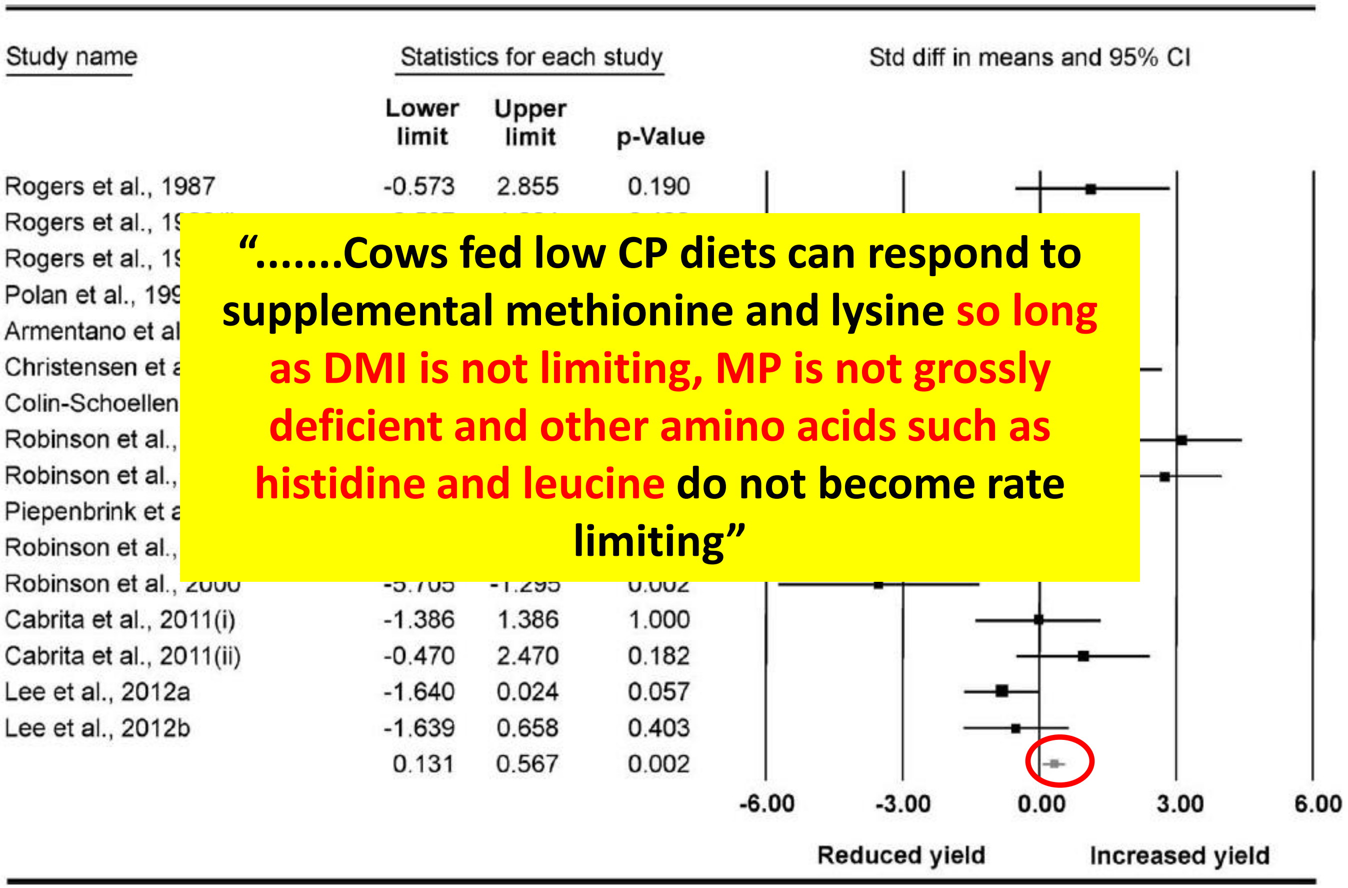


Study name	Lower limit	Upper limit	p-Value
Rogers et al., 1987	-0.666	2.744	0.232
Rogers et al., 1989(i)	-0.924	0.924	1.000
Rogers et al., 1989(ii)	-0.263	1.765	0.147
Polan et al., 1991	-0.160	0.596	0.259
Armentano et al., 1993	-0.939	0.496	0.546
Christensen et al., 1994	0.703	3.898	0.005
Colin-Schoellen et al., 1995	-0.598	0.789	0.788
Robinson et al., 1995(i)	1.571	4.041	0.000
Robinson et al., 1995(ii)	0.642	2.674	0.001
Piepenbrink et al., 1996	-1.701	0.119	0.088
Robinson et al., 1998	-0.609	1.152	0.546
Robinson et al., 2000	-3.912	-0.421	0.015
Cabrita et al., 2011(i)	-1.655	1.129	0.711
Cabrita et al., 2011(ii)	-0.008	3.166	0.051
Lee et al., 2012a	-1.658	0.009	0.052
Lee et al., 2012b	-2.636	-0.119	0.032
	-0.036	0.397	0.103

Diets were 14.6 and 14.3% CP

Sinclair et al. (2013)

MPY responses to RPMet and RPLys supplemented to low-protein diets



Study name	Lower limit	Upper limit	p-Value
Rogers et al., 1987	-0.573	2.855	0.190
Rogers et al., 19			
Rogers et al., 19			
Polan et al., 199			
Armentano et al			
Christensen et a			
Colin-Schoellen			
Robinson et al.,			
Robinson et al.,			
Piepenbrink et a			
Robinson et al.,			
Robinson et al., 2000	-5.705	-1.295	0.002
Cabrita et al., 2011(i)	-1.386	1.386	1.000
Cabrita et al., 2011(ii)	-0.470	2.470	0.182
Lee et al., 2012a	-1.640	0.024	0.057
Lee et al., 2012b	-1.639	0.658	0.403
	0.131	0.567	0.002

"…….Cows fed low CP diets can respond to supplemental methionine and lysine so long as DMI is not limiting, MP is not grossly deficient and other amino acids such as histidine and leucine do not become rate limiting"

Patton et al. (2015)

Effect of AA supplementation (expressed as additional duo AA flow)

es

“….plasma concentrations of EAA are linear functions of duodenal AA flow

……Met or Lys infused alone increased plasma concentration of the infused EAA and lowered the concentration of other EAA, particularly His

…..No evidence was found that EAA requirements are reflected in blood plasma concentrations”

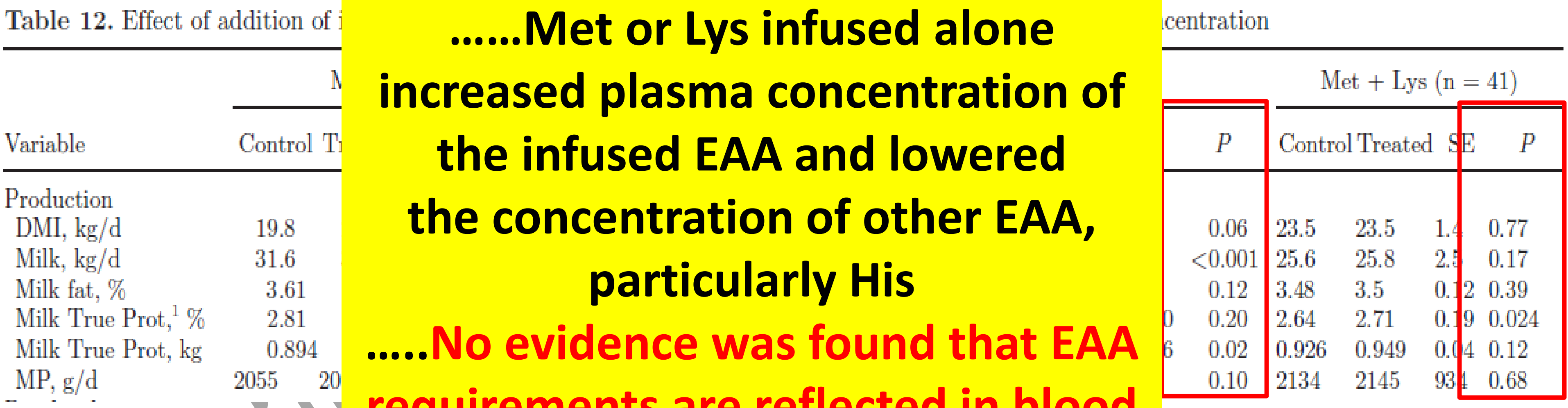


Table 12. Effect of addition of i … centration

Variable	Control	Tr		*P*	Control	Treated	SE	*P*
Production								
DMI, kg/d	19.8			0.06	23.5	23.5	1.4	0.77
Milk, kg/d	31.6			<0.001	25.6	25.8	2.5	0.17
Milk fat, %	3.61			0.12	3.48	3.5	0.12	0.39
Milk True Prot,[1] %	2.81		0	0.20	2.64	2.71	0.19	0.024
Milk True Prot, kg	0.894		6	0.02	0.926	0.949	0.04	0.12
MP, g/d	2055	20		0.10	2134	2145	934	0.68

Met + Lys (n = 41)

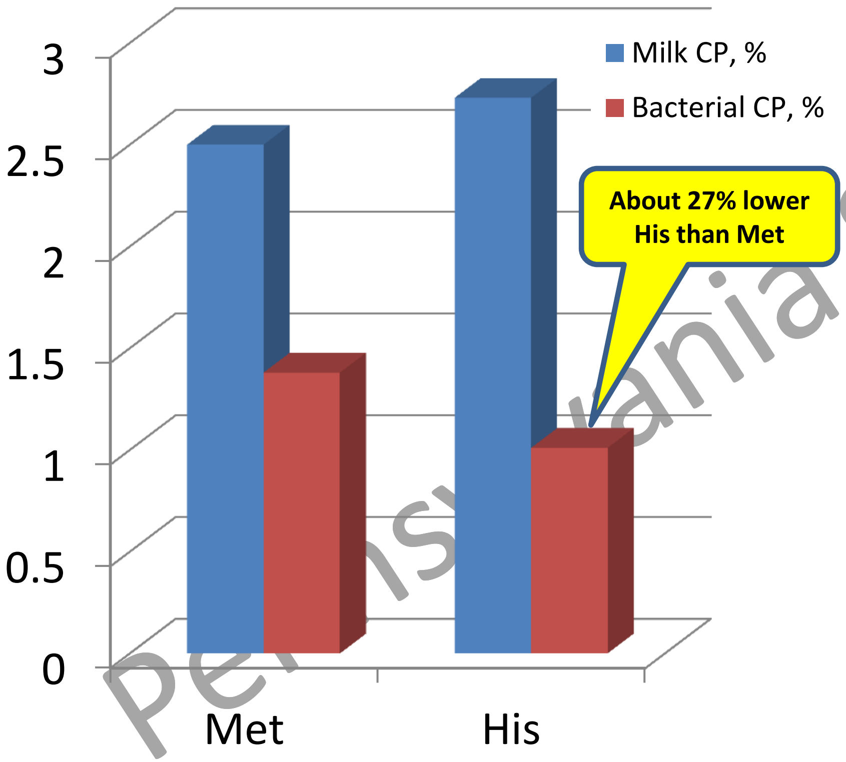
Histidine research

- Apparent drop in plasma His in long-term trials with low-CP diets
  - pools of labile His?
- On low-CP diets, microbial protein is becoming an increasingly important source of MP/AA for the cow
- Compared with Met, microbial protein may be a poorer source of His

Lee et al., 2012

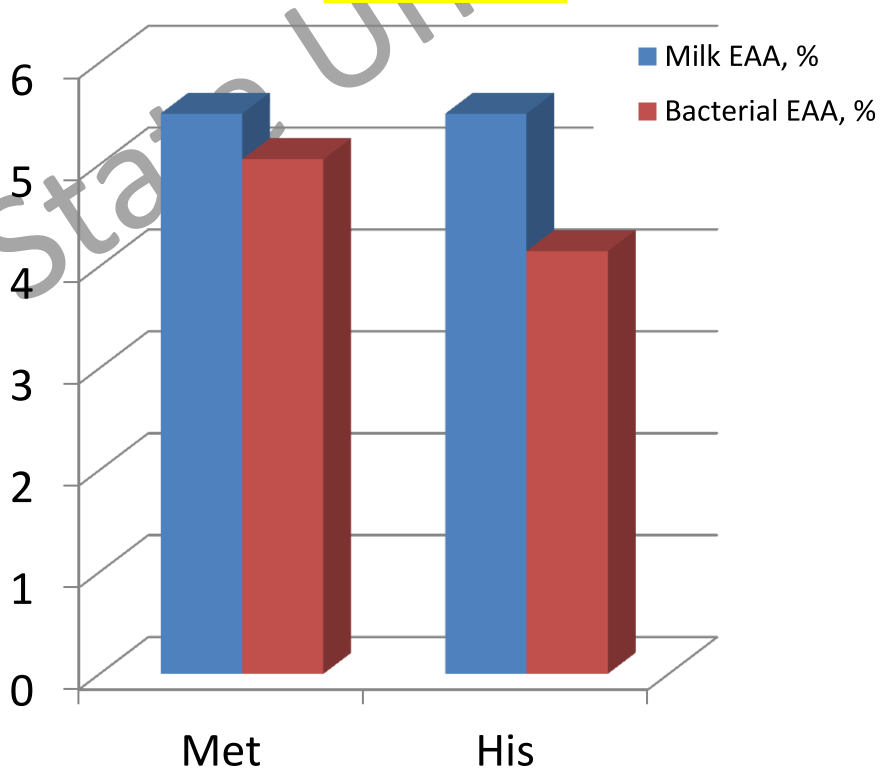
Met and His in milk protein vs. bacteria

Penn State trials

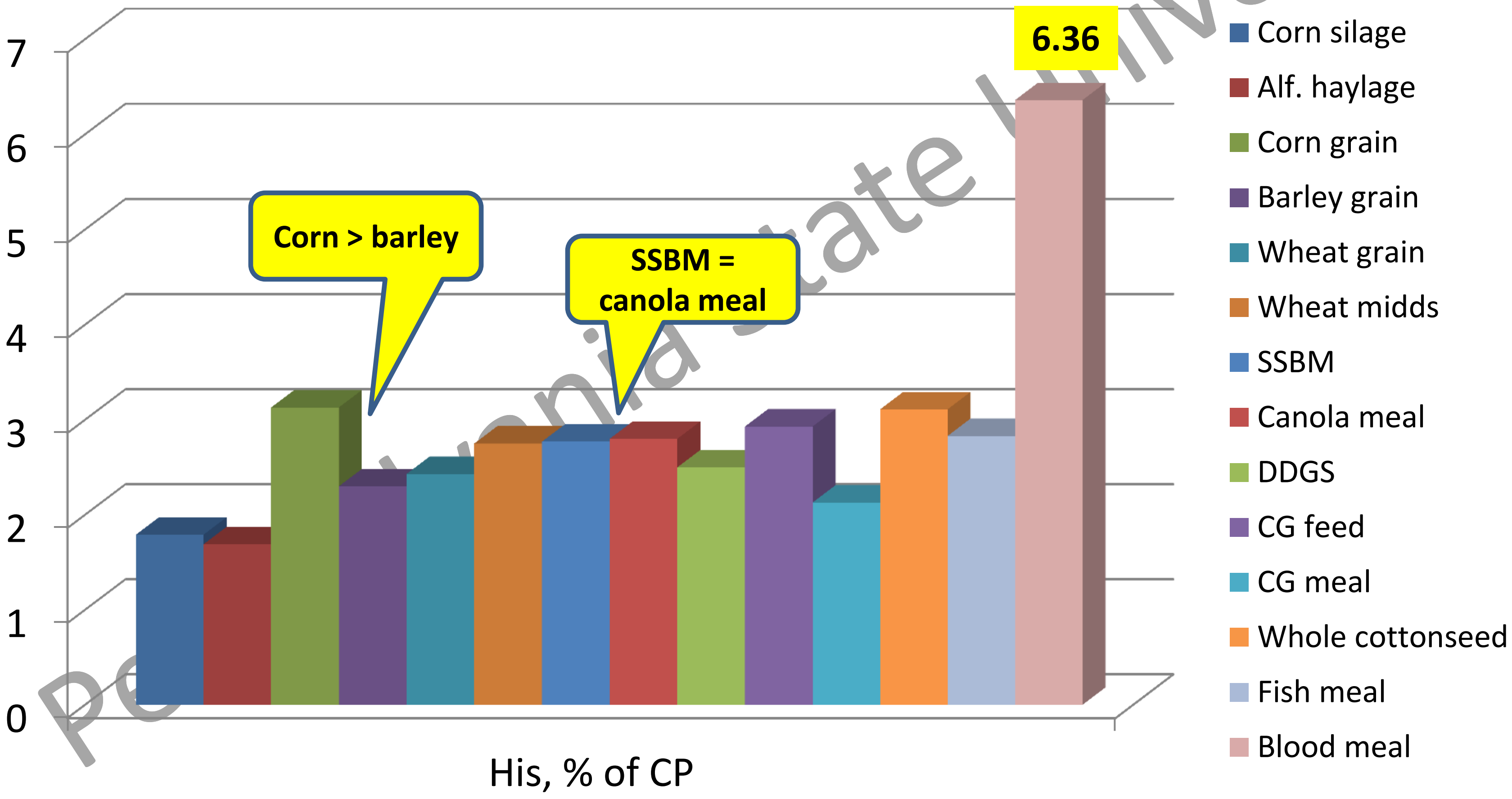


About 27% lower His than Met

NRC, 2001



His content of feeds (NRC, 2001)

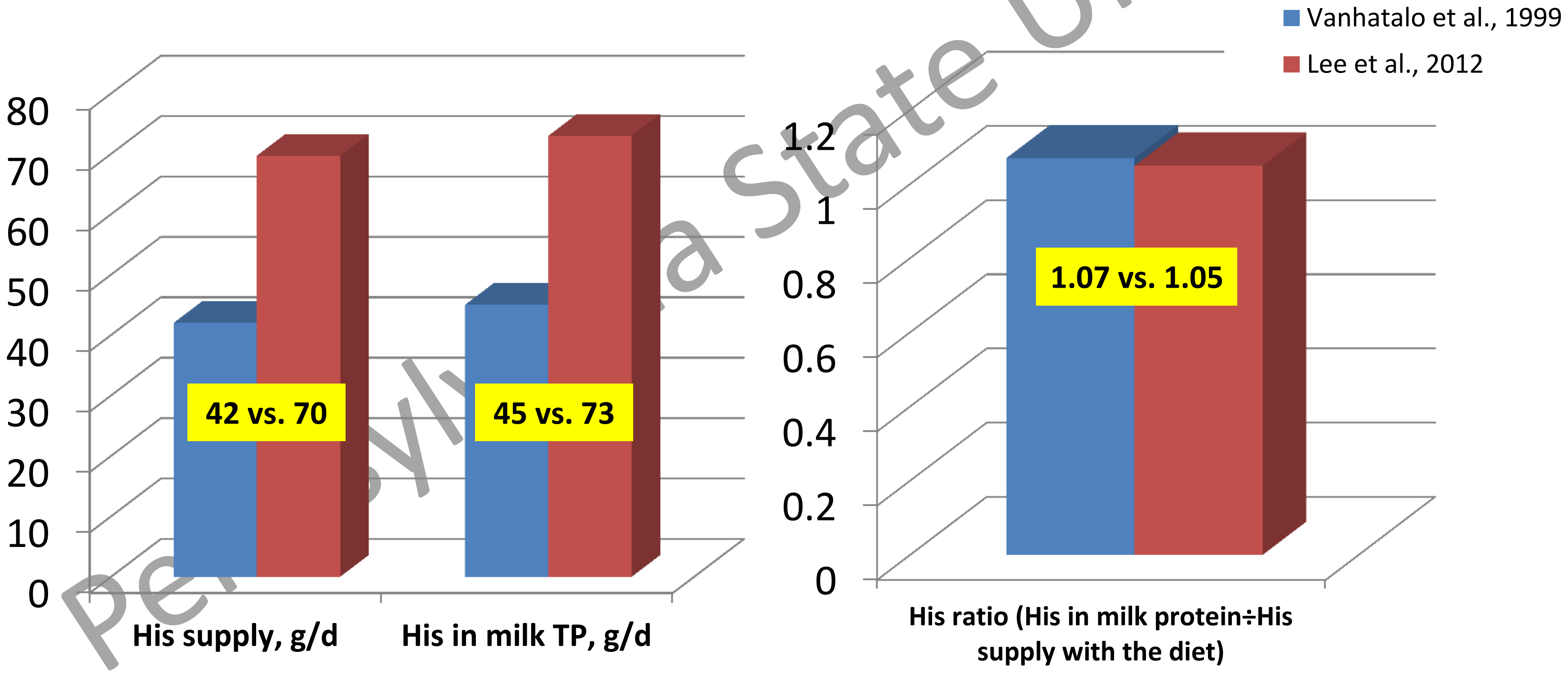


6.36

Corn > barley

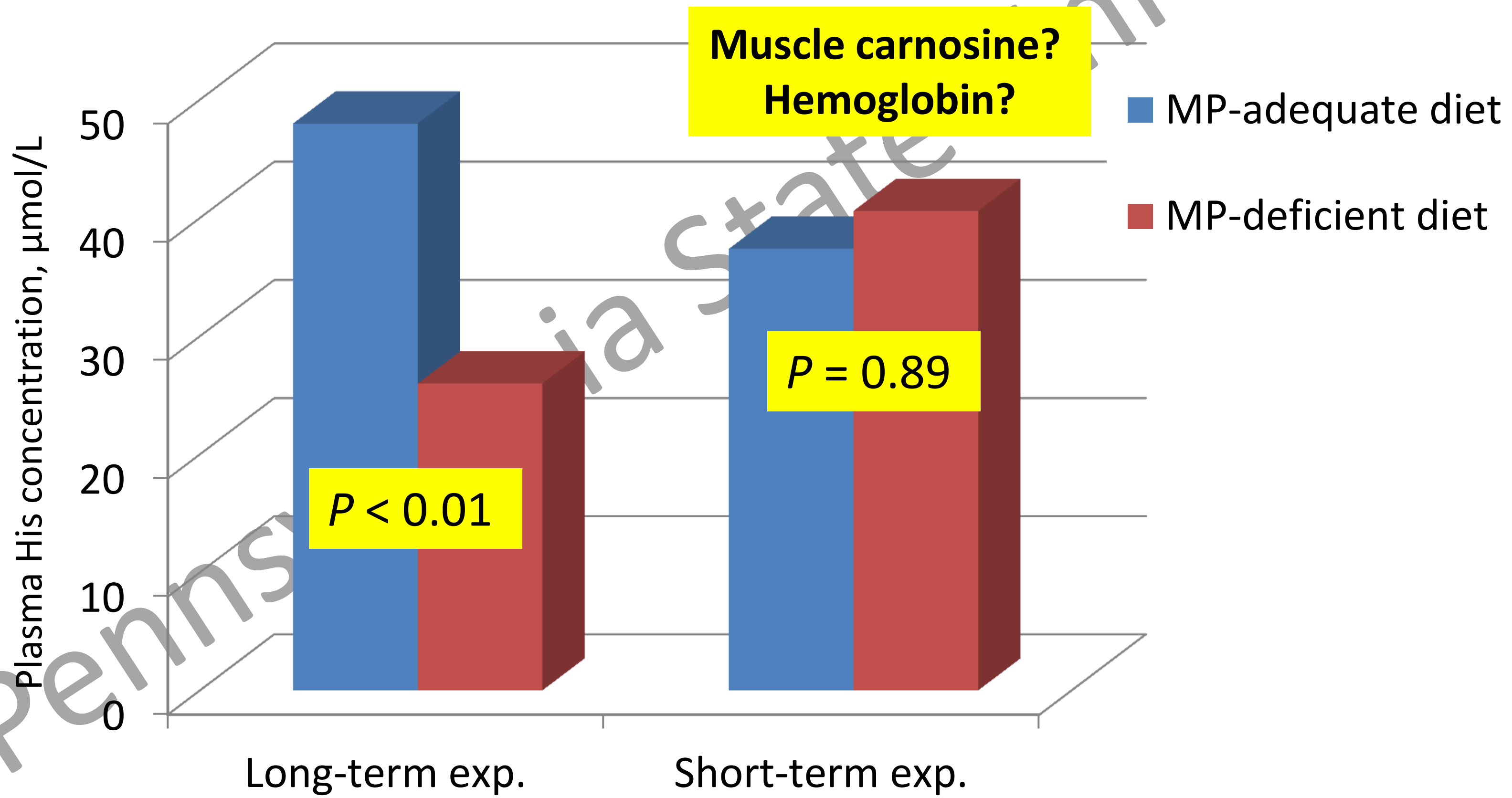
SSBM = canola meal

His supply ÷ output in grass- vs. corn-silage based diets



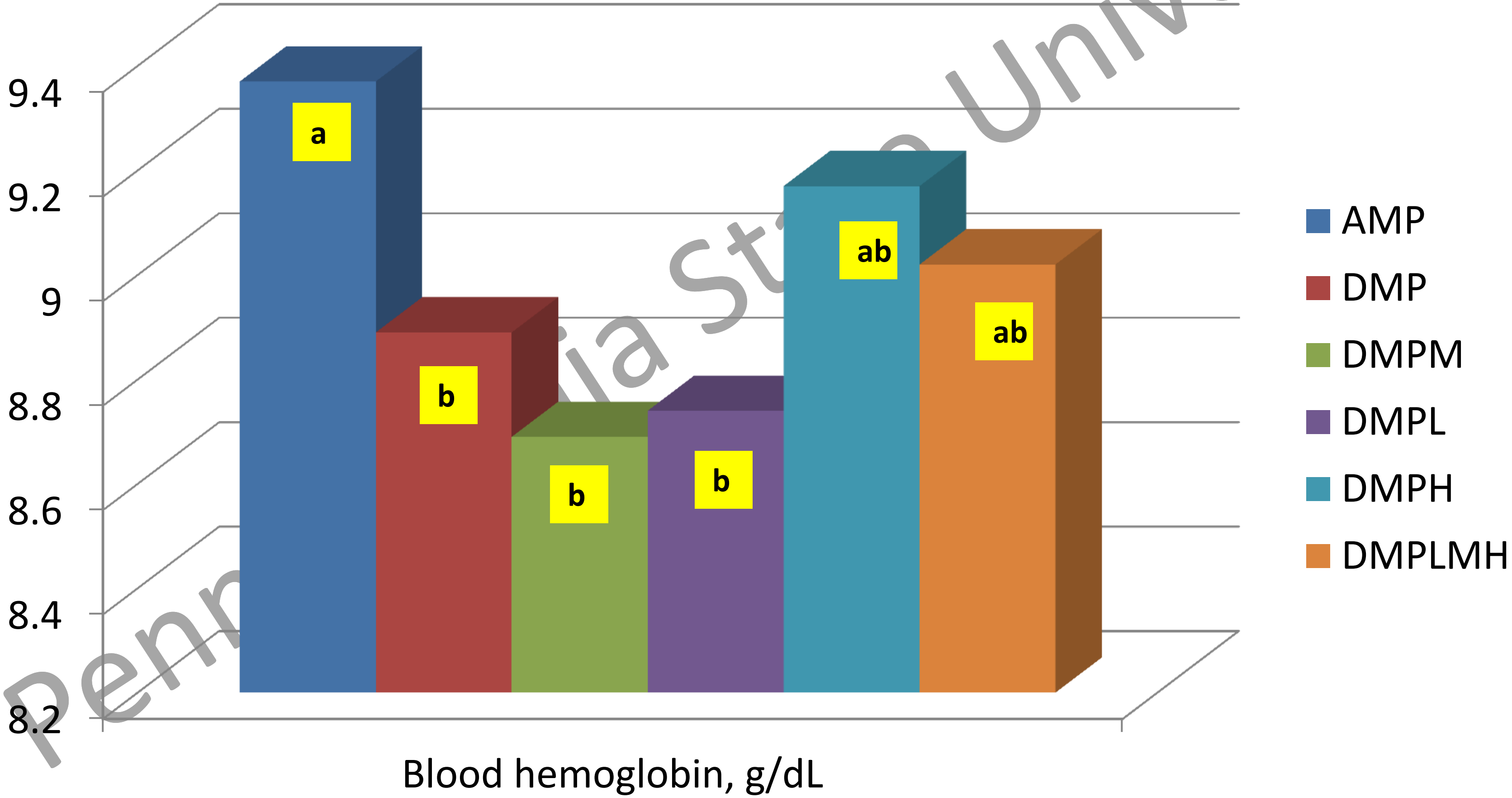
Lee et al., 2011, 2015

Endogenous His pools



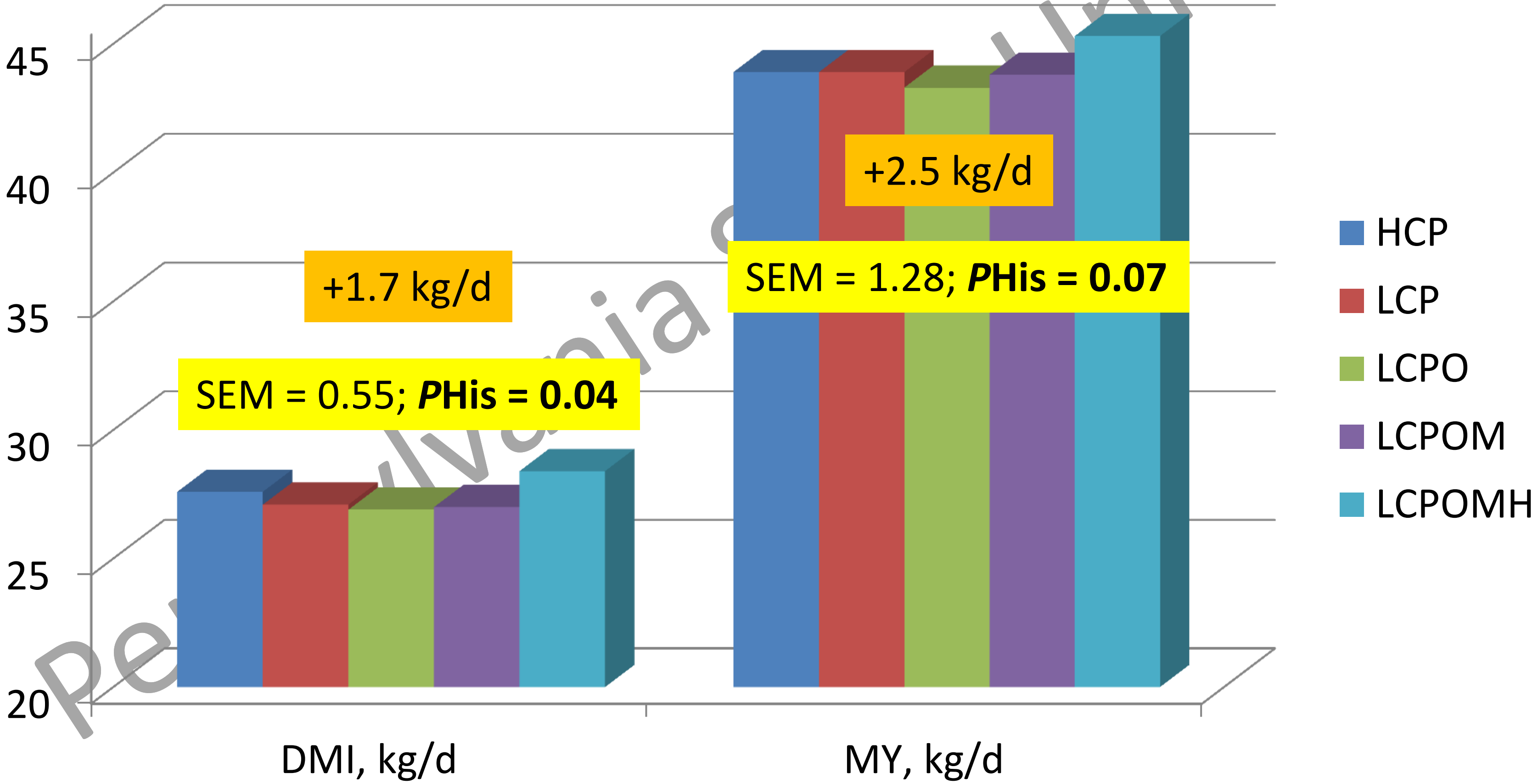
Giallongo et al., 2015b

Individual AA supplementation: blood hemoglobin



Giallongo et al., 2015a

AA supplementation experiments: DMI and milk yield effects



+1.7 kg/d

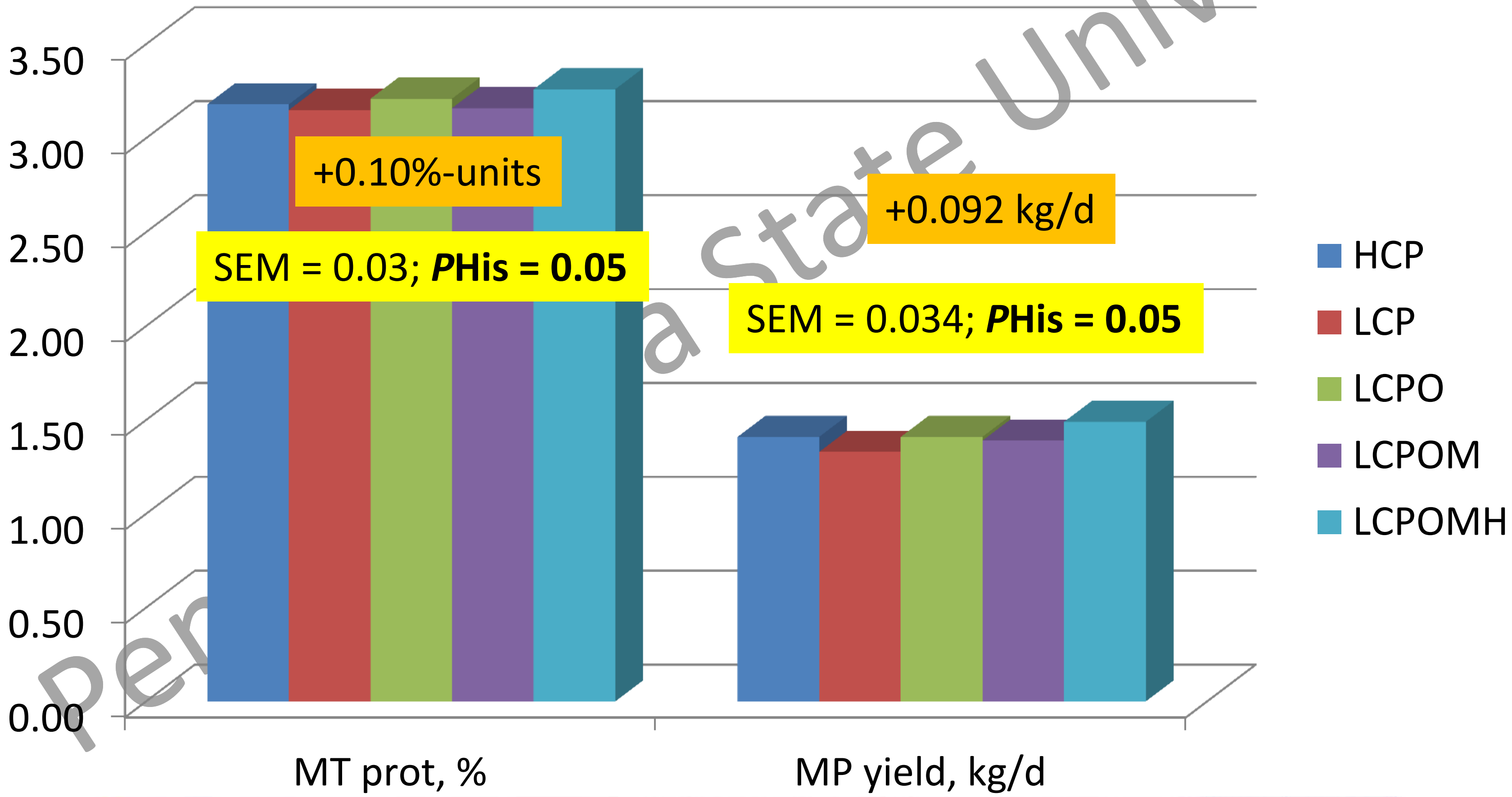
SEM = 0.55; ***P*His = 0.04**

+2.5 kg/d

SEM = 1.28; ***P*His = 0.07**

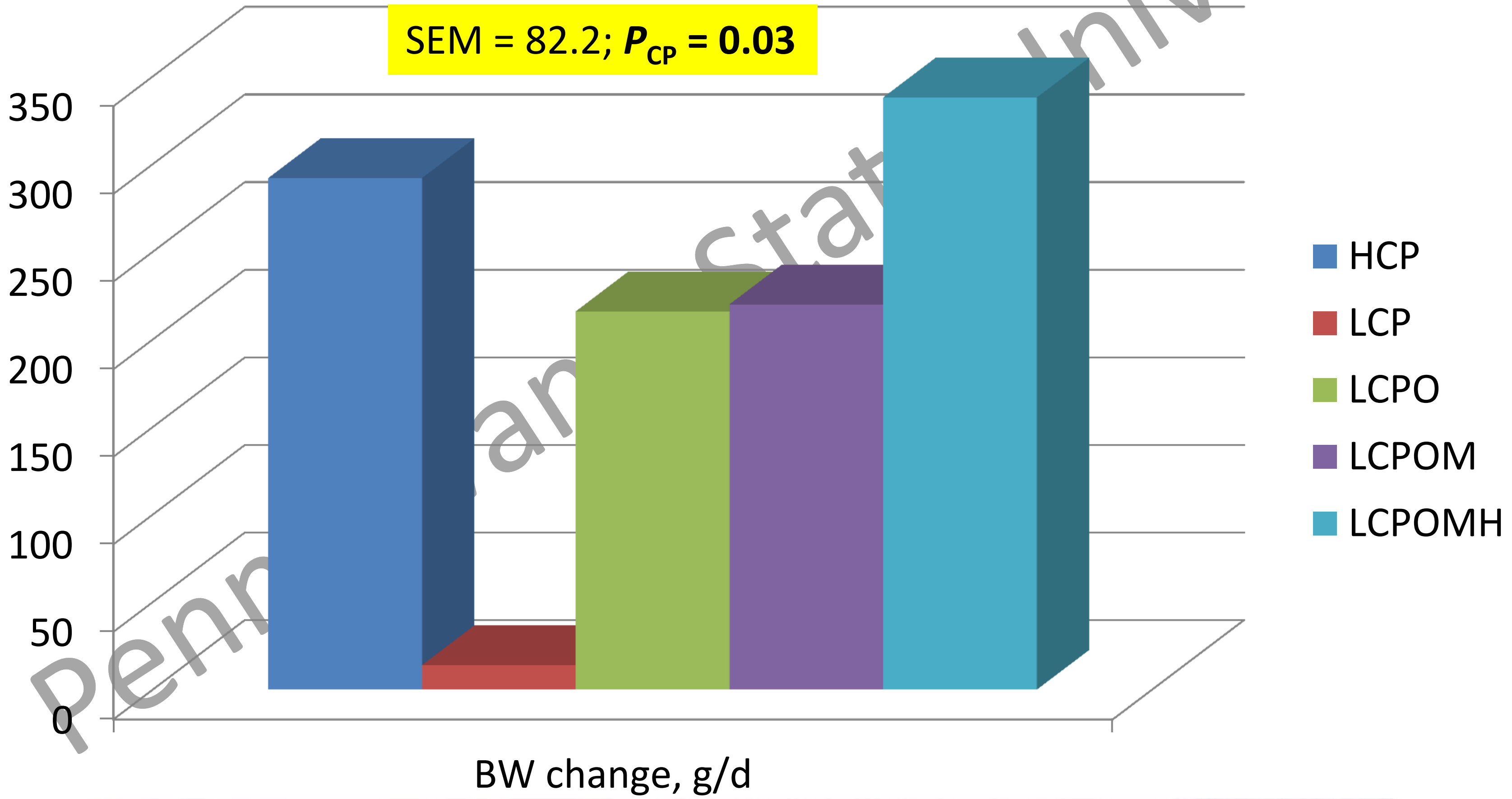
Giallongo et al., 2015a

AA supplementation experiments: Milk protein % and yield



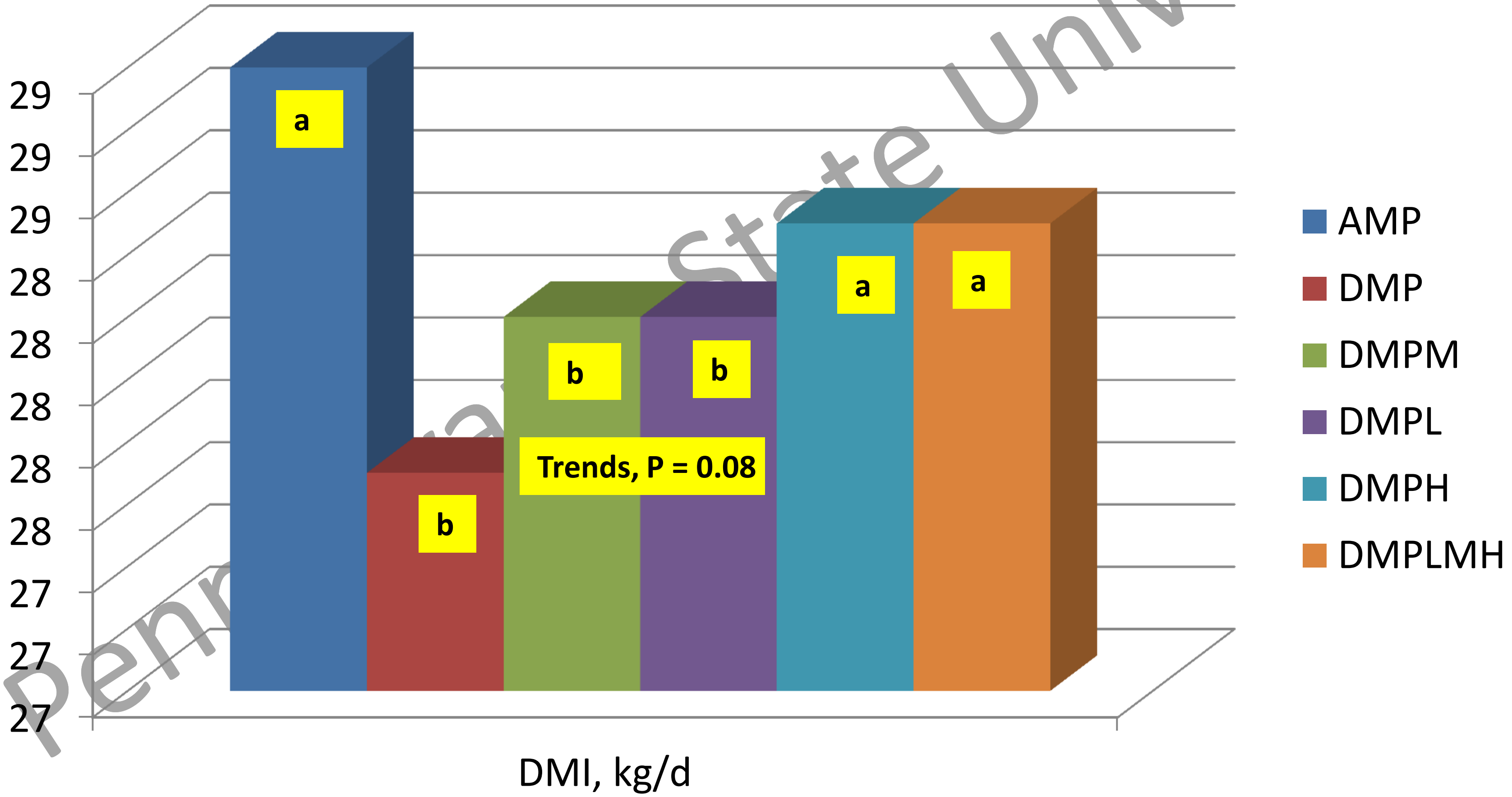
Giallongo et al., 2015a

AA supplementation experiments: BW change



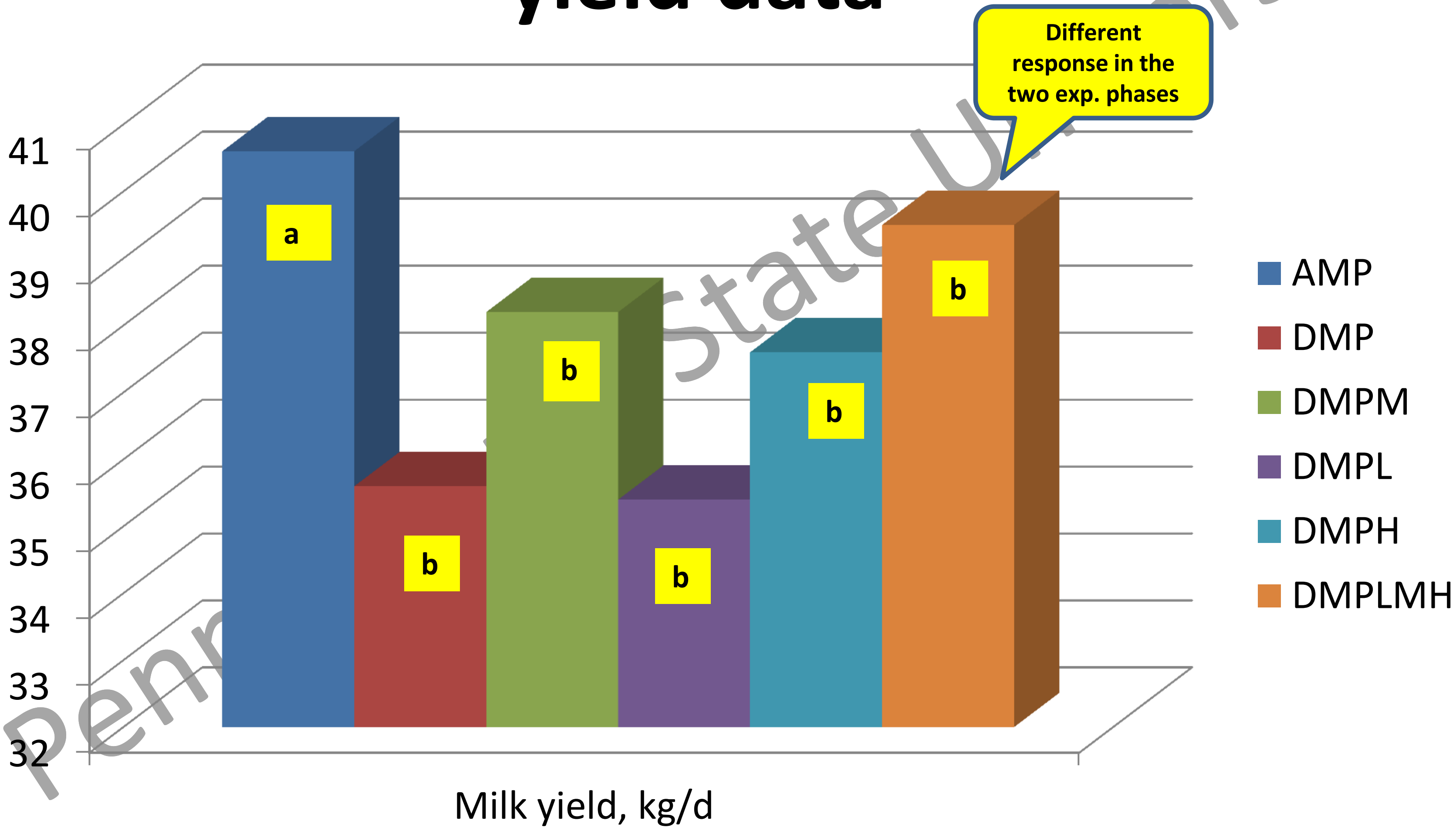
Giallongo et al., 2015b

Individual AA supplementation: DMI data



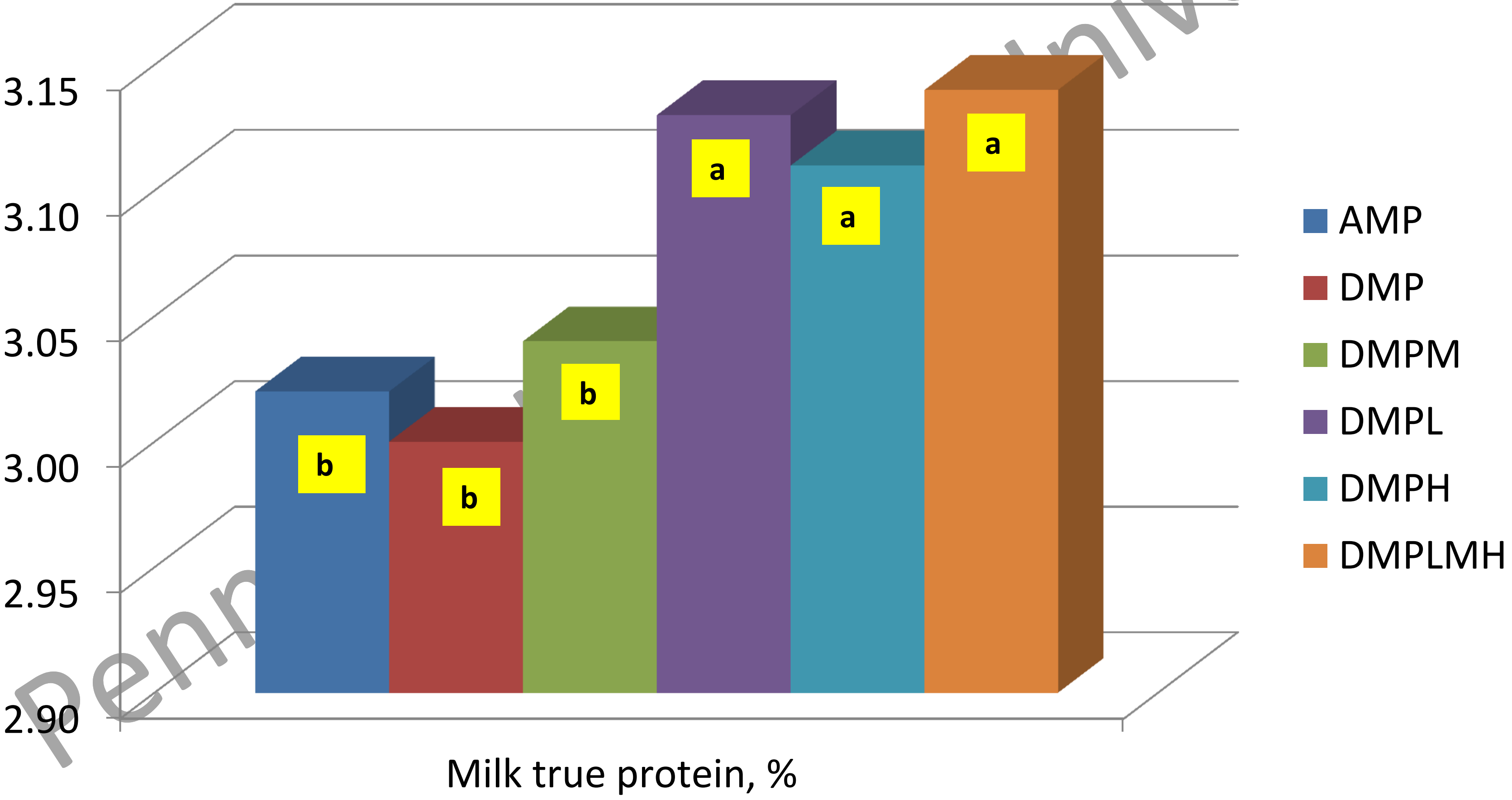
Giallongo et al., 2015b

Individual AA supplementation: Milk yield data



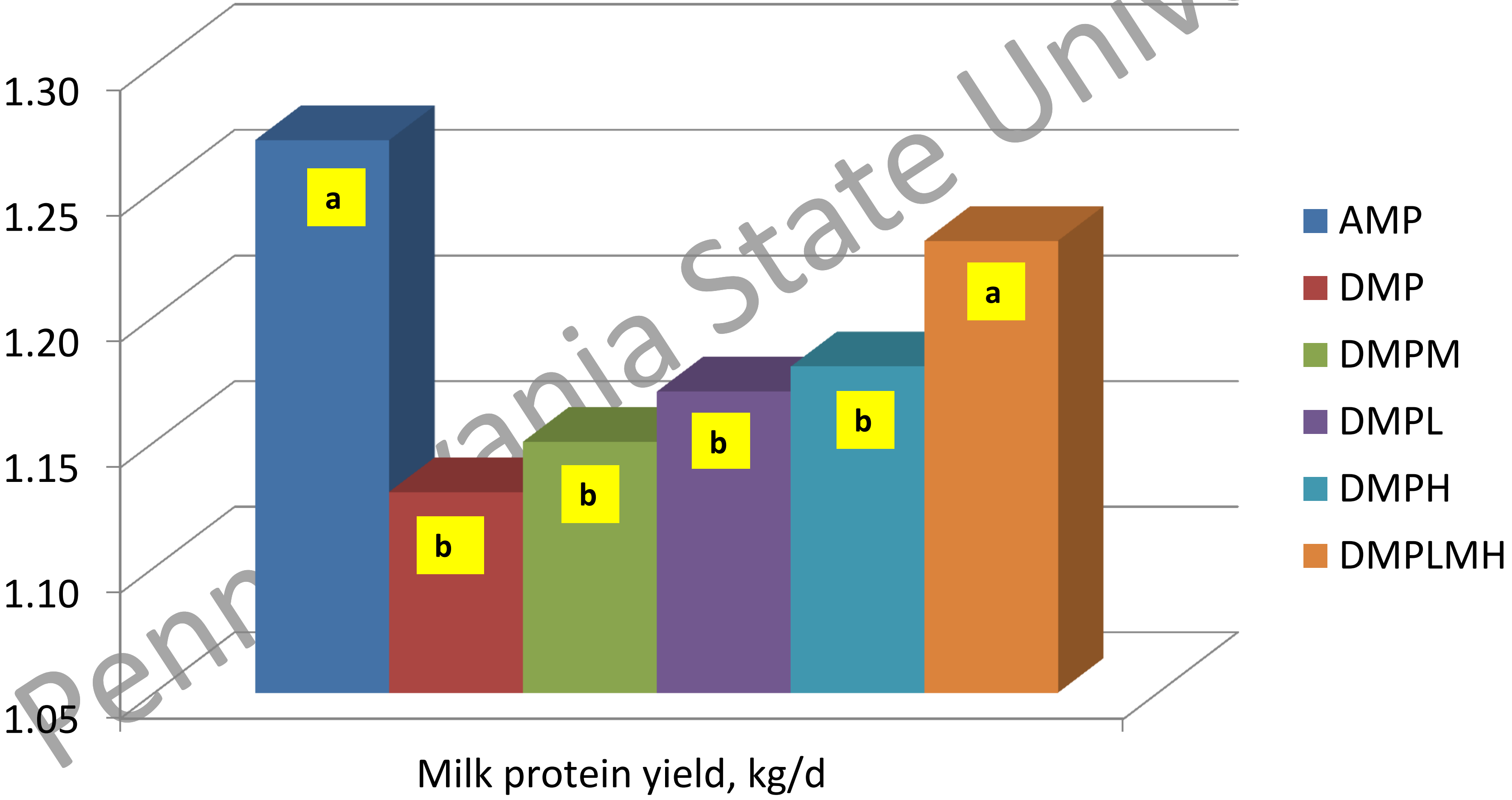
Giallongo et al., 2015b

Individual AA supplementation: Milk protein %



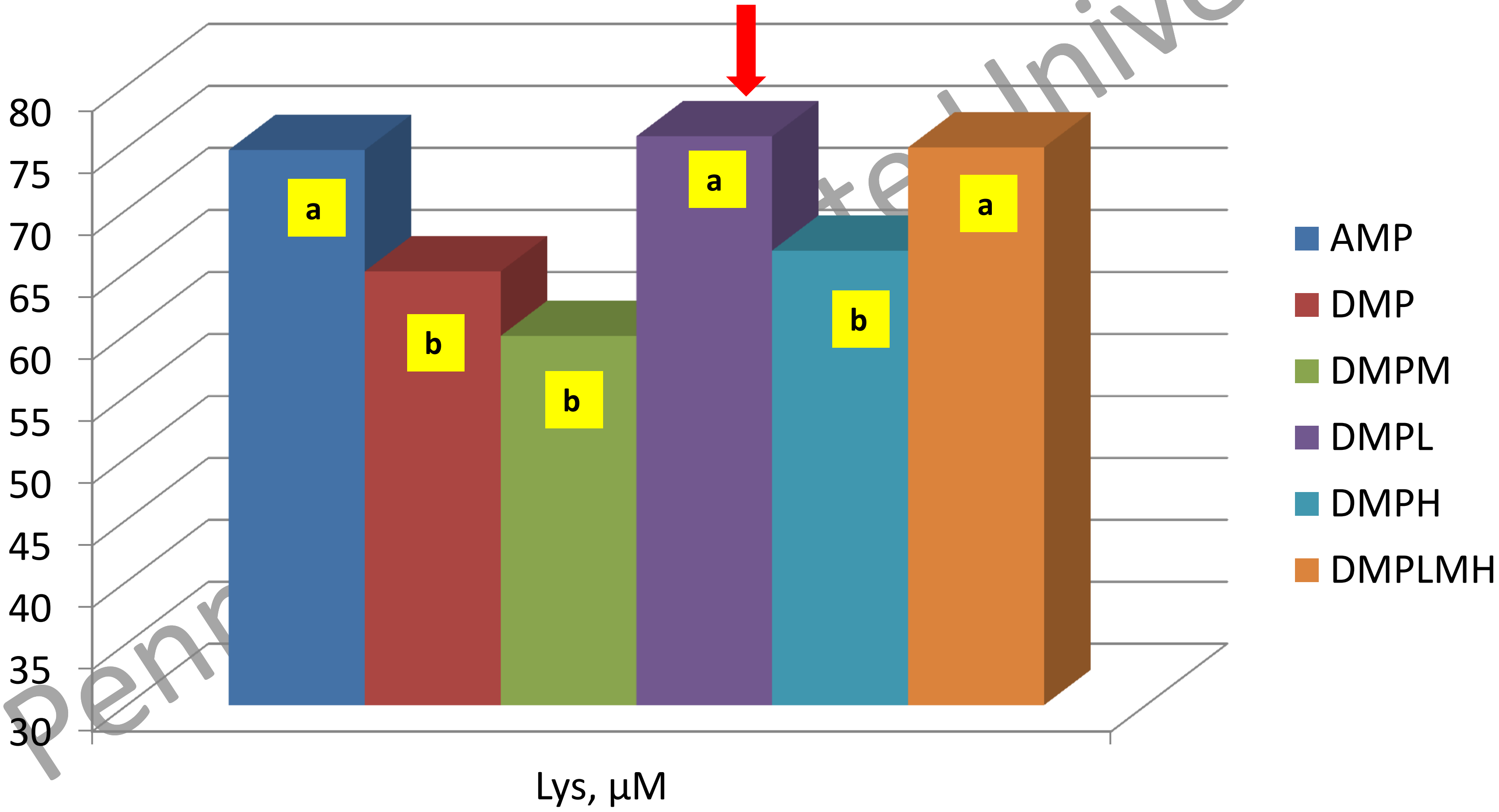
Giallongo et al., 2015b

Individual AA supplementation: Milk protein yield



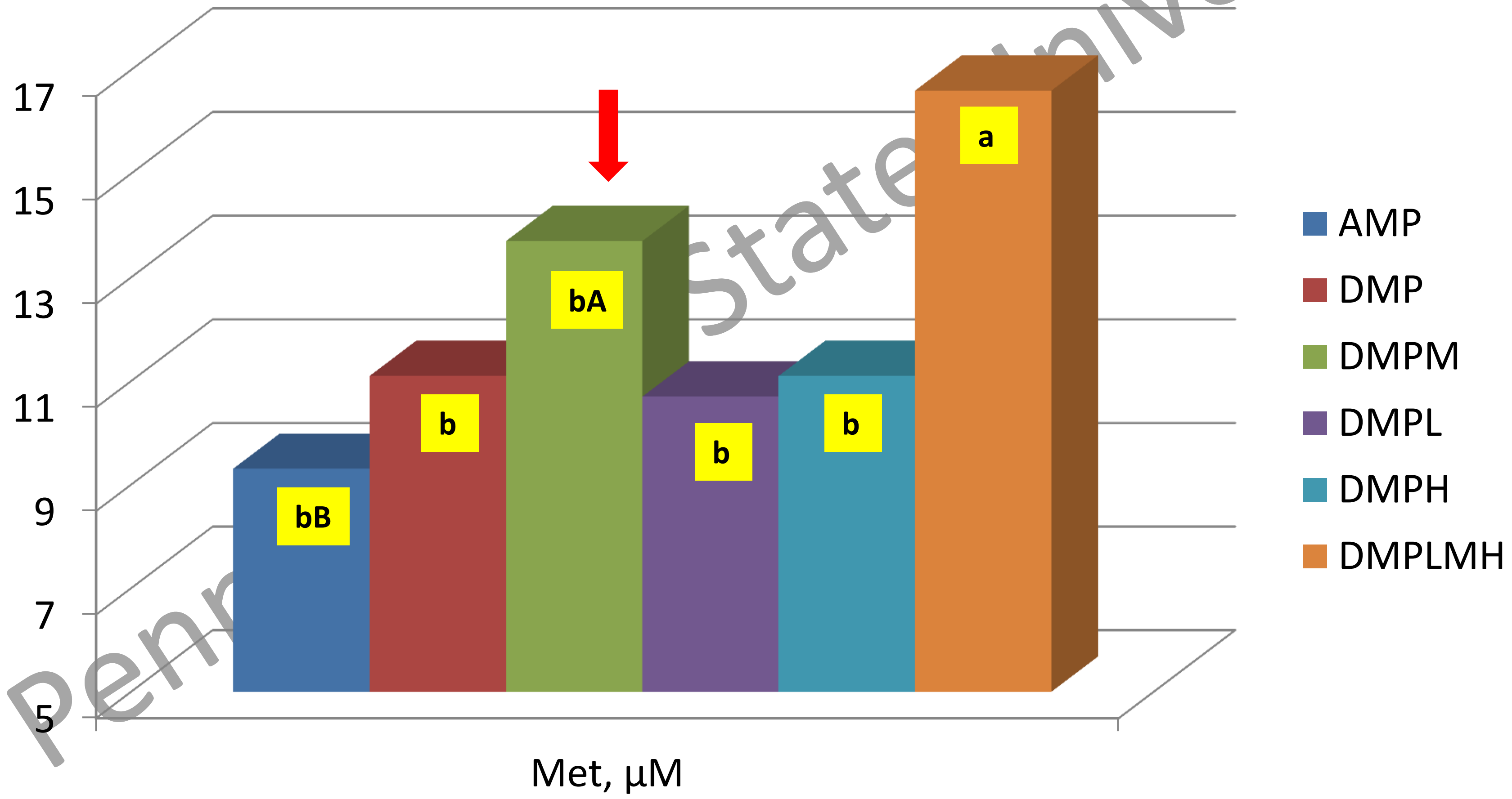
Giallongo et al., 2015b

Individual AA supplementation: plasma Lys



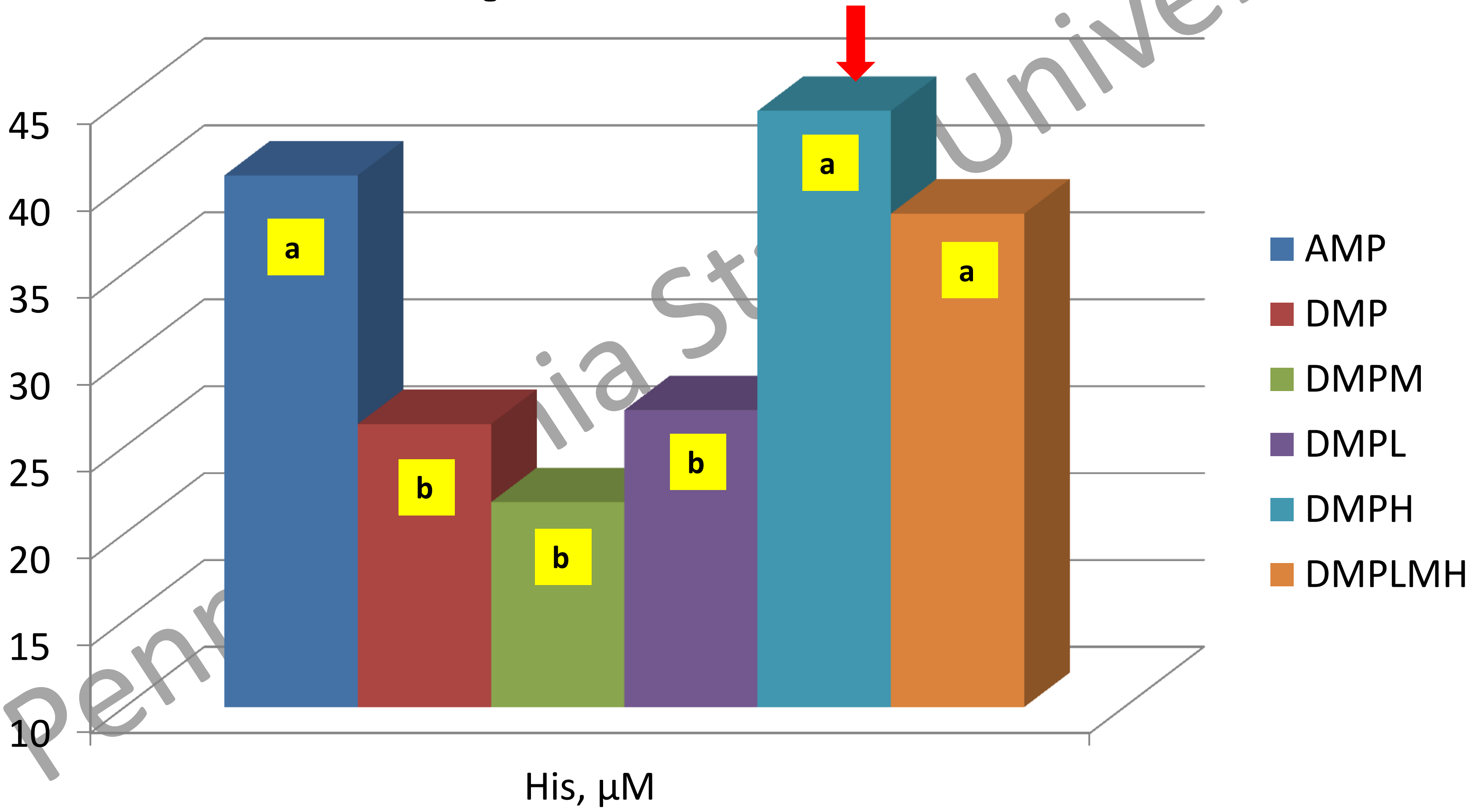
Giallongo et al., 2015b

Individual AA supplementation: plasma Met



Giallongo et al., 2015b

Individual AA supplementation: plasma His



Take-home message

- Dietary **protein intake is the most important factor determining milk nitrogen efficiency**, urinary nitrogen losses, and consequently, nitrate leaching and ammonia and nitrous oxide emissions from dairy cow manure.
- **Fiber digestibility may be decreased for diets with CP < 16% (RDP ≤ 10% of DM) and diets with CP <15% (MP deficiency of about <12%) will likely result in decreased milk yield**, partially through decreased DMI. **Early lactation, > 17% CP.**
  - **Production losses with low-protein diets are caused by:** (1) **depressed feed intake** due to impaired rumen function or physiological regulation of intake; (2) **deficiency of RDP**, which may cause decreased fiber digestion, microbial protein production, and milk fat and protein yields; and (3) **insufficient supply of key amino acids** limiting milk protein synthesis.
- Low protein diets (**CP <15%**) may benefit from supplementation with rumen-protected amino acids, limiting milk production.
  - **Our data show that His may also be a limiting amino acid in MP-deficient, corn silage/alfalfa haylage-based diets.**
  - Long-term trials showed that supplementation of such diets with rumen-protected His increased or tended to increase milk yield and milk protein percent and yield, **partially through increasing DMI.**

Automated calf feeders: What have we learned from producers and research?

Bob James

Dept. of Dairy Science

Department of Dairy Science at Virginia Tech · dasc.vt.edu

What is success? Different perspectives

- Calf
- Feeder
- Owner

Traditional calf nutrition

- Limit feed calves
  - 2 liters / feeding
  - Twice daily feeding
    - Interval between feeding?
- Why?
  - Convenience for labor
  - Limit feed to encourage weaning
- House calves individually – disease prevention

Why consider group housing and feeding?

- Labor
  - Efficiency – Repurposing labor
  - Work environment?
- <u>Opportunity</u> to feed more milk or milk replacer solids.
- Animal welfare - group interactions

Group housing feeding alternatives

Mob feeders

- Simple
- Low cost
- Control intake, knowledge of intake?
- Sanitation?

Acidified free choice

- Simple
- Palatability for young calf?
- High level of intake $$$
- Weaning
- Successful weaning

Automatic calf feeders

- Foerster Technik, Urban, Holm-Laue, Biotic,…….
- Controlled feeding plans
- Feeding behavior information – consumed, drinking speed, breaks……
- Consistency of temperature and solids level
- Technical support?
- Operator skills – observation, equipment?
- Cost?

Achieving success with calves in autofeeder systems

- Colostrum management
- Facility design
- Machine
  - Feeding plans
  - Diet ingredients
  - Sanitation
- People
- Service

Colostrum Management

- Poor calf performance?
  - Autofeeder is blamed
  - Measure serum proteins on calves <5 days of age.   85% > 5.5 g/dl.

Not colostrum again!

- Gallon
- High Ig – 50g/L
- Early in life <6 h
- Clean

E. coli entering intestine epithelial cell
Destruction of microvilli

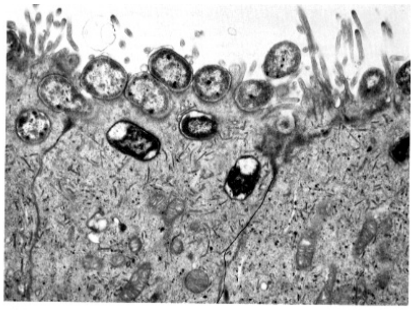


FIG. 2. Apical ends of several ileal epithelial cells from an *E. coli* exposed calf which had received no colostrum, The microvilli were largely absent at the sites of *E. coli* attachment. *E. coli* were also within the apical cytoplasm (approximately 16,000×).

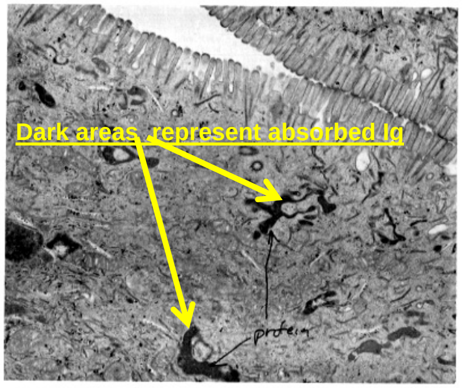


FIG. 4. Ileal epithelial cells from a calf which had received colostrum prior to *E. coli* were unaltered cytologically, Dark aggregations of colostral proteins were in the apical tubular system of the cells (approximately 14,000×).

Colostrum fed calf

Higher bacteria levels = earlier onset of closure.
Environment and colostrum can contain high levels of bacteria.

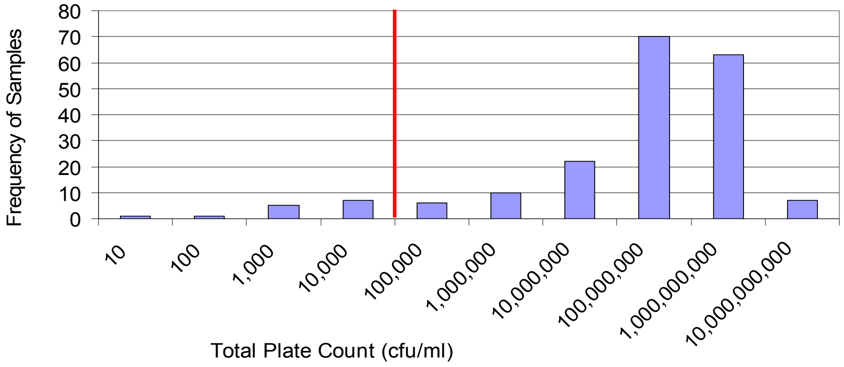
Total Bacteria Counts in Minnesota Colostrum

(Swan et al. 2007. JDSci. 90)

Median TPC = 615 million cfu/ml (73 to 104 billion)

93% of samples > 100,000 cfu/ml TPC

Goal is to have TPC less than 100,000 cfu/ml



From - S. Godden

Most colostrum problems are facility or people problems!

- Facilities – Location of close up cows, calving environment, newborn housing
  - Interval between calving and fresh cow milking?
  - Colostrum harvest – clean milking equipment, containers
  - Feeding the new born on a timely basis (<6 – 12 hr. of birth)
  - Growth of bacteria in colostrum / microbial exposure of the newborn.

Colostrum management

- Cool or feed within 30 minutes – one hour

People

Who is responsible for:

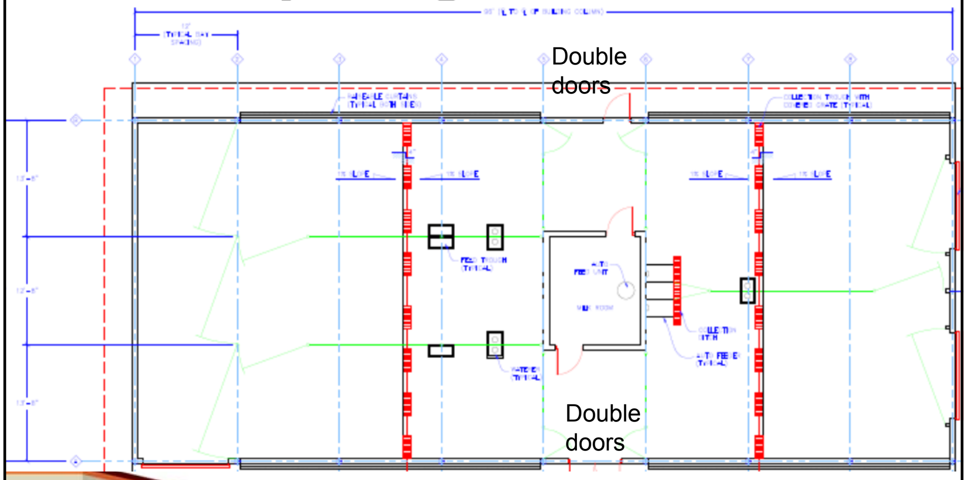
- Milking fresh cows?
- Handling colostrum?
- Feeding newborn calves?

Autofeeder Facility Design

- 38 Midwestern dairies with autofeeders
- 61% retrofitted older facilities
- 53% naturally ventilated
- 84% supplemented with positive pressure tubes.

Jorgensen et al , 2015

Facility design



Facility

- Central “kitchen(s)”
- Air conditioned
  - Reduce humidity for milk replacer
- Large sink
- Hot water supply
- Refrigerator
- Internet connection
- Drainage
- Elevations – same as feeding station

Facility design

- Bedding
  - Amount of bedding
  - Frequency of bedding
  - Drainage
  - Dust
- Feeding area –
  - Platform
  - Flat floor – heated?

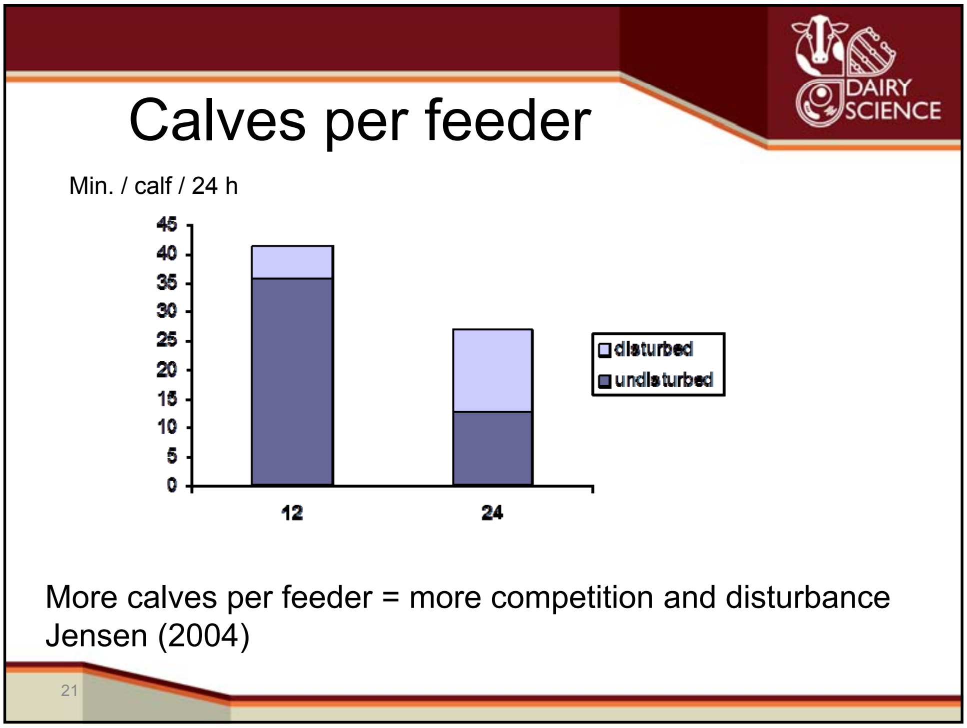
Preconditioning calves

- 0 – 14 days ~ 5 – 6 days
  - Strong appetite.
- Location of preconditioned calves
  - Inside or outside?
- Feed with nipple bottles!
- Same diet as on feeder

Age at introduction to group

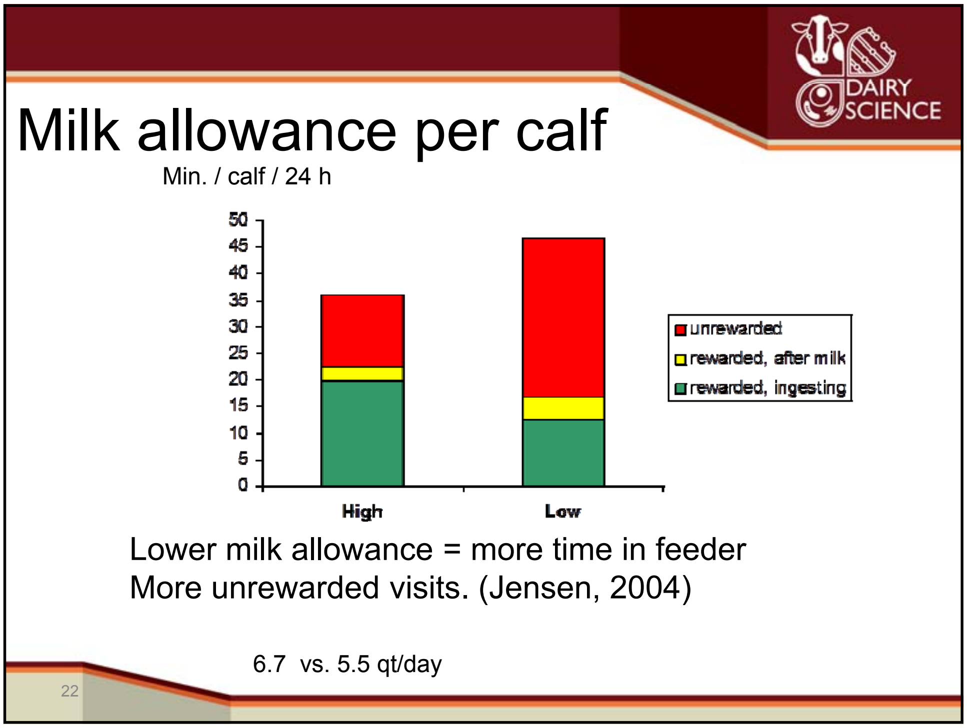
- Day 6 compared to Day 14?
  - More restless 1st day after introduction - Rasmussen et al, 2006)
  - Needed more guidance to feeder (Jensen, 2008)
- 50% less risk of respiratory disease if wait to 14 d (Svensson and Liberg, 2006)

Photo – Jensen - 2009



Calves per feeder

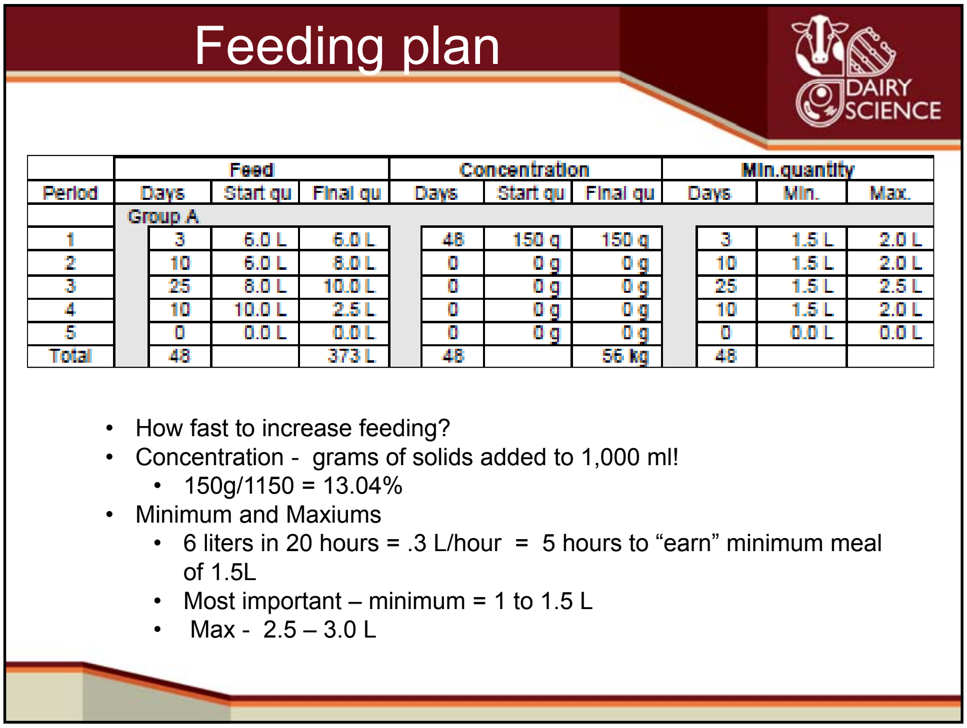
More calves per feeder = more competition and disturbance
Jensen (2004)



Milk allowance per calf

Lower milk allowance = more time in feeder
More unrewarded visits. (Jensen, 2004)

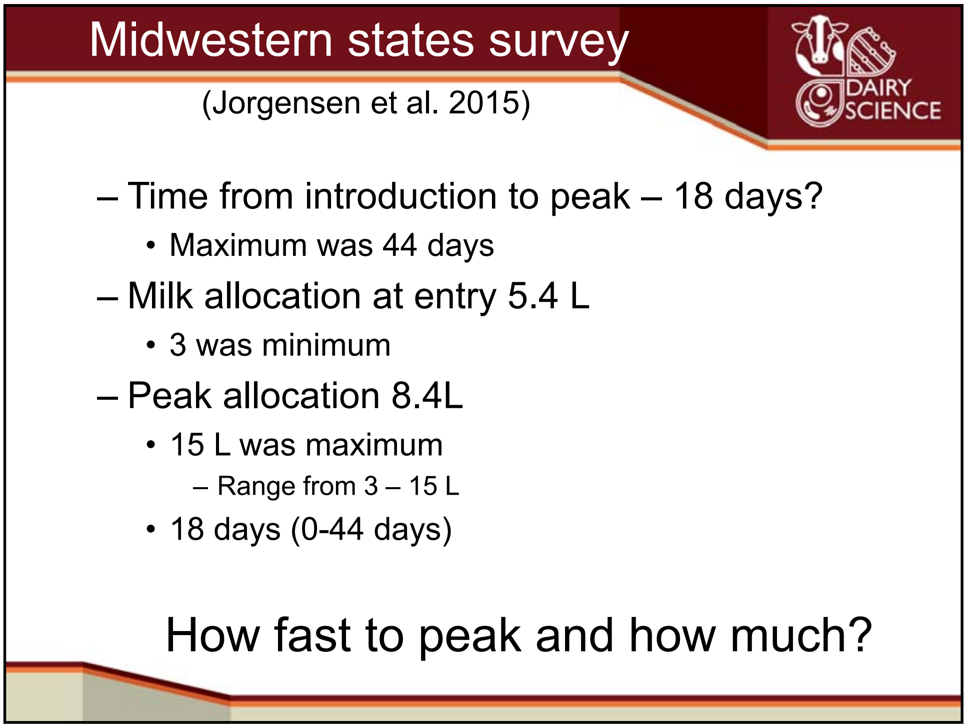
6.7 vs. 5.5 qt/day



Feeding plan

	Feed			Concentration			Min.quantity		
Period	Days	Start qu	Final qu	Days	Start qu	Final qu	Days	Min.	Max.
	Group A								
1	3	6.0 L	6.0 L	48	150 g	150 g	3	1.5 L	2.0 L
2	10	6.0 L	8.0 L	0	0 g	0 g	10	1.5 L	2.0 L
3	25	8.0 L	10.0 L	0	0 g	0 g	25	1.5 L	2.5 L
4	10	10.0 L	2.5 L	0	0 g	0 g	10	1.5 L	2.0 L
5	0	0.0 L	0.0 L	0	0 g	0 g	0	0.0 L	0.0 L
Total	48		373 L	48		56 kg	48		

- How fast to increase feeding?
- Concentration - grams of solids added to 1,000 ml!
  - 150g/1150 = 13.04%
- Minimum and Maxiums
  - 6 liters in 20 hours = .3 L/hour = 5 hours to “earn” minimum meal of 1.5L
  - Most important – minimum = 1 to 1.5 L
  - Max - 2.5 – 3.0 L



Midwestern states survey

(Jorgensen et al. 2015)

- Time from introduction to peak – 18 days?
  - Maximum was 44 days
- Milk allocation at entry 5.4 L
  - 3 was minimum
- Peak allocation 8.4L
  - 15 L was maximum
    - Range from 3 – 15 L
  - 18 days (0-44 days)

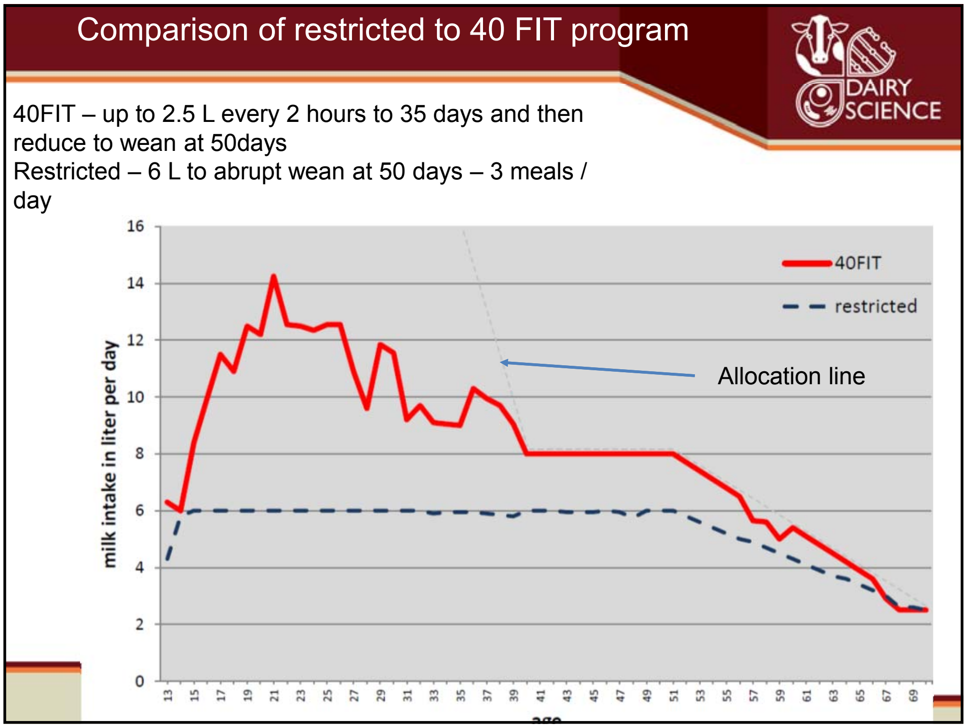
How fast to peak and how much?

FÖRSTER TECHNIK
Automatisch besser.

Effects of two feeding systems on the development of dairy calves
- 40FIT vs. Restricted Feeding –

Masterthesis Nina Jurkewitz

German dairy farm – 940 cows
1st 13 days bucket feeding – 4 calves / pen
13 days – autofeeder in group pen – 16 calves / pen

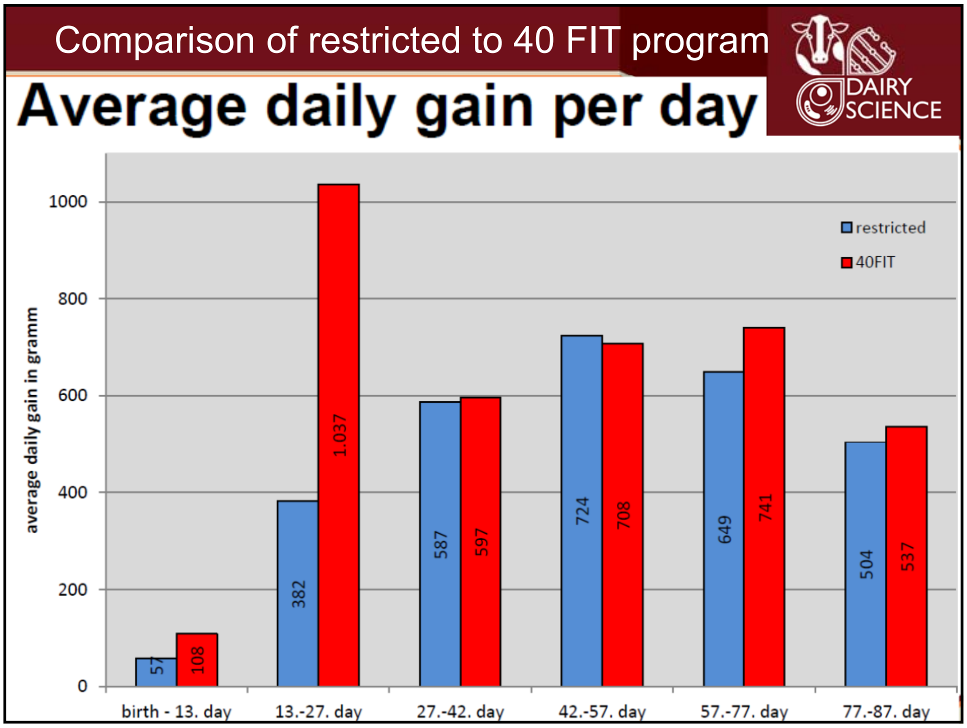


Comparison of restricted to 40 FIT program

DAIRY SCIENCE

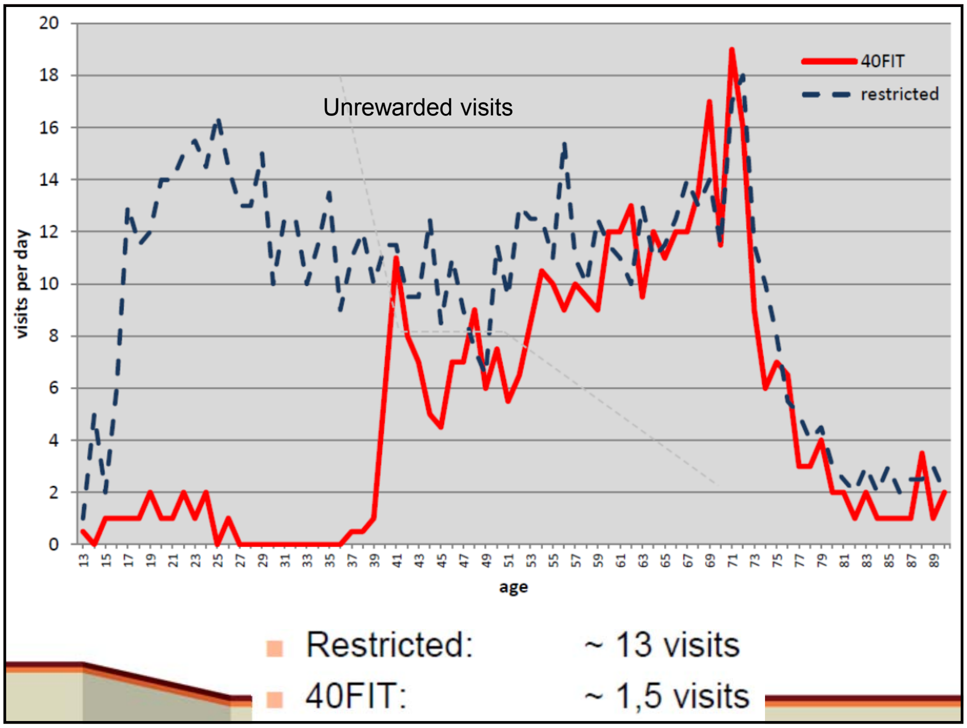
40FIT – up to 2.5 L every 2 hours to 35 days and then reduce to wean at 50days
Restricted – 6 L to abrupt wean at 50 days – 3 meals / day

Allocation line



Comparison of restricted to 40 FIT program

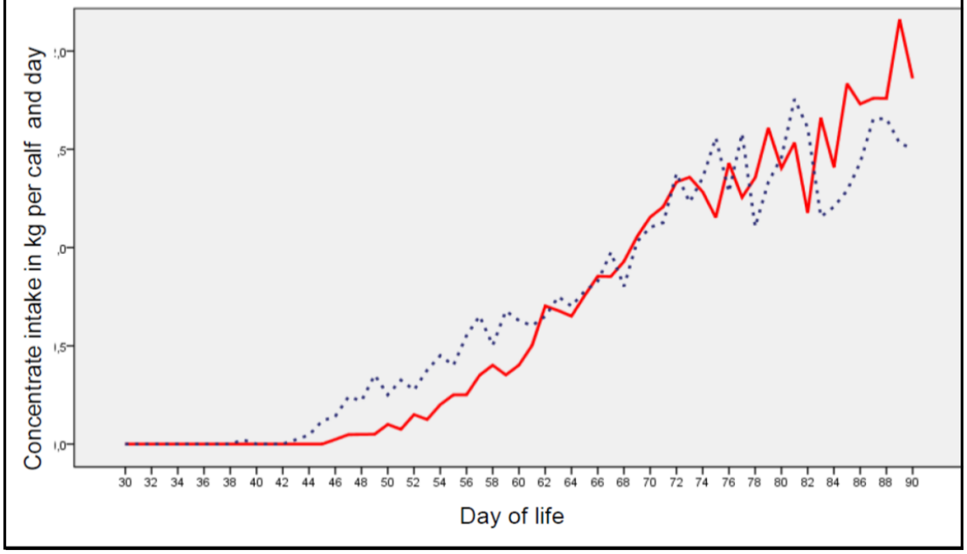
Average daily gain per day



- Restricted: ~ 13 visits
- 40FIT: ~ 1,5 visits

Comparison of restricted to 40 FIT program

Concentrate intake *(N. Jurkewitz, 2012)*



Liquid diet for autofeeders ?

- Jorgensen study
  - 68% fed milk replacer
  - 24% waste milk plus balancer
  - 8% waste milk
- Va. Tech study – all milk replacer
  - 6 Virginia herds - 20:20 - 27:10
  - 4 Minnesota herds - 2 waste milk, 2 milk replacer

Guidelines for milk replacer

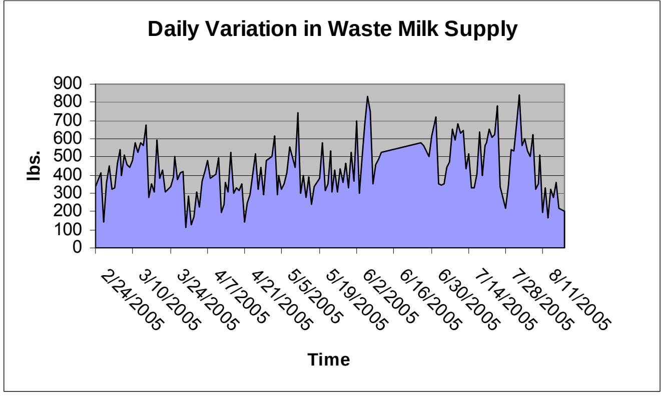
- High quality - ???
- Flow through the hopper
- Meet the nutrient requirements for growth at higher intake – 26% protein
- Fat levels according to season?
- Intake of solids is more important than %

Challenges of using whole milk

- Managing whole(waste)milk
  - Pasteurizer?
  - Two tanks – raw milk and pasteurized milk
  - Conveyance from storage tank to autofeeder
  - Account for:
    - Varying supply of waste milk
    - Varying solids level of waster milk
  - Foerster Technik will blend waste milk with milk replacer to create desired solids level

Feeding waste milk in an autofeeder

Managing variation in waste milk supply



M. C. Scott, M.S. Thesis

Sanitation Management

- Cleaning cycles
  - Circuit cleaning
  - Mixer/heat exchanger cleaning
- Cleaning agents – chlorinated alkaline
  - Follow directions
  - Freshness of cleaners
  - Temperature
- Material replacement

Bacteria Goals

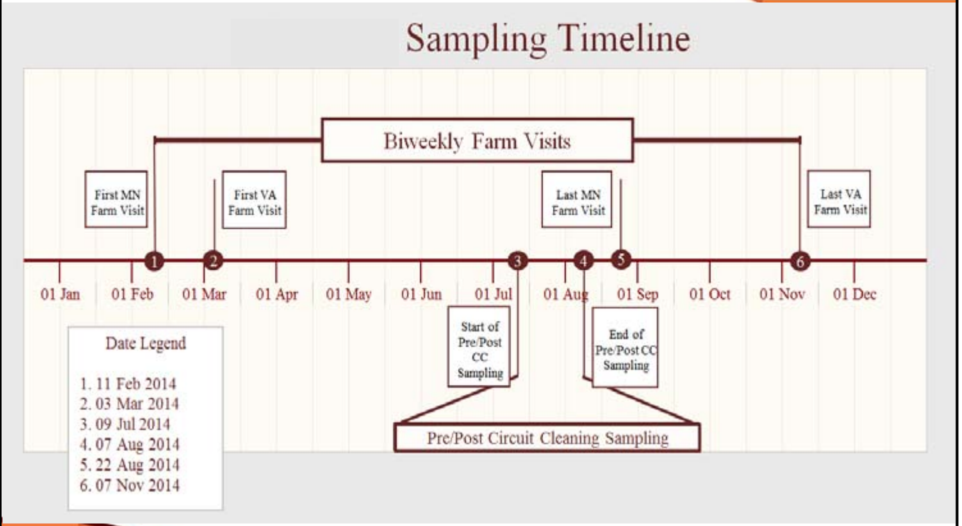
- Not well-established or tested

Recommendations					
	SPC[1]	Coliform[1]	Environmental Strep[2]	CNS[2]	Noncoliform[2]
Goal (cfu/ml)	< 20,000	< 100	< 5,000	< 5,000	< 5,000

[1]Pasteurized Milk Ordinance, 2011; [2]McGuirk, 2003

Va. Tech / Minnesota study - 10 farms, > 1,000 calves

Alyssa Dietrich, M.S. Thesis, 2015



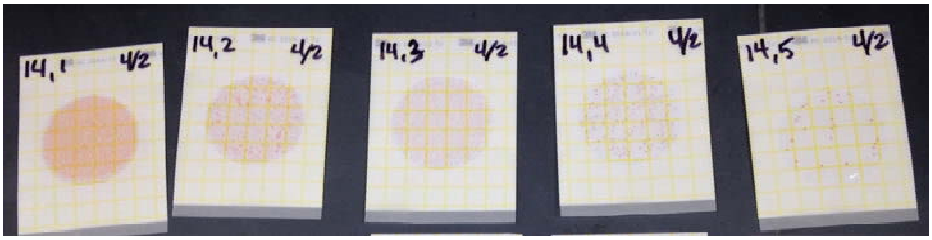
Sampling Timeline

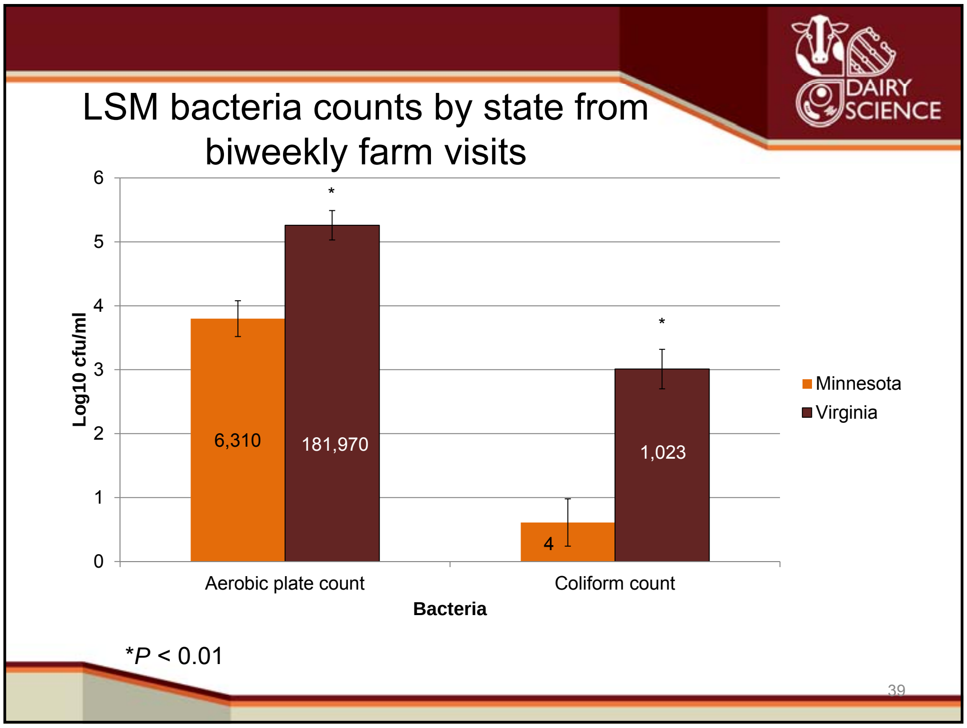
Date Legend

1. 11 Feb 2014
2. 03 Mar 2014
3. 09 Jul 2014
4. 07 Aug 2014
5. 22 Aug 2014
6. 07 Nov 2014

Bacteriology

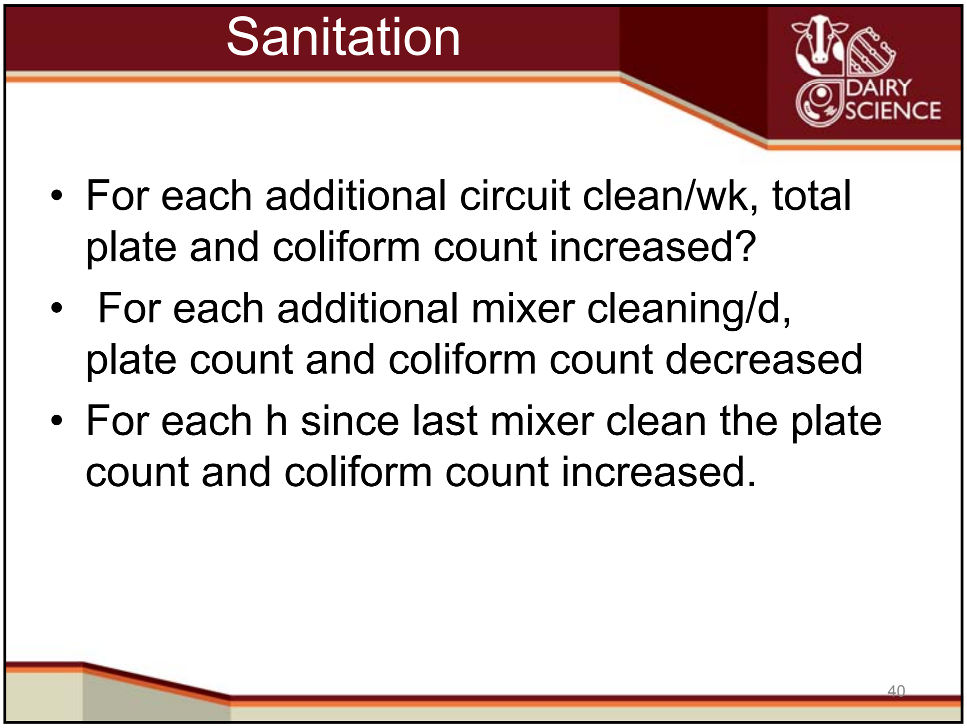
- MMR samples thawed and plated on 3M Petrifilms in tenfold serial dilutions
- Aerobic plate count incubated at 37°C for 48 ± 3 h
- Coliform count incubated at 37°C for 24 ± 2 h





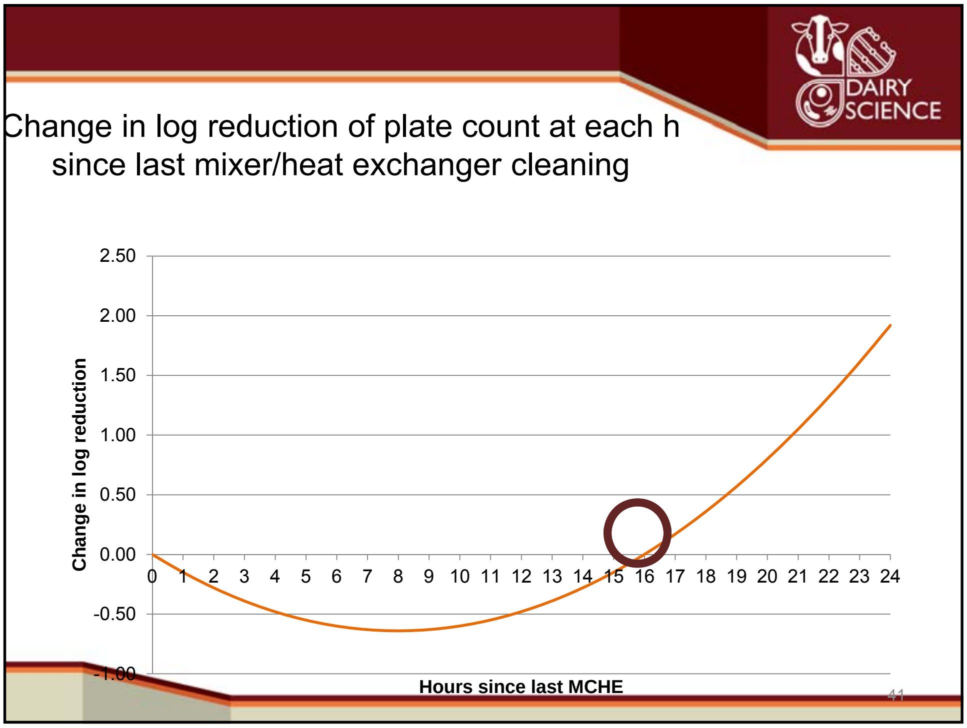
LSM bacteria counts by state from biweekly farm visits

*$P < 0.01$

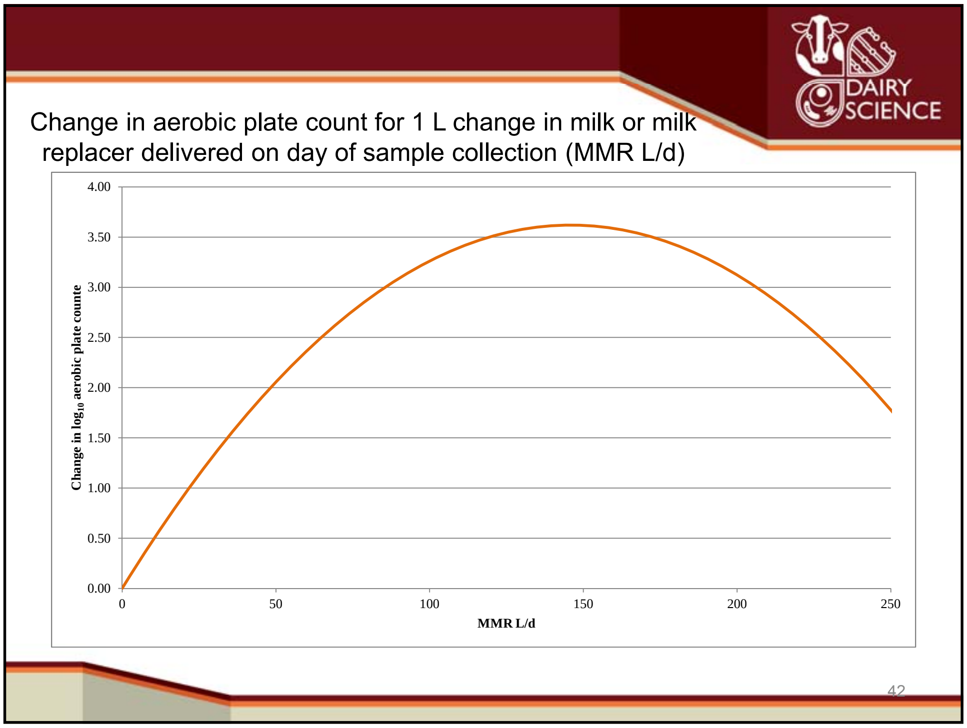


Sanitation

- For each additional circuit clean/wk, total plate and coliform count increased?
- For each additional mixer cleaning/d, plate count and coliform count decreased
- For each h since last mixer clean the plate count and coliform count increased.



Change in log reduction of plate count at each h since last mixer/heat exchanger cleaning



Change in aerobic plate count for 1 L change in milk or milk replacer delivered on day of sample collection (MMR L/d)

What does this mean?

- Circuit cleaning not as effective as mixer cleaning.
- Do circuit clean once a day when working calves – remove nipple, hand clean, rotate.
- Schedule at least 3 mixer cleanings / day before heavy calf feeding times.

Feeder hoses

Replace with FT hose, from mixer to milk line

Milk lines to nipples
Use low cost hose

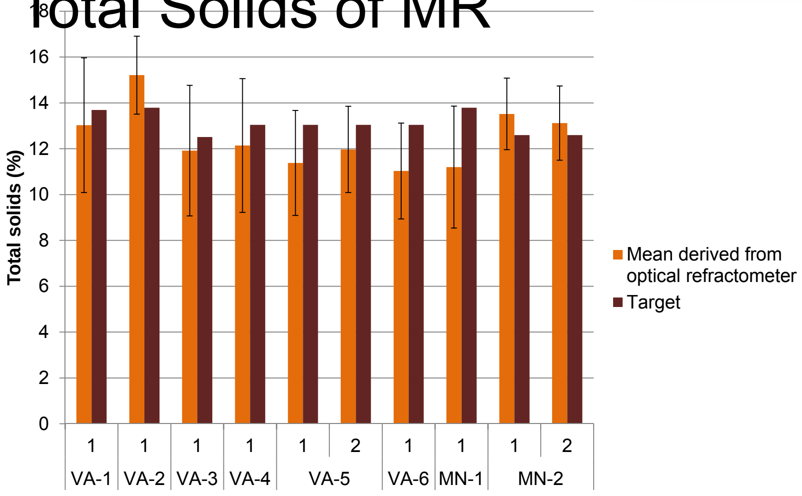
How accurately do they mix milk replacer?

- Temperature? - need to check and calibrate
- Solids – depends on MR delivery mechanism.
- FT autocalibrates - Warning periodically – ? g weight provided.

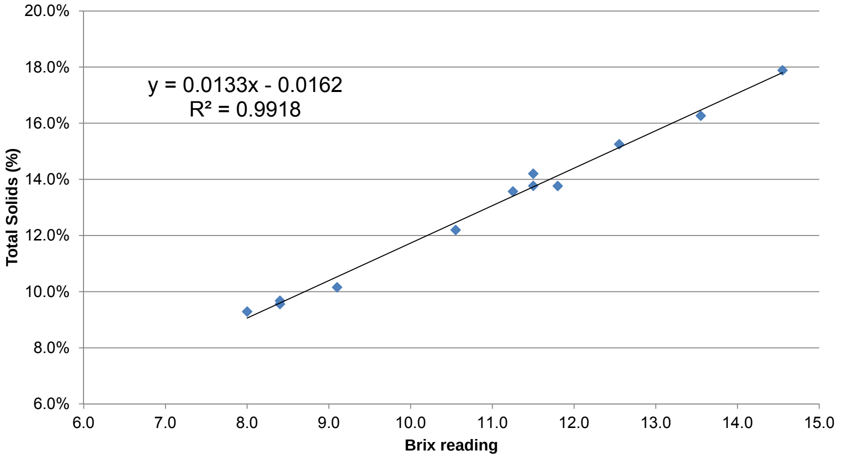
Total Solids Analysis

- Milk replacer samples thawed and vortexed for ≥ 10 s (or until solids were not separated)
- 3 drops pipetted onto 1 optical and 1 digital Brix refractometer
  - Repeated once after inverting sample
- For each different milk replacer, the most variable samples of the same type were dried in forced air oven to determine % total solids (TS)
- % TS data plotted against average refractometer readings to determine a line of best fit for both refractometers and each milk replacer type

Total Solids of MR



Refractometer Reading vs. TS



Correlation between optical and digital - >.9

Conclusions of VT/MN study

- Management
  - Variety of protocols in practice
  - Need for consistent recommendations
- Sanitation
  - Circuit cleaning cannot be relied on to maintain low bacteria counts
  - 4x/d mixer/heat exchanger cleanings is easily-implemented method of reducing bacteria
- Total solids of milk replacer
  - Nearly 40% of samples not within 2% of target. May be due to our sampling.

Feeding Plan Management

- Variety of feeding plans represented in study

Calf Growth Across Study Farms (lb)

Average Daily Gain	1.66
Range	1.25 – 1.99
Standard Deviation	0.27

People

- Observational skills
  - – Observe calves first
  - – Dehydration, nose, eyes, attitude
- Data oriented
  - – Alarms
    - Drinking speed
    - Allocation
- Details oriented
  - – Sanitation, daily routine.

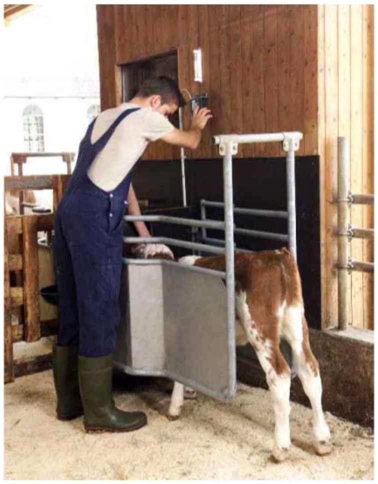
Service

- Autofeeders are not high dollar item for most milking equipment dealers
- Dealer volume with autofeeders – parts, service experience
- Tech Service from company

The daily routine

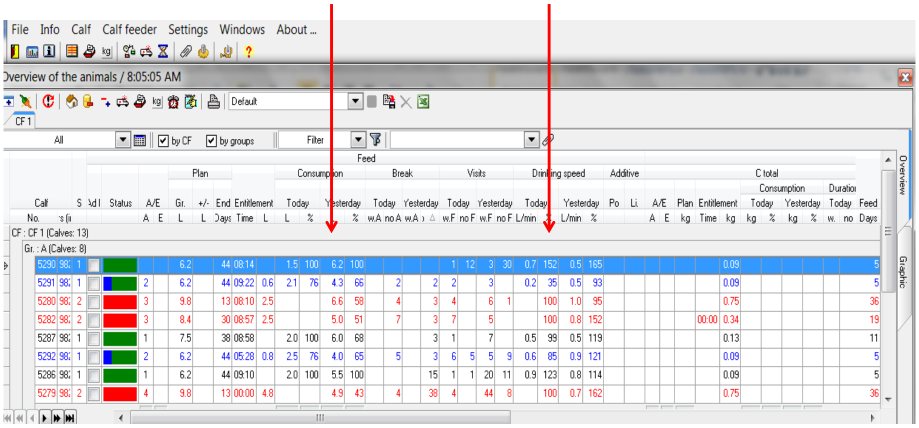
- A.M. - Machine operating normally – winter time?
- Walk the pens and look at calves
- Return to put machine and review data.
  - Drinking speed declines - .5L to 1L/min is normal
  - Allocation
  - Breaks
- Conduct circuit cleaning and clean nipples.

- Training calves
  - Move in evening
  - Train to feeder in A.M.
  - Careful and slow



Foerster Technik slide

Kalbmanager



Overview of the animals / 8:05:05 AM

CF 1

Default

All ☑ by CF ☑ by groups Filter

CF : CF 1 (Calves: 13)

Gr. : A (Calves: 8)

Calf No.	's (i	S	Ad l	Status	A/E A	A/E E	Feed Plan Gr. L	Plan +/- L	End Days	Entitlement Time	Entitlement L	Consumption Today L	Consumption Today %	Consumption Yesterday	Consumption Yesterday %	Break Today w.A	Break Today no A	Break Yesterday w.A	Break Yesterday △	Visits Today w.F	Visits Today no F	Visits Yesterday w.F	Visits Yesterday no F	Drinking speed Today L/min	Drinking speed Today %	Drinking speed Yesterday L/min	Drinking speed Yesterday %	Additive Po	Additive Li.	C total A/E A	C total A/E E	Plan kg	Entitlement Time	Entitlement kg	Consumption Today kg	Consumption Today %	Consumption Yesterday kg	Consumption Yesterday %	Duration Today w.	Duration Today no	Feed Days
5290	98:	1	☐	🟩			6.2		44	08:14		1.5	100	6.2	100					1	12	3	30	0.7	152	0.5	165							0.09							5
5291	98:	1	☐	🟦🟩	2		6.2		44	09:22	0.6	2.1	76	4.3	66		2		2	2		3		0.2	35	0.5	93							0.09							5
5280	98:	2	☐	🟥	3		9.8		13	08:10	2.5			6.6	58		4		3	4		6	1		100	1.0	95							0.75							36
5282	98:	2	☐	🟥	3		8.4		30	08:57	2.5			5.0	51		7		3	7		5			100	0.8	152						00:00	0.34							19
5287	98:	1	☐	🟩	1		7.5		38	08:58		2.0	100	6.0	68				3	1		7		0.5	99	0.5	119							0.13							11
5292	98:	1	☐	🟦🟩	2		6.2		44	05:28	0.8	2.5	76	4.0	65		5		3	6	5	5	9	0.6	85	0.9	121							0.09							5
5286	98:	1	☐	🟩	1		6.2		44	09:10		2.0	100	5.5	100				15	1	1	20	11	0.9	123	0.8	114							0.09							5
5279	98:	2	☐	🟥	4		9.8		13	00:00	4.8			4.9	43		4		38	4		44	8		100	0.7	162							0.75							36

Feeding behavior

- MN CVM studying feeding behavior and disease
- Reduction in drinking speed. Not absolute but change.
- Sick calves may eat allocation but more slowly
- Breaks?

Feed intake

5280 Transmitter 369080098 Feeding day 36

Behavior of calves when managed in groups

- Calves not “conditioned” to feeding time.
  - Influenced by # milk intake and availability of milk.
- Early life social adaptation
  - Calves raised in pairs less post weaning “slump” problems – Chua et al (2001)

Individual vs. group housing – welfare impact?

Nutrition of group-fed calves

- Concept of formulating diets for desired rate of gain - 1 – 2 lb. of gain / day
- Feeding 1.5 to 2.5 lb of milk or milk replacer solids / day
- 2.5 lb. / 12.5% solids = 8.8 L per day.
- 2.5 lb./ 15% solids = 7.3 L per day

Critical items with autofeeders

- Limit feeding – < 1 lb. of solids/day of 4 L = competition at feeder
- Daily allocation - >9L+/day – stocking rate < 25/feeder
- Sq. ft/ heifer - 30+?
- Bedding amount and frequency of bedding

Challenges observed in the field

- Feeding plans – increase to slowly
- Using the data to evaluate calves.
- Cleaning protocols
- Calibration
  - Autocalibration monitors
- Water quality – Mineral and bacterial
- Personnel management
- Facility ventilation and environment

However…..

- Opportunity to feed more solids in smaller more frequent meals
- Socialization of calves
  - No post weaning slump
- Long term impact?

Contribution of Individual Fatty Acids to Cow Performance

Tom Jenkins
Department of Animal & Veterinary Sciences
Clemson University
Clemson, South Carolina

Fat = Lipid = Fatty Acid

- **Lipid** - soluble in solvents but not water
  - **Fat** – solid at room temp
    mostly saturated
    mostly animal based
    - **Contaminants**
      glycerol, vit, water
    - **Fatty Acids**
  - **Oil** – liquid at room temp
    mostly unsaturated
    mostly plant based
    - **Contaminants**
      Pigments, glycerol, vit, water, waxes
    - **Fatty Acids**

Methyl **Acid**

CH_3-C-C-C-C-C-C-C-C=C-C-C-C-C-C-C-C-COOH

CH_3-C-C-C-C-C=C-C-C=C-C-C-C-C-C-C-C-COOH

CH_3-C-C=C-C-C=C-C-C=C-C-C-C-C-C-C-C-COOH

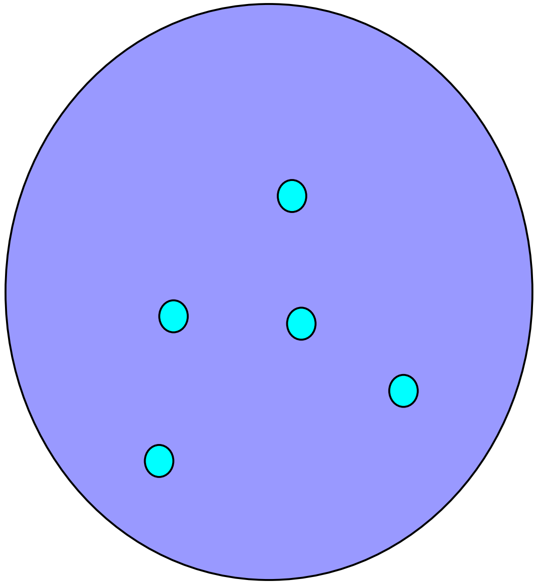
Ether Extract vs Fatty Acids

Forage	Ether Extract (%)	Fatty Acid (% of EE)
Alfalfa hay	1.61	0.89
Corn grain	4.30	4.10
Corn Silage	3.20	2.22

From NDS v 3.8.10.05

Rumen Input of FA in Cows Fed Fat

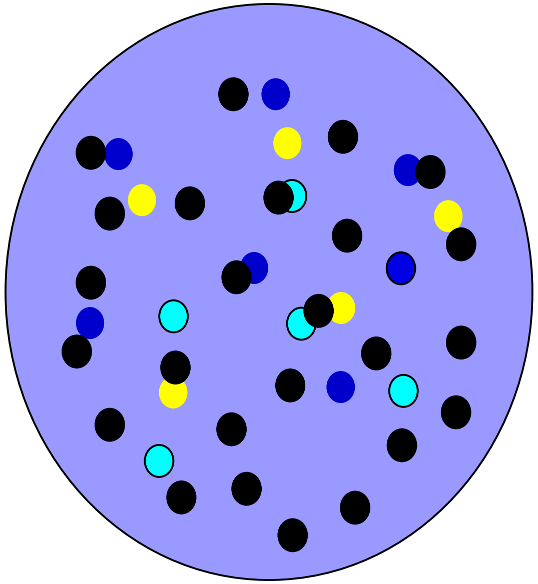
From J. Nutr. 2012. 142:1437-1448.



● 16:0, 18:0
18:1, 18:2, 18:3

Rumen Output of FA in Cows Fed Fat

From J. Nutr. 2012. 142:1437-1448.



○ Feed (n=5)
● Microbial trans FA (n=5)
● Microbial CLA (n=7)
● Microbial FA (n=28)

Where do all the FA come from?

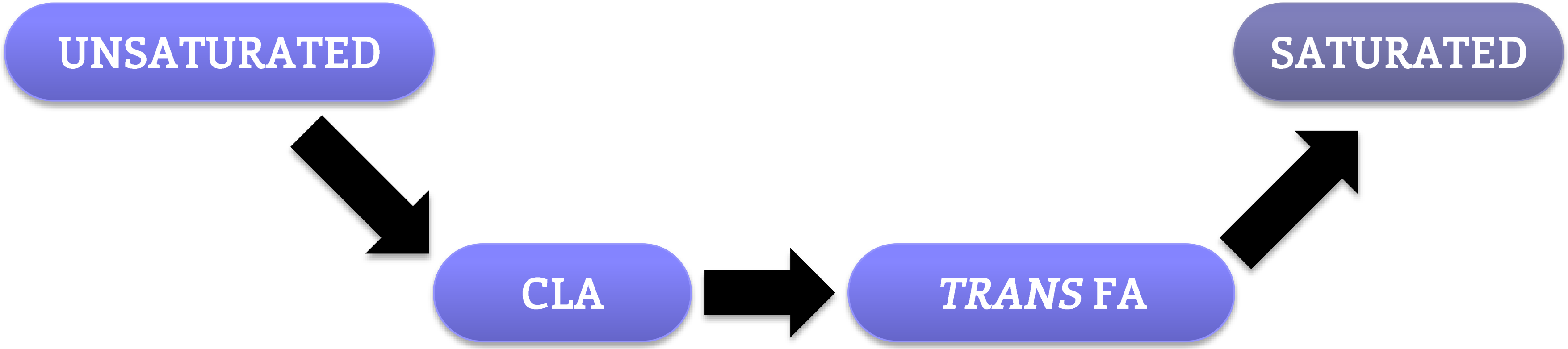
MAINLY
UNSATURATED
IN FEED

BIOHYDROGENATION

MAINLY
SATURATED
IN INTESTINES

Intermediates of Biohydrogenation

Effects on Animal Performance?



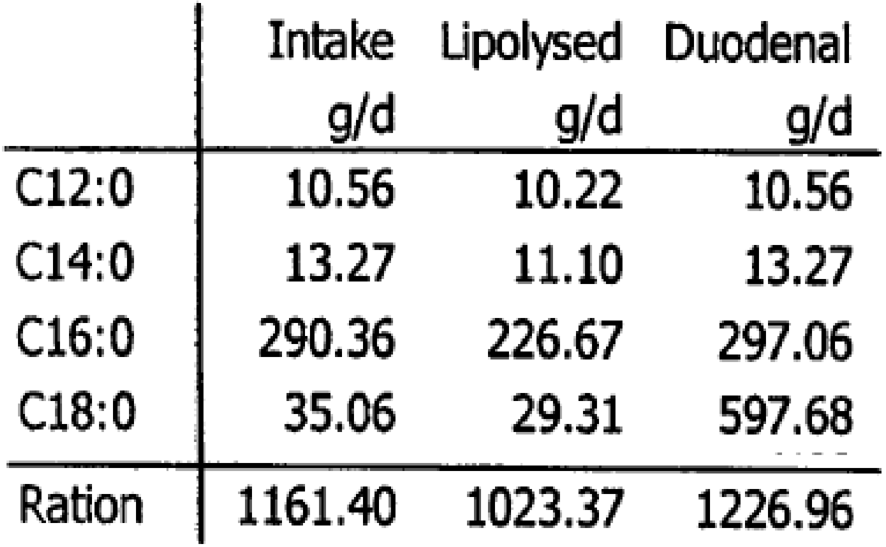
UNSATURATED

CLA

TRANS FA

SATURATED

Saturated



	Intake g/d	Lipolysed g/d	Duodenal g/d
C12:0	10.56	10.22	10.56
C14:0	13.27	11.10	13.27
C16:0	290.36	226.67	297.06
C18:0	35.06	29.31	597.68
Ration	1161.40	1023.37	1226.96

Basic Rules of Fat Energy

- **Adding fat will always increase TMR energy density (Mcal/lb).**

- **Adding fat increases DE intake (Mcal/day) and milk/BW unless;**
  - reduces intake
  - reduces digestibility of other diet nutrients
  - fat itself is poorly digested

DE Breakeven for Fat

			Depression Target		
	Control	**+ 2.7% FA**	**Intake**	**Int. Dig.**	**Rumen Dig**
DMI, lb/d[a]	55.0	55.0	**53.0**	55.0	55.0
Basal	55.0	53.3	51.4	53.3	53.3
Fat		1.7	1.6	1.7	1.7
DE, % GE					
Basal	67.5	67.5	67.5	67.5	**64.6**
Fat	82.3	82.3	82.3	**34.9**	82.3
DE, Mcal/d	77.3	80.4	77.3	77.3	77.3

Bypass Fats

J. Dairy Sci. 95:3225–3247
http://dx.doi.org/10.3168/jds.2011-4895

Effect of fat additions to diets of dairy cattle on milk production and components: A meta-analysis and meta-regression

A. R. Rabiee,* K. Breinhild,* W. Scott,* H. M. Golder,* E. Block,† and I. J. Lean*[1]
*SBS*cibus*, PO Box 660, Camden 2570, New South Wales, Australia
†Church and Dwight Co. Inc., 469 North Harrison Street, Princeton, NJ 08543

	All Fats n=86	Prilled Fats n=4
DMI, lb/d	-1.9*	-0.19
Milk, lb/d	2.3*	2.2
Milk fat, %	-0.04*	0.10

*Estimated mean differences (95% CI) differed from zero.

3.5% Added Fatty Acids on 24 h Rumen In Vitro

	Control	+ 18:0	+ 18:2
Ac/Pr	5.27^a	4.87^a	2.90^b
F. succinogenes	2.04^c	2.69^a	1.37^b
Methane, mmol	1.03^a	0.99^a	0.75^b
Protozoa	2.99^a	2.26^b	1.80^c

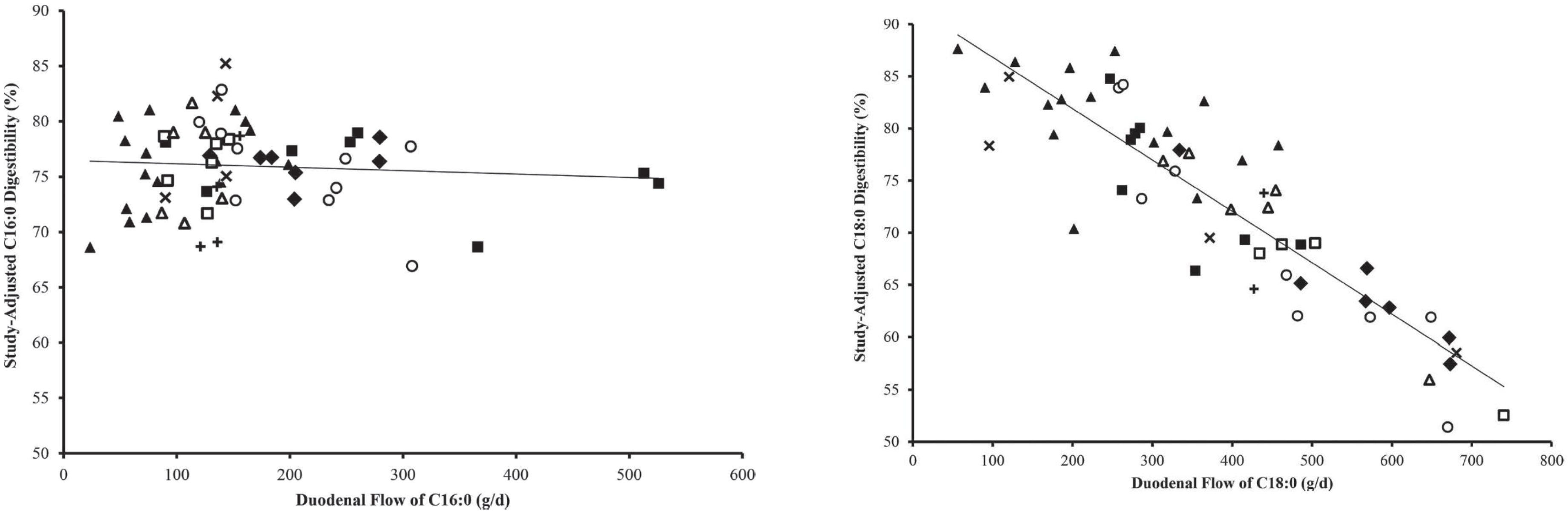
^{abc} Means with different superscripts within a row differ ($P < 0.05$).
Zhang et al. (2008) Anim. Feed sci. Tech. 146:256-269.

	Moate et al. 2004	Glasser et al. 2008	Jenkins 1999	Boerman et al. 2015
16:0	0.725			0.771
18:0	0.728	0.63	0.530	0.728
18:1	0.669	0.86	0.781	0.802
18:2	0.776	0.80	0.827	0.735
18:3	0.775	0.74	0.880	0.805
Duo to feces	X (Int BH NS)		X	
Duo to ileum		X		X
Species	dairy	Dairy, beef, sheep (NS)	dairy	Lactating dairy
n (studies, obs)	8,36	77, 294	11,49	?, 10-18
Outliers deleted	HT, WS	HT		PHT

J. Dairy Sci. 98:1–15
http://dx.doi.org/10.3168/jds.2015-9592

Intestinal digestibility of long-chain fatty acids in lactating dairy cows: A meta-analysis and meta regression

J. P. Boerman,* J. L. Firkins,† N. R. St-Pierre,† and A. L. Lock*[1]
*Department of Animal Science, Michigan State University, East Lansing 48824
†Department of Animal Sciences, The Ohio State University, Columbus 43210



3% Added Saturated Fatty Acids

	CON	SFA
TMR FA, % DM	2.94	6.57*
Milk, lb/d	90.9	93.5
Fat, %	3.59	3.94*

* Con and SFA differed ($P < 0.05$).
Taken from Weiss et al. 2011. J. Dairy Sci. 94 :931–939

Saturated FA on Milk Yield

	0 SFA	1.5% SFA	3% SFA
Milk, lb/d	58.1	63.0	63.0
Milk Fat, lb/d	1.96	2.31	2.40
FA intake, lb/d[a]	1.63	2.25	2.88

[a] Estimated as EE-1. Fat sources were 54% C16 and 34% C18.

Wang et al. 2010.

Metabolic Limit
FA intake = Milk fat yield

Palmitate (C16)^1 Effects on Milk Fat

	Milk Fat, %		Study length	Cows	
g added C16	**- C16**	**+ C16**	**d**	**n**	**Reference**
384	3.75	3.60*	35	214	Warntges et al., 2008
449	3.14	3.22	14	24	Rico and Harvatine, 2011
412	3.44	3.93*	16	18	Mosley et al. 2012
361	3.88	4.16*	25	16	Lock et al., 2013
545	3.29	3.40*	21	32	Piantoni et al, 2013

[1] All supplemented sources were > 85% C16.

Palmitic Acid

- Good Points
  - Same energy as other bypass fats
  - Research results more often than not show increased milk fat (0.1 to 0.3 % units)
- Questions
  - Responses over longer time?
  - Responses in studies with more cows?
  - Responses when comparing to other bypass fats?

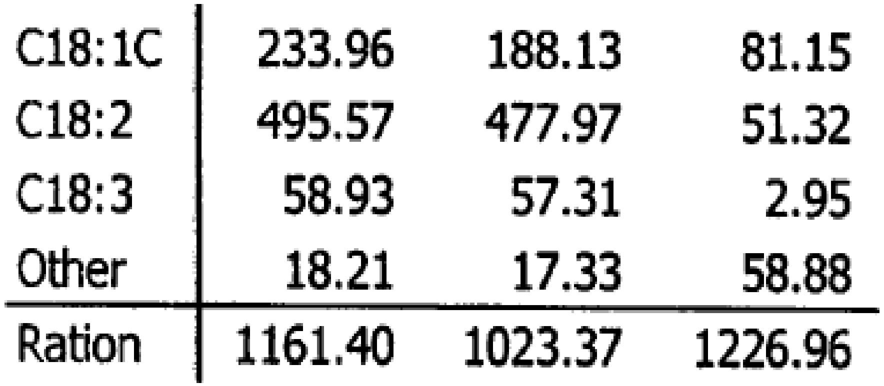
Glycosylphosphatidylinositol – anchored proteins (GPI-AP)

- Anchor more than 100 proteins to cell membrane
  - Hydrolytic enzymes
  - Receptors
  - Adhesion molecules
- During synthesis, UFA are replaced by SFA (stearic) for full function

GPI-AP: function of saturated FA

- Results from Jaensch et al. Traffic 2014. 15:1305.
  - FA remodeling from UFA to SFA not needed for intracellular transport after synthesis
  - FA remodeling was needed for cell surface expression of GPI-AP

Unsaturated



C18:1C	233.96	188.13	81.15
C18:2	495.57	477.97	51.32
C18:3	58.93	57.31	2.95
Other	18.21	17.33	58.88
Ration	1161.40	1023.37	1226.96

Fats Alter Rumen Microorganisms

- Feeding flaxseed to dairy cows (Animal 2012. 6:1784).
  - Caused a 49% reduction in 16S rRNA targeting methanogens
- Feeding coconut oil to sheep (Trop. Anim. Health Prod. 2012. 44:1541).
  - Decreased methanogens by 77%
  - Decreased ruminal fungi by 85-95%
  - Increased Ruminococcus flavefaciens by 25-70%
- Feeding fish oil to dairy cows (J. Nutr. 2012. 142:1437.).
  - Caused reduction in key Butyrivibrio spp.
- Defatting DDG in vitro (J. Dairy Sci. 2010. 93:4735).
  - Increased fibrolytic bacteria from 27 to 39%.
  - Increased proteolytic bacteria from 26 to 37%.
  - Decreased lactate-utilizing bacteria from 3 to 1.4%

3.5% Added Fatty Acids on 24 h Rumen In Vitro

	Control	Stearic	Oleic	Linoleic	Linolenic
Ac/Pr	5.27^{a}	4.87^{a}	4.13^{b}	2.90^{c}	2.08^{d}
F. succinogenes	2.04^{c}	2.69^{a}	2.26^{b}	1.37^{d}	1.13^{e}
Methane, mmol	1.03^{a}	0.99^{ab}	0.94^{b}	0.75^{c}	0.56^{d}
Protozoa	2.99^{a}	2.26^{b}	1.96^{c}	1.80^{c}	1.30^{c}

^{abc} Means with different superscripts within a row differ ($P < 0.05$).
Zhang et al. (2008) Anim. Feed sci. Tech. 146:256-269.

Addition of Fat to 40% Starch Diets Fed to Feedlot Steers

	% Yellow Grease		
	0	4	8
Rumen OMD, %[a]	59.1	54.1	49.5
Rumen ADFD, % [a]	27.3	19.0	6.7
Rumen A/P[a]	3.74	2.46	2.04

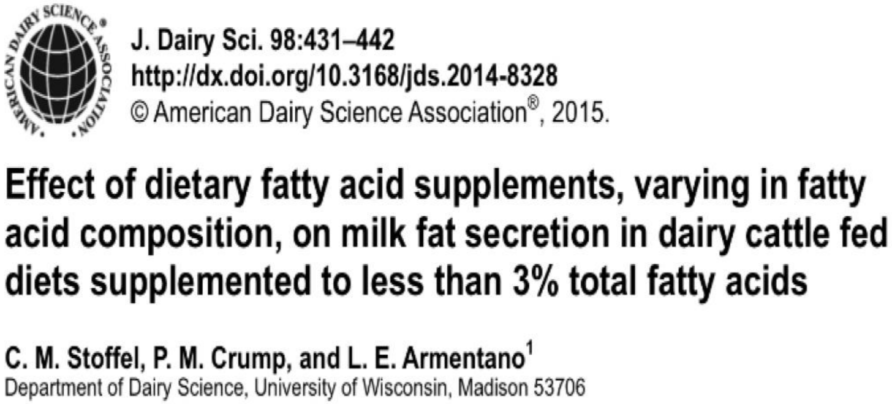
[a] Linear effect ($P < 0.05$).

From J. Anim. Sci. 1989. 67:1038-1049.

Addition of 6% Rapeseed Oil Fed to Lactating Cows

	-RO	+RO	P <
Total tract			
OMD	73.6	70.0	<0.05
NDFD	56.9	46.9	<0.05
Rumen			
A/P	4.34	2.94	<0.05

From Can. J. Anim. Sci. 1993. 73:547-557.



J. Dairy Sci. 98:431–442
http://dx.doi.org/10.3168/jds.2014-8328

Effect of dietary fatty acid supplements, varying in fatty acid composition, on milk fat secretion in dairy cattle fed diets supplemented to less than 3% total fatty acids

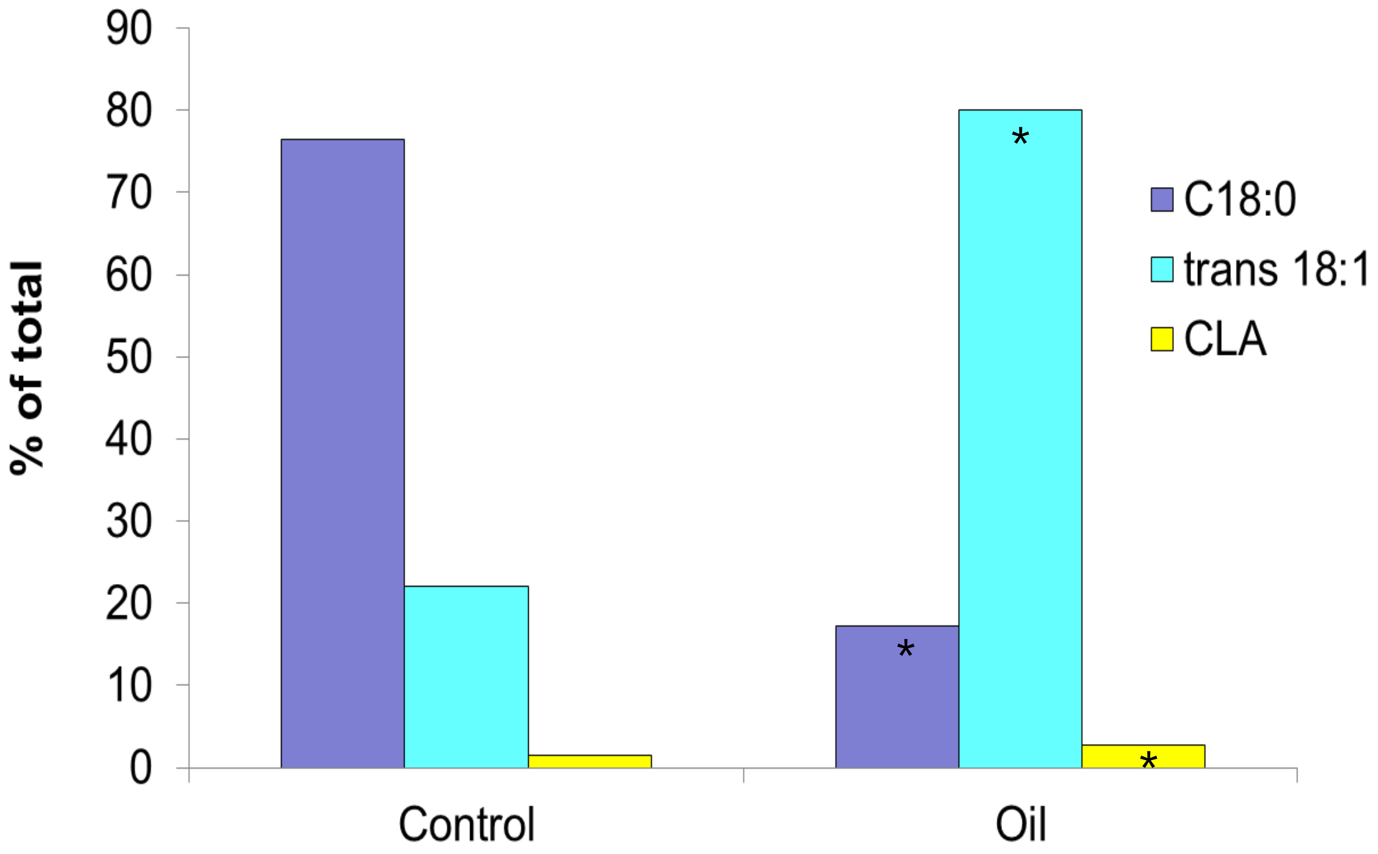
C. M. Stoffel, P. M. Crump, and L. E. Armentano[1]
Department of Dairy Science, University of Wisconsin, Madison 53706

	CON	1.7% Added Oil[1]
DMI, lb/d	60.3	59.2
Milk, lb/d	99.2	96.4*
Milk fat, %	3.53	3.03*
Milk protein, %	3.20	3.14*

*CON and FAT diets differed ($P < 0.05$).

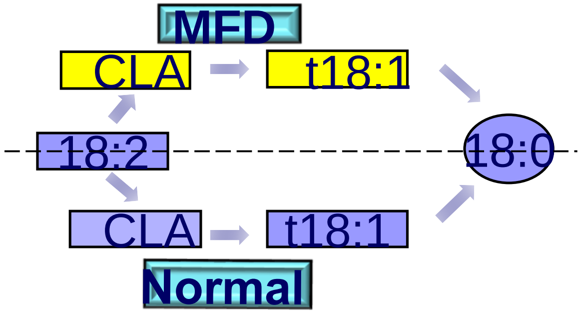
[1] Fat sources were corn and safflower oil.

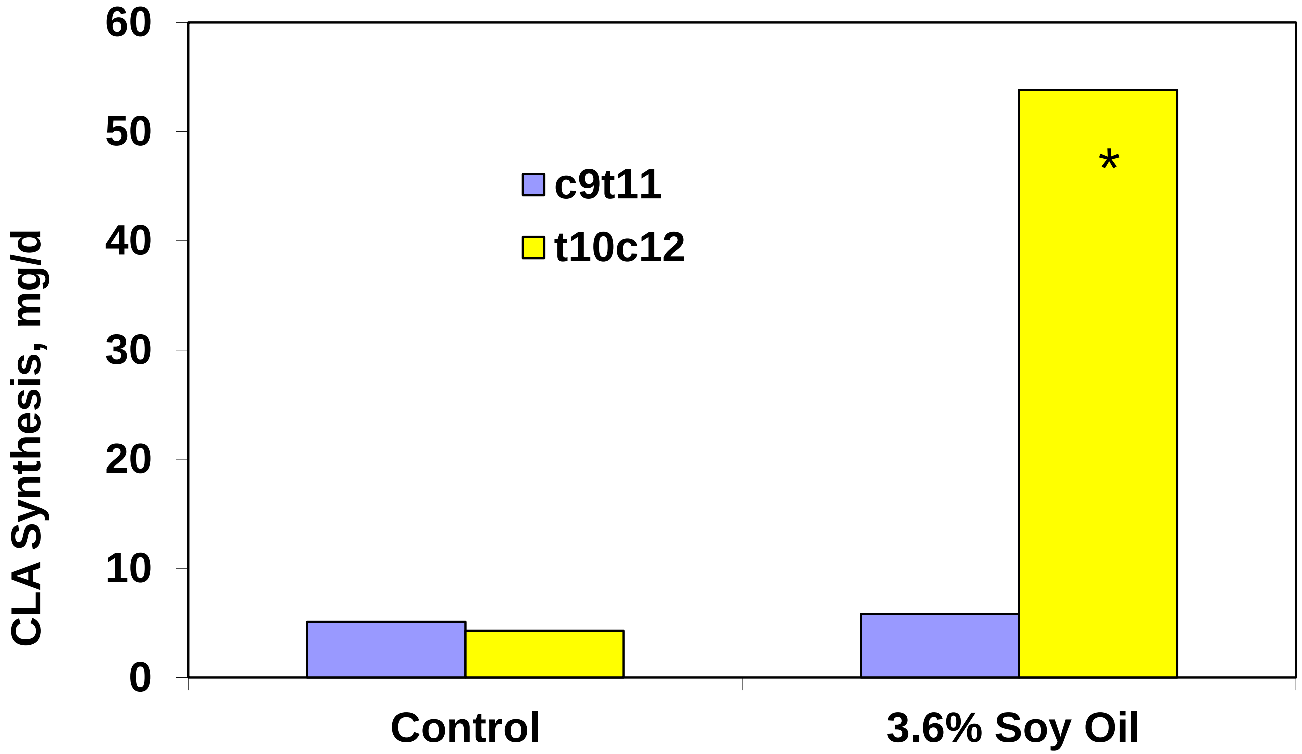
Fat Effects on Biohydrogenation



***Differed from control (P < 0.05).**
Gudla et al., 2012. Anim. Feed Sci Tech. 171:108.

Amount and Type of Fat


MFD
CLA → t18:1
18:2
18:0
CLA → t18:1
Normal

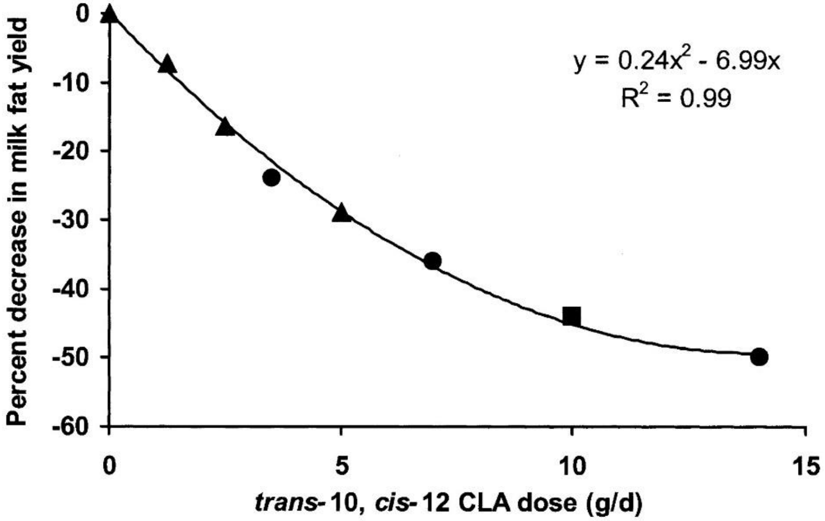


Continuous culture data from Jenkins et al. (2014).

3.4% Added Soybean Oil

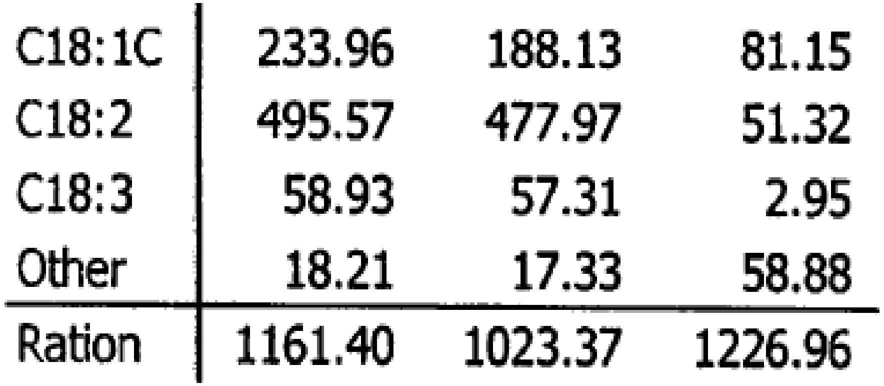
	CON	SBO
Milk fat, lb/d	2.27	2.02*
Milk fat, %	3.76	3.14*

*CON and FAT diets differed ($P < 0.05$).
Taken from AlZahal et al., 2008.
J. Dairy Sci. 91:1166–1174.



Essential Fatty Acids

- Linoleic and linolenic
- Forage and grain lipids are rich in EFA.
- Most of the EFA are destroyed by rumen bacteria during BH.



C18:1C	233.96	188.13	81.15
C18:2	495.57	477.97	51.32
C18:3	58.93	57.31	2.95
Other	18.21	17.33	58.88
Ration	1161.40	1023.37	1226.96

Essential Fatty Acids

- Linoleic (ω-6) and linolenic (ω-3)
- Forage and grain lipids are rich in EFA.
- Most of the EFA are destroyed by rumen bacteria during BH.

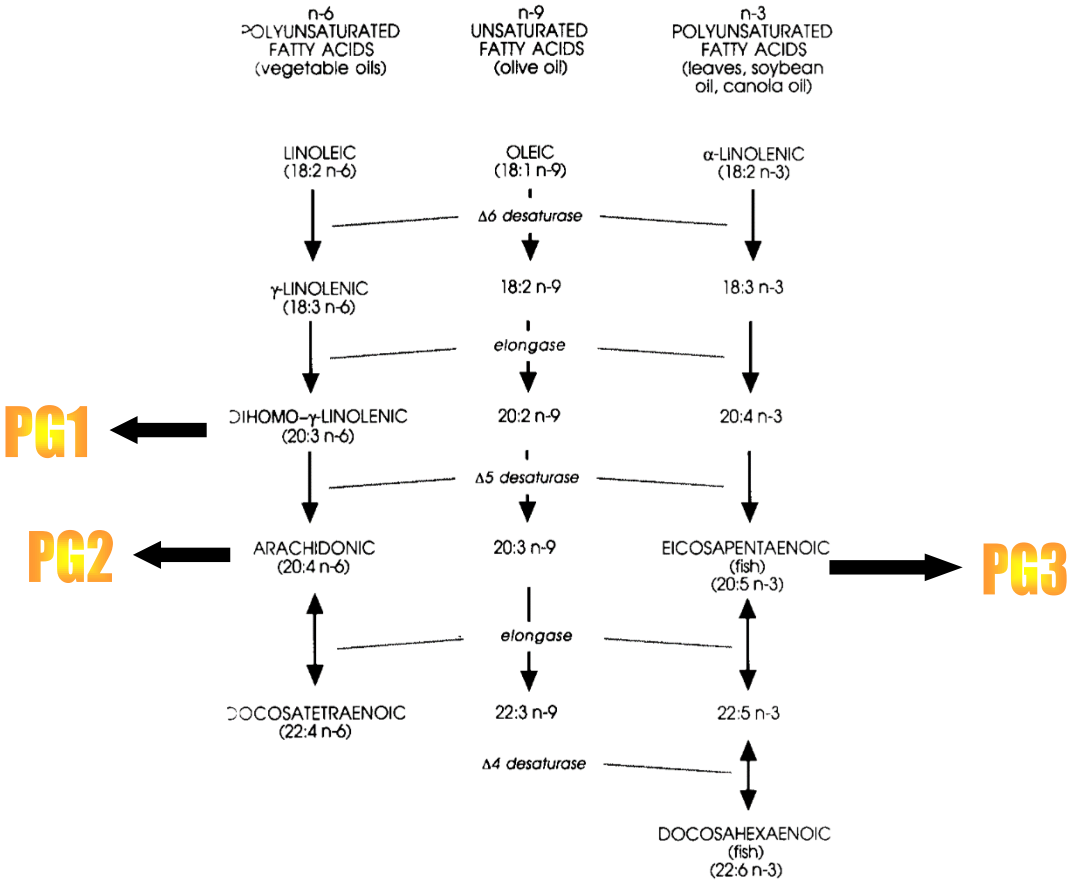


Figure 1 Outline of pathways of desaturation and elongation of dietary unsaturated fatty acids; the same enzymes are involved for each of the n-3, n-6, and n-9 fatty acid families

Human health benefits of omega FA

Physiological

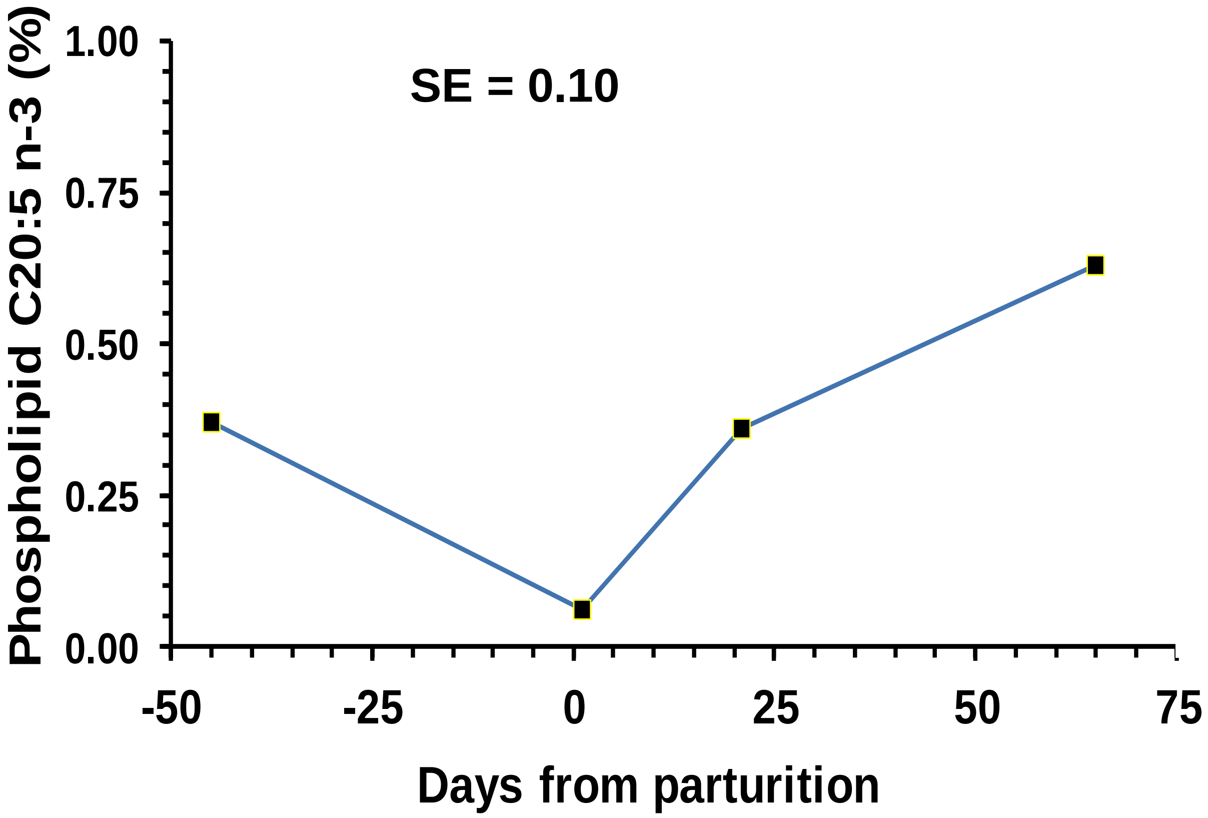
- Antinflammatory and anticlotting
- Decrease fat build up in arteries
- Decrease incidence of arrhythmia
- Lower TG and cholesterol
- Reduce the risk of bone loss and certain cancers

Psychological

- Lowered incidence of depression and post-partum depression
- Improve cognitive and visual fetal development
- Reduce neurological disorders such as Alzheimer’s disease

http://ific.org/publications/factsheets/omega3fs.cfm#Health

Are Transition Cows EFA-Deficient?



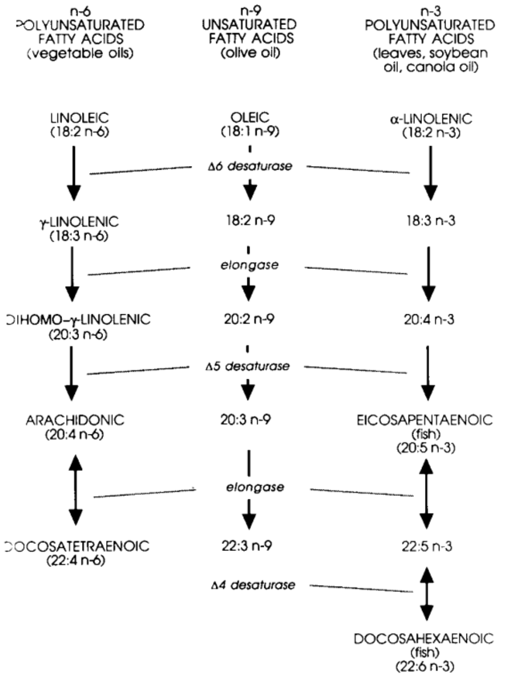


Figure 1 Outline of pathways of desaturation and elongation of dietary unsaturated fatty acids; the same enzymes are involved for each of the n-3, n-6, and n-9 fatty acid families

Day (*P* < 0.01)

Douglas et al., 2002

Essential Fatty Acids and Reproduction

- Increase CL diameter
- Increase synthesis of series 3 prostaglandins
- Increased pregnancy rates
  - Increased first, second service conception
  - **Increased early embryo survival**
    - ☐ 15 more pregnant cows for every 100 confirmed pregnant

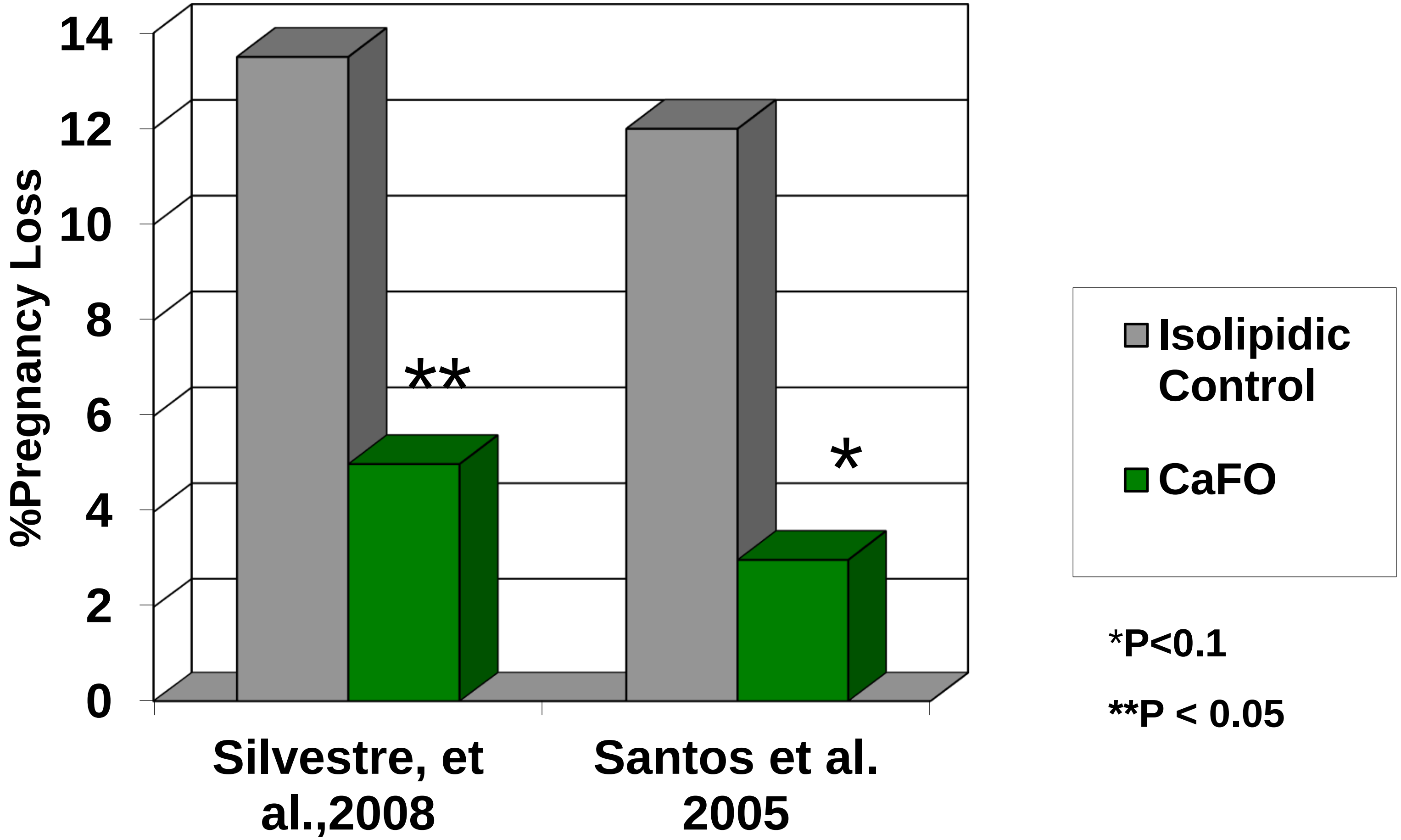
Effects of Ca18:2 on Reproduction

	Ca-LCFA	Ca-LCFA+EFA
Ovulations		
n	63	57
# ovulations	17	28
Ovulations, %	27	49*
Uterine health by 60 DIM		
n	1,312	708
Treated	32.1*	26.3
Retreated	21.4*	10.2
Total treated	38.9*	29.0

*$P < 0.05$

Jones et al. The Professional Animal Scientist 24 (2008):500–505

1st Service Day 32 to 60 Post-insemenation Pregnancy Loss



*P<0.1

**P < 0.05

J. Dairy Sci. 98:5601–5620
http://dx.doi.org/10.3168/jds.2015-9528

Effects of dietary fat on fertility of dairy cattle: A meta-analysis and meta-regression

R. M. Rodney,*†[1] P. Celi,† W. Scott,* K. Breinhild,* and I. J. Lean*
*SBScibus, Camden, New South Wales, Australia 2570
†Dairy Science Group, Faculty of Veterinary Science, The University of Sydney, Camden, New South Wales, Australia 2570

- Fat feeding in the transition period from 17 studies showed;
  - 27% increase in first service to pregnancy
  - Reduced interval from calving to pregnancy

$$\overbrace{CH_3\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C}^{\textbf{Omega 9}}{=}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}COOH$$

$$\overbrace{CH_3\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C}^{\textbf{Omega 6}}{=}C\text{-}C\text{-}C{=}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}COOH$$

$$\overbrace{CH_3\text{-}C\text{-}C}^{\textbf{Omega 3}}{=}C\text{-}C\text{-}C{=}C\text{-}C\text{-}C{=}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}COOH$$

Where are the Omega’s?

Omega 6(Ω6)	Omega 3(Ω3)
	EPA DHA
18:2	18:3, 20:5, 22:6
Alfalfa hay and silage	Fresh grass
Corn grain	Fresh alfalfa
Corn silage	Flaxseed
Distillers grains	Fish meal (oil)
Soybean meal	Fish oil
Whole cottonseed	Algae
Whole soybeans	

Varying Ratio of w6/w3 Fatty Acids

- 45 cows d 15 to 105
- Cows randomly assigned to three identical diets (3.3% total fatty acids).
- 1.43% added fat as blends of Ca Salts palm oil, safflower oil, and fish oil.
  - 369 g C18:2 and 10 g EPA/DHA (total w6/w3 6:1)
  - 330 g C18:2 and 15 g EPA/DHA (total w6/w3 5:1)
  - 298 g C18:2 and 20 g EPA/DHA (total w6/w3 4:1)

Greco et al.2013 ADSA Abstract #648

Thank You!!!

Effective Decision Making in Cattle Production

Daryl Nydam, DVM, PhD; Calvin Booker, DVM, MSc; Ryan Rademacher, DVM; Kee Jim, DVM

Cornell University

ABSTRACT

Establishing a decision-making process is an important component of each cattle production enterprise, and there are various methods that could be used. However, understanding the process by which each decision is made so that the underlying strengths, limitations, and implications are known may be as important as the decision itself. We can break these decision making processes down into six methods: Method I – Casual Observations, Method II – First Principles, Method III – Decision Tree Analysis, Method IV – Benchmarking, Method V – Evidence-Based, and Method VI – Commercial Field Trial Results.

In Method I – Casual Observations, anecdotal evidence or comparisons are used to make decisions and this requires extremely large differences to be present in order to be a useful method. Method II – First Principles, uses foundational principles or assumptions from specific disciplines as the basis of a course of action with not much consideration for validation. Going one step further, Method III – Decision Tree Analysis, begins to tie in the economics of a decision, and when available, uses known or expected probabilities of different outcomes to determine expected costs of each decision. Method IV – Benchmarking, can be useful for monitoring and forecasting, and has some value for making decisions in systems that are well-defined with little natural variability. However, this method becomes less useful as a decision making tool in systems with a high degree of natural variability, such as those seen in cattle production.

A commonly used method in cattle production and veterinary medicine is the “Evidence Based Approach” (Method V). Evidence based decision making aims to apply evidence gained from the scientific method to certain parts of medical practice and production. Many systems have been developed to stratify evidence by quality. In general, these systems all follow a similar hierarchy, with the most valuable and highest quality evidence being derived from properly designed, randomized, controlled trials. Multiple trials following this design can be evaluated together through the use of meta-analysis and systematic reviews to provide an even higher level of quality and value. On the other end of the spectrum, the lowest level of evidence available is derived from expert opinion, bench research, first principles, and anecdotal observations. While not typically useful in the decision making process, these forms of evidence are typically the basis behind a great deal of research which eventually leads to the development of higher forms of evidence.

The final decision making method, Method VI – Commercial Field Trial Results, utilizes data from commercial field trials as the basis of the decision making process. This method requires relevant data describing important production variables. Data generated from these trials can then be used to build economic models that accurately simulate all aspects of production to apply a dollar value to each decision. Results from small-pen field trials or trials performed in a research setting are useful for screening multiple options and/or refining the specific hypothesis to be tested in a large-pen commercial trial. The use of the large-scale commercial setting allows for strong external validity; meaning that results are more directly applicable to the production systems used in commercial cattle production. As part of the economic modeling done with the observed results, an economic sensitivity analysis can be performed to further determine the relative value of different decisions in varying production and economic scenarios.

In summary, various methods exist for use in the decision making process for a cattle production enterprise. Each has underlying strengths and limitations, and each may be useful for the decision making process in different scenarios. It is important that the strengths, limitations, and implications of the process by which each decision is made be known in order to ensure that the correct method is used for the scenario at hand.

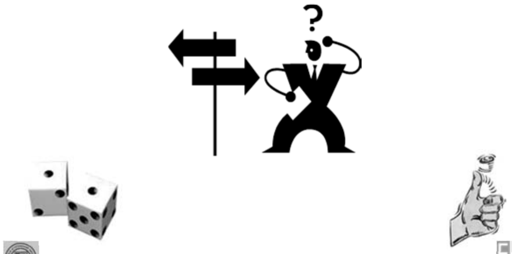
Effective Decision Making in Cattle Production

Daryl Nydam, B.Sc., D.V.M., Ph.D.
College of Veterinary Medicine, Cornell University

Calvin Booker, D.V.M., M.Vet.Sc.
Feedlot Health Management Services Ltd.

Feedlot Health
Management Services

Paper vs. Rock vs. Scissors



Introduction

Method I	Casual Observation
Method II	First Principles
Method III	Decision Tree Analysis
Method IV	Benchmarking
Method V	Evidence-Based
Method VI	Based on Results of Commercial Field Trials

Method I – Casual Observation

- Anecdotal evidence
- “Year to year” comparisons
- “Farm to farm” comparisons
- Extremely large differences are required for this method to be successful!

Method II – First Principles

- Making decisions using basic, foundational propositions or assumptions from specific disciplines
- Usually involves generation of a theory, hypothesis, and course of action with direct application and not much consideration for validation

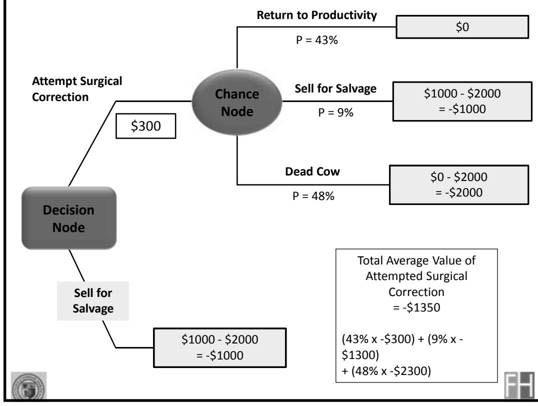
---

Method III – Decision Tree Analysis

- Decision tree analysis can be used to model decisions on a cash basis

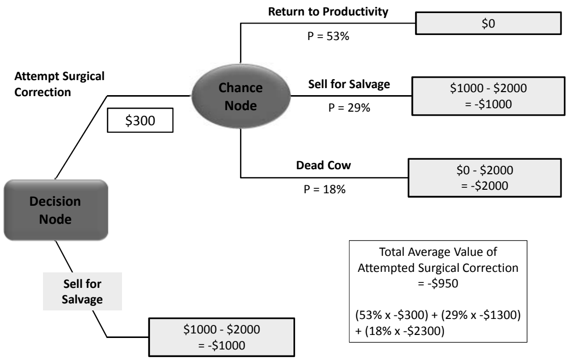
Method III – Decision Tree Analysis

- Unsuccessful toggle-pin fixation of a left displaced abomasum - what to do next?
- For the average commercial dairy cow:
  - Attempt surgical correction
    or
  - Sell for salvage



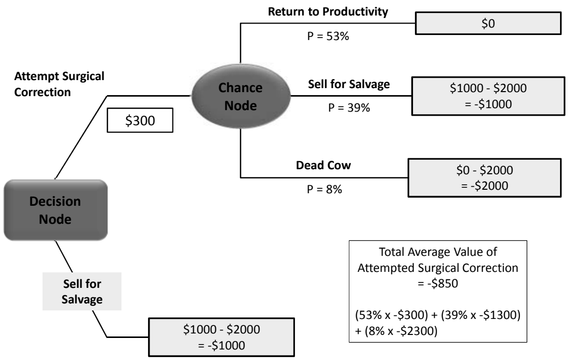
Total Average Value of Attempted Surgical Correction = -$1350

(43% x -$300) + (9% x -$1300) + (48% x -$2300)



Total Average Value of Attempted Surgical Correction = -$950

(53% x -$300) + (29% x -$1300) + (18% x -$2300)



Total Average Value of Attempted Surgical Correction = -$850

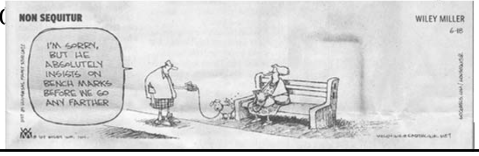
(53% x -$300) + (39% x -$1300) + (8% x -$2300)

Method III – Decision Tree Analysis

- Simple or complex decision trees can easily be constructed
- The major limitation of decision tree analysis is that the actual probabilities associated with each chance node in the decision tree are usually unknown

Method IV - Benchmarking

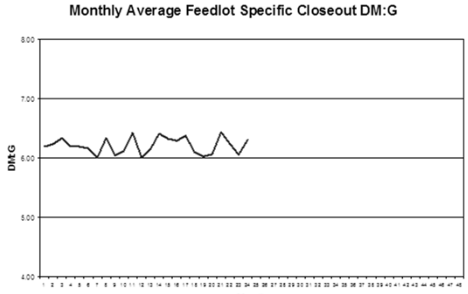
- Benchmarking is the process of comparing a population of interest to a standard or reference population
- The method of comparison can be simple and straightforward or complex and formalized, such as Statistical Processing (



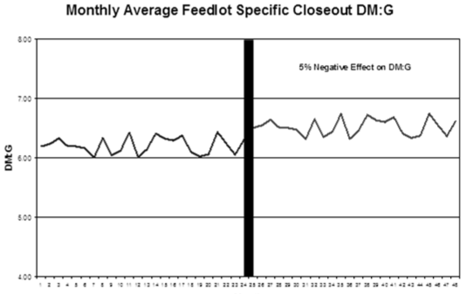
Method IV - Benchmarking

- Objectives of benchmarking
  - monitoring
  - forecasting or modeling
  - decision making??

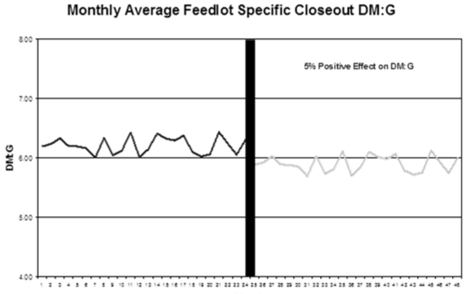
Method IV - Benchmarking



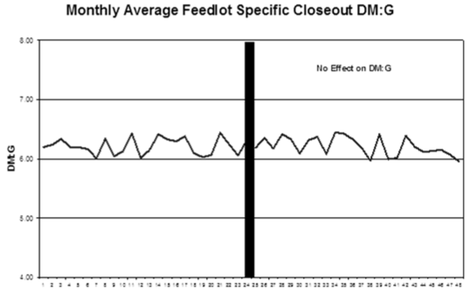
Method IV - Benchmarking



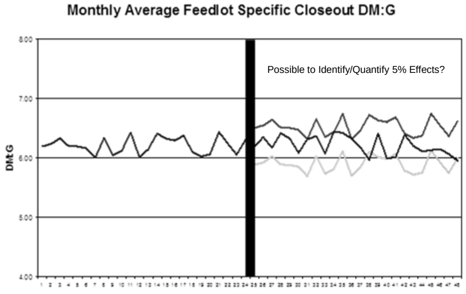
Method IV - Benchmarking



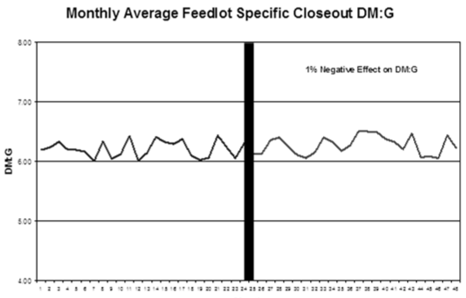
Method IV - Benchmarking



Method IV - Benchmarking

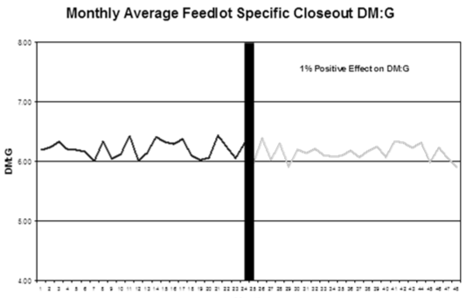


Method IV - Benchmarking


Monthly Average Feedlot Specific Closeout DM:G

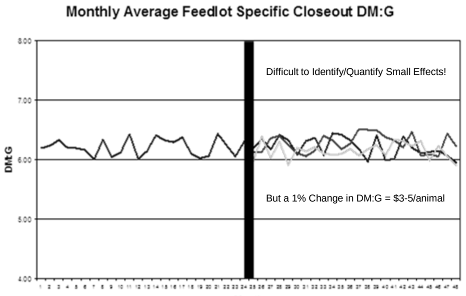
1% Negative Effect on DM:G

Method IV - Benchmarking


Monthly Average Feedlot Specific Closeout DM:G

1% Positive Effect on DM:G

Method IV - Benchmarking


Monthly Average Feedlot Specific Closeout DM:G

Difficult to Identify/Quantify Small Effects!

But a 1% Change in DM:G = $3-5/animal

Method IV - Benchmarking

- Benchmarking as a decision making tool:
  - Very applicable in well-defined, non-biologic processing or manufacturing systems
  - May be applicable in animal agriculture systems where natural variability due to genetic and environmental factors has been controlled or eliminated
  - Not very applicable in situations where there is a lot of natural variability and the processing or manufacturing system is not well-defined

Method IV - Benchmarking

- Benchmarking is a more appropriate decision making tool in some biologic systems than in others:

– Poultry	+++
– Swine	++
– Aquaculture	++
– Dairy	-
– Feedlot	--
– Cow-calf	---

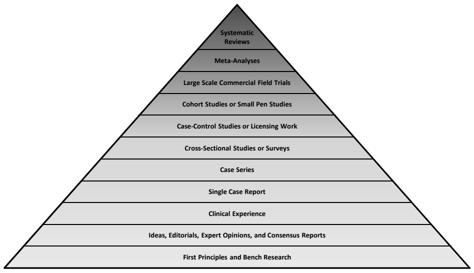
Method IV - Benchmarking

- Summary of benchmarking use in cattle production systems:
  - a useful tool for monitoring and forecasting
  - limited usefulness for decision making

Method V – Evidence Based Approach

- "Evidence-based medicine is the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients." (Sackett 1996)
- Aims to apply evidence gained from the scientific method to certain parts of medical practice

Method V – Evidence Based Approach



Adapted from Figure 4 – Relative strengths of evidence provided by different methods used in clinical research illustrated diagrammatically in the so-called pyramid of evidence. Strength of association increases from the base to the peak of the pyramid.

JAVMA, Vol 235, No. 9, November 1, 2009

Method V – Evidence Based Approach

- An originally focused idea that gets very easily diluted with very low quality evidence when high quality evidence is not readily available
- <u>The critical issue is knowing what quality of evidenced is being used to make each decision</u>

Method VI – Based on Results of Commercial Field Trials

- Making decisions based on relevant data generated from commercial field trials

Method VI – Based on Results of Commercial Field Trials

- Data-based decision making requires relevant data describing important feedlot production variables

• Feedlot Performance	- ADG and DM:G
• Carcass Characteristics	- Quality Grade - Yield Grade - Carcass Size
• Animal Health	- Morbidity & Mortality

Method VI – Based on Results of Commercial Field Trials

- Economic models that accurately simulate all aspects of production are used as part of the data-based decision making process to ascribe economic values to the important feedlot production variables

Method VI – Based on Results of Commercial Field Trials

- Field trials conducted in small-pen facilities or research settings provide the basis for commercial field trials
- Field trials conducted under commercial production conditions provide the most relevant data

Method VI – Based on Results of Commercial Field Trials

- Antimicrobial selection for on arrival metaphylaxis *(Vet Ther 2007; 8: 183-200)*
  - Tilmicosin (Micotil) and long-acting oxytetracycline (LA20) have been proven to be effective metaphylactic antimicrobials for reducing UF/BRD morbidity and mortality rates and/or overall mortality rates, and improving average daily gain and/or feed efficiency

Method VI – Based on Results of Commercial Field Trials

- Antimicrobial selection for on arrival metaphylaxis...continued
  - Tulathromycin (Draxxin) is a triamilide member of the macrolide antimicrobial class that was recently licensed for the control of UF/BRD in feedlot cattle at high risk of developing UF/BRD
  - The pharmacokinetics, microbiological characteristics, and clinical safety and efficacy of this new antimicrobial have been recently studied in small-scale, pre-licensing trials

Method VI – Based on Results of Commercial Field Trials

- Antimicrobial selection for on arrival metaphylaxis...continued
  - Theoretically, tulathromycin (Draxxin) may be a more efficacious metaphylactic antimicrobial than tilmicosin (Micotil) or long-acting oxytetracycline (LA20); however, it is two to three times more expensive

Method VI – Based on Results of Commercial Field Trials

- Antimicrobial selection for on arrival metaphylaxis...continued
  - Data from a large-scale, commercial field trial are necessary to determine the relative cost-effectiveness of tulathromycin as compared to other antimicrobials that are commonly used for the prevention and control of UF/BRD in feedlot calves

Method VI – Based on Results of Commercial Field Trials

Antimicrobial selection for on arrival metaphylaxis...continued

Morbidity data summary from a study to compare the efficacy of metaphylactic tulathromycin, tilmicosin and oxytetracycline in feedlot calves.

	Experimental Group						
Morbidity Variable	**DRAX**	**MIC**	**TET**	**Comparison**	**RR**	**95% CI**	***P-value***
Number of Animals	3,304	3,304	3,302				
Initial UF Treatment	113 (3.42)	464 (14.04)	562 (17.02)	DRAX vs. MIC	0.24	0.19 - 0.31	< 0.001
				DRAX vs. TET	0.20	0.16 - 0.26	< 0.001
First UF Relapse	26 (23.01)	179 (38.58)	218 (38.79)	DRAX vs. MIC	0.59	0.41 - 0.83	0.013
				DRAX vs. TET	0.59	0.40 - 0.82	0.012
Initial NF Treatment	118 (3.57)	252 (7.63)	276 (8.36)	DRAX vs. MIC	0.47	0.39 - 0.56	< 0.001
				DRAX vs. TET	0.43	0.35 - 0.52	< 0.001
First NF Relapse	42 (35.59)	89 (35.32)	121 (43.84)	DRAX vs. MIC	1.03	0.77 - 1.38	0.891
				DRAX vs. TET	0.81	0.62 - 1.07	0.248
Overall Chronicity	32 (0.97)	75 (2.27)	96 (2.91)	DRAX vs. MIC	0.43	0.30 - 0.62	< 0.001
				DRAX vs. TET	0.33	0.23 - 0.48	< 0.001
Overall Wastage	20 (0.61)	29 (0.88)	31 (0.94)	DRAX vs. MIC	0.69	0.38 - 1.26	0.231
				DRAX vs. TET	0.65	0.38 - 1.09	0.102

1. DRAX is Draxxin, MIC is Micotil, and TET is Tetradure LA-300

Method VI – Based on Results of Commercial Field Trials

Antimicrobial selection for on arrival metaphylaxis...continued

Morbidity data summary from a study to compare the efficacy of metaphylactic tulathromycin, tilmicosin and oxytetracycline in feedlot calves.

	Experimental Group						
Mortality Variable	**DRAX**	**MIC**	**TET**	**Comparison**	**RR**	**95% CI**	***P-value***
Number of Animals	3,304	3,304	3,302				
Overall Mortality	75 (2.27)	162 (4.90)	199 (6.03)	DRAX vs. MIC	0.46	0.37 - 0.58	< 0.001
				DRAX vs. TET	0.38	0.30 - 0.47	< 0.001
BRD Mortality	10 (0.30)	62 (1.88)	84 (2.54)	DRAX vs. MIC	0.16	0.07 - 0.35	< 0.001
				DRAX vs. TET	0.12	0.06 - 0.26	< 0.001
Histophilosis Mortality	9 (0.27)	34 (1.03)	29 (0.88)	DRAX vs. MIC	0.26	0.12 - 0.52	< 0.001
				DRAX vs. TET	0.31	0.14 - 0.63	0.002
Metabolic Mortality	27 (0.82)	28 (0.85)	38 (1.15)	DRAX vs. MIC	0.97	0.61 - 1.52	0.881
				DRAX vs. TET	0.71	0.45 - 1.13	0.145
Arthritis Mortality	4 (0.12)	2 (0.06)	8 (0.24)	DRAX vs. MIC	2.01	0.36 - 11.18	0.427
				DRAX vs. TET	0.50	0.15 - 1.69	0.264
Miscellaneous Mortality	25 (0.76)	36 (1.09)	40 (1.21)	DRAX vs. MIC	0.70	0.41 - 1.15	0.163
				DRAX vs. TET	0.63	0.38 - 1.02	0.066

1. DRAX is Draxxin, MIC is Micotil, and TET is Tetradure LA-300

Method VI – Based on Results of Commercial Field Trials

Antimicrobial selection for on arrival metaphylaxis...continued

Economic analysis summary from a study to compare the efficacy of metaphylactic tulathromycin, tilmicosin and oxytetracycline in feedlot calves.

Variable	**DRAX vs. TET**	**DRAX vs. MIC**
Initial Undifferentiated Fever Treatment	$4.49	$3.50
First Undifferentiated Fever Relapse	$0.11	$0.11
Initial No Fever Treatment	$0.64	$0.43
Overall Mortality	$25.58	$17.89
Average Daily Gain	$1.61	$2.08
Dry Matter Intake to Gain Ratio	N/A	-$7.68
Quality Grade Canada Prime	$0.82	$0.79
Quality Grade Canada AAA	$2.89	N/A
Quality Grade Canada A	$0.52	N/A
Yield Grade Canada 1	-$1.29	-$1.47
Yield Grade Canada 3	-$0.75	N/A
Metaphylactic Antimicrobial Cost	-$17.66	-$11.86
Total Economic Advantage for DRAX	$16.96	$3.79

1. DRAX is Draxxin, MIC is Micotil, and TET is Tetradure LA-300

Method VI – Based on Results of Commercial Field Trials

- The emphasis of the decision making process is switched from a **theoretical and/or "least-cost" approach to a "maximum net benefit" approach**
- The interpretation of existing data and/or the ability to generate original data are required

Summary

- Whenever possible, use a decision making model based on the results of scientifically valid commercial field trials because it is the most accurate and reliable method currently available provided that:
  - the field trial design and methods were appropriate and valid for the hypothesis tested – scientific/internal validity
  - extrapolation of the results is appropriate for the production scenario in question – external validity

Marginal Feed Costs

What is the (extra) feed cost / 100#?

Does not matter if:

50 cows increase 2#
10 cows increase 10#
200 cows increase 0.5#

Marginal Feed Costs

We need to know the additional feed required if an existing group of cows produces 100 pounds more milk.

The maintenance feed is similar regardless of the milk production differences.

Income Over Feed Costs at Different Production Levels

production	dry	25	50	75	100
maintenance feed costs	3.00				
feed cost for the milk					
total feed cost per day				7.50	
feed costs per cwt milk					
milk revenue produced					
income over feed costs					

Rules of profitability

- Efficient use of resources
- Early, wise adoption of technology
  - Innovators, early adopters, majority, late adopters
- Economies of scale
- Good decision making
- Cost control
  - This is not least cost production…
  - It implies maximum net benefit…

Rules of dairy profitability

- 1. Make more Milk
- 2. Reduce Expenses
  - Unless it breaks rule 1
  - (or you are past the point of diminishing returns)

(Dr. John Fetrow)

Production Curves

- Describe relation between outputs and inputs as successive units of input are added
- Marginal Inputs and Marginal Outputs

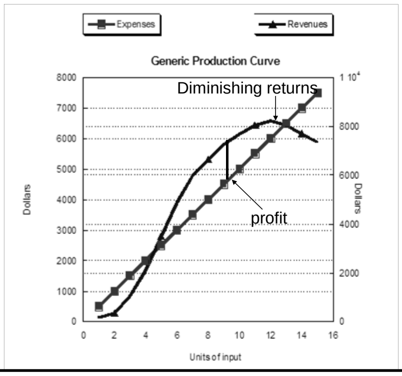
Production Curves

- Is expense line always linear?
  - No
- Does revenue line always follow this shape?
  - No
- Do most dairies know where on the production curve they are?
  - No

Production Curves

- Where is the best place to be on the curve?
  - Lowest input?
  - Highest output?
- Max profit:
  - where declining revenue slope = expense slope

Production Curves



Production Curves

- Max production = max profit
  - (unless inputs are free)
- BUT
  - Few dairies are near max production!
- Almost always, some bottleneck is restricting production
- Are the scaffold for marginal decision making/analysis

Emerging topics in transition cow nutrition

Thomas R. Overton, Ph.D.
Professor of Dairy Management
Director, PRO-DAIRY program
Associate Director, Cornell Cooperative Extension
Cornell University, Ithaca NY

A partial list…….

- Nutrition/management/immune interactions (tomorrow)
- DCAD revisited (tomorrow)
- AA and protein metabolism in the transition cow
- Specific considerations for fresh cow rations

Summary guidelines -- dry period nutritional strategies

- Far-off
  - Keep energy down (0.59 to 0.63 Mcal/lb; 1.30 to 1.39 Mcal/kg of NEL; 110 to 120% of energy requirements
  - Macromineral balances not important (within reason)
- Close-up (if same ration fed to heifers and older cows)
  - Low to moderate energy (0.64 to 0.66 Mcal/lb; 1.40 to 1.45 Mcal/kg of NEL; 110 to 130% of energy requirements
  - Supplement with RUP (MP for Holsteins 1200 to 1300 g/d)
  - Macromineral relationships (K, Mg, Na, S, Cl; maybe Ca) critically important; Vitamins D and E; trace elements
- Feeding management/consistency critical during both periods

What about MP levels and AA supplementation to transition cow diets?

Table 1. Estimated peripartal MP supply and its effect on postpartum performance and metabolism from studies that differed in prepartum CP or RUP. Data were expressed as relative performance within study in comparison with a control group (diet with lower CP, RUP or lower energy and protein content).

		Postpartum									
Study	Prepartum MP, g/d	Days	DMI, kg/d	MP, g/d (balance, %)	Milk, kg/d	Protein, % or kg/d	Fat, % or kg/d	MUN, mg/dL	BW loss, kg	3-MH, nmol/mL	NEFA, mEq/L
Van Saun et al., 1993	791, 872	42	--	--	NS	↑	NS	--	NS	--	--
Putnam & Varga, 1998	916, 976, 1032	91	NS	1710 – 1850 (~75)	NS	NS	NS	--	NS	--	NS ↓[a]
Huyler et al., 1999	834, 1028, 1282	70	NS	--	NS	NS	NS	--	NS		NS
Vandehaar et al., 1999	948, 1008	70	NS	--	NS[b]	--	--	--	NS	NS[b]	NS
Vandehaar et al., 1999	721, 1172	70	NS	--	NS[b]	--	--	--	NS	NS[b]	↑
Dewhurst et al., 2000	429, 814, 895	154	NS	--	NS	NS	NS	--	--	--	--
Greenfield et al., 2000	932, 976, 1090, 1306	56	↓	2300 – 2750 (~105)	NS	↓	↓	NS	↑		NS
Hartwell et al., 2000	1169, 1231	120	↓	2500 – 2800 (~110)	NS	↓	NS	NS	NS	--	NS
Santos et al., 2001	1222, 1365	120	--	--	NS:M ↑:P	NS:M ↑:P	NS:M ↑:P	--	--	--	NS
Doepel et al., 2002	1067, 1405	42	NS	1900 (80)	NS	NS	NS		NS	↓	NS
Doepel et al., 2002	1067, 1600	42	NS	1680 (75)	NS	NS	NS		NS	↓	NS
Park et al., 2002	1334, 1442, 1470, 1744, 1741	90	NS	3000 – 3210 (120)	Qu[c]	Q[c]	C[c]	Q[c]	Q[c]	--	--

Ji and Dann, 2013 CNC

Summary of responses to transition period AA

Study	**Treatment**	**Response**
Overton et al., 1996	RPMet	**↑ 2.7 kg/d FCM**
Socha et al., 2005	Met, Met+Lys	**↑ 2.9 kg/d ECM for Met + Lys**
Piepenbrink et al., 2004	HMTBa (13 g pre; 28 g post) HMTBa (27 g pre; 44 g post)	**↑ 3.0 kg/d milk** **NS**
Preynat et al., 2009; 2010	RPMet w/wo folic acid + B12	**NS – milk yield** **↑ milk CP (2.94 vs. 3.04%)**
Ordway et al., 2009	HMBi RPMet	**No effect on milk yield** **Both trts ↑ milk protein %**
Osorio et al., 2013	HMBi RPMet	**↑ 3.8 kg/d ECM** **↑ 4.0 kg/d ECM**

Mechanisms for improved performance of cows supplemented with AA during transition period?

- Likely NOT related to liver lipid metabolism/ketosis
  - No differences in liver TAG for cows fed RPMet or HMTBa

- Limiting AA mechanism?

- Role in immune function/oxidative stress?
  - Met increased neutrophil phagocytosis at d 21 postpartum (Osorio et al., 2013)
  - Met increased antioxidant capacity and decreased proinflammatory signaling (Osorio et al., 2014)

Retrospective Study Analysis

- Review published transition cow studies and model rations
- Objective: Determine if a nutritional model can predict a productive response to prefresh nutrient supply
- Used studies with rations and cows adequately described to model in CNCPS v6.1
  - 18 studies, 45 treatments, 601 cows
- Data were analyzed in JMP®
  - Metabolizable Protein, Metabolizable Methionine (mMet), Metabolizable Lysine (mLys)

Courtesy Dr. Patrick French

Retrospective Study Database

Study	Trt	N
Caldari-Torres et al., 2011 (FL)	2	20
DeFrain et al., 2005 (SD)	4	40
DeGroot et al., 2010 (OR)	4	36
Doepel et al., 2002 (CAN)	4	28
Janovick and Drackley, 2010 (IL)	3	24
Ji et al., 2012 (IL)	2	14
Liu et al., 2013 (CN)	2	20
Moreira et al., 2009 (LA)	1	52
Morey et al., 2011 (KS)	1	7
Osorio et al., 2013 (IL)	3	39
Peterson et al., 2005 (MI)	3	42
Sadri et al., 2009 (IRA)	4	32
Schaff et al., 2013 (DE)	2	19
Smith et al., 2005 (NY)	2	72
Stone et al., 2012 (NY)	2	70
Weich et al., 2013 (MN)	3	53
Winkelman et al., 2008 (OH)	2	18
Yuan et al., 2012 (WI)	1	15
Total	45	601

Prefresh Dietary Summary

Item	Mean	SD	Min	Max
DMI, lbs	28.5	4.1	16.0	38.6
ME Bal, Mcal	2.3	4.5	-7.0	13.3
MP, g/d	1,265	251	692	1901
MP Bal, g	170	208	-202	644
CP, %	14.8	1.1	12.5	17.5
NDF, %	41.2	4.3	32.3	52.7
Starch, %	19.6	5.0	8.7	29.7
Met, g/d	28	5	16	42
Lys, g/d	85	16	49	116

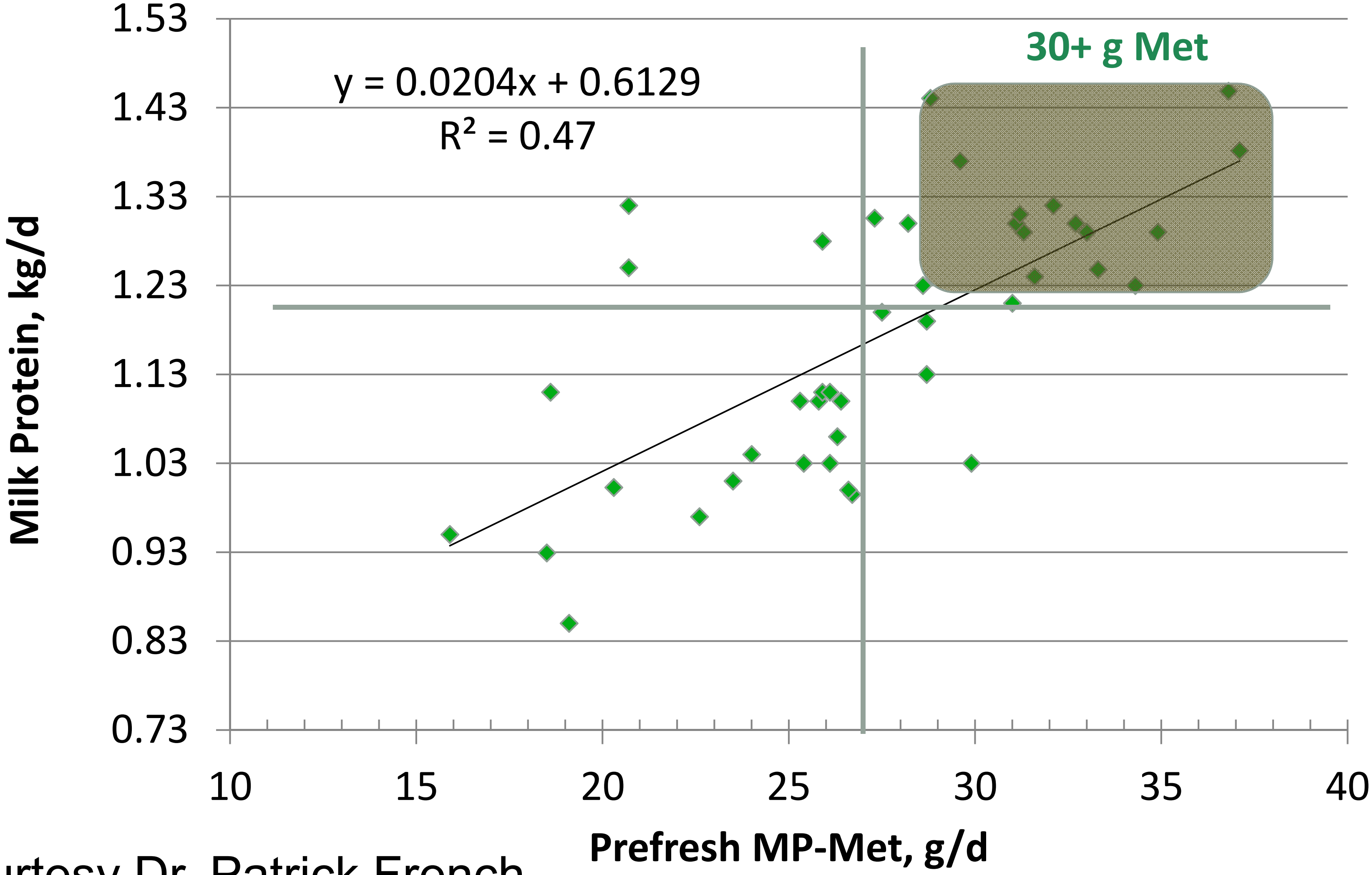
Courtesy Dr. Patrick French

Postfresh Dietary Summary

Item	Mean	Min	Max
DMI	38.2	28.7	44.3
ME Bal, Mcal	-13.5	-21.3	0.8
MP Bal, g	-488	-818	-47
CP, %	17.6	16.7	19.3
NDF, %	33.2	28.7	38.0
Starch, %	23.5	19.5	29.5
Met, g/d	42	32	56
Lys, g/d	128	91	160

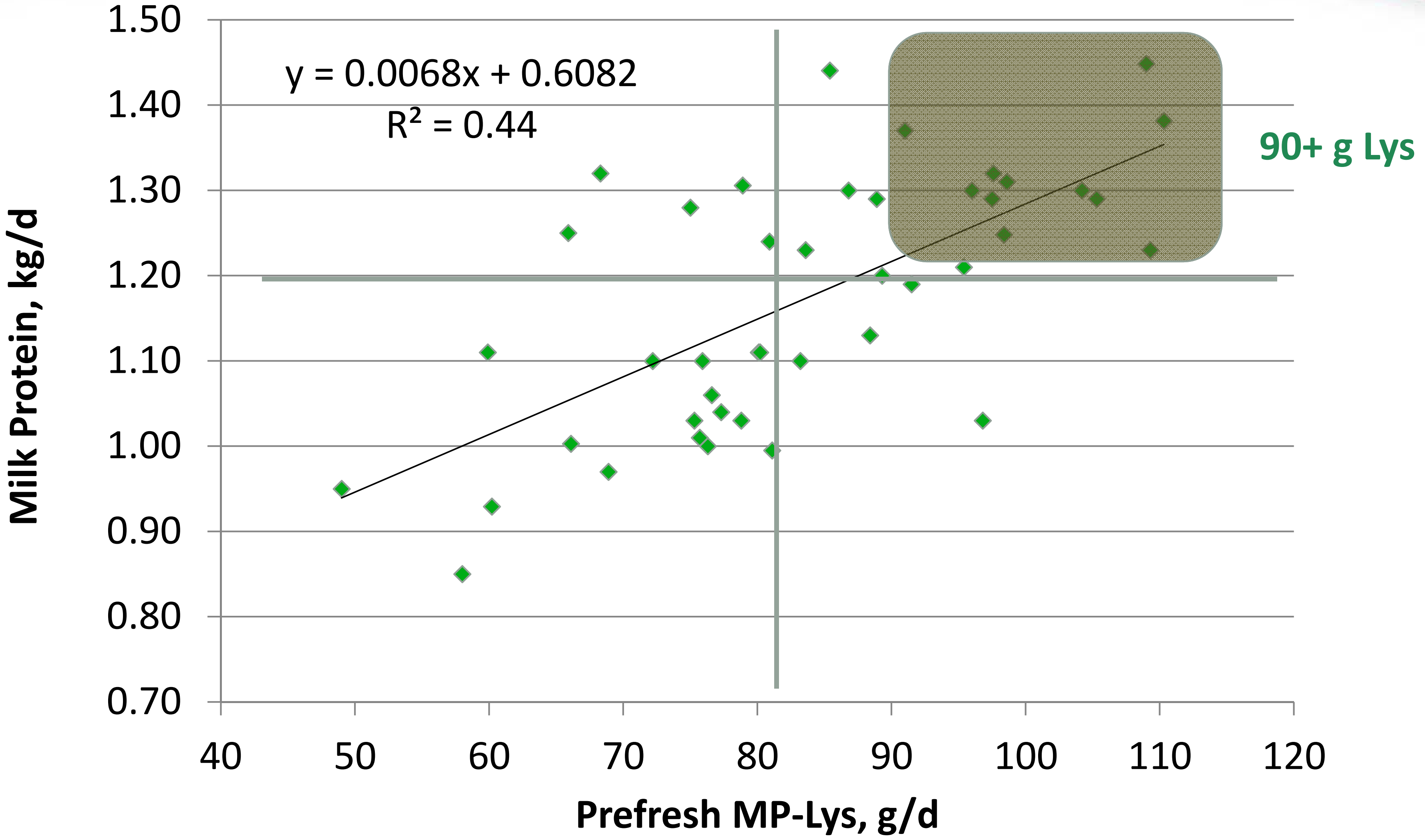
Courtesy Dr. Patrick French

Effect of Prefresh Met on Protein Yield



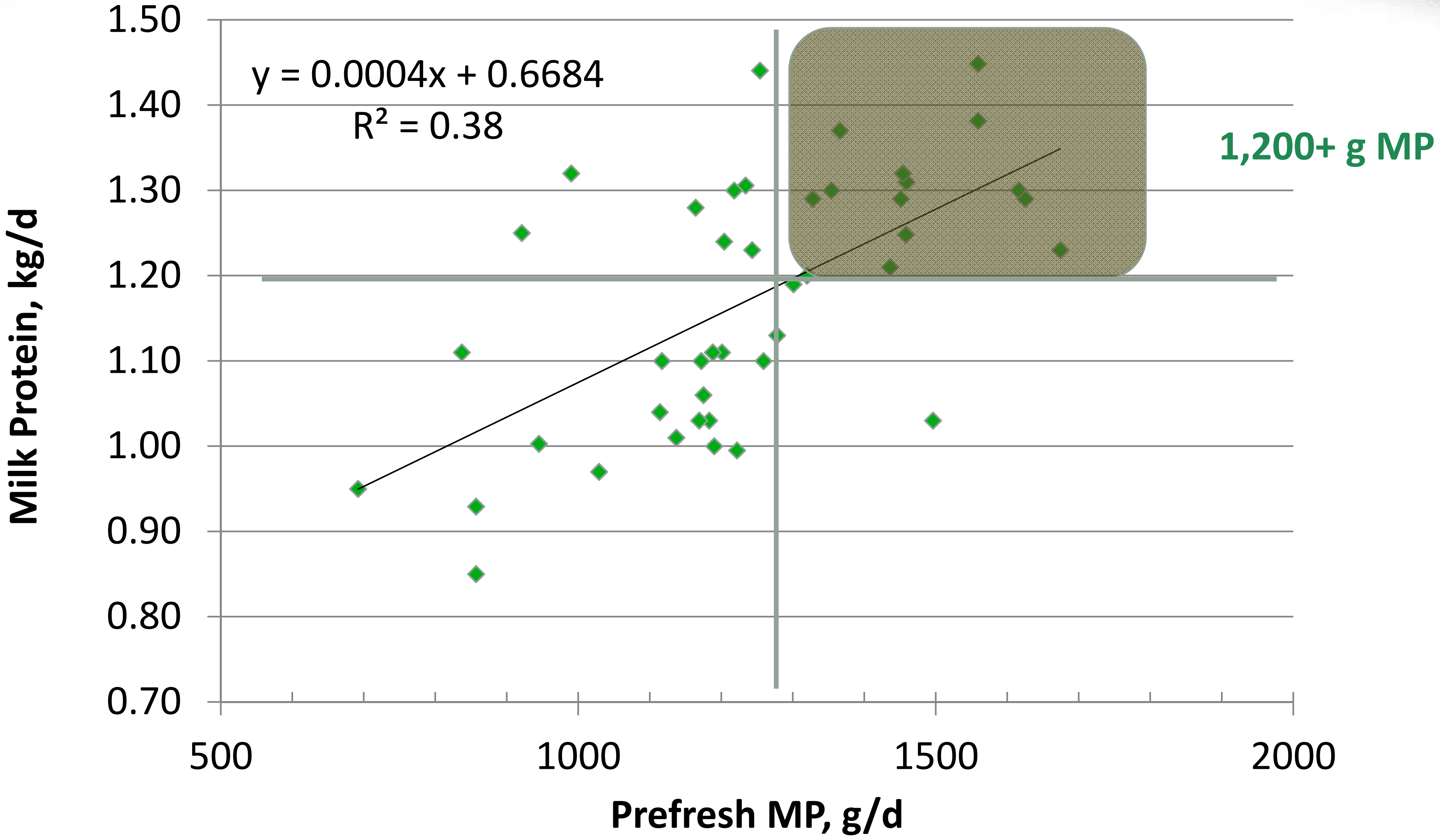
Courtesy Dr. Patrick French

Effect of Prefresh Lys on Protein Yield



Courtesy Dr. Patrick French

Effect of Prefresh MP on Protein Yield



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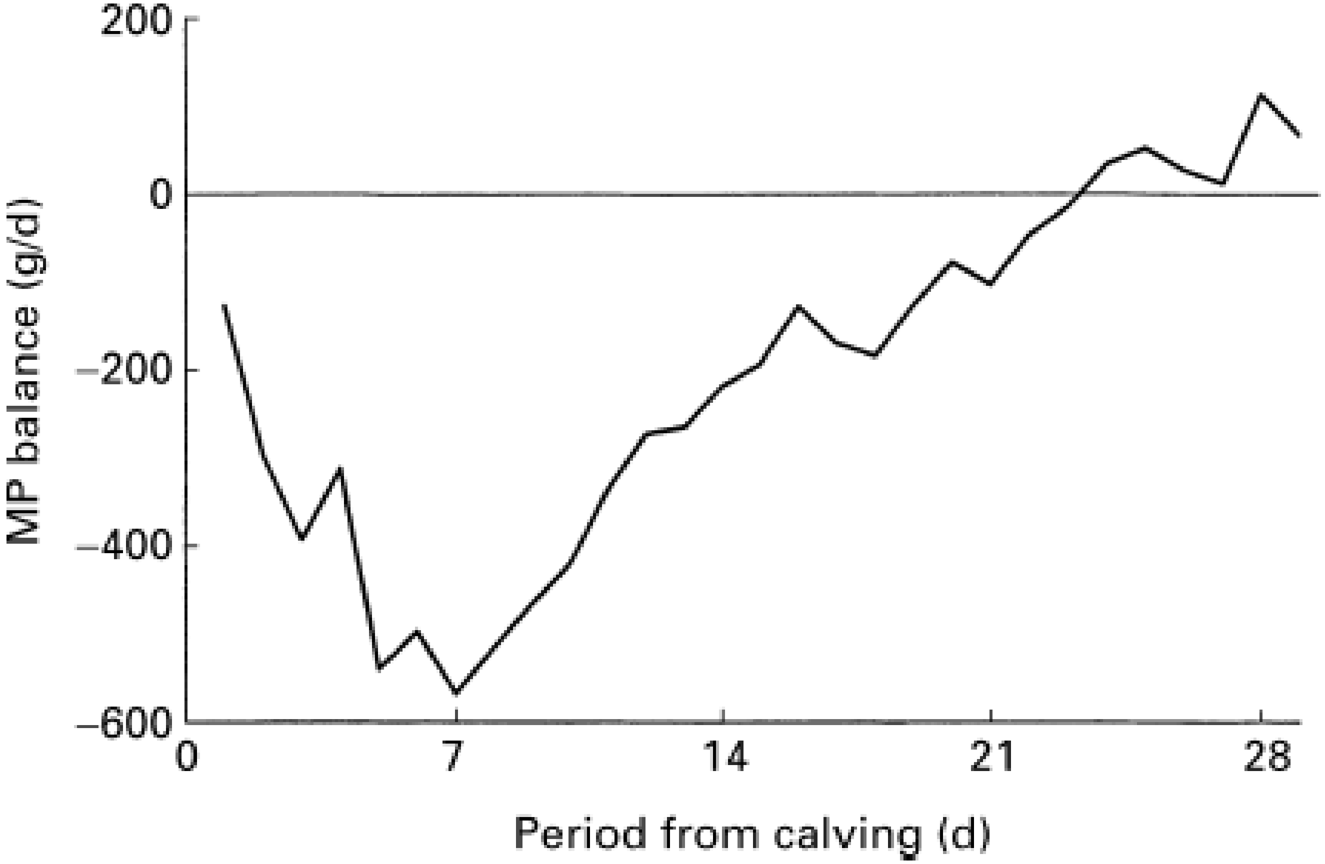


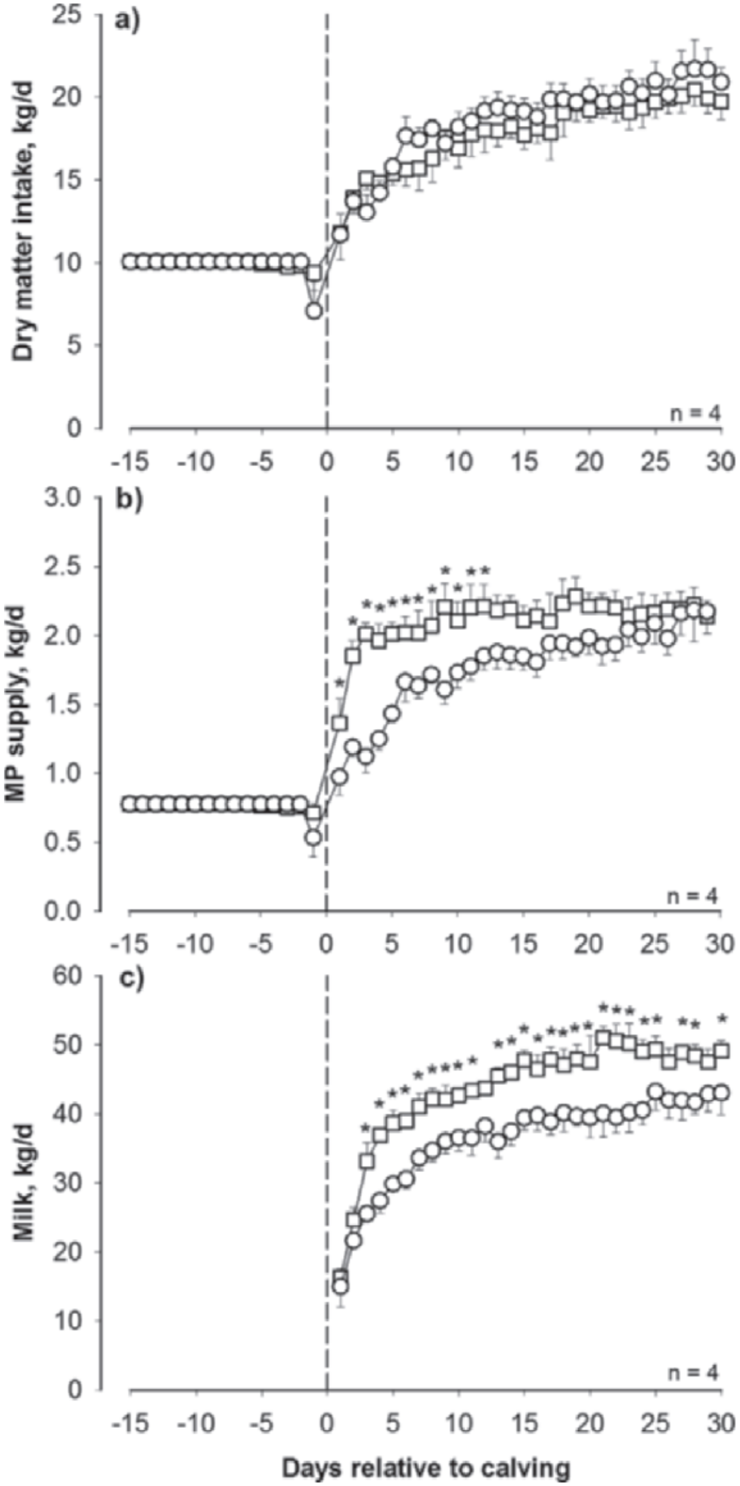
Fig. 1. Calculated metabolizable protein (MP) balance in post-parturient cows (*n* 80) fed on a ration containing (/kg DM) 178 g crude protein (nitrogen × 6·25) and 7·0 MJ net energy for lactation. Individual values were calculated from daily individual measurements of crude protein intake and milk yield, and weekly measurements of milk composition.

Bell et al., 2000

Increasing MP supply postpartum?

- 8 Holstein cows entering second lactation
- Received either water (control) or casein infused into the abomasum to meet approximate calculated deficit in MP
- Casein was planned to supply 360 g/d at 1 DIM, 720 g/d at 2 DIM, followed by daily reductions of 19.5 g/d ending at 194 g/d at 29 DIM.

Larsen et al., 2014. J. Dairy Sci. 97:5608–5622



Milk yield was increased (~ 7.2 kg/d) in cows receiving additional MP by casein infusion postpartum

From Larsen et al., 2014. J. Dairy Sci. 97:5608–5622

Transition cow nutrition

- Virtually all controlled research during the past 20 years on transition cow nutrition has focused on the ***dry*** cow
- Most lactating cow nutrition studies did not start until three to four weeks after calving
- Very little nutritional work has focused specifically on the fresh cow
- More attention to this because of focus on intake regulation (e.g., hepatic oxidation theory)

Fresh cow diets – common themes

- Frequently based upon high cow diet
- Some common “tweaks”
  - Lower starch
  - Higher physically effective fiber
    - Usually less than 1.5 lbs of chopped straw/hay
  - Additional RUP/AA
  - Additional fat
  - Strategic addition of other nutrients (e.g., RP-choline)
- Success usually gauged by farm-level outcomes

CORNELL UNIVERSITY FOUNDED A.D. 1865

Some questions

- How fermentable should fresh cow diets be?
  - do we need to feed lower starch diets to fresh cows?
- How important is physically effective NDF in fresh cow diets?
  - “High bulk, high fermentability” fresh cow diets?

To starch, or not to starch?

Three experiments conducted by the Cornell and Miner groups

- Starch level in fresh diet
  - Dann and Nelson, 2011 CNC
  - Williams et al., 2015 ADSA-ASAS JAM

- Starch level in fresh diet and peripartal monensin
  - McCarthy et al., 2015a. J. Dairy Sci. 98:3335-3350.
  - McCarthy et al., 2015b. J. Dairy Sci. 98:3351-3365.

Dann and Nelson, 2011 Cornell Nutrition Conference

- 72 Holstein cows (2nd and greater lactation)
- Fed high straw controlled energy diet for 40-d dry period
- At calving, one of three starch regimes
  - Low starch (~ 21%) for first 91 DIM
  - Medium starch (~23%) for first 21 d followed by high starch (~25.5%) until 91 DIM
  - High starch (~25.5%) for first 91 DIM

Table 1. Ingredient and analyzed chemical composition (mean ± standard error) of low, medium, and high starch diets fed to early lactation Holstein cows.

Item	Low	Medium	High
Ingredients, % of DM			
Corn silage	34.6 ± 0.1	34.6 ± 0.1	34.6 ± 0.1
Haylage	11.4 ± 0.4	11.7 ± 0.3	11.4 ± 0.4
Wheat straw	4.1	4.1	4.1
Corn meal	6.9 ± 0.4	11.1 ± 0.1	16.7 ± 0.4
Soybean meal	11.4 ± 0.1	11.9 ± 0.1	11.9 ± 0.1
Soybean hulls	9.7	6.5 ± 0.2	3.2
Wheat middlings	6.1	3.9 ± 0.1	1.8 ± 0.1
Canola meal	3.1	6.1	6.1
AminoPlus	2.5	-	-
Other	10.2 ± 0.3	10.1 ± 0.3	10.2 ± 0.2
Chemical composition			
DM, %	49.5 ± 0.7	50.1 ± 0.9	49.6 ± 0.7
CP, %	17.3 ± 0.1	17.0 ± 0.2	16.7 ± 0.2
NDF, %	35.7 ± 0.3	33.9 ± 0.4	31.9 ± 0.3
Sugar, %	6.1 ± 0.1	5.8 ± 0.1	5.9 ± 0.1
Starch, %	21.0 ± 0.3	23.2 ± 0.3	25.5 ± 0.3
Rumen fermentable starch, %	16.8 ± 0.5	18.9 ± 0.6	20.2 ± 0.5
Digestibility			
24-h NDF, % NDF	58.4 ± 0.6	57.3 ± 0.5	54.0 ± 0.8
7-h starch, % starch	76.5 ± 1.4	76.7 ± 1.2	74.5 ± 1.2

Dann and Nelson, 2011 CNC

DMI and milk during first 13 wk of lactation for cows fed varying levels of starch in early lactation

Item	Low-low	Medium-High	High-High	SEM	P, Trt	P, Trt x wk
DMI, kg/d	25.2^{x}	24.9^{xy}	23.7^{y}	0.5	0.06	0.09
Milk, kg/d	47.9^{ab}	49.9^{a}	44.2^{b}	1.6	0.04	0.75
SCM, kg/d	47.4	47.9	43.5	1.5	0.09	0.39
NEFA, uEq/L (wk 1-3)	452^{aby}	577^{ax}	431^{by}	43	0.03	0.11
BHBA, mg/dL (wk 1-3)	9.3	8.8	7.8	1.1	0.15	0.97

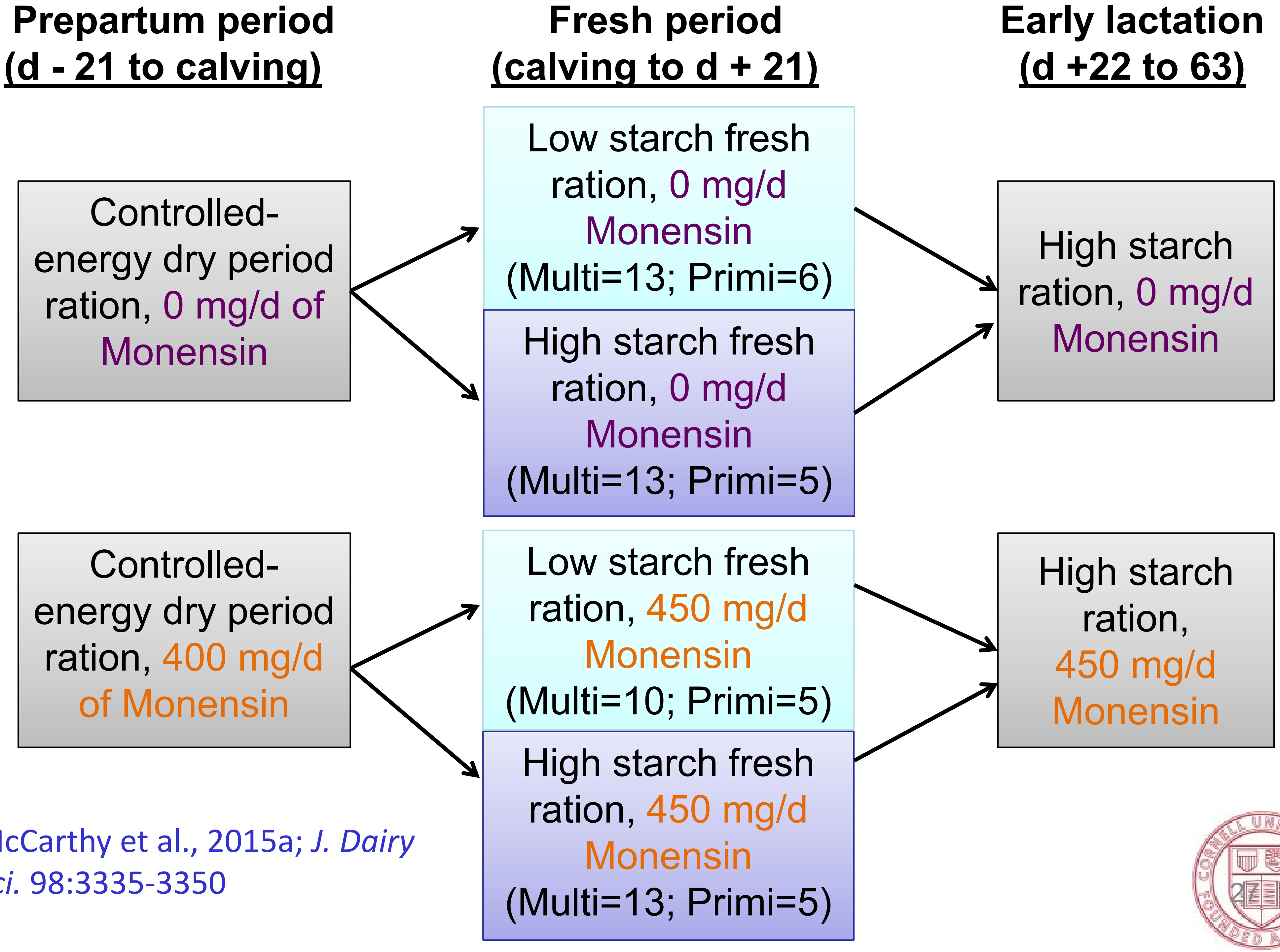
^{ab} Least squares means within a row without a common superscript differ ($P \le 0.05$).
^{xy} Least squares means within a row without a common superscript differ ($P \le 0.10$).

Dann and Nelson, 2011 CNC

McCarthy et al., 2015a; J. Dairy Sci. 98:3335-3350
McCarthy et al., 2015b; J. Dairy Sci. 98:3351-3360

- How do fresh cow ration starch content and monensin affect intake and production?

- How do fresh cow ration starch content and monensin affect aspects of energy metabolism?



Prepartum period
(d - 21 to calving)

Fresh period
(calving to d + 21)

Early lactation
(d +22 to 63)

Controlled-energy dry period ration, 0 mg/d of Monensin

Low starch fresh ration, 0 mg/d Monensin (Multi=13; Primi=6)

High starch fresh ration, 0 mg/d Monensin (Multi=13; Primi=5)

High starch ration, 0 mg/d Monensin

Controlled-energy dry period ration, 400 mg/d of Monensin

Low starch fresh ration, 450 mg/d Monensin (Multi=10; Primi=5)

High starch fresh ration, 450 mg/d Monensin (Multi=13; Primi=5)

High starch ration, 450 mg/d Monensin

McCarthy et al., 2015a; *J. Dairy Sci.* 98:3335-3350

Diet Composition, % of DM

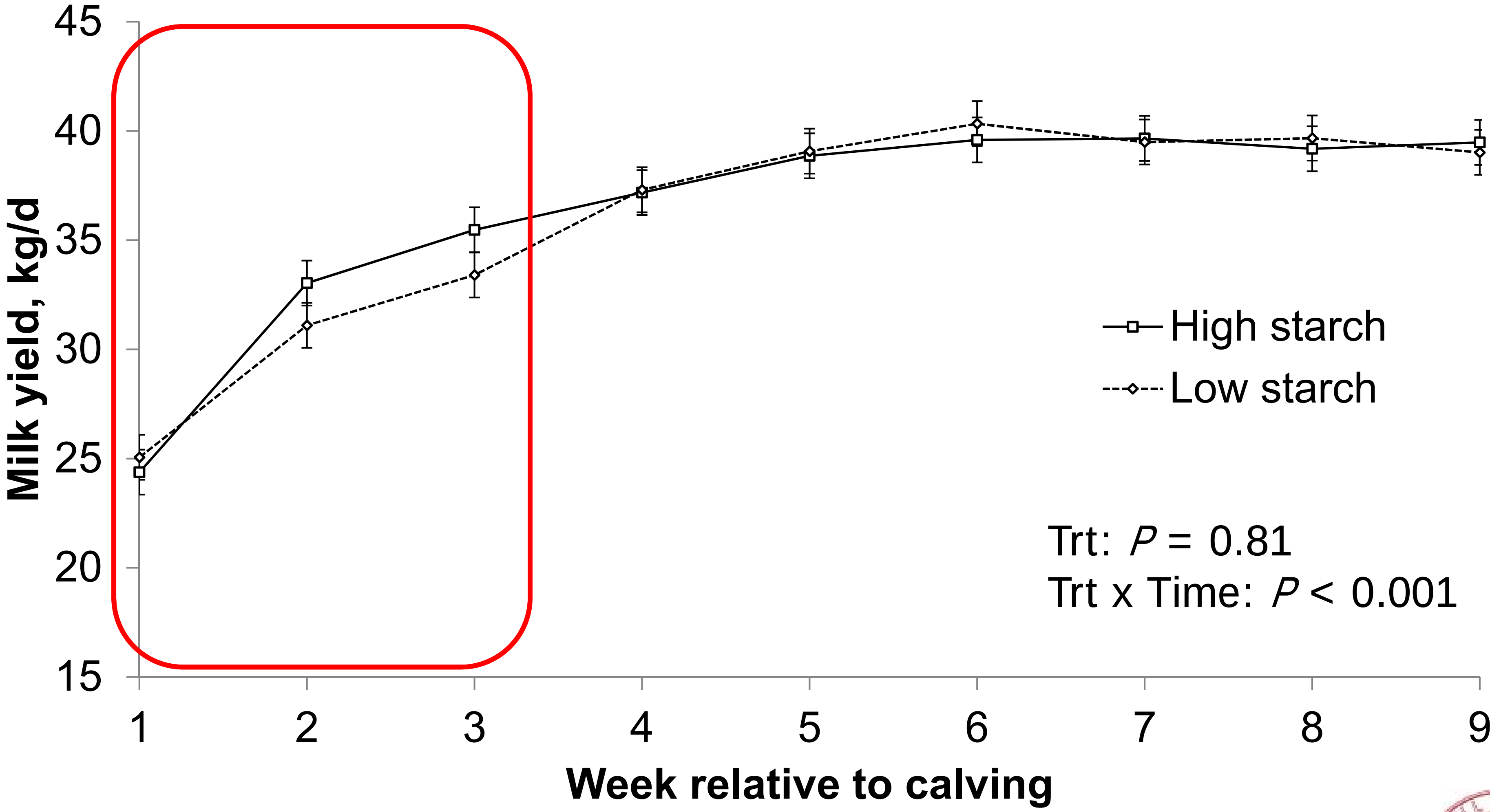
Item	Prepartum	Postpartum	
		High Starch	Low Starch
Corn Silage	39.5	—	—
BMR Corn Silage	—	37.0	37.0
Haylage	—	9.3	9.3
Wheat Straw	20.5	11.1	11.1
Corn meal, finely ground	3.9	20.2	9.9
Corn Germ Meal	—	2.4	5.4
Citrus Pulp	6.6	0.9	6.7
Soy Hulls	6.6	—	3.4
Soybean Meal	5.0	5.5	3.7
Canola Meal	4.3	2.6	2.0
Blood Meal	1.0	1.9	1.9
Supplements	6.6	5.3	5.9
Topdress	6.1	4.2	4.2

McCarthy et al., 2015a; *J. Dairy Sci.* 98:3335-3350

Analyzed Diet Composition(± SD)

Item	Prepartum	Postpartum		Topdress	
		High Starch	Low Starch	No Monensin	Monensin
DM, %	50.7 (2.4)	48.3 (2.7)	48.0 (3.2)	93.2 (1.0)	93.7 (1.2)
CP, %	13.0 (0.8)	15.5 (1.2)	15.4 (0.8)	37.5	37.0
ADF, %	28.2 (1.2)	22.7 (1.2)	25.2 (1.2)	11.1	12.9
NDF, %	42.9 (2.0)	34.3 (1.5)	36.9 (1.5)	22.6	21.3
30 h NDFD, %	—	18.9 (1.2)	20.7 (1.1)	—	—
30 h NDFD, % of NDF	—	55.1 (2.0)	56.1 (1.4)	—	—
Sugar, %	4.9 (0.8)	3.5 (0.6)	4.5 (0.4)	10.6	11.3
Starch, %	17.4 (1.2)	26.2 (1.2)	21.5 (1.0)	13.1	13.8
Fat, %	2.6 (0.2)	4.0 (0.2)	2.2 (0.6)	2.4	2.5

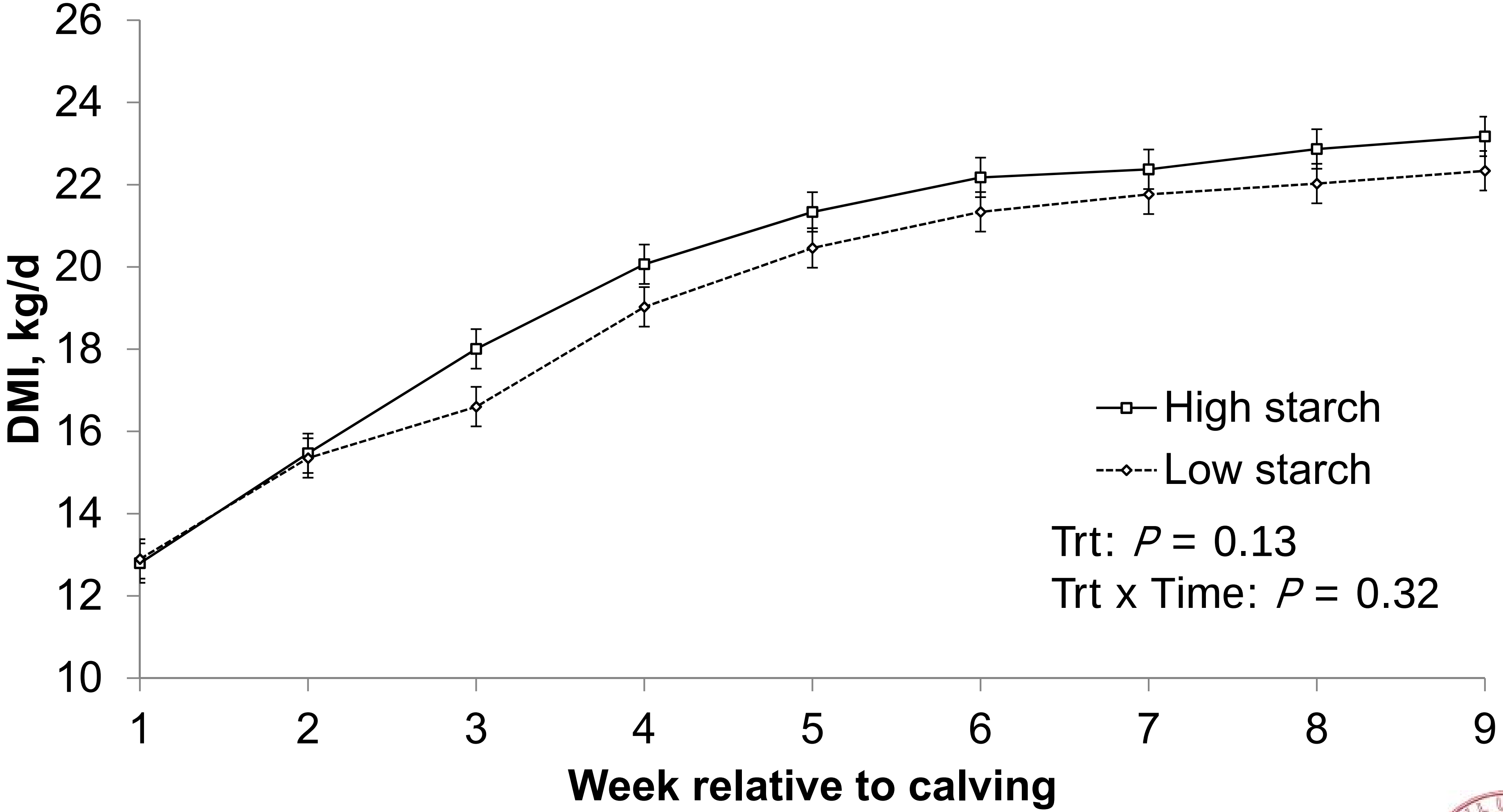
Higher starch ➔ faster increase in milk



Trt: $P = 0.81$
Trt x Time: $P < 0.001$

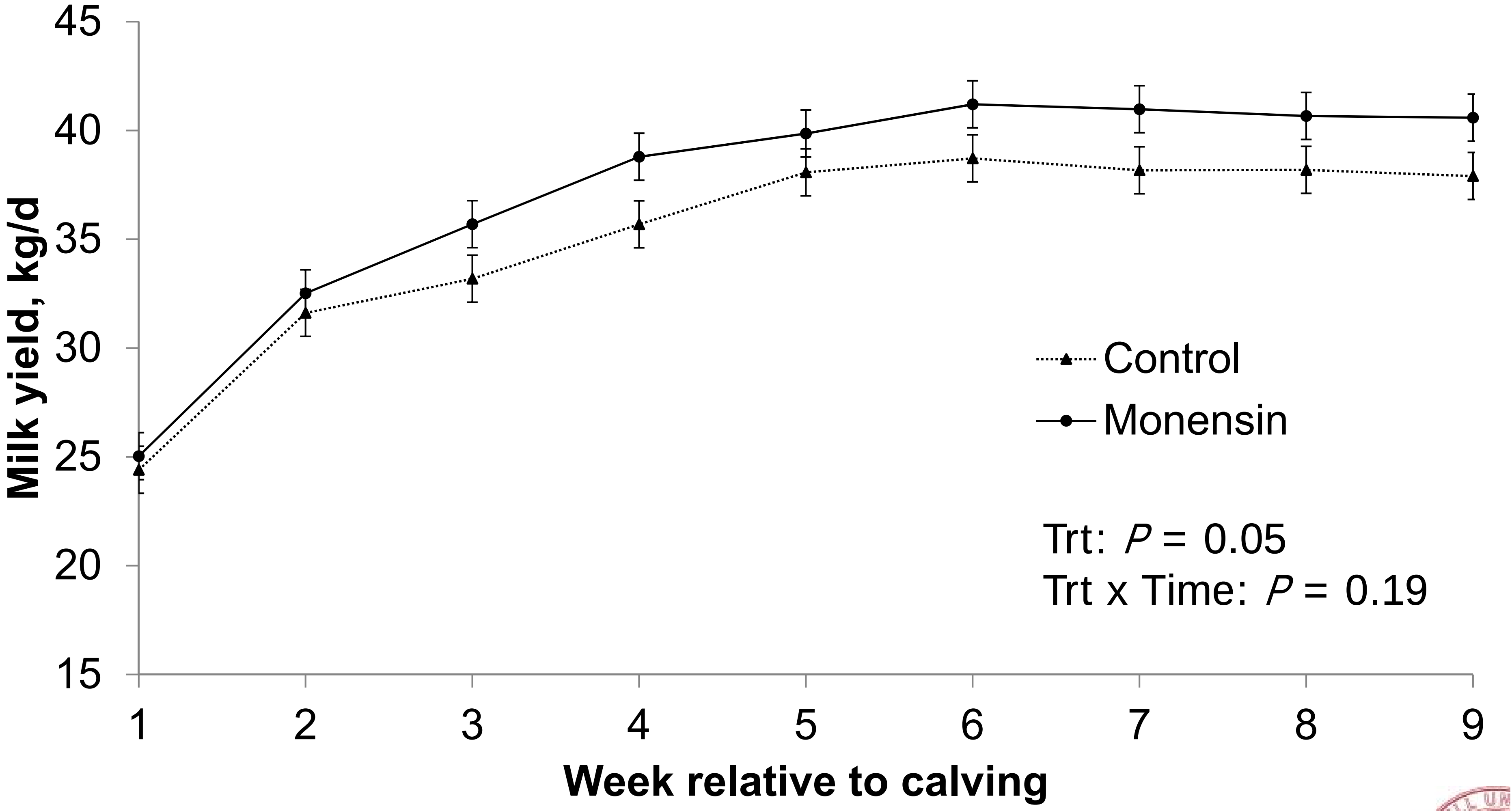
McCarthy et al., 2015a; *J. Dairy Sci.* 98:3335-3350

Higher starch → trend for greater overall DMI



McCarthy et al., 2015a; *J. Dairy Sci.* 98:3335-3350

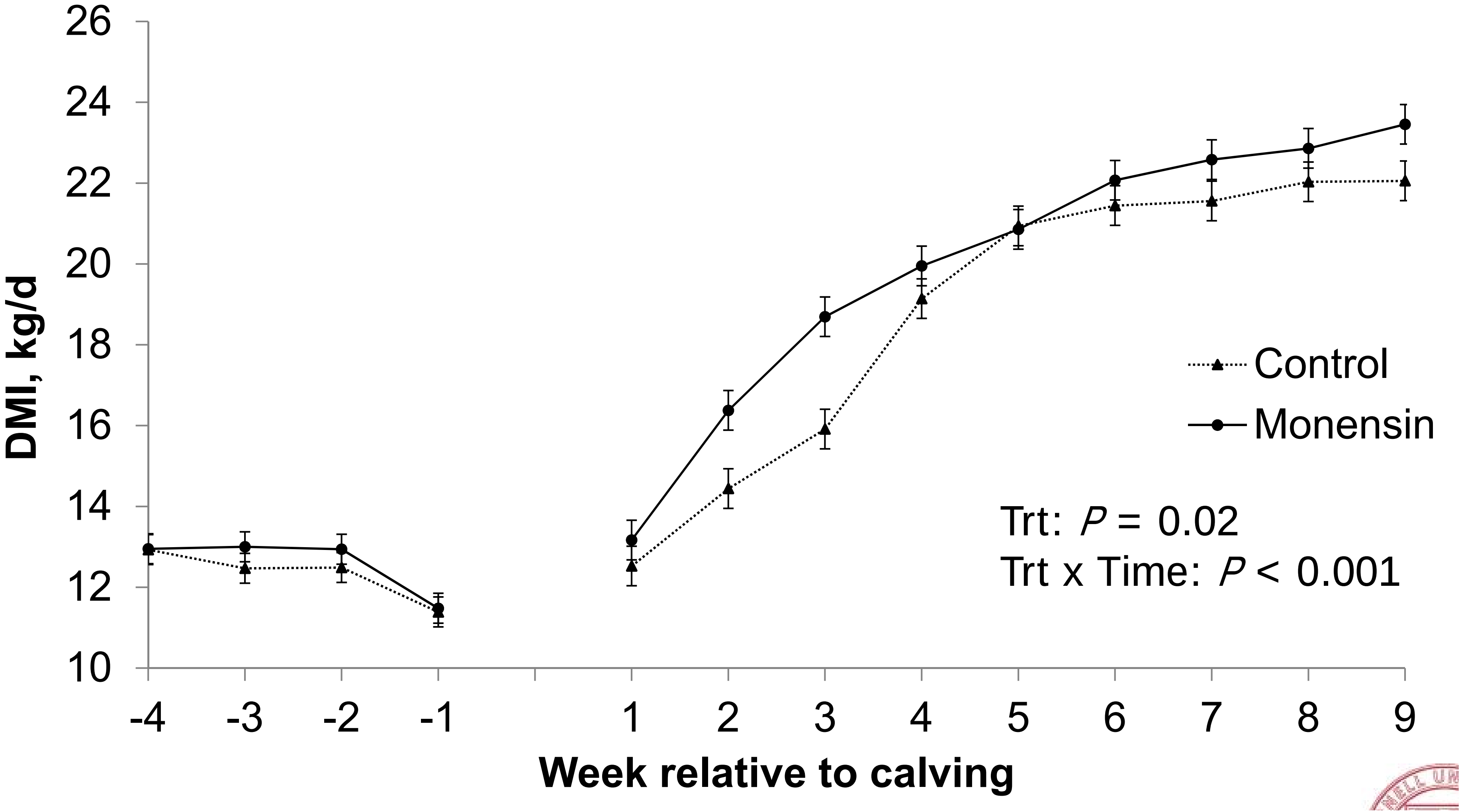
Transition period monensin ➔ greater early lactation milk yield



Trt: P = 0.05
Trt x Time: P = 0.19

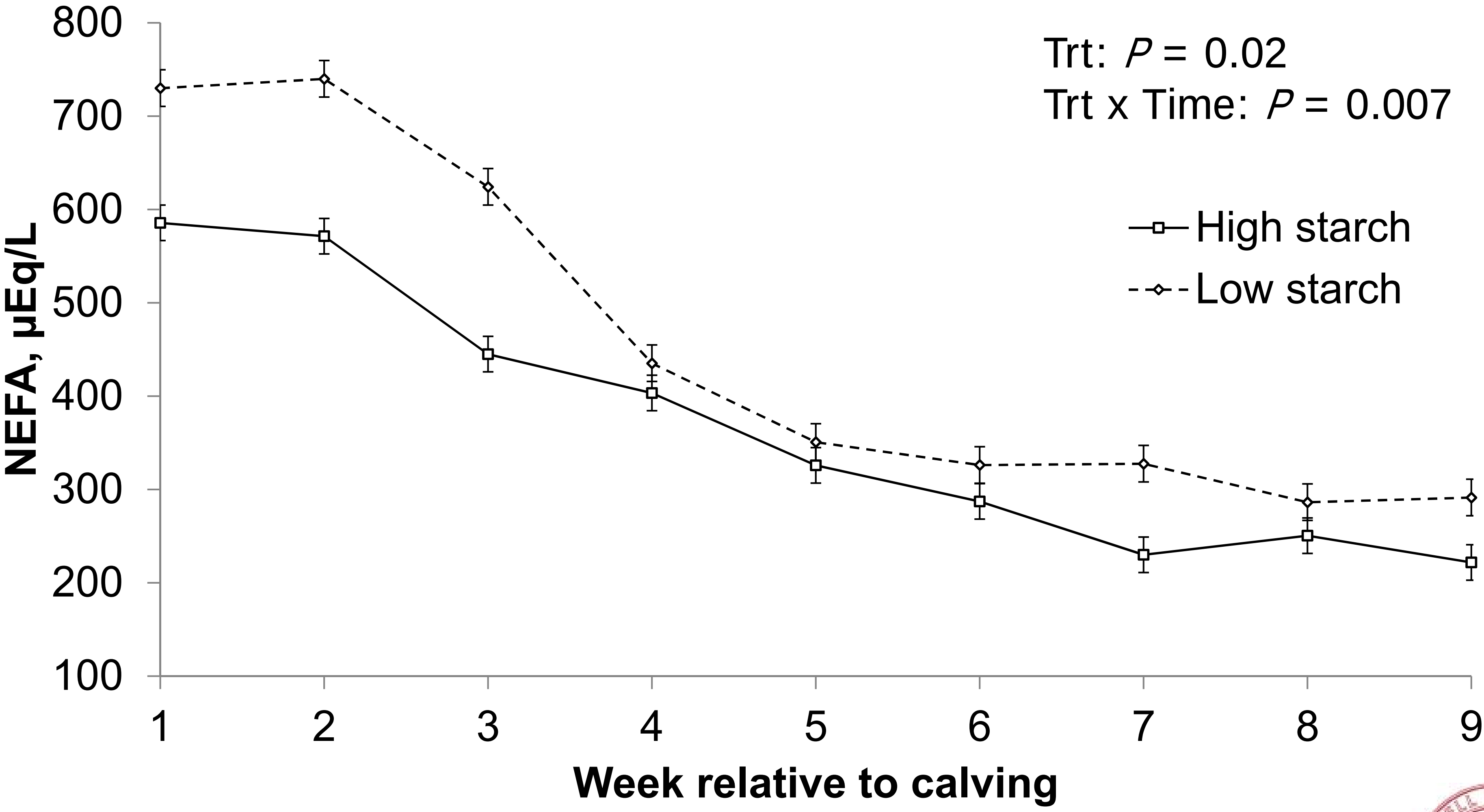
McCarthy et al., 2015a; *J. Dairy Sci.* 98:3335-3350

Transition period monensin ➔ faster increase in post calving DMI



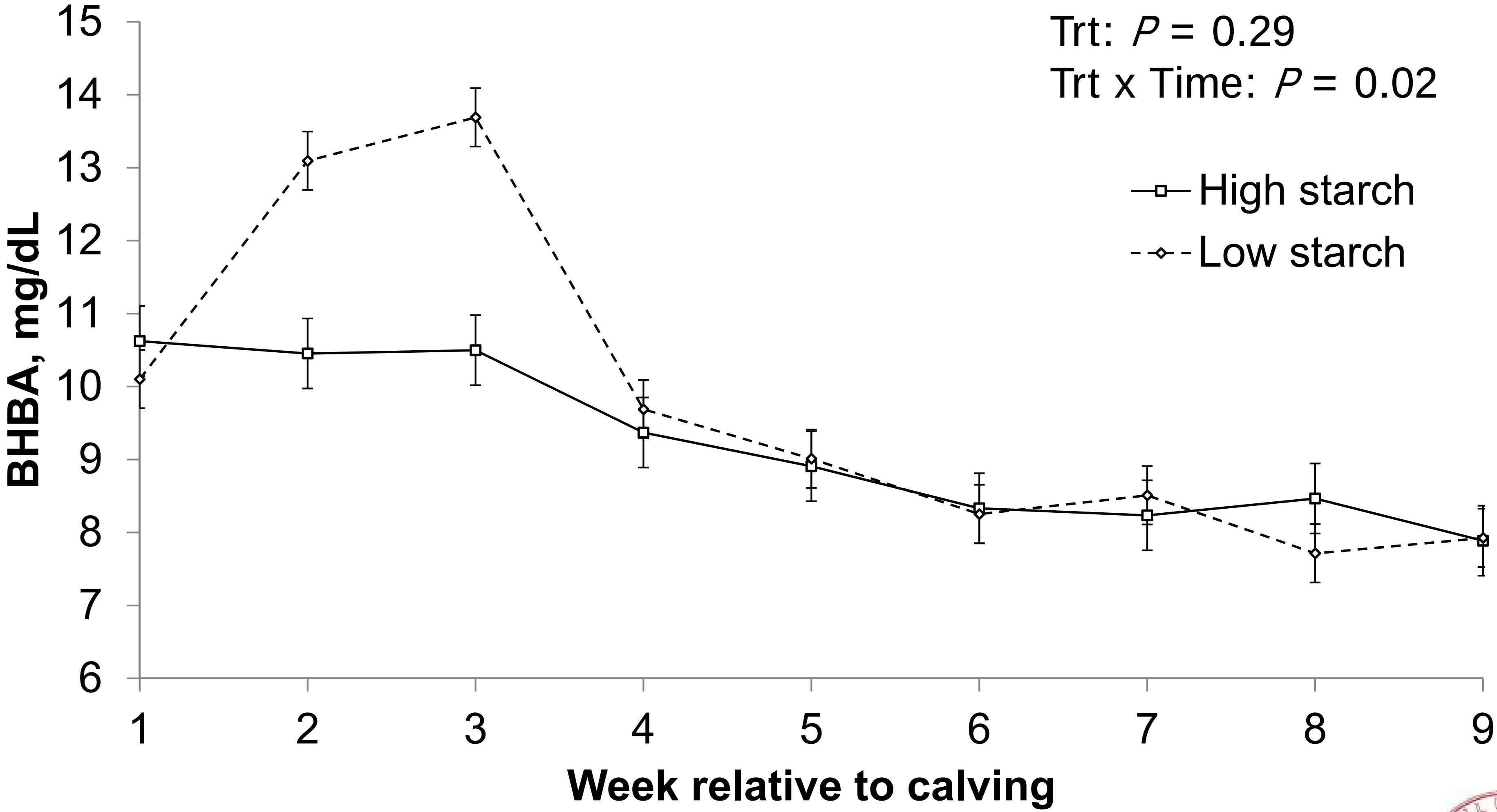
McCarthy et al., 2015a; *J. Dairy Sci.* 98:3335-3350

Higher starch → lower NEFA concentrations


Trt: $P = 0.02$
Trt x Time: $P = 0.007$

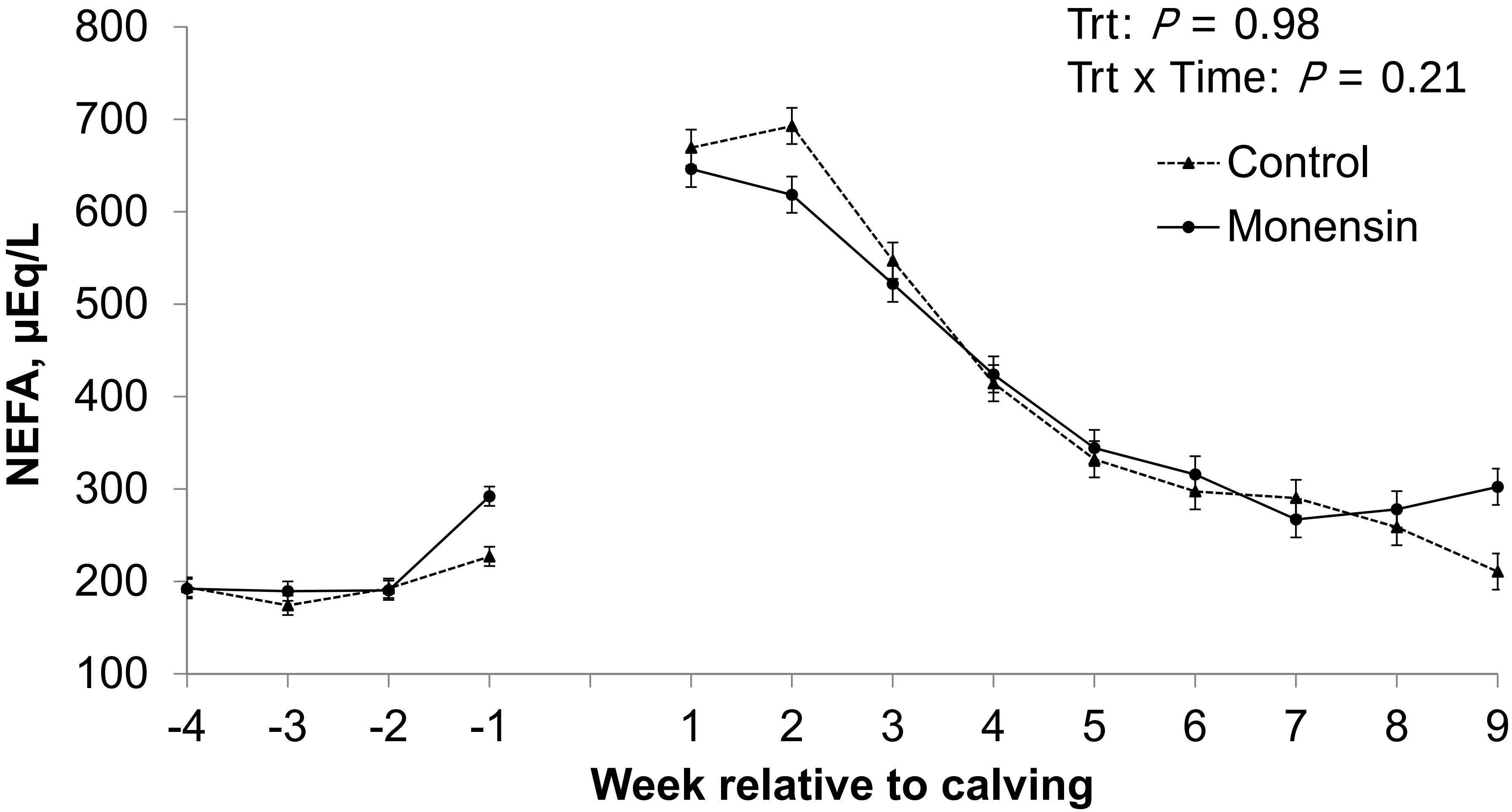
McCarthy et al., 2015b; *J. Dairy Sci.* 98:3351-3360

Higher starch ➔ lower BHBA concentrations



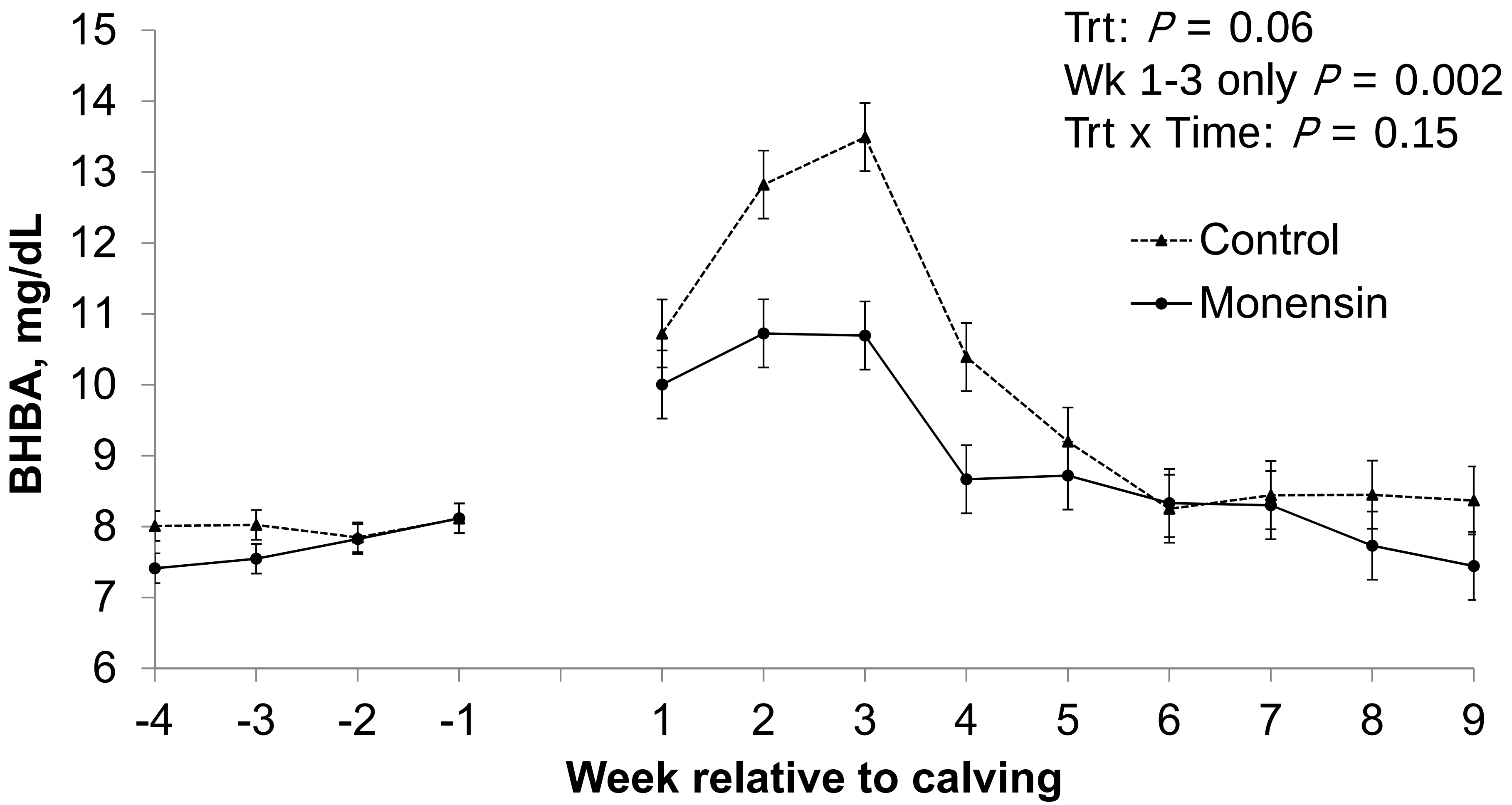
McCarthy et al., 2015b; *J. Dairy Sci.* 98:3351-3360

No effect of monensin on NEFA concentrations



McCarthy et al., 2015b; *J. Dairy Sci.* 98:3351-3360

Transition period monensin ➔ lower BHBA concentration



McCarthy et al., 2015b; *J. Dairy Sci.* 98:3351-3360

So why the differences?

Study & Group	Starch, %DM	Fermentable Starch, %DM	Fermentable Starch, % Total Fermentable CHO	Total Fermentable CHO, %DM
Miner				
Dry	13.5	11.5	29.7	39.4
Low	21.0	16.8	40.1	42.4
High	25.5	20.2	50.3	44.1
Cornell				
Close-up	17.4	15.3	36.3	42.2
Low	21.5	16.8	42.1	39.9
High	26.2	21.5	53.2	40.4

Slide courtesy of H.M. Dann, Miner Institute

Ruminal adaptations during the transition period

- Relatively poorly studied
- Early focus was on ruminal papillae development from feeding higher energy close-up rations (myth)
  - Supported by only one study (Dirksen et al., 1985)
  - More applicable studies indicated minimal papillae changes during the transition period (Andersen et al., 1999; Reynolds et al., 2004)
- Potential benefits of modulating ruminal microbial populations
  - Microbial adaptation
  - Increase supply of propionate
  - Increase microbial protein yield

Severity of ruminal acidosis during the transition period

- Primiparous cows

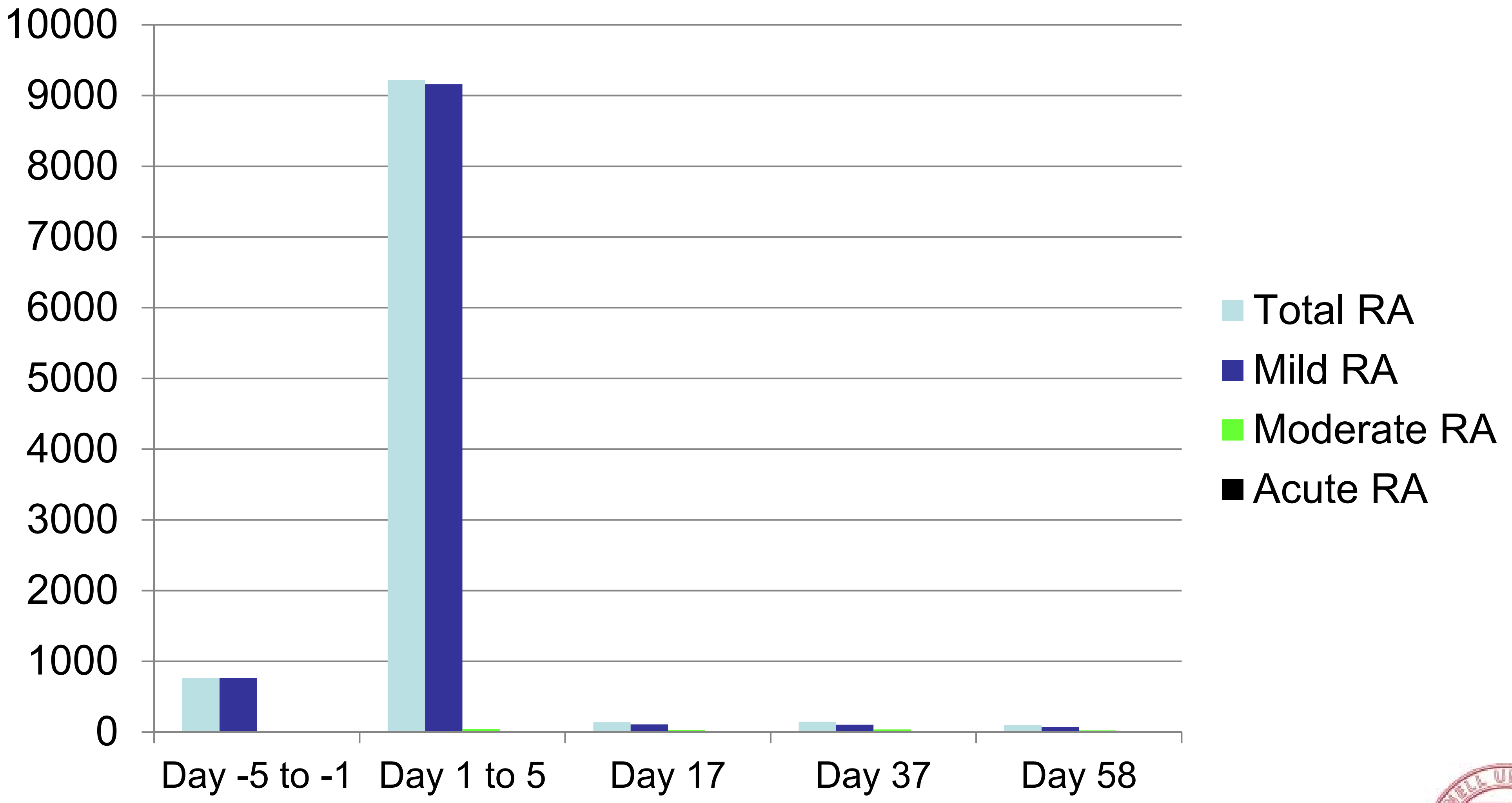
- Controls (80:20; F:C) far-off followed by (54:26; F:C) close-up

- High concentrate
  - 68:32 from d – 60 to -43
  - 60:40 from d – 42 to -25
  - 52:48 from d - 24 to – 13
  - 46:54 from d – 12 to calving

- Characterized varying degrees of ruminal acidosis (RA)
  - No RA – pH > 5.8
  - Mild RA – 5.8 > pH > 5.5
  - Moderate RA – 5.5 > pH > 5.2
  - Acute RA – pH < 5.2

Penner et al., 2007

Severity of ruminal acidosis during the transition period (RA total area – pH x min)



Penner et al., 2007

Fresh cow starch levels and acute phase response (Miner Institute and Zennoh)

- Randomized design with 16 multiparous Holstein cows
- 55-d dry period and fed close-up diet fed starting 21 d before expected calving
- Treatments from calving to 21 DIM
  - Lower starch diet (21% starch, 37% NDF)
  - Higher starch diet (27% starch, 32% NDF)

Williams et al., 2015. J. Dairy Sci. 98(Suppl. 1):741-742.

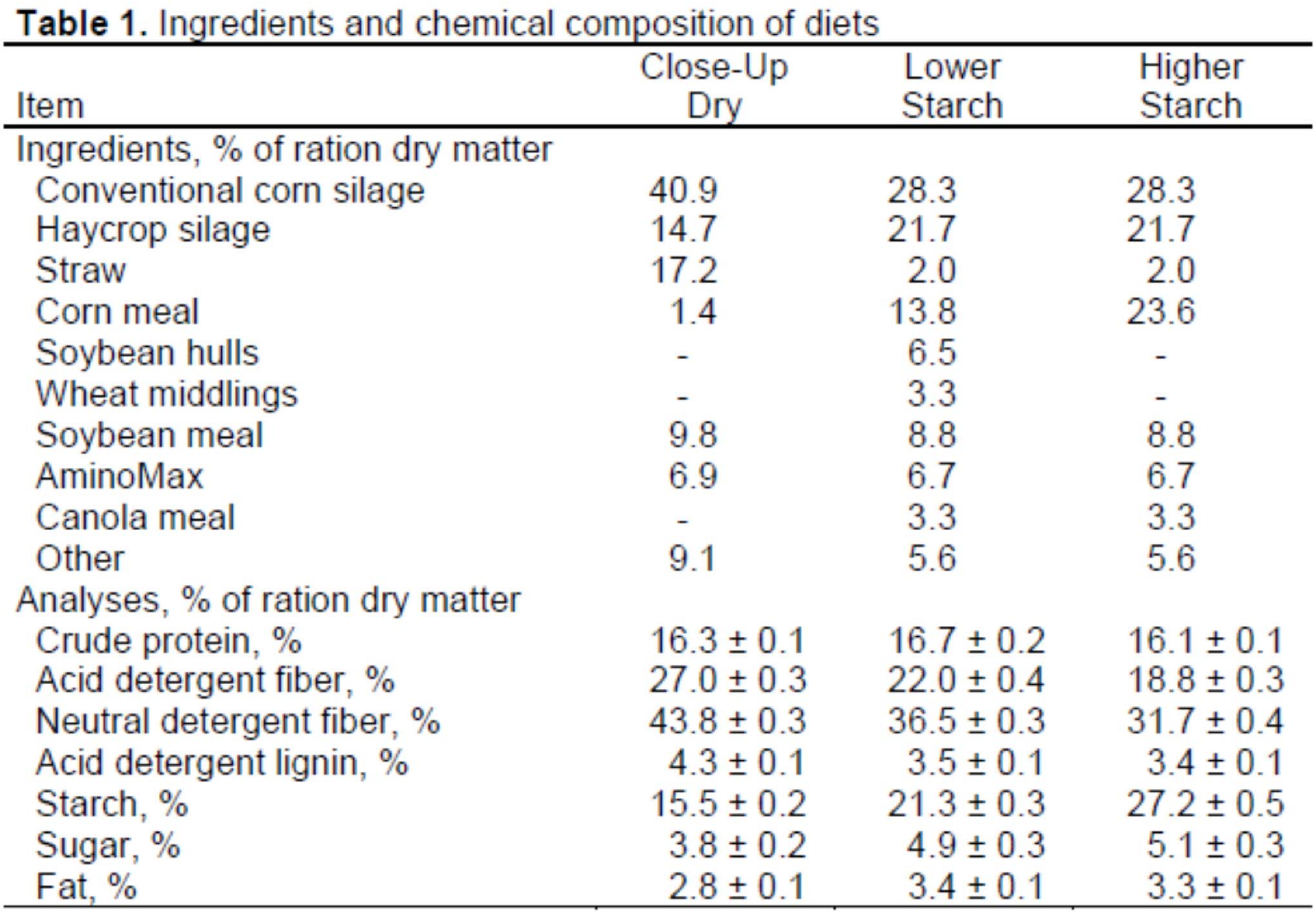


Table 1. Ingredients and chemical composition of diets

Item	Close-Up Dry	Lower Starch	Higher Starch
Ingredients, % of ration dry matter			
Conventional corn silage	40.9	28.3	28.3
Haycrop silage	14.7	21.7	21.7
Straw	17.2	2.0	2.0
Corn meal	1.4	13.8	23.6
Soybean hulls	-	6.5	-
Wheat middlings	-	3.3	-
Soybean meal	9.8	8.8	8.8
AminoMax	6.9	6.7	6.7
Canola meal	-	3.3	3.3
Other	9.1	5.6	5.6
Analyses, % of ration dry matter			
Crude protein, %	16.3 ± 0.1	16.7 ± 0.2	16.1 ± 0.1
Acid detergent fiber, %	27.0 ± 0.3	22.0 ± 0.4	18.8 ± 0.3
Neutral detergent fiber, %	43.8 ± 0.3	36.5 ± 0.3	31.7 ± 0.4
Acid detergent lignin, %	4.3 ± 0.1	3.5 ± 0.1	3.4 ± 0.1
Starch, %	15.5 ± 0.2	21.3 ± 0.3	27.2 ± 0.5
Sugar, %	3.8 ± 0.2	4.9 ± 0.3	5.1 ± 0.3
Fat, %	2.8 ± 0.1	3.4 ± 0.1	3.3 ± 0.1

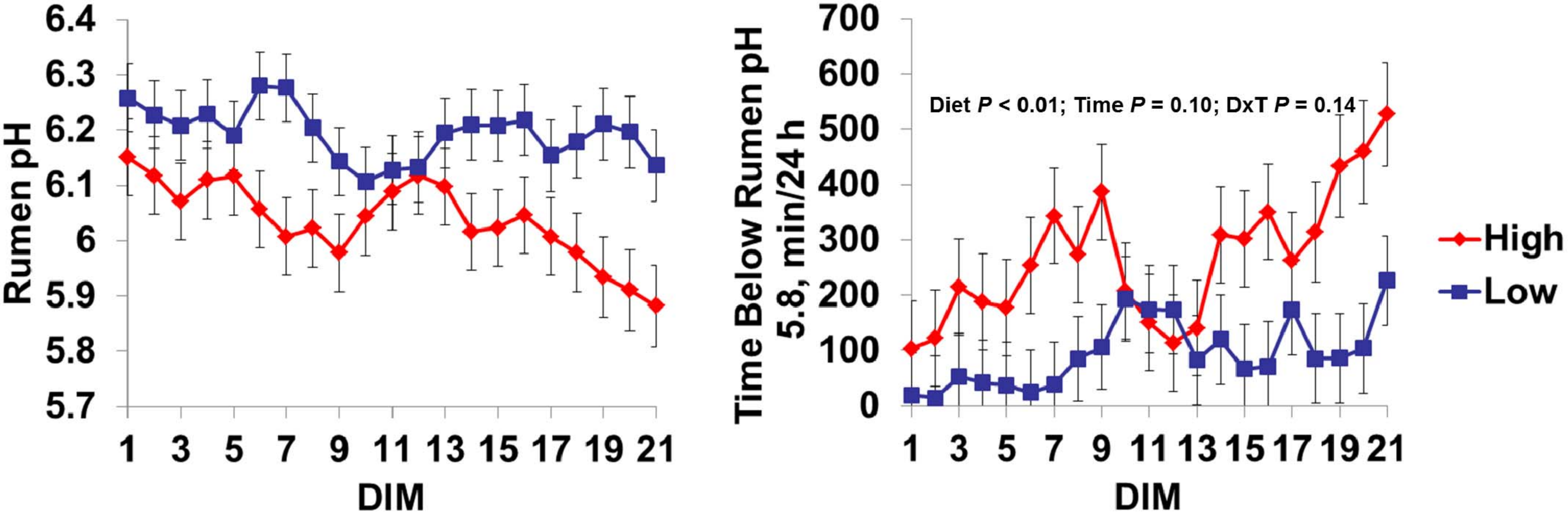
Williams et al., 2015. J. Dairy Sci. 98(Suppl. 1):741-742.

Characterization of intake and lactational performance

Item	Lower Starch	Higher Starch	SE
Close-up DMI, kg/d	13.7		0.3
Fresh DMI, kg/d	20.0	20.8	0.7
Fresh DMI, % of BW	2.74	2.86	0.10
Milk, kg/d	40.2	43.9	1.9
Milk fat, %	4.67	4.61	0.17
Milk true protein, %	3.59	3.46	0.07
MUN, mg/dL	17.3	13.6	0.8

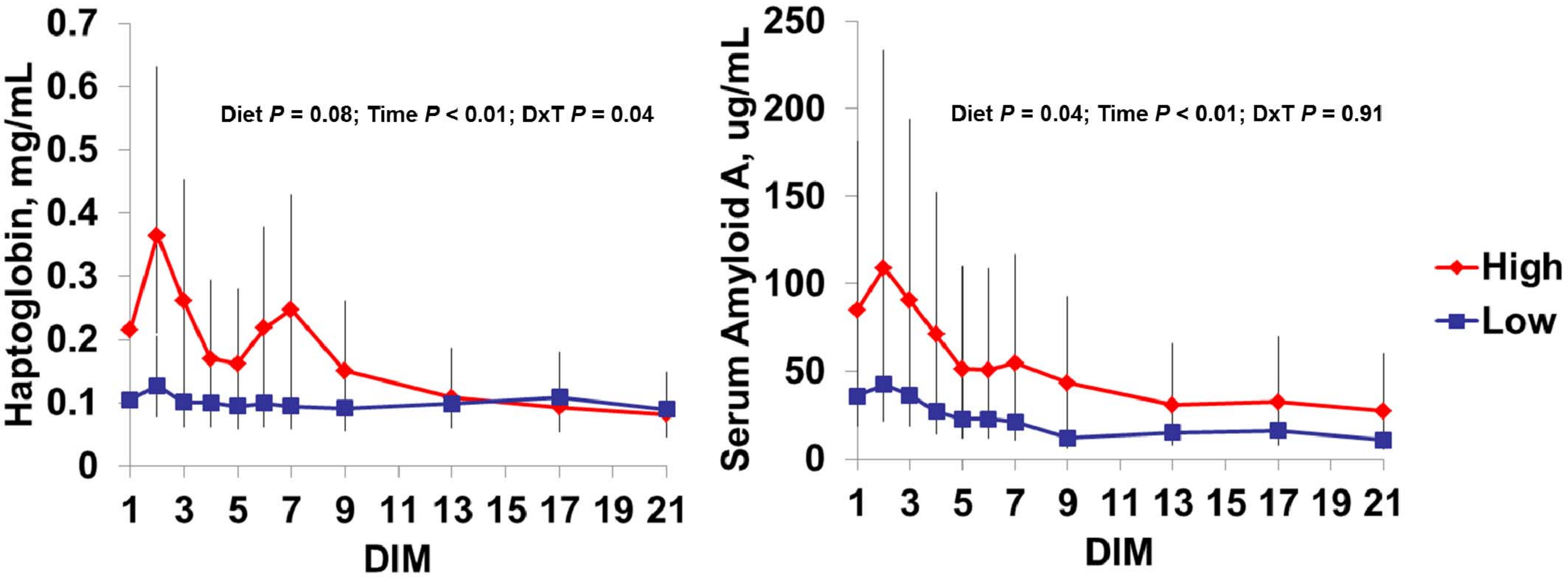
Williams et al., 2015. J. Dairy Sci. 98(Suppl. 1):741-742.

Rumen pH and time below pH 5.8 for cows fed high and low starch fresh diets

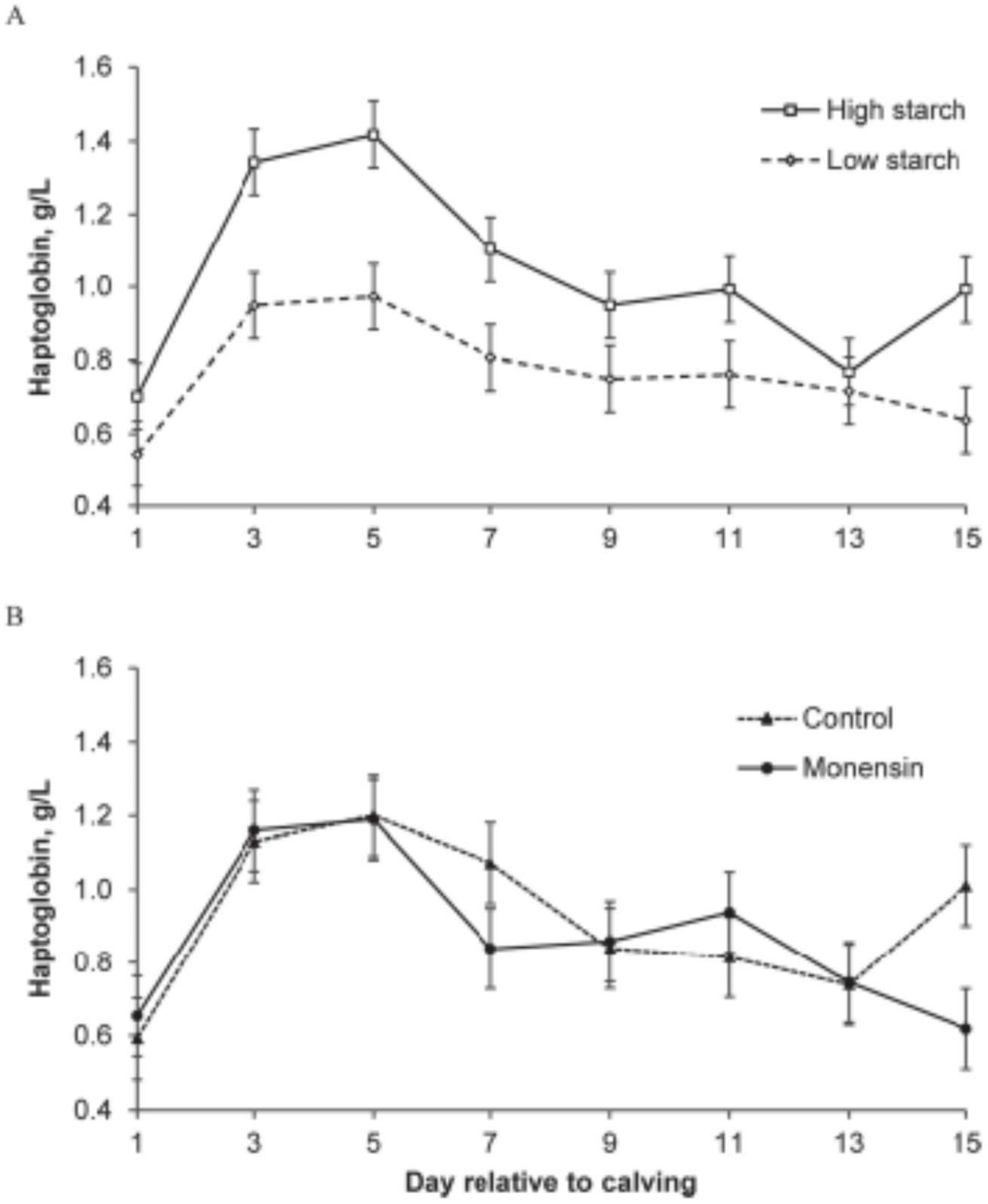


Williams et al., 2015. J. Dairy Sci. 98(Suppl. 1):741-742.

Acute phase proteins in cows fed high and low starch fresh diets



Williams et al., 2015. J. Dairy Sci. 98(Suppl. 1):741-742.



Plasma haptoglobin for cows fed high or low starch fresh diets and monensin

Effect of starch, P = 0.04

McCarthy et al., 2015b

Adequate physically effective NDF in rations is probably very important in fresh cows

A case study

- Cornell study evaluating high or low starch diets for fresh cows
- Controlled energy/high straw dry cow approach starting 28 to 35 days before calving
- At calving, one of two fresh diets until 21 DIM
- First cows that calved onto either ration developed significant health problems

Table 2. Health events for cows fed either high or low starch diets for the first 3 wk postpartum before and after postpartum ration changes.

	Postpartum ration[1]				Parity		*P*-values[2]		
Item[3]	HSLF	LSLF	HSHF	LSHF	Primi	Multi	S	F	P
Multiparous, n	3	8	27	28					
Primiparous, n	4	2	11	11					
Clinical ketosis[3]	4	1	4	6	6	9	0.23	0.05	0.14
DA[4]	4	2	0	0	4	2	0.22	<0.001	0.06
RP[5]	1	2	2	1	3	3	0.32	0.05	0.20
Total disorders	9	5	6	7					

[1] HSLF = high starch, low fiber (pre-change); LSLF = low starch, low fiber (post-change); HSHF = high starch, high fiber (post change); LSHF = low starch, high fiber (post-change).

[2] S = effect of starch; F = effect of fiber; P = effect of parity.

[3] Clinical ketosis defined as rapidly decreased milk production and DMI and blood BHBA ≥ 2.6 mmol/L using Precision Xtra, displaced abomasum by auscultation

[4] Displaced abomasium diagnosed by auscultation.

[5] Placenta retained for ≥ 24 h postcalving.

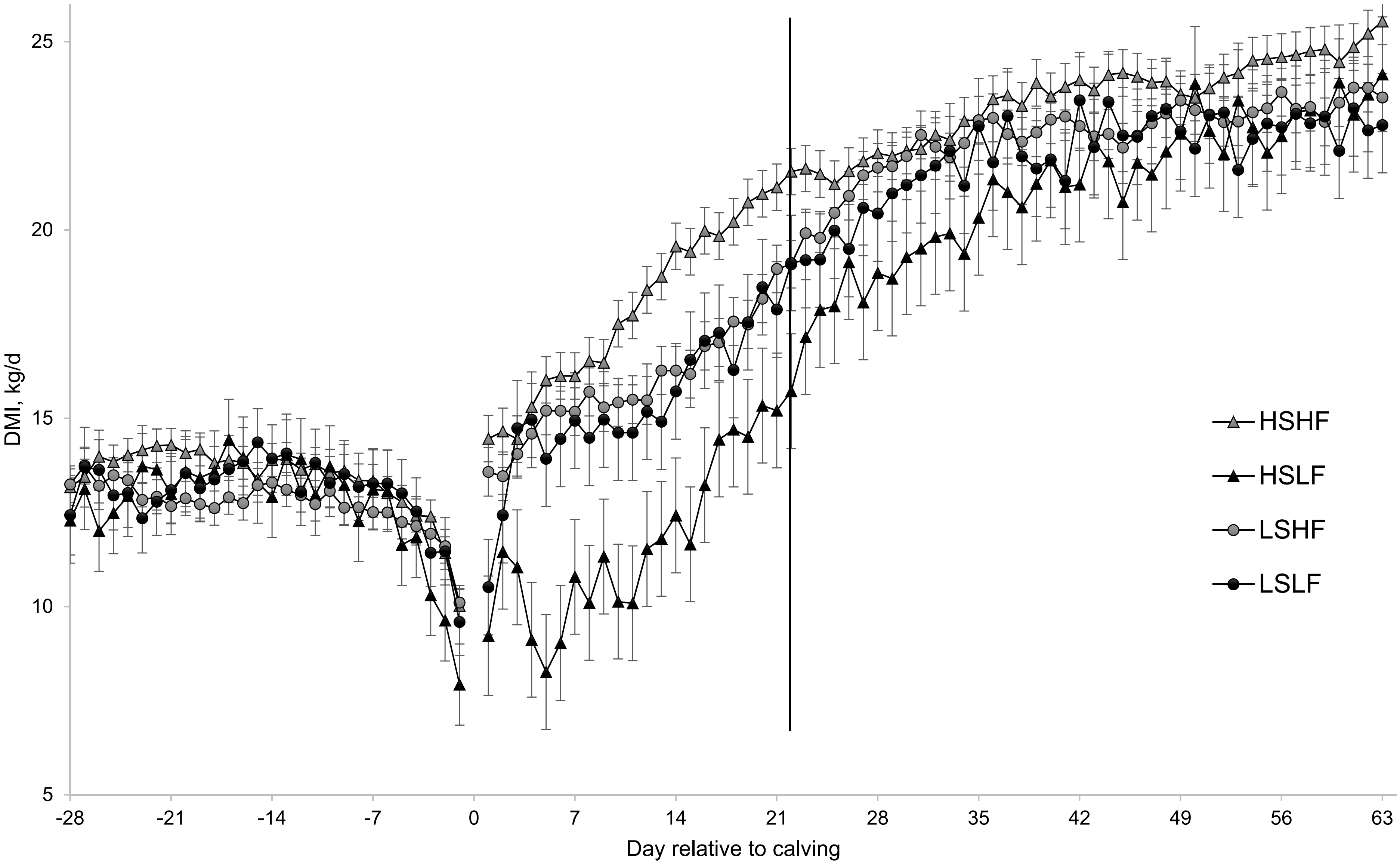
Table 3. Ingredient and chemical composition of diets (± SD[1]) before and after postpartum ration changes (DM basis)

		Postpartum[2]			
Item	Prepartum	HSLF	LSLF	HSHF	LSHF
Ingredient (% of DM)					
Corn silage, conv.	42.1	---	---	---	---
BMR corn silage	---	46.1	46.1	38.5	38.5
Wheat straw	21.2	3.84	3.84	11.5	11.5
Legume silage	---	9.62	9.62	9.62	9.62
Corn meal, fine	4.28	21.0	10.3	21.0	10.3
Citrus pulp	7.23	1.01	7.15	1.01	7.15
Corn germ meal	---	2.52	5.56	2.52	5.56
Soybean hulls	7.08	---	3.58	---	3.58
Soybean meal	5.27	5.87	3.86	5.87	3.86
Canola meal	4.63	2.73	2.08	2.73	2.08
Blood meal	1.05	1.94	1.93	1.94	1.93
Expeller soy	1.78	1.70	2.34	1.70	2.34
Bypass fat	---	0.77	0.96	0.77	0.96
Anionic suppl.	1.33	---	---	---	---
Sodium bicarbonate	---	0.86	0.85	0.86	0.85
Minerals/vitamins	3.35	1.99	1.72	1.99	1.72
Chemical					
CP, %	13.0 ± 0.8	16.5	15.3	15.5 ± 1.2	15.4 ± 0.8
ADF, %	28.2 ± 1.2	17.7	22.3	22.7 ± 1.2	25.2 ± 1.2
NDF, %	42.9 ± 2.0	26.4	31.5	34.3 ± 1.5	36.9 ± 1.5
Sugar, %	4.9 ± 0.8	3.1	3.9	3.5 ± 0.6	4.5 ± 0.4
Starch, %	17.4 ± 1.2	28.3	22.0	26.2 ± 1.2	21.5 ± 1.0
Fat, %	2.6 ± 0.2	3.2	3.1	4.0 ± 0.2	2.2 ± 0.6
uNDF$_{240}$,[3] % of DM	14.9	7.7	8.9	10.5	10.9

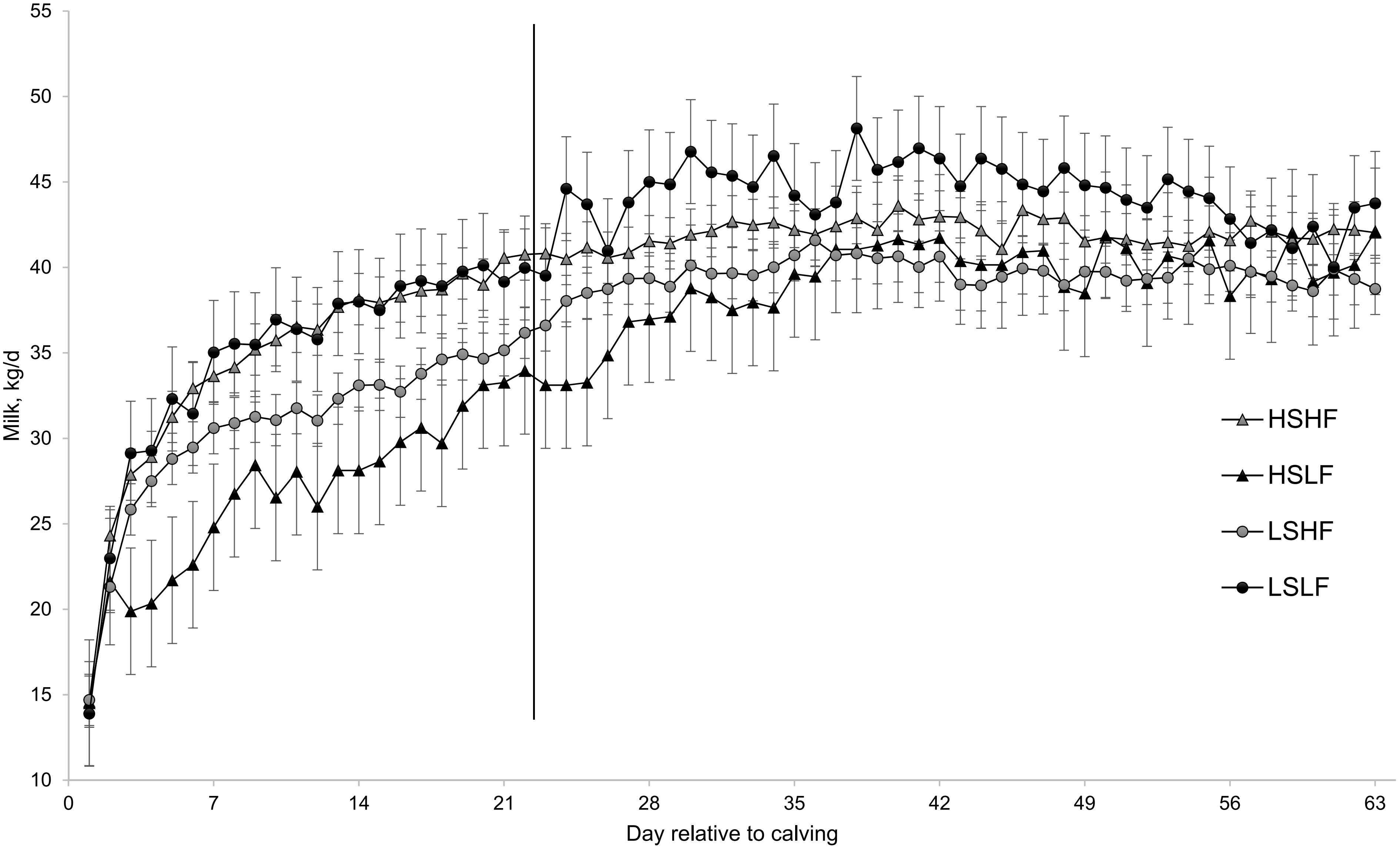
[1] Chemcial composition was analyzed on 4-wk composite samples (n = 1 for HSLF, n = 1 for LSLF, n = 7 for HSHF, and n = 6 for LSHF).

[2] HSLF = high starch, low fiber (pre-change); LSLF = low starch, low fiber (post-change); HSHF = high starch, high fiber (post change); LSHF = low starch, high fiber (post-change).

[3] Determined using wet chemistry methods on a single composite sample from each diet (Cumberland Valley Analytical Services, Hagerstown, MD)



McCarthy et al., unpublished



McCarthy et al., unpublished

Overall implications

- Evolution in fresh cow feeding strategies over next few years
- Interactions appear to exist between prepartum and postpartum feeding strategies
- If low starch (< 15%) prepartum:
  - likely best fresh strategy 21 to 23% starch
- If higher starch (17 to 19% prepartum
  - likely OK to go to 26 to 27% starch fresh diet
- Higher fiber/peNDF/uNDF240 diet postcalving may help cows adapt to higher starch diet

Thanks!!

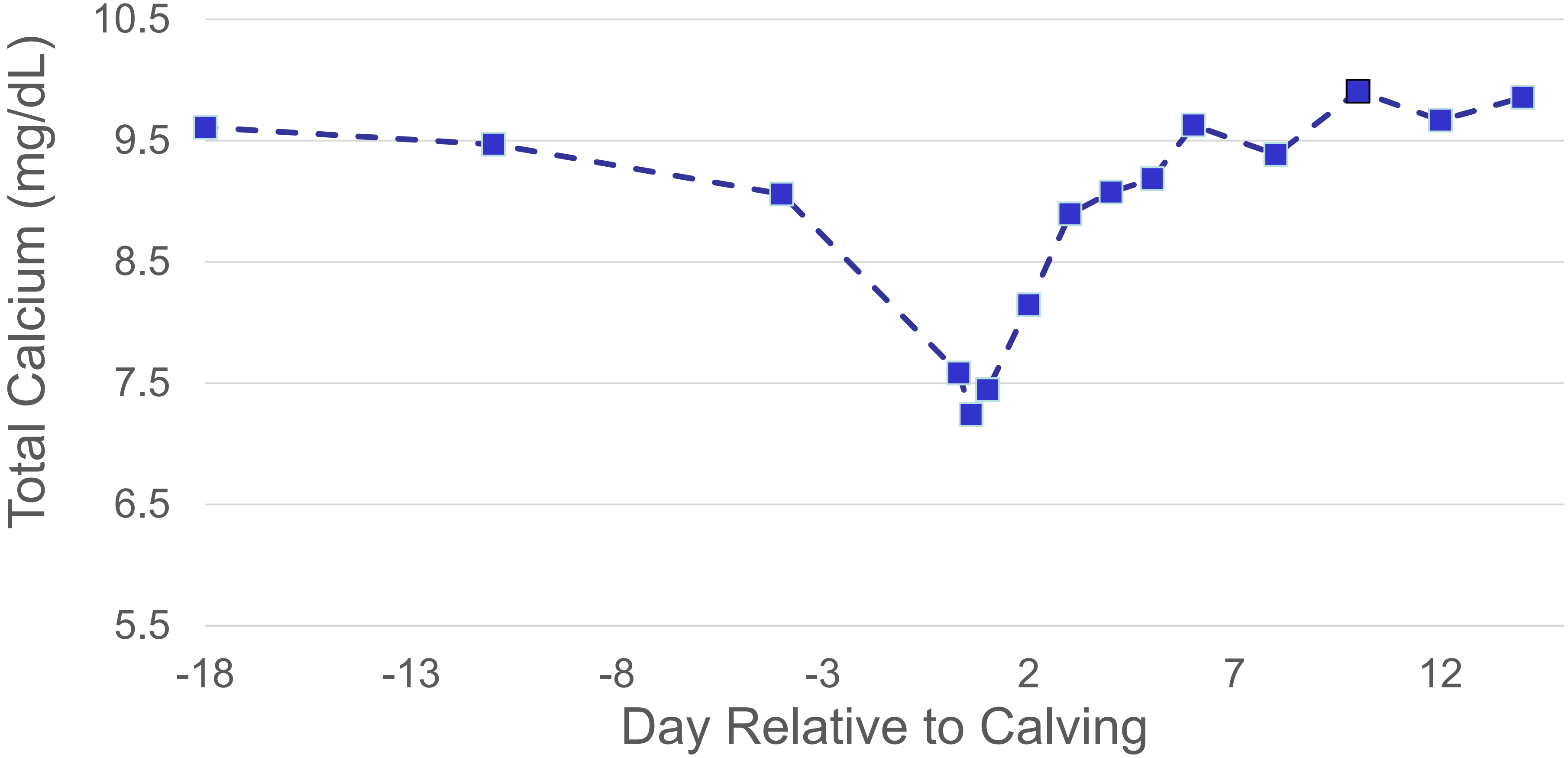
tro2@cornell.edu

Implementing and managing DCAD dietary strategies for dry cows

Thomas R. Overton and Brittany M. (Sweeney) Leno
Department of Animal Science
Cornell University
Ithaca, NY

Refocus on calcium metabolism -- hypocalcemia -- in the transition cow

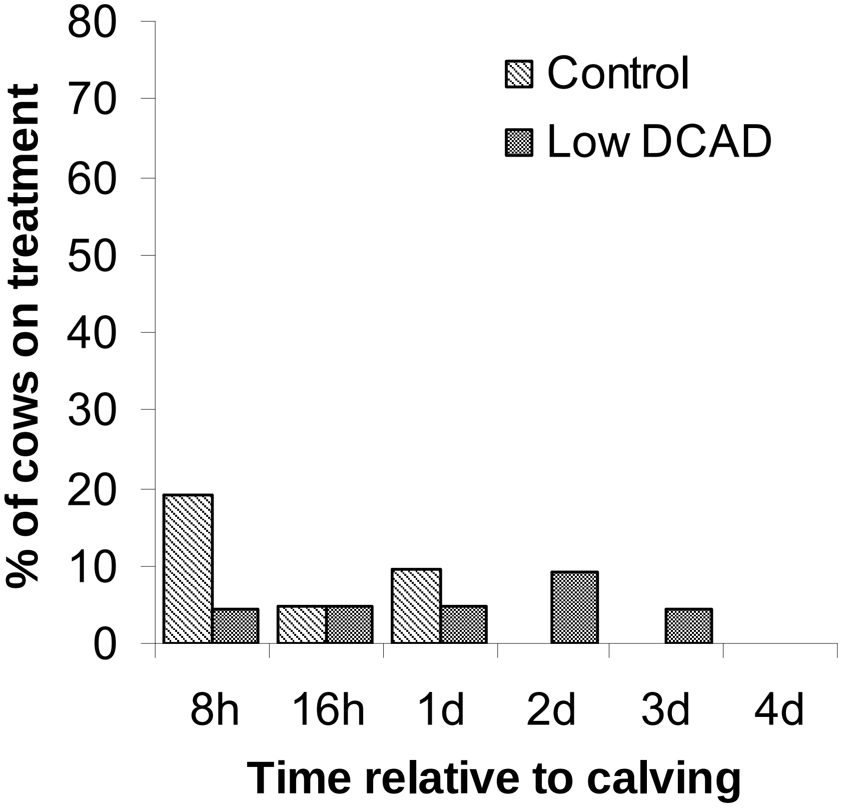
Calcium Status in the Transition Period



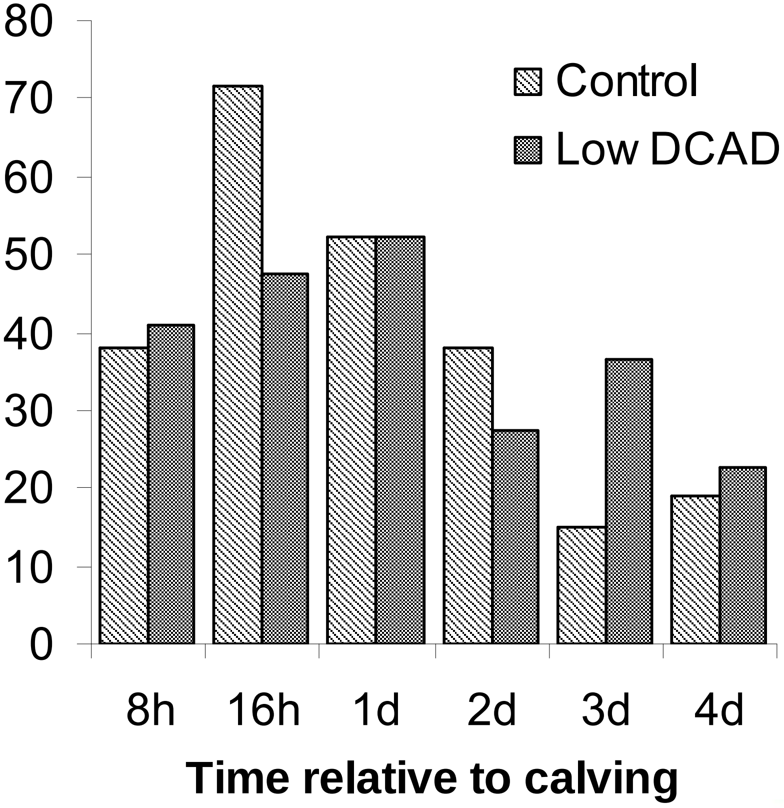
Sweeney et al., 2015. J. Dairy Sci 98 (Suppl. 2):128.

Hypocalcemia incidence analysis

Clinical hypocalcemia (< 5 mg/dL)

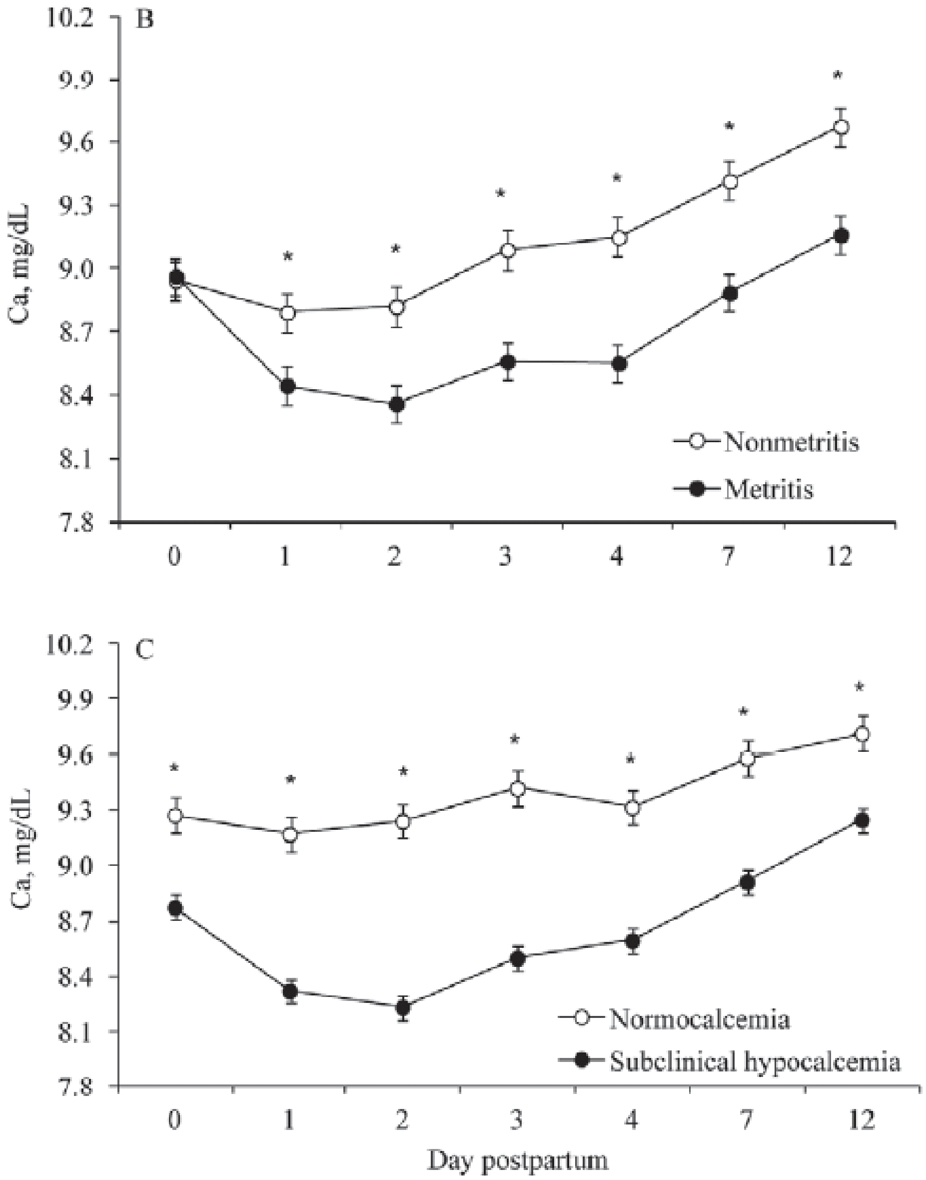


Subclinical hypocalcemia (5 - 8 mg/dL)



Ramos-Nieves et al., 2009

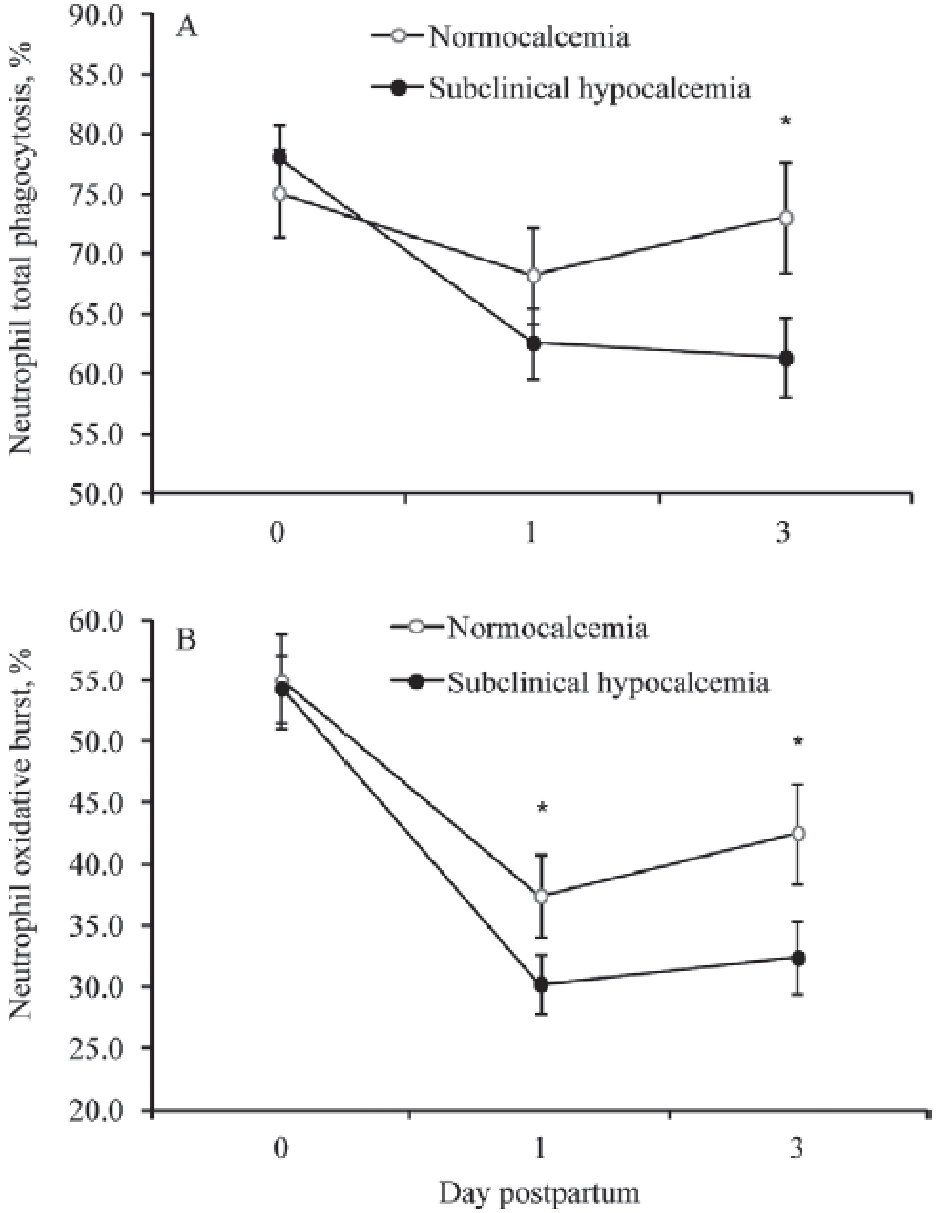
Cows with metritis have lower blood Ca concentrations



Martinez et al., 2012. J. Dairy Sci. 95 :7158–7172

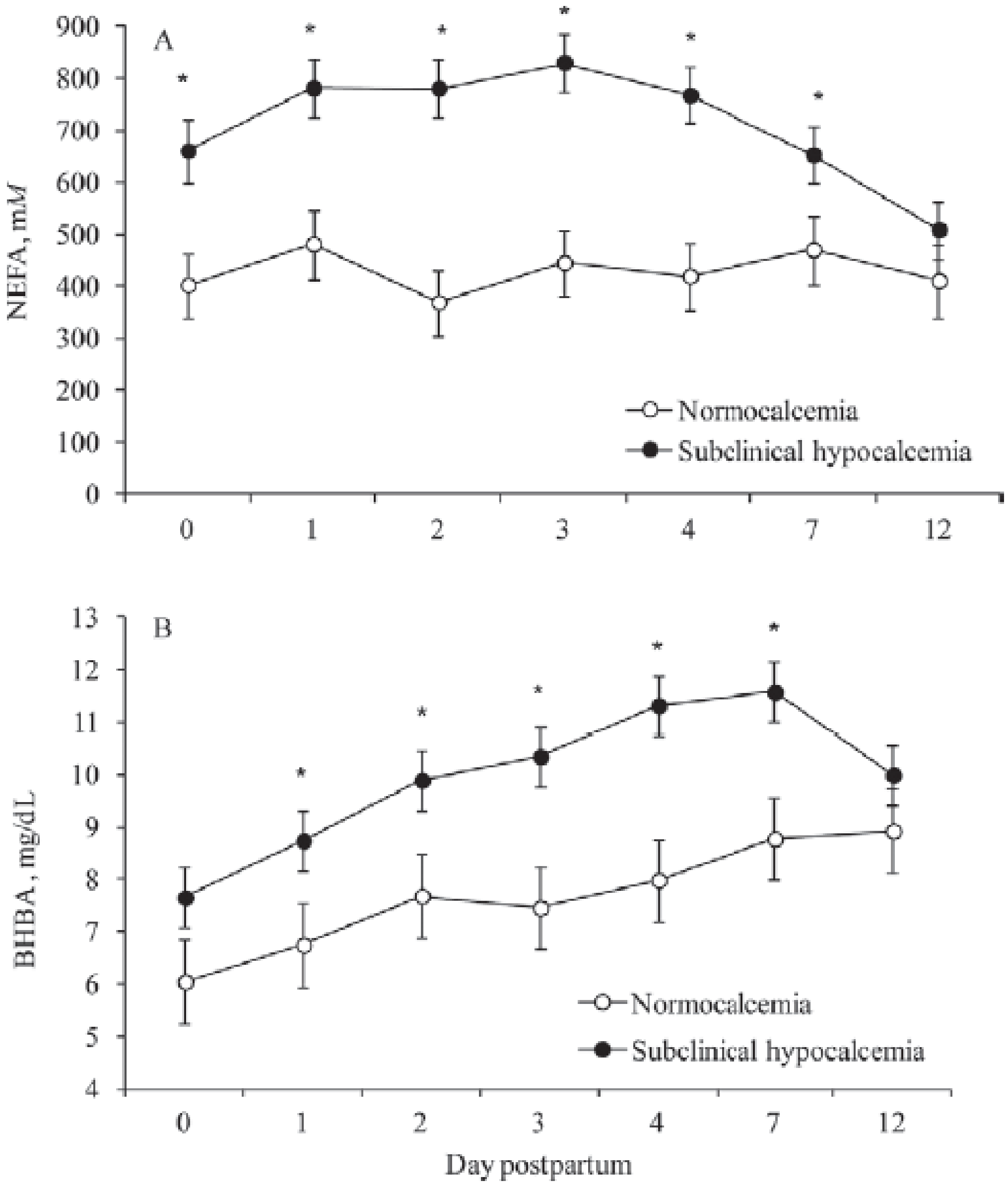
Subclinical hypocalcemia defined as one or more samples with Ca < 8.6 during first 3 DIM

Cows with subclinical hypocalcemia have impaired immune function



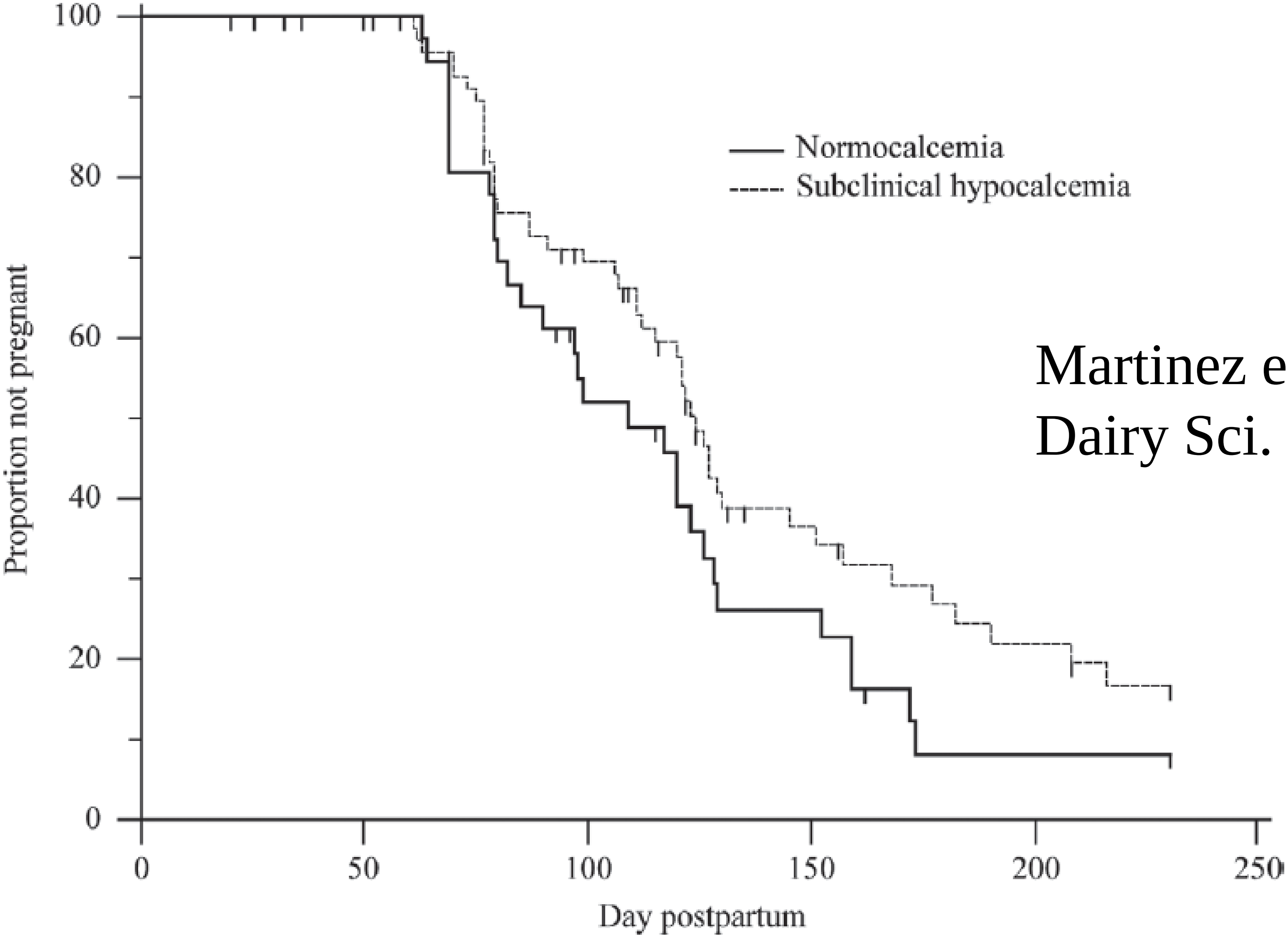
Martinez et al., 2012. J. Dairy Sci. 95 :7158–7172

Cows with subclinical hypocalcemia have higher NEFA and BHBA



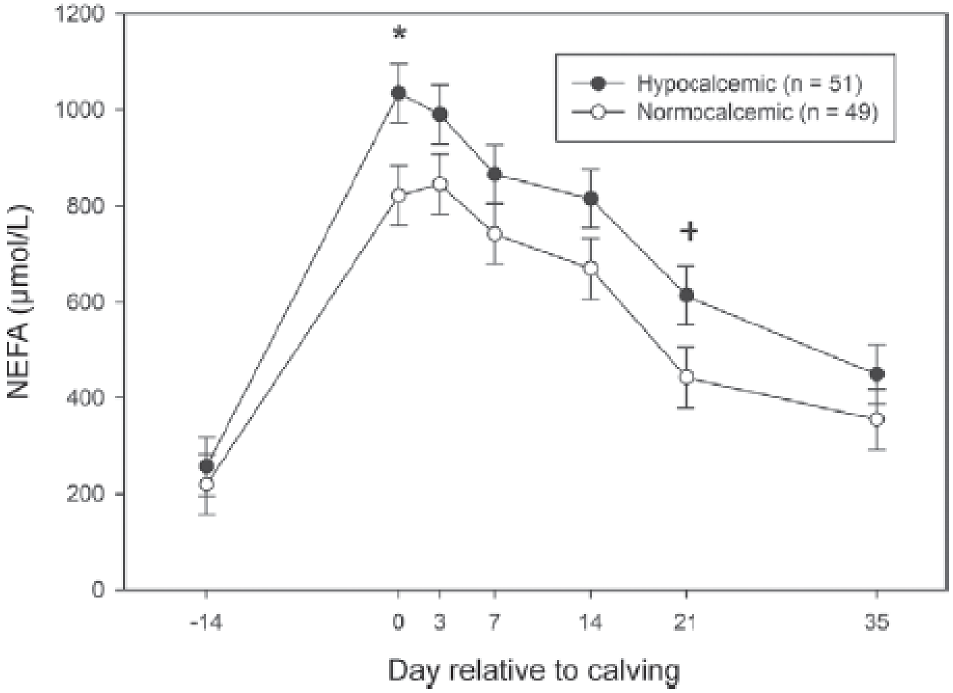
Martinez et al., 2012. J. Dairy Sci. 95 :7158–7172

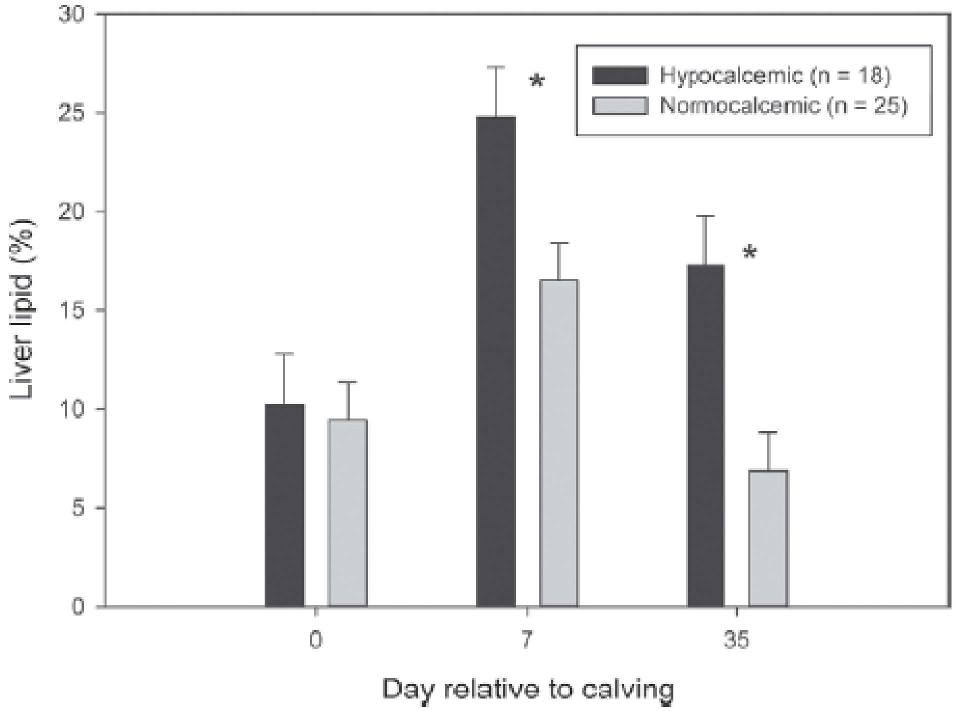
Cows with subclinical hypocalcemia have delayed reproduction



Martinez et al., 2012. J. Dairy Sci. 95 :7158–7172

Hypocalcemic cows have higher NEFA and liver TG





Chamberlin et al., 2013. J. Dairy Sci. 96:7001-7013.

Chapinal et al., 2012. JDS 95:5676-5682

- 55 herds in US and Canada
- Cows sampled 1X/wk from wk -1 to wk +3 relative to calving
- Median number of cows sampled/herd – 36
- 27% of animals sampled were first lactation
- Focus on Ca, NEFA, and BHBA

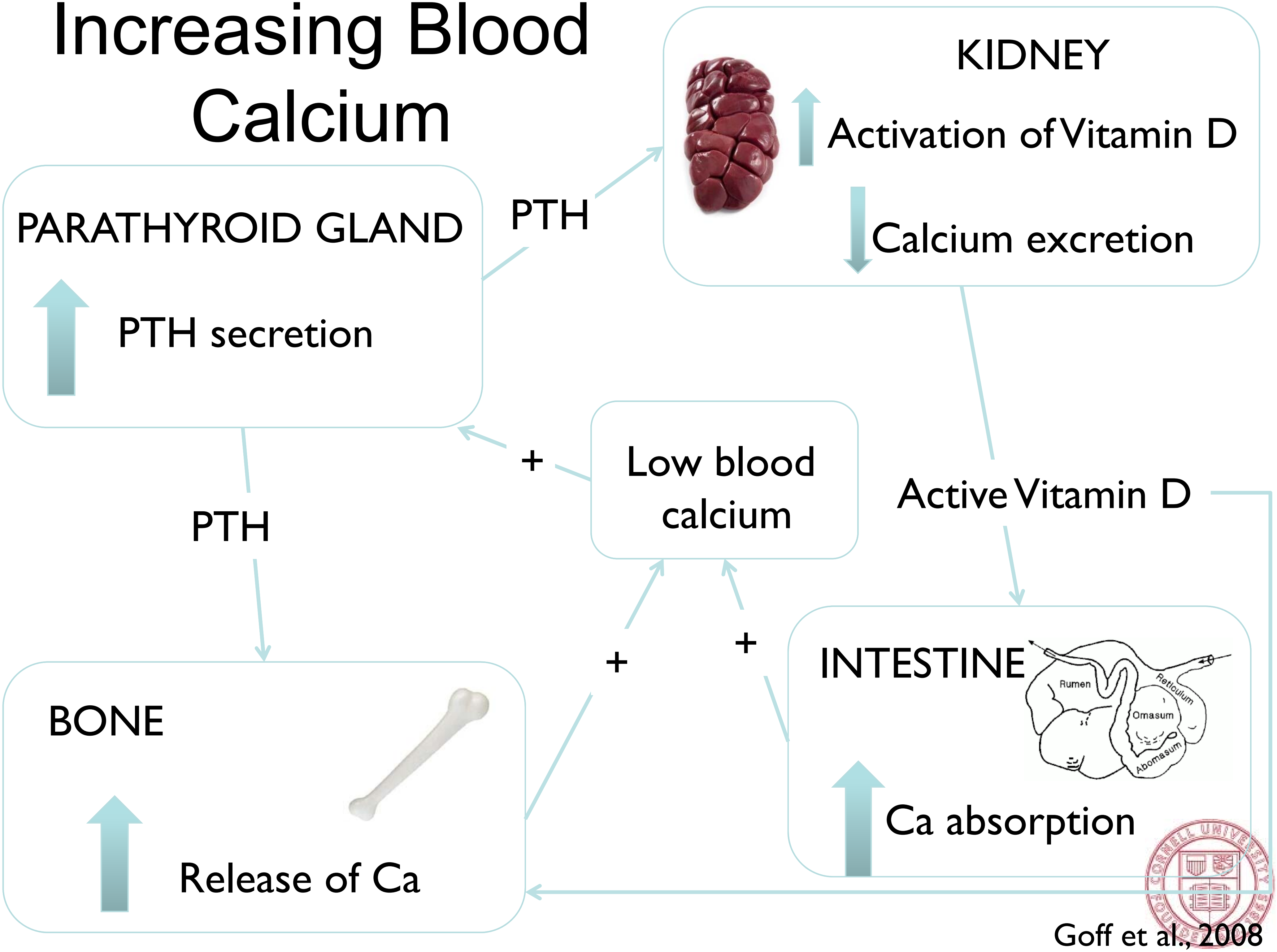
Herd-level associations of low Ca during wk +1 (< 2.1 mM; 8.4 mg/dL) with outcomes

Item	**Herd-level threshold (%)**	**Farms above threshold (%)**	**Outcome**	**P-value**
DA (all cows)	≥ 35	24	OR = 2.4	0.003
DA (multiparous)	≥ 30	43	OR = 1.9	0.004
Milk[1] (all cows)	≥ 15	73	- 3.8 kg/d	0.01
Milk (multiparous)	≥ 25	55	- 2.9 kg/d	0.05
Pregnancy 1st AI (all cows)	≥ 25	40	OR = 0.7	0.02

[1] At 1st DHI test day

Chapinal et al., 2012. JDS 95:5676-5682

Increasing Blood Calcium



PARATHYROID GLAND

↑ PTH secretion

PTH

KIDNEY

↑ Activation of Vitamin D

↓ Calcium excretion

Low blood calcium

\+

Active Vitamin D

PTH

BONE

↑ Release of Ca

\+

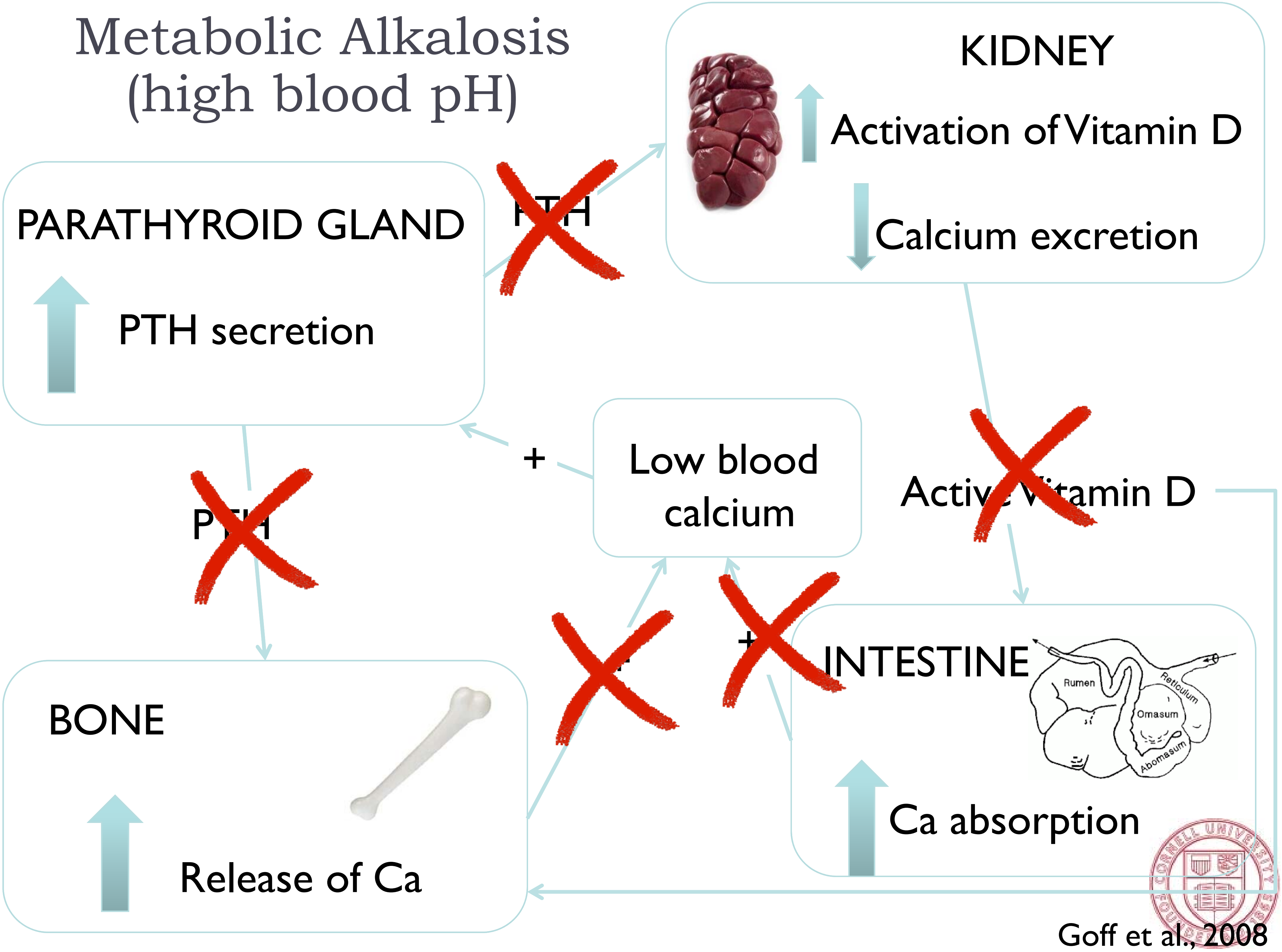
\+

INTESTINE

↑ Ca absorption

Goff et al., 2008

Metabolic Alkalosis
(high blood pH)



PARATHYROID GLAND

↑ PTH secretion

~~PTH~~

KIDNEY

↑ Activation of Vitamin D

↓ Calcium excretion

Low blood calcium

+

~~Active Vitamin D~~

~~PTH~~

BONE

↑ Release of Ca

~~+~~

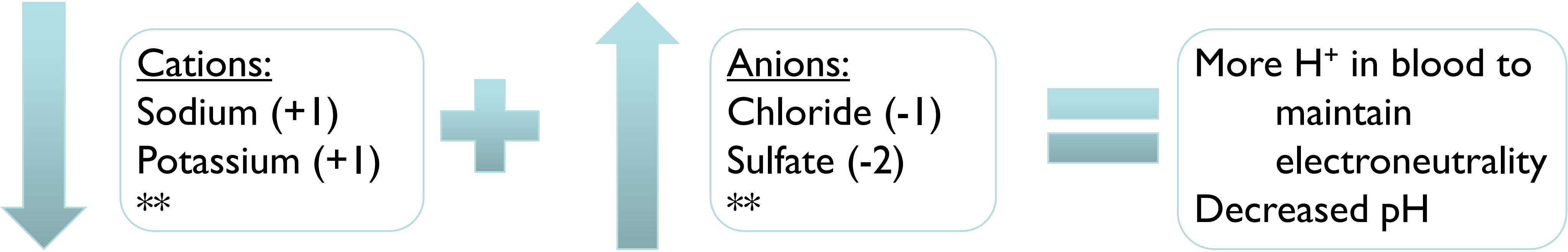
~~+~~

INTESTINE

↑ Ca absorption

Goff et al., 2008

Altering Ca metabolism via DCAD



<u>Cations:</u>
Sodium (+1)
Potassium (+1)
**

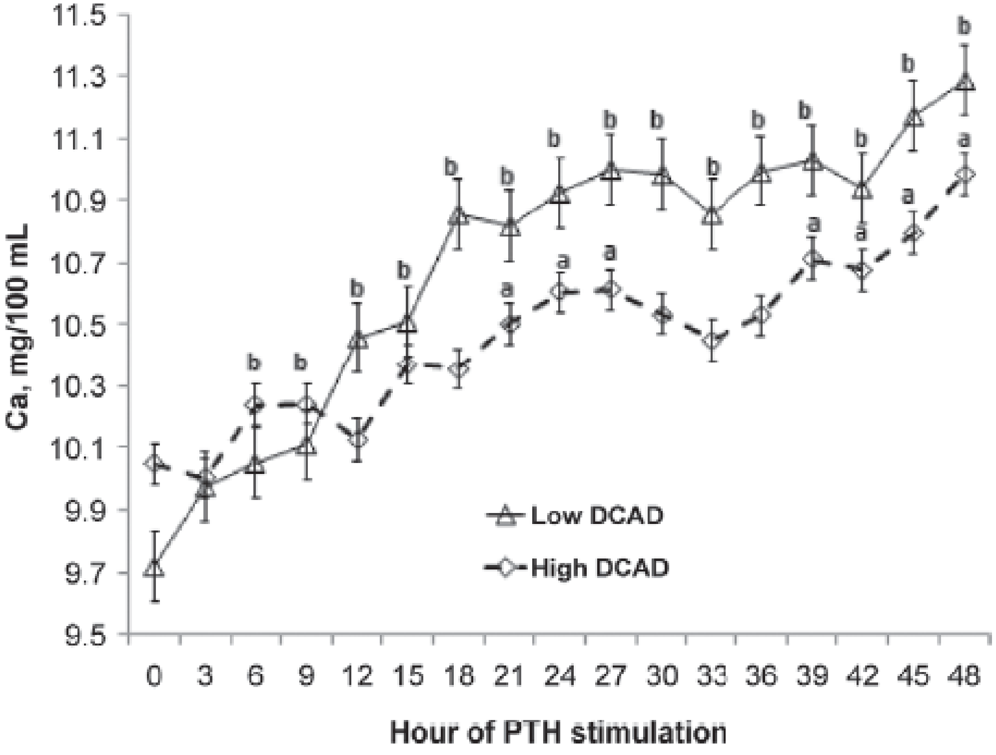
<u>Anions:</u>
Chloride (-1)
Sulfate (-2)
**

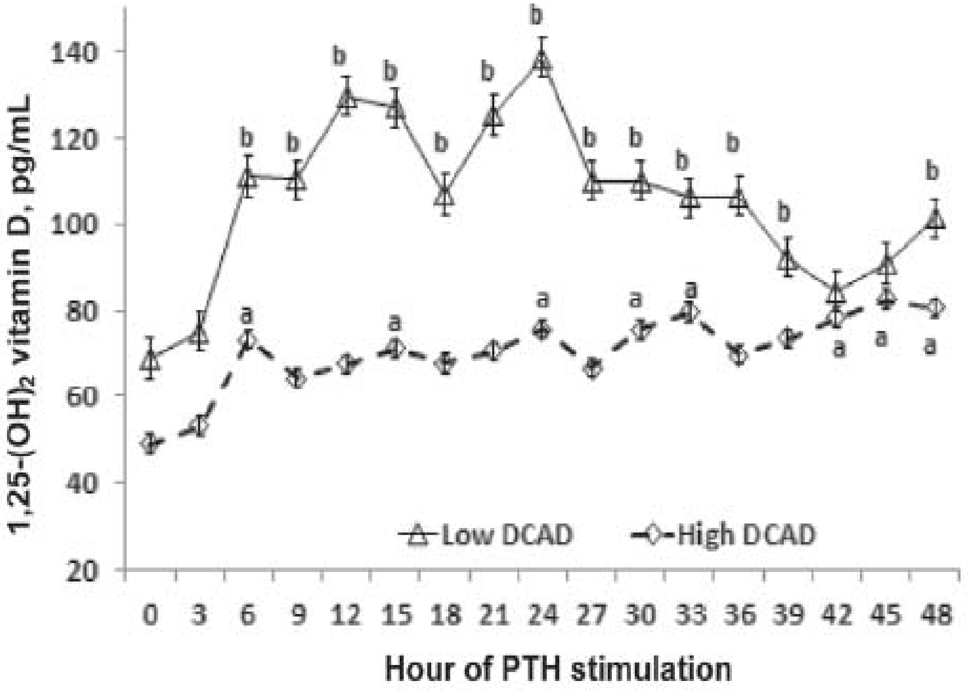
More H^+ in blood to maintain electroneutrality
Decreased pH

- DCAD = Dietary Cation Anion Difference
  - Manipulated in prepartum diet
- Result:
  - better sensitivity of PTH receptor to PTH stimulation
  - Ca release from bone to offset pH drop (excreted from kidney until hypocalcemic condition occurs) (Goff and Horst, 2003)

Goff et al., 2008

Cows fed low DCAD have higher Ca and 1,25-$(OH)_2$ vitamin D after PTH administration





Goff et al., 2014; J. Dairy Sci. 97:1520-1528

Major strategies for application of DCAD for close-up dry cows

- Focus on feeding low K (and Na) forages and feeds to close-up dry cows
  - *Calculated DCAD ~ +10 mEq/100 g of DM*
  - *Urine pH ~ 8.3 to 8.5*

- Feeding low K forages along with partial use of anionic supplement in close-up ration or one-group dry cow ration
  - *Calculated DCAD ~ 0 mEq/100 g of DM*
  - *Urine pH ~ 7.5*

- Feeding low K forages along with full use of anionic supplement in close-up ration or one-group dry cow ration
  - *Calculated DCAD ~ -10 to -15 mEq/100 g of DM*
  - *Urine pH ~ 5.5 to 6.0 – need to monitor weekly and adjust DCAD supplementation if out of range*
- Need to also supplement Mg (dietary target ~ 0.45%) during close-up
- Recommend supplementing Ca (0.9 to 1.0% if low K only; 1.4 to 1.5% if full anionic diet)

Prepartum Diets, lbs DM; Sweeney et al., 2015

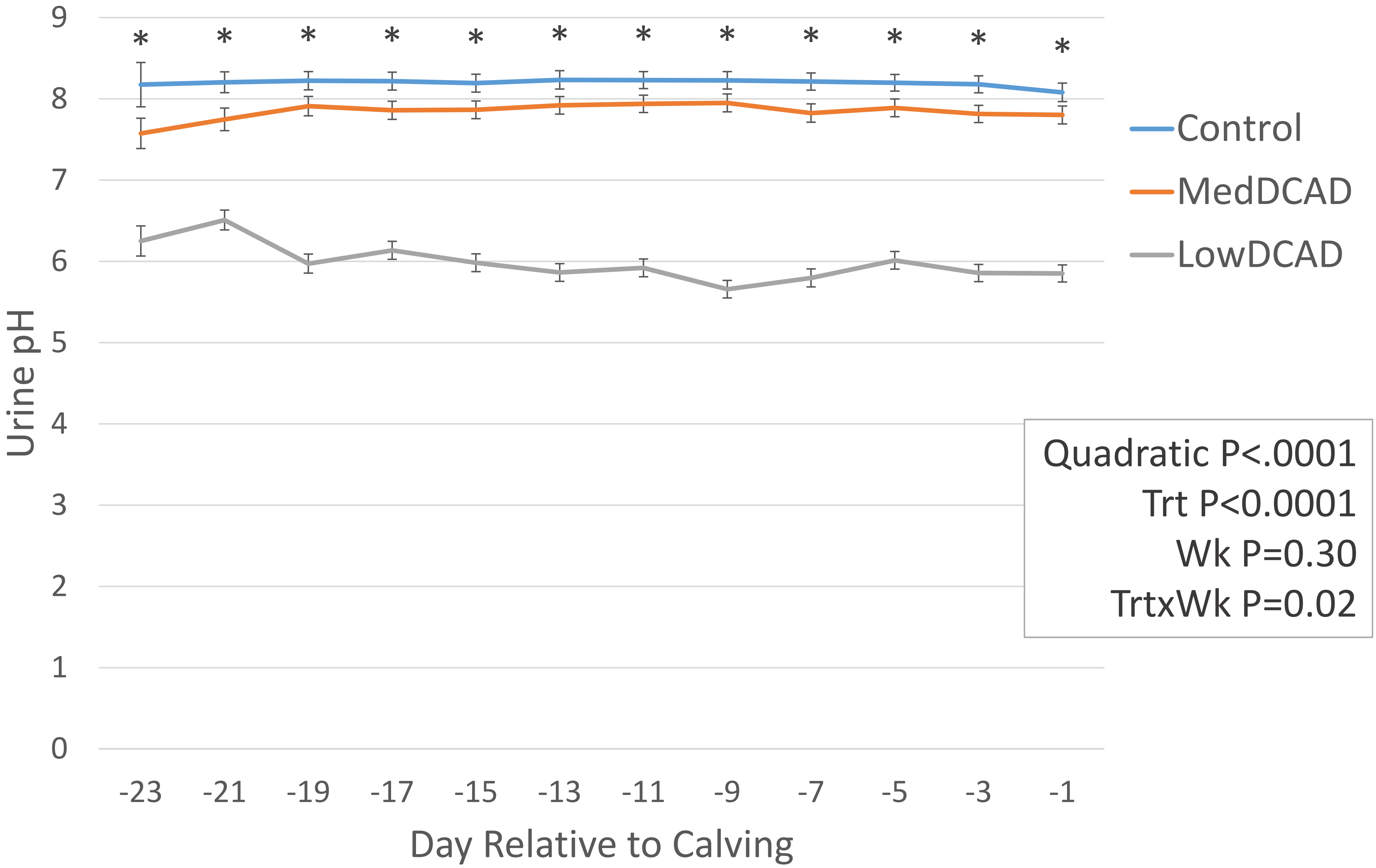
Ingredient (lbs DM/d)	Control	MedDCAD	LowDCAD
BMR Corn Silage	12.77	12.77	12.77
Wheat Straw	8.00	8.00	8.00
Amino Plus	2.30	2.30	2.30
Citrus Pulp	0.95	0.95	0.95
Soybean Hulls	0.66	0.66	0.66
Canola Meal	0.63	0.63	0.63
Molasses	0.19	0.19	0.19
Calcium diphosphate	0.13	0.13	0.13
Ground corn grain	0.12	0.12	0.12
Salt	0.07	0.07	0.07
Vitamin Mix	0.04	0.04	0.04
Rumensin (mg)	318	318	318
Animate	-	0.56	1.14
Wheat Midds	0.92	0.74	0.55
Calcium carbonate	0.82	0.80	0.77
Corn Distillers Ethanol	0.63	0.37	0.11
Magnesium Oxide	0.16	0.12	0.07
Urea	0.12	0.06	-

Analyzed (mean +/- SD) composition of experimental diets

	CON	MedDCAD	LowDCAD	Lactating
DM (%)	46.3 ± 1.6	46.5 ± 1.3	46.4 ± 1.1	45.7 ± 1.8
CP (% DM)	13.0 ± 0.3	13.2 ± 0.4	13.2 ± 0.5	15.7 ± 0.2
ADF (% DM)	30.2 ± 0.7	30.5 ± 1.3	30.1 ± 1.3	20.6 ± 0.8
NDF (% DM)	44.3 ± 1.2	44.0 ± 2.1	43.2 ± 1.8	31.1 ± 1.0
Starch (% DM)	17.0 ± 0.5	16.0 ± 0.8	16.3 ± 0.9	26.0 ± 0.7
NFC (% DM)	33.6 ± 0.9	34.3 ± 2.5	35.0 ± 1.9	45.8 ± 1.2
Fat (% DM)	1.1 ± 0.1	1.3 ± 0.2	1.1 ± 0.3	2.3 ± 0.2
Ca (% DM)	1.54 ± 0.12	1.57 ± 0.14	1.57 ± 0.07	0.95 ± 0.03
P (% DM)	0.44 ± 0.01	0.43 ± 0.01	0.41 ± 0.01	0.41 ± 0.02
Mg (% DM)	0.47 ± 0.01	0.48 ± 0.03	0.50 ± 0.03	0.44 ± 0.02
K (% DM)	1.28 ± 0.07	1.26 ± 0.06	1.24 ± 0.07	1.37 ± 0.05
S (% DM)	0.20 ± 0.01	0.30 ± 0.02	0.41 ± 0.02	0.29 ± 0.01
Na (% DM)	0.13 ± 0.01	0.13 ± 0.01	0.14 ± 0.01	0.44 ± 0.02
Cl (% DM)	0.27 ± 0.03	0.47 ± 0.05	0.69 ± 0.04	0.40 ± 0.02
DCAD (mEq/100g DM)	18.3 ± 0.8	5.9 ± 3.4	-7.4 ± 3.6	25.0 ± 1.5
Predicted MP (g/kg DM)	93.8	93.23	92.26	116.56

Sweeney et al., 2015. J. Dairy Sci 98(Suppl. 2):128.

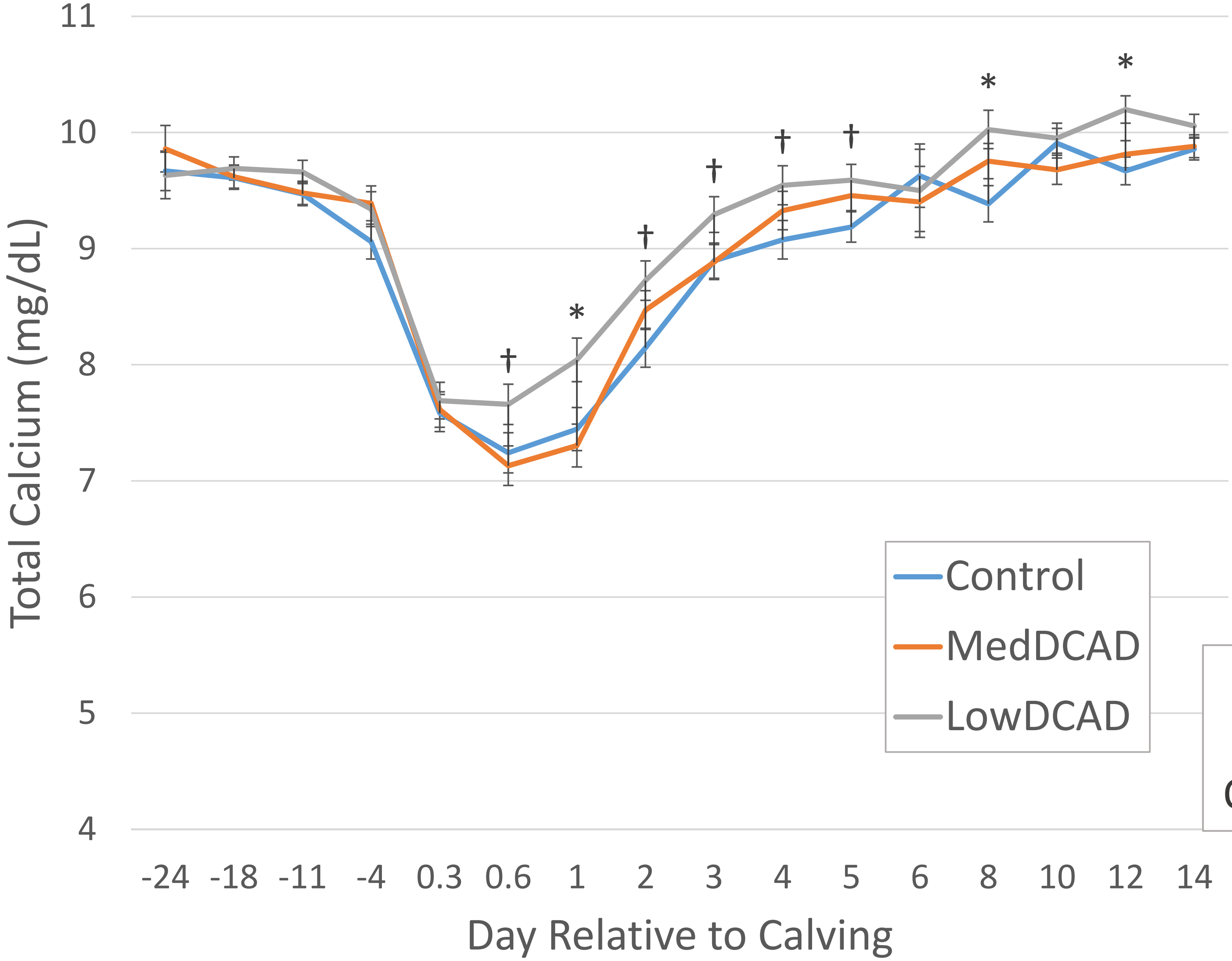
Urine pH



Quadratic P<.0001
Trt P<0.0001
Wk P=0.30
TrtxWk P=0.02

Sweeney et al., 2015. J. Dairy Sci 98(Suppl. 2):128.

Plasma Calcium



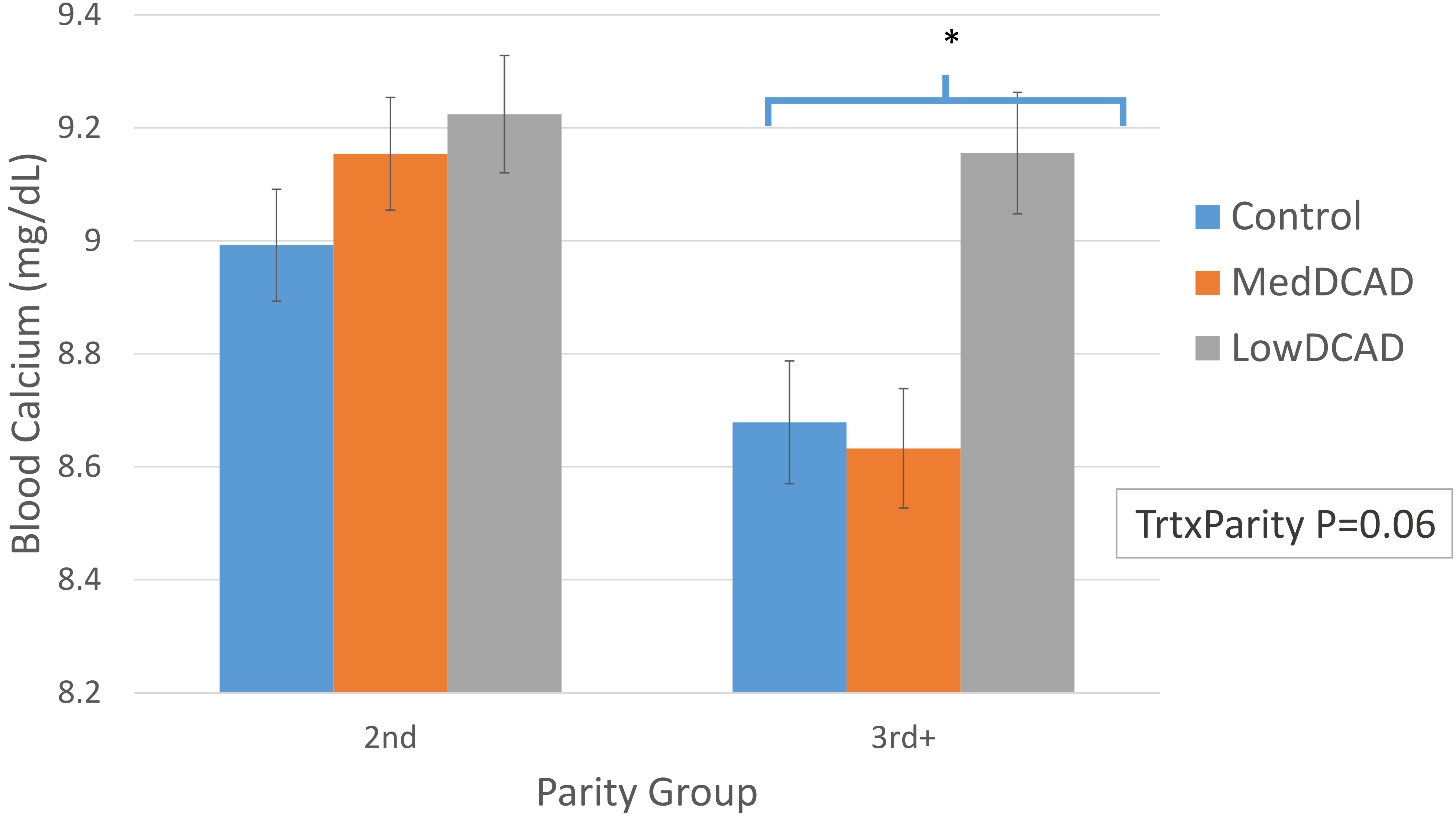
Prepartum
Trt P=0.52
Day P=0.0003
TrtxDay P=0.64

Postpartum
Trt P=0.005
Day P<.0001
TrtxDay P=0.06

Postpartum
Linear P=0.002
Quadratic P=0.23

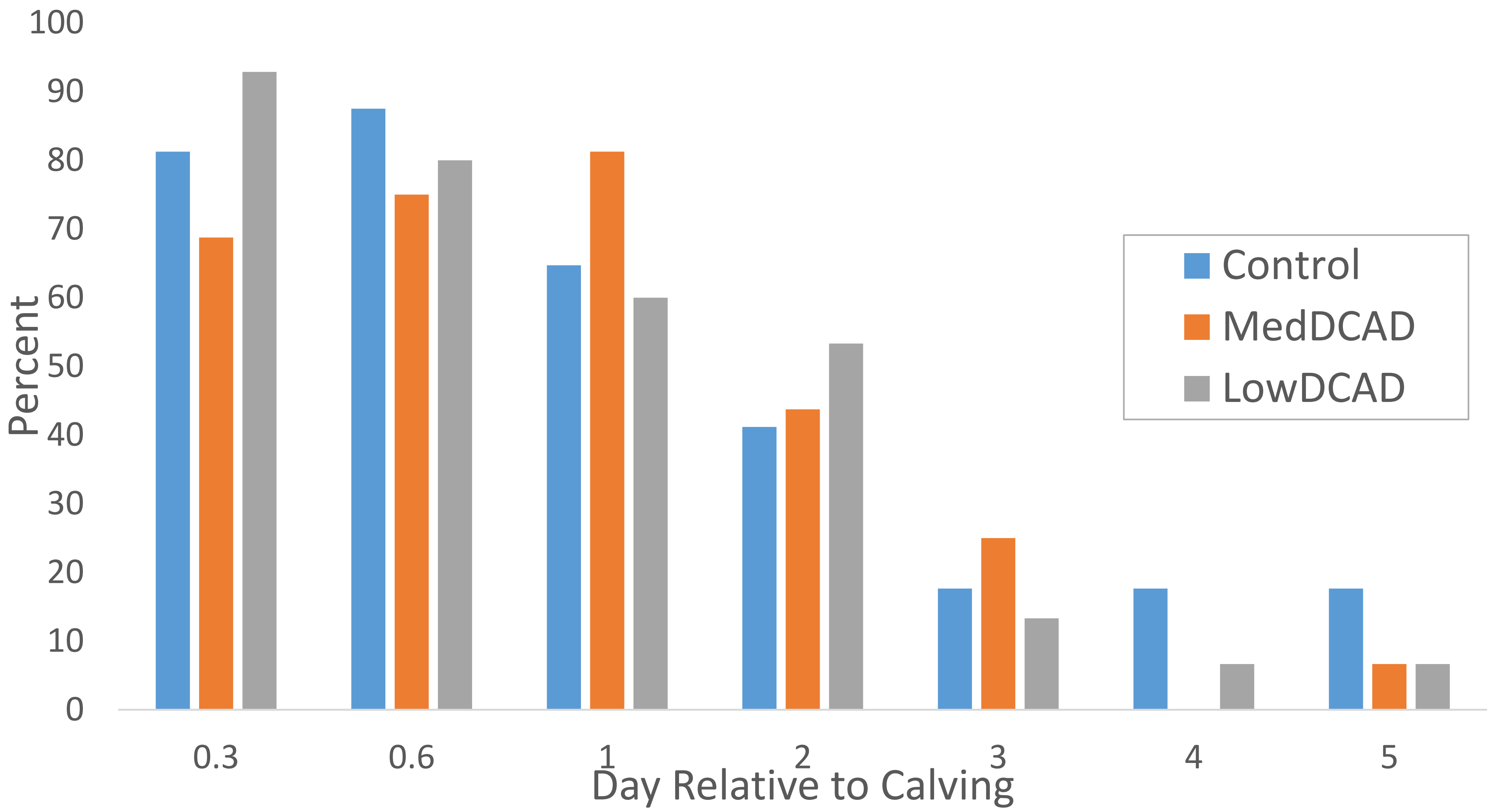
Sweeney et al., 2015. J. Dairy Sci 98(Suppl. 2):128.

Postpartum Blood Calcium Treatment by Parity Interaction



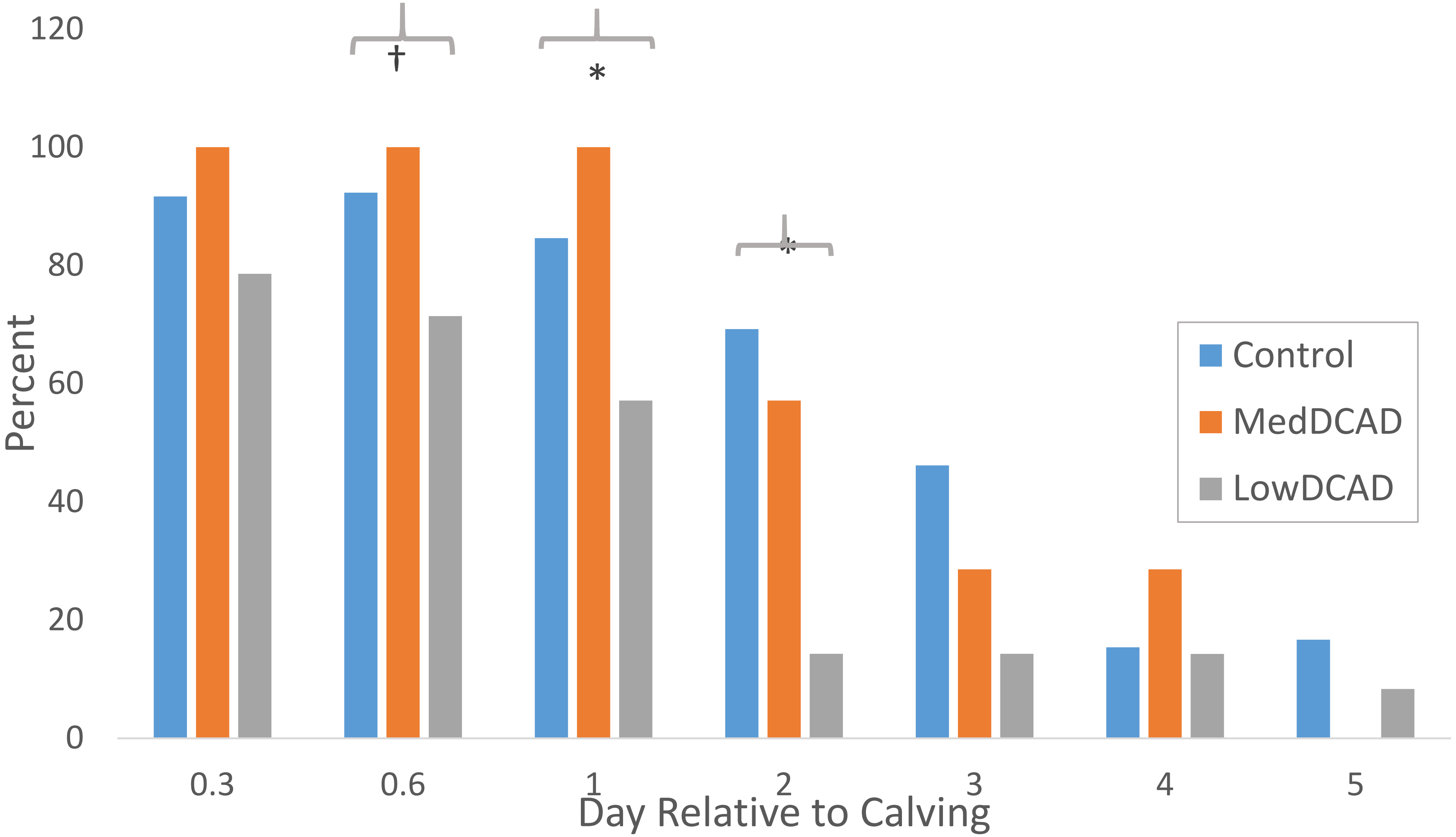
Sweeney et al., 2015. J. Dairy Sci 98(Suppl. 2):128.

Hypocalcemia (Ca <8.5 mg/dL): 2nd Lactation



Sweeney et al., 2015. J. Dairy Sci 98 (Suppl. 2):128.

Hypocalcemia (Ca <8.5 mg/dL): 3^{rd}+ Lactation



Sweeney et al., 2015. J. Dairy Sci 98 (Suppl. 2):128.

Dry Matter Intake

	Prepartum Diet				P-values		
	CON	Med	Low	SEM	Linear	Quad	Trt×Wk
Prepartum							
DMI, kg/d	14.55	15.08	14.08	0.23	0.15	**0.007**	0.45
DMI, % of BW	1.87	1.89	1.80	0.03	0.16	0.22	0.38
Postpartum (wk 1 to 3)							
DMI, kg/d	20.99	21.74	22.30	0.50	**0.07**	0.88	0.24
DMI, % of BW	2.94	3.04	3.15	0.07	**0.03**	0.99	0.37

Sweeney et al., 2015. J. Dairy Sci 98(Suppl. 2):128.

Milk Production: Weeks 1 to 3

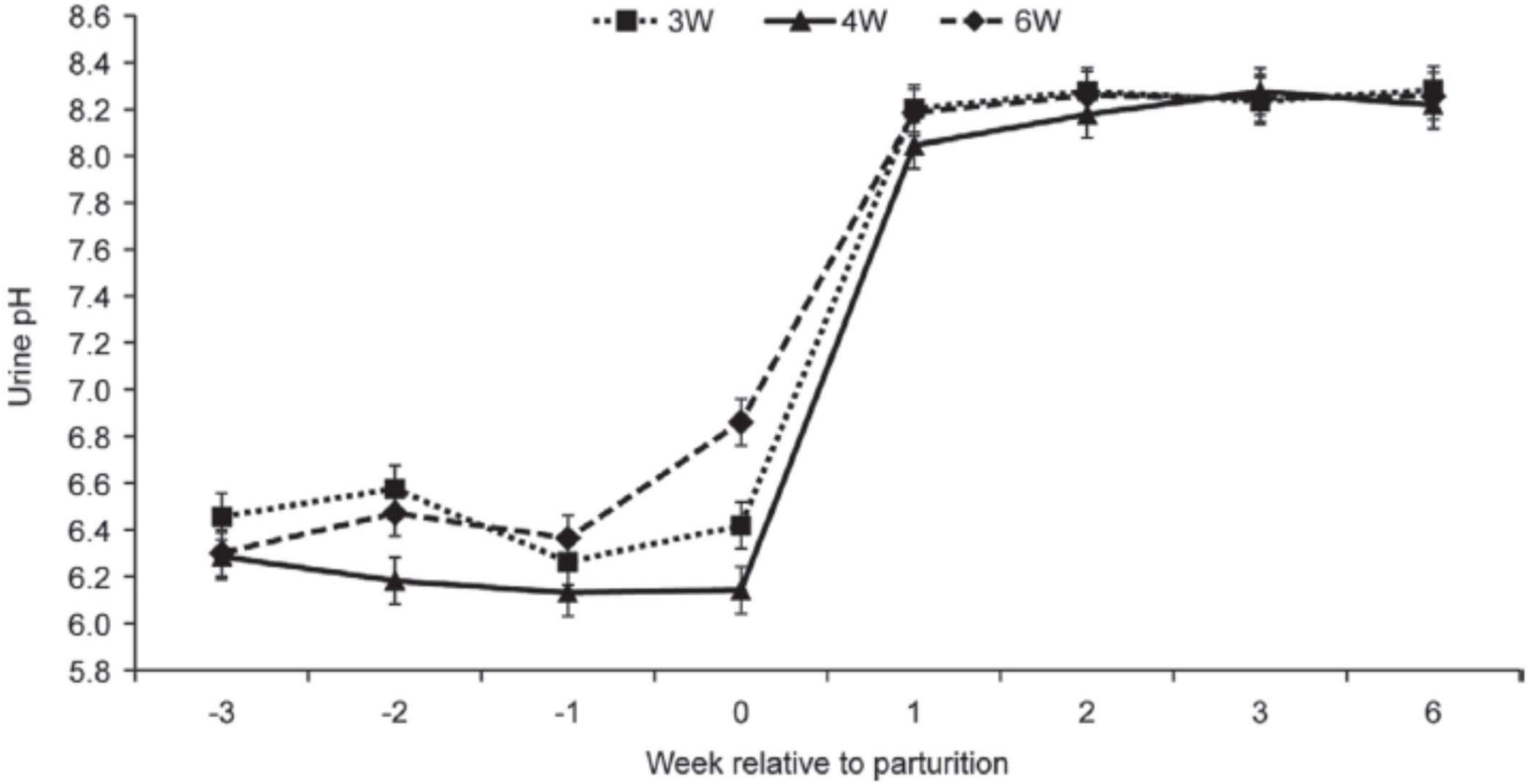
	Prepartum Diet				P-values		
	CON	Med	Low	SEM	Linear	Quad	Trt×Wk
Milk yield, kg/d	40.54	42.13	43.79	1.05	**0.03**	0.97	0.35
Fat, %	4.38	4.36	4.24	0.08	0.21	0.63	**0.10**
True protein, %	3.54	3.49	3.27	0.07	**0.005**	0.33	0.36
Lactose, %	4.64	4.67	4.69	0.03	0.25	0.94	0.38
Total Solids, %	13.63	13.61	13.27	0.10	**0.01**	0.20	**0.10**
ECM, kg/d	46.12	48.04	49.50	1.35	**0.08**	0.89	0.39
MUN, mg/dL	10.32	9.72	9.44	0.30	**0.04**	0.67	0.17
SCS	2.62	3.26	2.73	0.25	0.75	**0.06**	0.27

Sweeney et al., 2015. J. Dairy Sci 98(Suppl. 2):128.

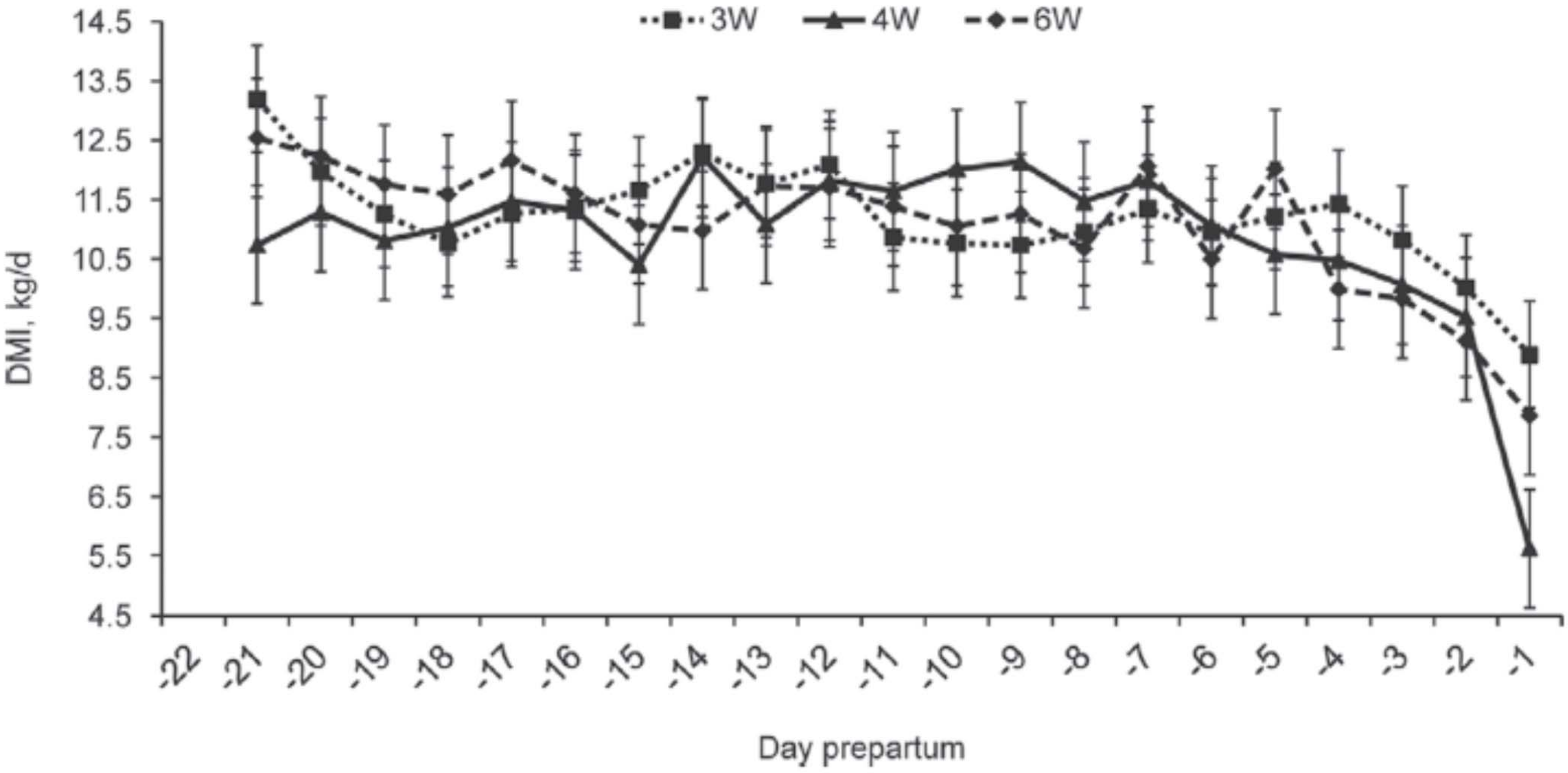
What about length of time fed a low DCAD diet?

Wu et al., 2014. J. Dairy Sci. 97:7133–7143

- Fed cows at low DCAD diet (-21 mEq/100 g DM)
- Different time periods
    - 3 wk
    - 4 wk
    - 6 wk



Wu et al., 2014. J. Dairy Sci. 97:7133–7143



Wu et al., 2014. J. Dairy Sci. 97:7133–7143

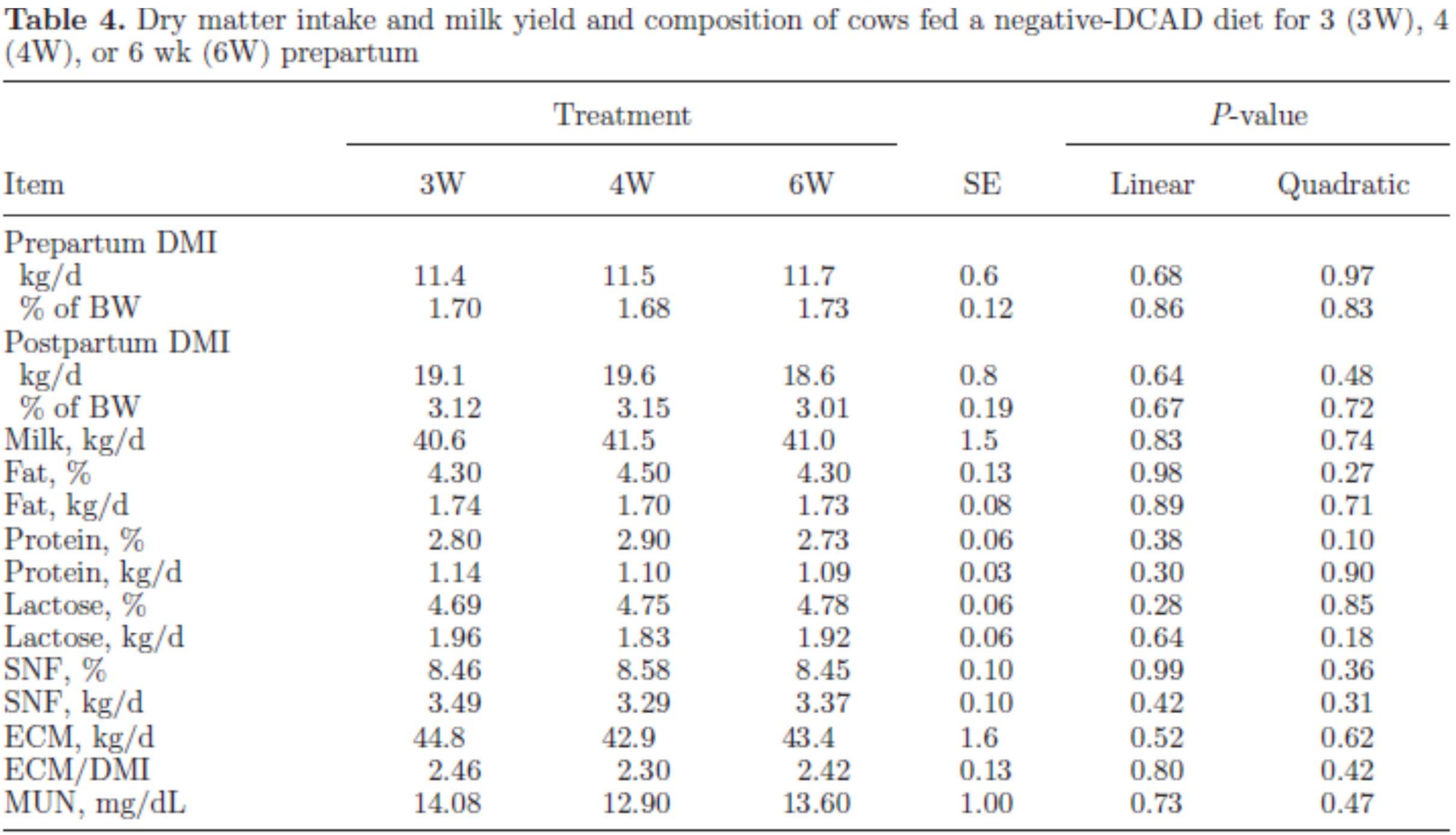
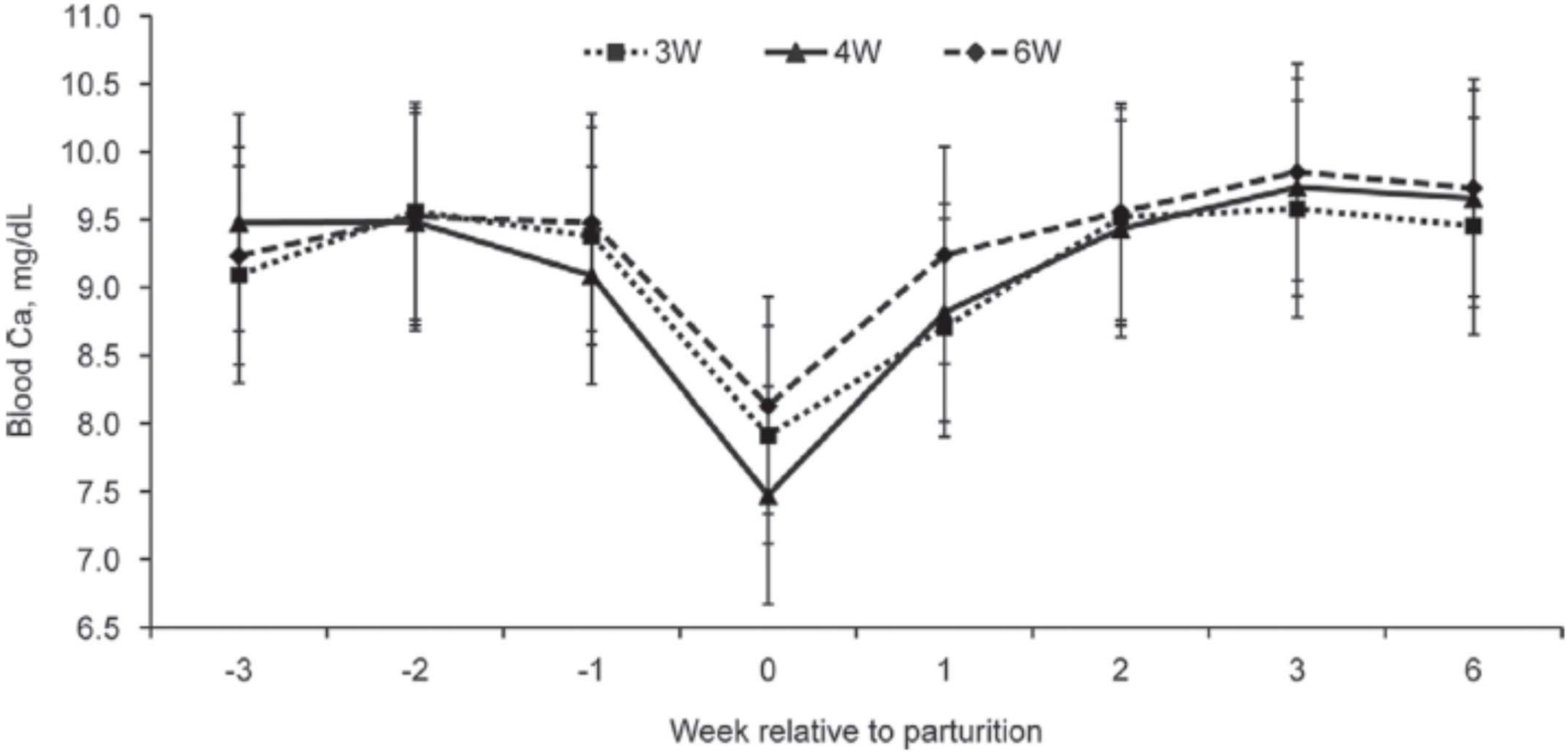


Table 4. Dry matter intake and milk yield and composition of cows fed a negative-DCAD diet for 3 (3W), 4 (4W), or 6 wk (6W) prepartum

	Treatment				*P*-value	
Item	3W	4W	6W	SE	Linear	Quadratic
Prepartum DMI						
kg/d	11.4	11.5	11.7	0.6	0.68	0.97
% of BW	1.70	1.68	1.73	0.12	0.86	0.83
Postpartum DMI						
kg/d	19.1	19.6	18.6	0.8	0.64	0.48
% of BW	3.12	3.15	3.01	0.19	0.67	0.72
Milk, kg/d	40.6	41.5	41.0	1.5	0.83	0.74
Fat, %	4.30	4.50	4.30	0.13	0.98	0.27
Fat, kg/d	1.74	1.70	1.73	0.08	0.89	0.71
Protein, %	2.80	2.90	2.73	0.06	0.38	0.10
Protein, kg/d	1.14	1.10	1.09	0.03	0.30	0.90
Lactose, %	4.69	4.75	4.78	0.06	0.28	0.85
Lactose, kg/d	1.96	1.83	1.92	0.06	0.64	0.18
SNF, %	8.46	8.58	8.45	0.10	0.99	0.36
SNF, kg/d	3.49	3.29	3.37	0.10	0.42	0.31
ECM, kg/d	44.8	42.9	43.4	1.6	0.52	0.62
ECM/DMI	2.46	2.30	2.42	0.13	0.80	0.42
MUN, mg/dL	14.08	12.90	13.60	1.00	0.73	0.47

Wu et al., 2014. J. Dairy Sci. 97:7133–7143

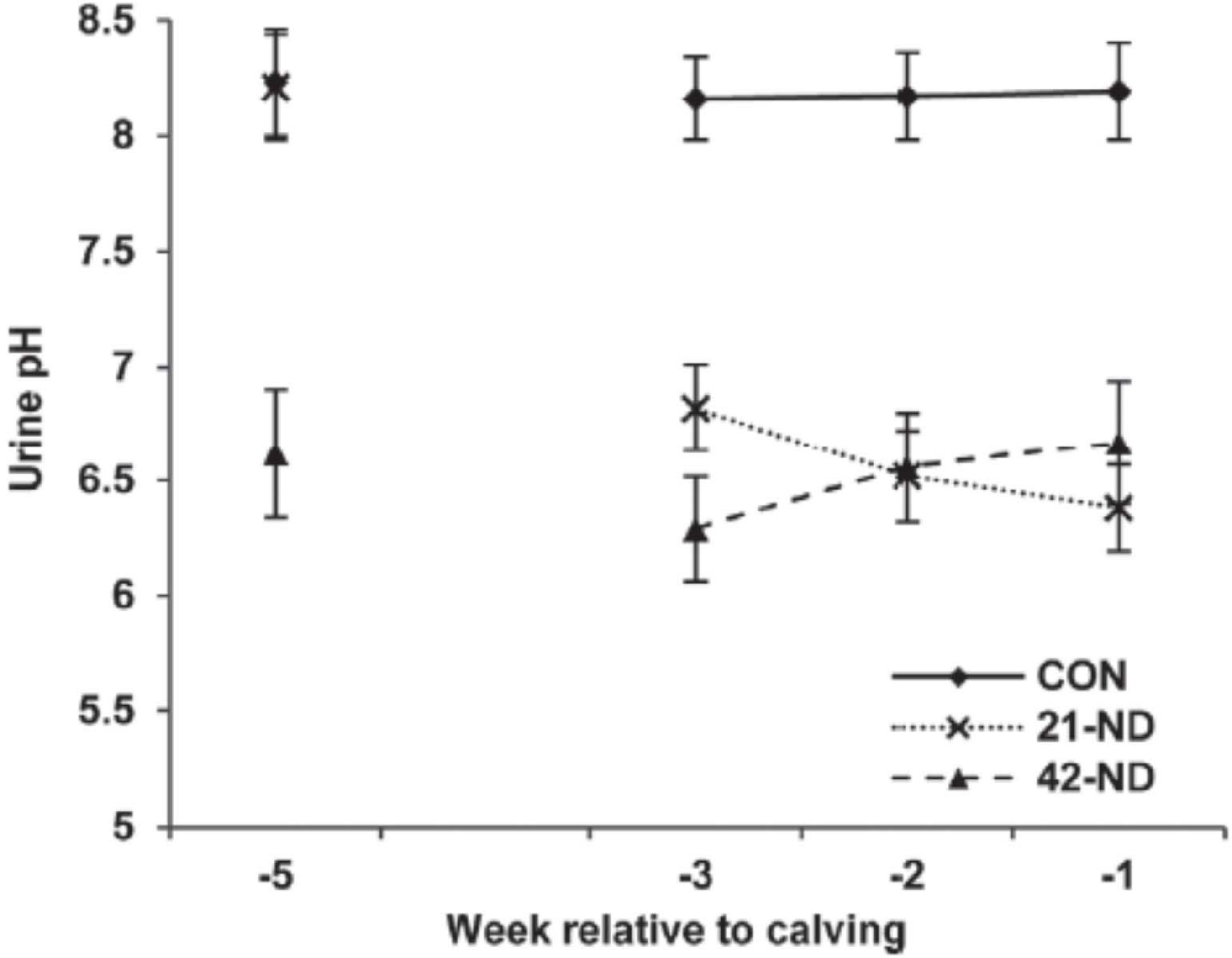


Wu et al., 2014. J. Dairy Sci. 97:7133–7143

Weich et al., 2013. J. Dairy Sci. 98:5780-5792

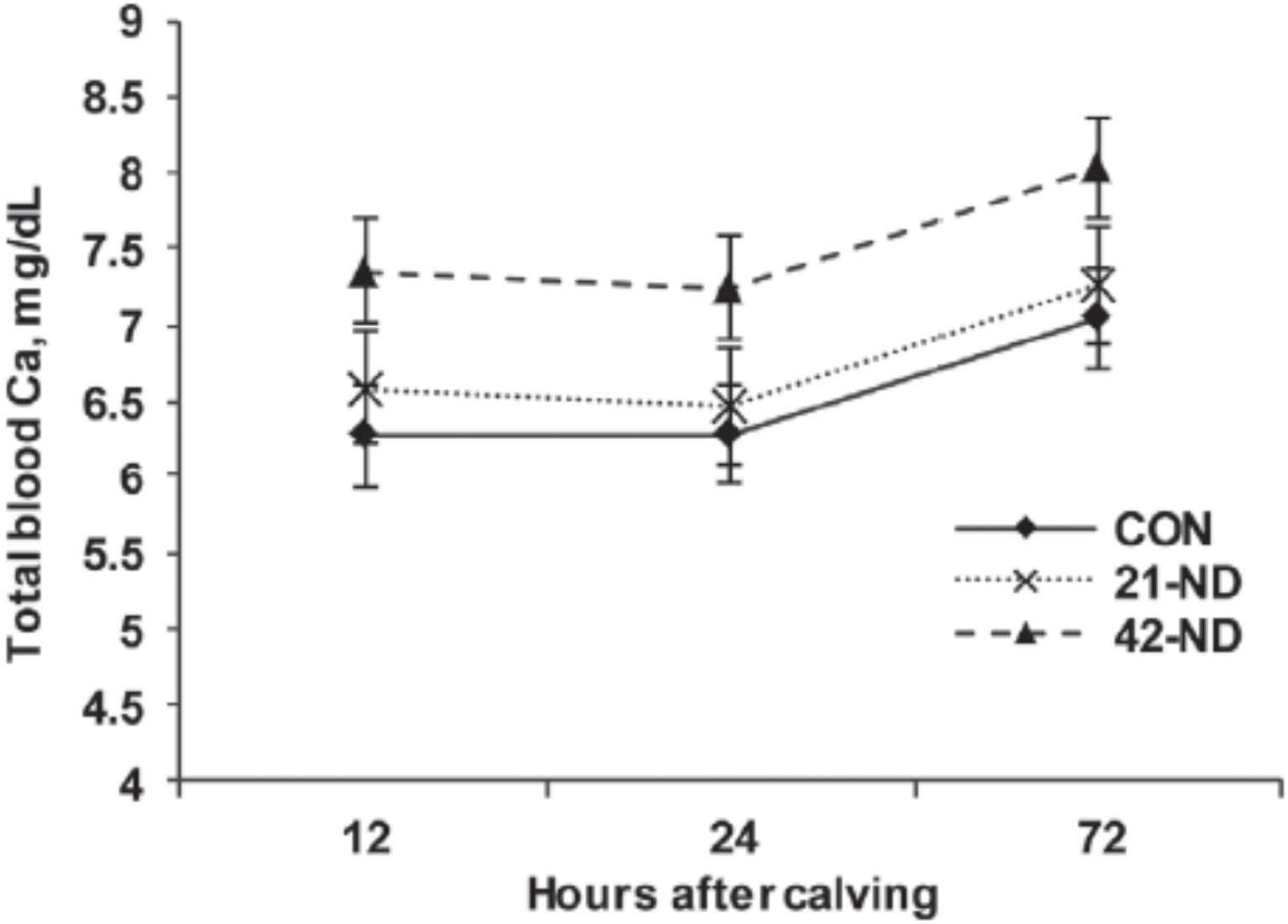
- 60 Holstein and Holstein-cross cows
- Three prepartum treatments
  - Control -- +12 mEq/100 g DM
  - 21 d -- - 16 mEq/100 g DM for last 21 d
  - 42 d -- - 16 mEq/100 g DM for last 42 d

Urine pH for cows fed a control or negative DCAD diet for 21 or 42 d prepartum



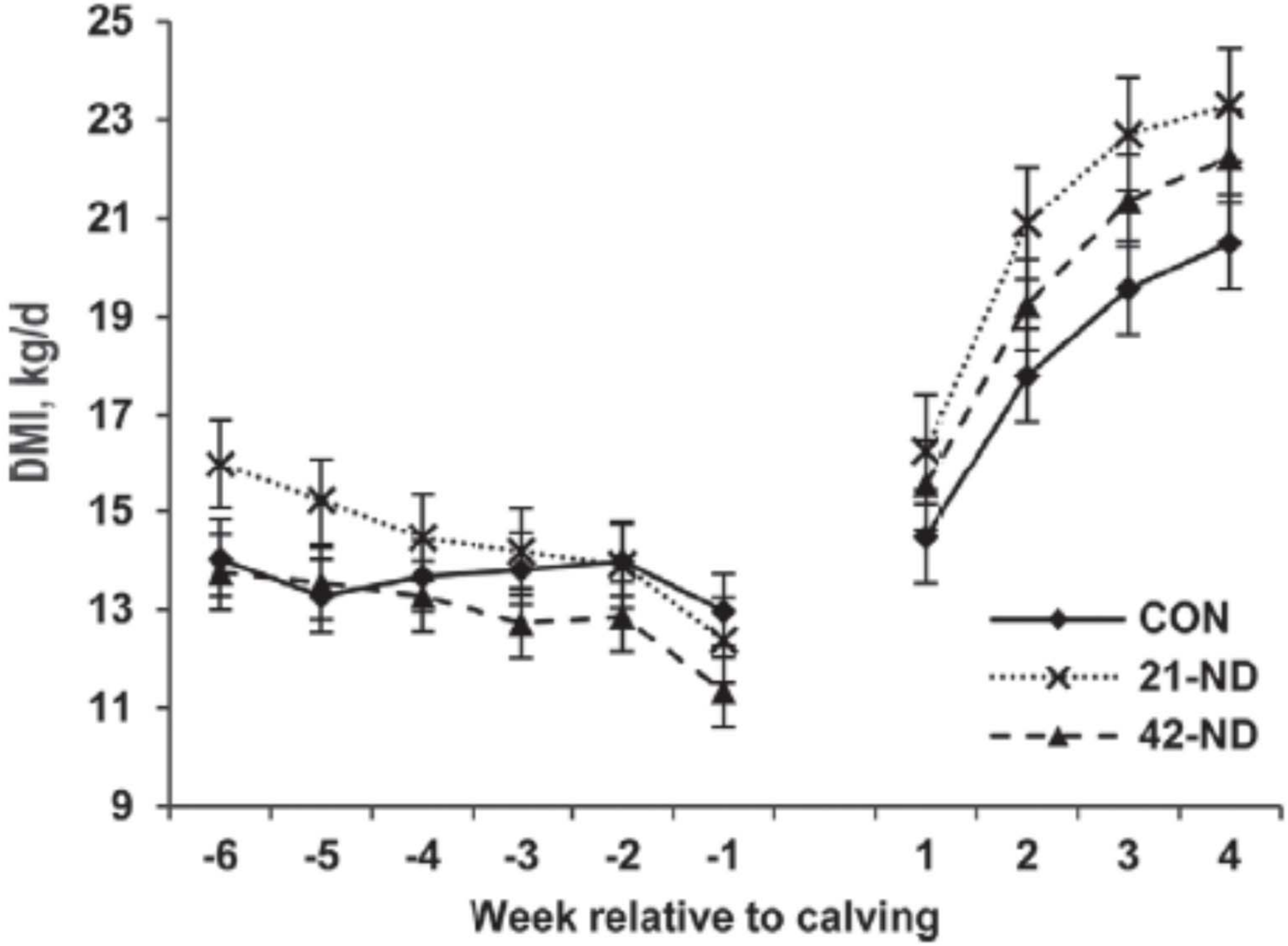
Weich et al., 2013. J. Dairy Sci. 98:5780-5792

Postpartum blood Ca for cows fed a control or negative DCAD diet for 21 or 42 d prepartum



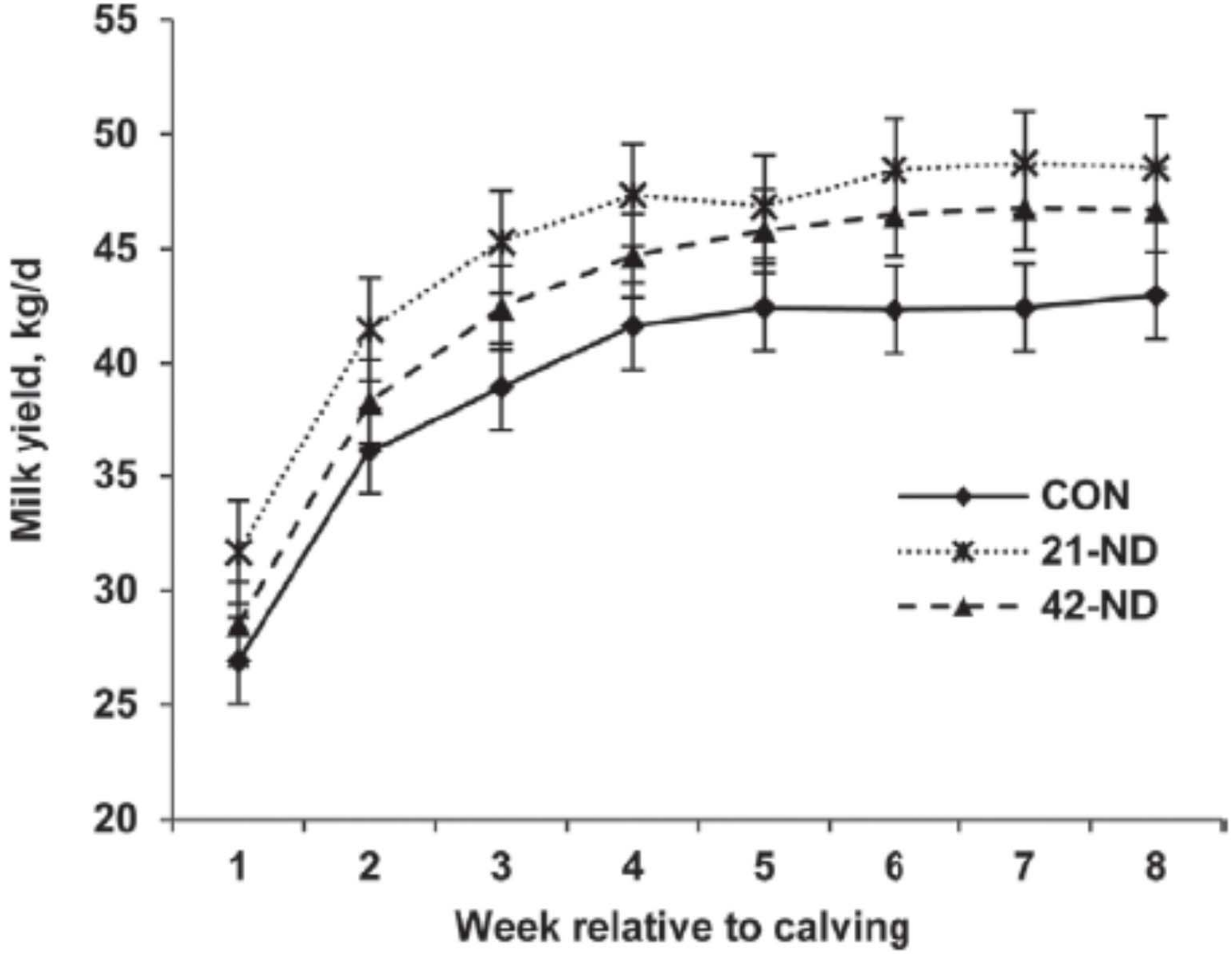
Weich et al., 2013. J. Dairy Sci. 98:5780-5792

Peripartal DMI for cows fed a control or negative DCAD diet for 21 or 42 d prepartum



Weich et al., 2013. J. Dairy Sci. 98:5780-5792

Postpartum milk yield for cows fed a control or negative DCAD diet for 21 or 42 d prepartum



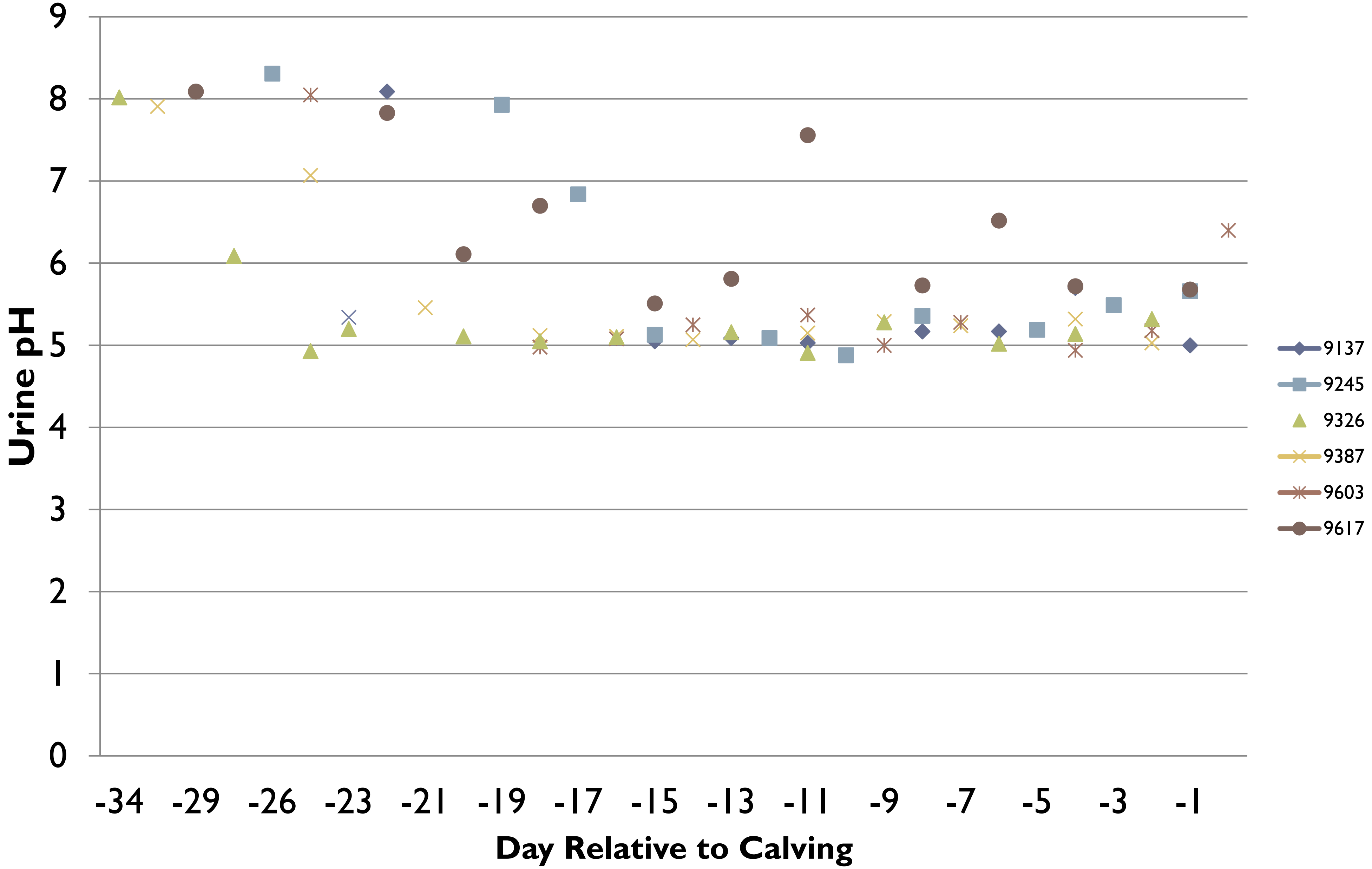
Weich et al., 2013. J. Dairy Sci. 98:5780-5792

Urine pH monitoring

General guidelines

- Weekly….
- 12 to 15 cows that have been fed the diet for at least a week
- If possible, 4 to 6 hours postfeeding
  - More important to be consistent within a herd
- Can be a terrific monitor of feeding management in herds feeding anionic diets

Low DCAD (-13 mEq/100 g DM) Urine pHs



Sweeney et al., unpublished

	4/30/2015	5/7/2015	5/14/2015	5/23/2015	6/4/2015	6/11/2015	6/19/2015	6/25/2015	7/2/2015	7/9/2015	7/16/2015	7/23/2015
Median	6.40	6.20	6.00	7.50	7.60	7.20	6.80	6.60	6.40	6.50	7.20	7.20
MEAN	6.47	6.49	6.18	7.16	7.45	7.04	6.77	6.82	6.51	6.61	6.99	7.11
StDev	0.60	0.67	0.50	0.81	0.56	0.71	0.64	0.66	0.58	0.61	0.77	0.53
CV	0.09	0.10	0.08	0.11	0.08	0.10	0.09	0.10	0.09	0.09	0.11	0.08
Ration K, % of DM	1.24	1.24	1.18	1.22	1.09	1.25	1.25	1.25	1.24	1.24	1.24	1.29
Ration Anionic Suppl, % of DM	1.62%	1.62%	1.62%	1.60%	1.54%	1.82%	1.97%	2.13%	2.25%	2.25%	2.25%	2.25%
Expected DCAD, mEq per 100 g ration DM (Na + K - Cl - S)	-3.3	-3.3	-4.5	-4.9	-2.9	-4.9	-6.0	-7.1	-8.5	-8.5	-8.5	-7.5

	7/30/2015	8/7/2015	8/21/2015	8/27/2015	9/3/2015	9/10/2015	9/17/2015	9/24/2015	10/1/2015	10/8/2015
Median	7.40	7.40	6.20	7.00	6.80	6.20	6.20	6.00	6.00	6.00
MEAN	7.19	7.18	6.35	6.85	6.85	6.24	6.26	6.17	6.21	6.14
StDev	0.63	0.63	0.49	0.61	0.67	0.44	0.45	0.39	0.37	0.39
CV	0.09	0.09	0.08	0.09	0.10	0.07	0.07	0.06	0.06	0.06
Ration K, % of DM	1.24	1.24	1.24	1.24	1.24	1.04	1.04	1.04	1.04	1.04
Ration Anionic Suppl, % of DM	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%
Expected DCAD, mEq per 100 g ration DM (Na + K - Cl - S)	-8.5	-8.5	-8.5	-8.5	-8.5	-12.0	-12.0	-12.0	-12.0	-12.0

Courtesy: Dairy Health and Management Services

Keys to feeding management of dry cow TMR

- Minimize sorting
  - Particle size of straw/hay
    - Longest particles < 1.5 in (4 cm)
  - Moisture content of TMR
    - Target 46 to 48 DM % -- add water if necessary

You HAVE to chop the %(*(#*@&# straw/hay

3.5 lbs straw in 26 lb DM package

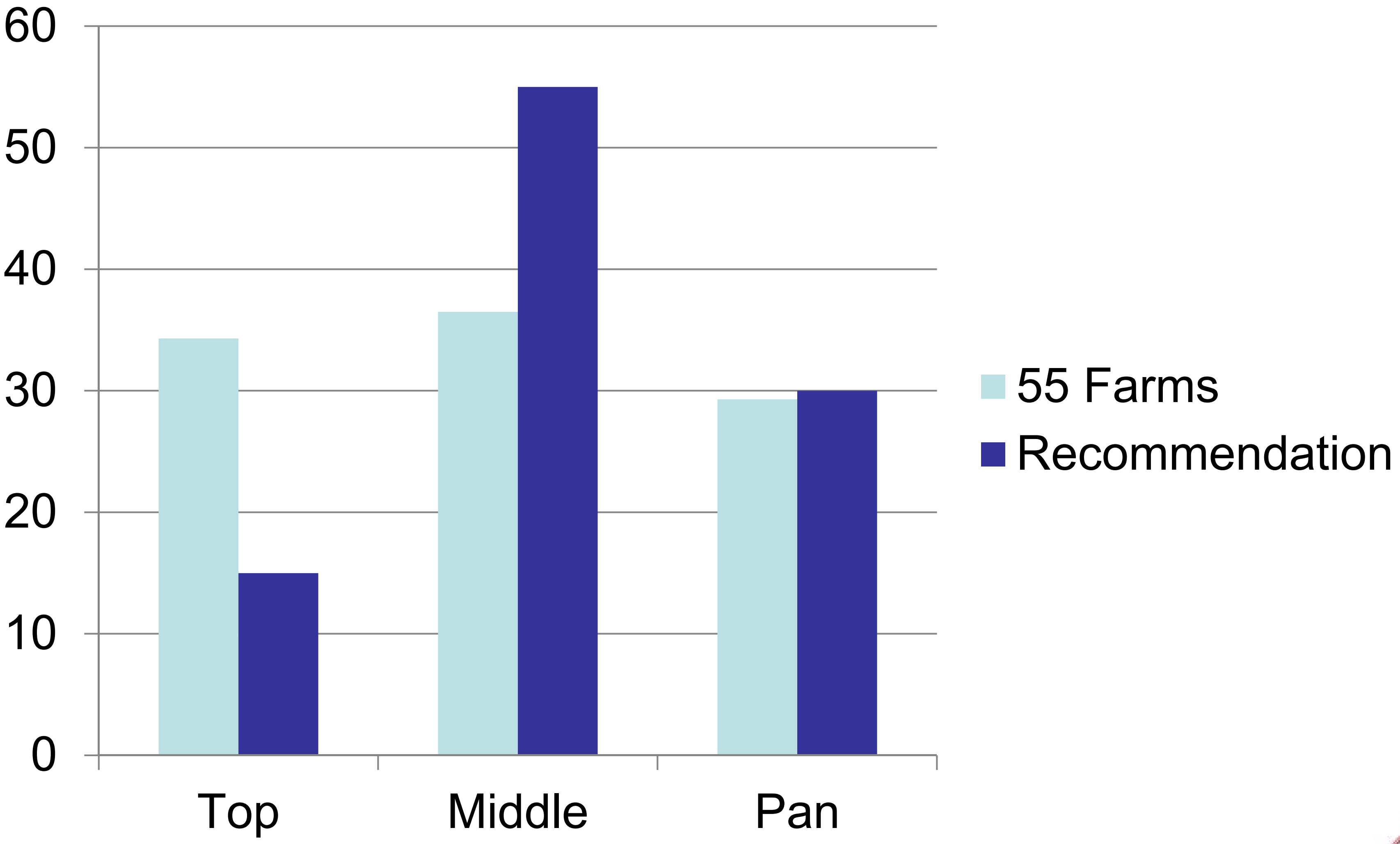
6 lbs straw in 27 lb DM package

Particle size recommendations using Penn State Particle Separator

Screen	Lactating cow TMR	Dry cow or heifer TMR	Corn silage	Hay crop silage	Straw/dry hay for TMR
Top (> 0.75” sieve)	6 to 10%	10 to 20%	5 to 10%	10 to 20%	33%
Middle (0.31 to 0.75 in sieve)	45 to 55%	50 to 60%	45 to 65%	45 to 75%	33%
Bottom (< 0.31 in sieve)	< 50%	< 40%	30 to 40%	20 to 30%	33%

Adapted from Penn State guidelines by T. Overton 9/2013

Commercial farm study – prefresh TMR samples from 55 farms (Lawton et al., 2015)



Thanks!!

tro2@cornell.edu