B-Vitamins for Dairy Cows

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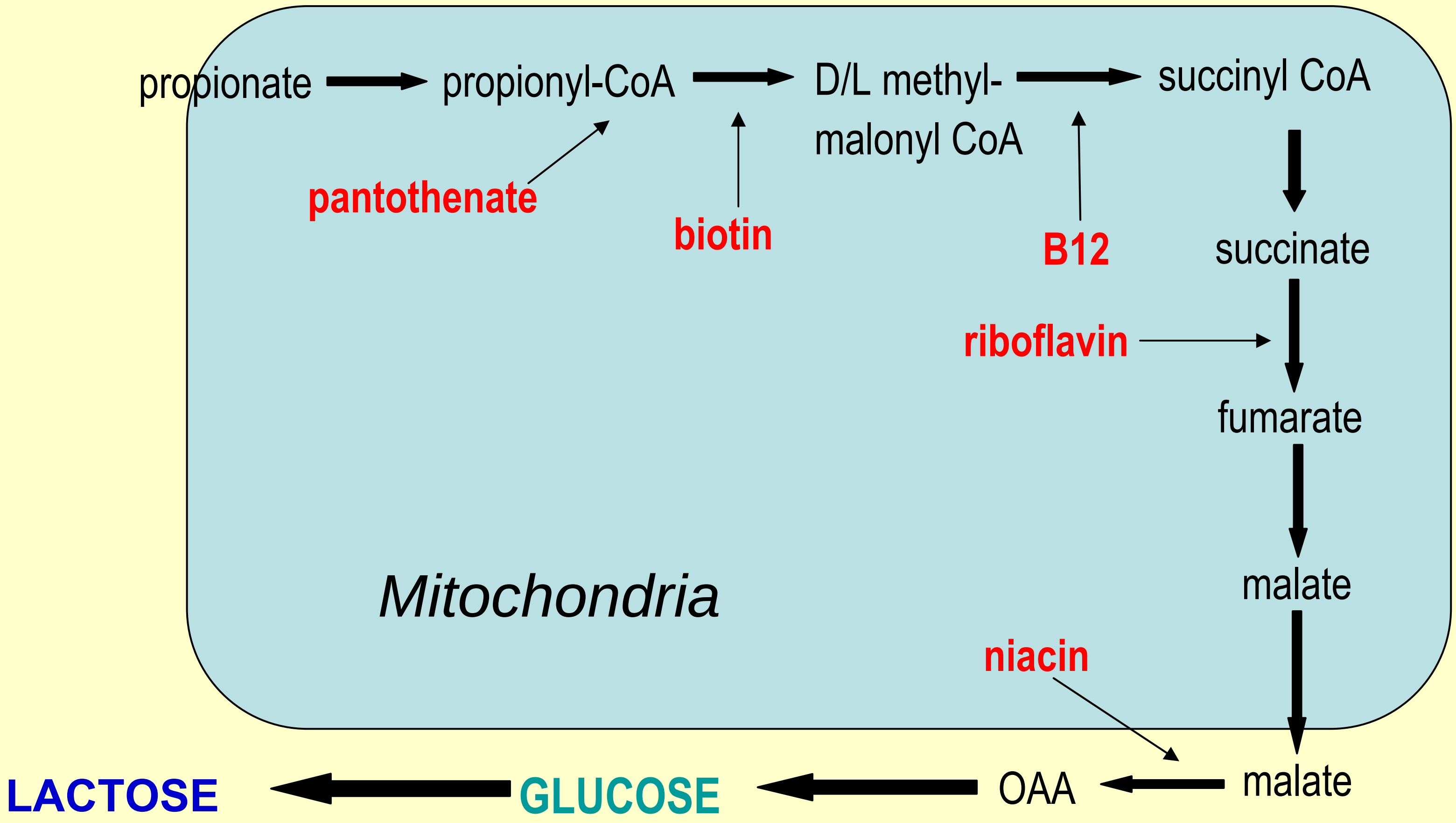
➢ B-Vitamin Complex

- Thiamin (**B_1**)
- Riboflavin (**B_2**)
- Niacin (**B_3**)
  - Nicotinic Acid & Nicotinamide
- Pantothenic acid (**B_5**)
- **B_6** complex
  - Pyridoxal → aldehyde
  - Pyridoxine → alcohol
  - Pyridoxamine → amine
- Biotin (**B_8** or Vitamin H)
- Folic acid (**B_9**)
- Cobalamins (**B_{12}**)

Metabolic Importance

- Role as enzymatic cofactors in the metabolism of CHO’s, proteins, and lipids
- i.e.: production of glucose from propionate in liver



Stages of Ruminant B-Vitamin Research

- 1940's to 1960's – "Concentration" – steers, sheep
  - Concentrations in digesta > diets
    - Attributed to microbial synthesis
  - Changing dietary ingredients altered concentrations
- 1970's to Current – "Amount" – steers, sheep, cows
  - Duodenal flow > intake
  - Ruminal synthesis influenced by diet, digestibility, & DMI
- 1980's to current: "Production responses" – cows
- 2001 NRC: "…*B-vitamin requirements can be met through synthesis by ruminal microorganisms and escape of dietary sources from the rumen*."
  - If *requirement* = avoid clinical deficiency, THEN TRUE
  - If *requirement* = maximize performance, THEN ???

Questions

In lactating dairy cows…

- Ruminal fate of feed or supplemental B-vitamins?
  - Are they degraded?
  - Are they absorbed?
- Amounts synthesized ruminally by microbes?
- Post-ruminal absorption coefficients?
- What are cow requirements?
- What have the effects of supplementation been?

Ruminal Metabolism of B-Vitamins

- Ruminal microbes require and produce B-vitamins
- Ruminal absorption absent or minimal in *fed* ruminants, but occurs in *evacuated* rumens (Rerat, 1958; Hoeller, 1977; Erickson et al., 1991; Girard, 2001)
- B-vitamins sequestered in bacteria
  - Concentrations 125 to 5000 fold higher in bacteria than particle-free fluid (Santschi, 2004)
- Supplemental dietary B-vitamins → vary in ability to escape ruminal degradation

Ruminal Degradation

- Zinn et al., 1987 and Santschi et al., 2005 data combined

B-Vitamin	Degradation (%)
Thiamin	48 - 68
Riboflavin	99 & 99
Niacin	94 - 99
B_6	0 - 41
Biotin	0 - 45
Folic acid	97 & 97
B_{12}	63 - 90

Potential for rumen protection?

Ruminal Apparent Synthesis

- AS = amounts flowing to duodenum minus intake
  - Does not assess microbial degradation or possible ruminal absorption
- Schwab et al., 2006 (JDS)
  - Eight ruminally and duodenally cannulated lactating cows
  - 4 × 4 Latin Square design
  - TMR's contained (% DM):
    - 2 contents of forage (35 and 60%)
    - 2 contents of NFC within forage content (30 and 40%)
- Santschi et al., JDS, 2005
  - Four ruminally and duodenally cannulated cows
  - Single TMR: 58% Forage, 18% CP, 28% NDF, 44% NFC

Ruminal Apparent Synthesis

Schwab et al., 2005

B-Vitamin mg/d	35% F 30% NFC	35% F 40% NFC	60% F 30% NFC	60% F 40% NFC
Thiamin	61	48	44	50
Riboflavin	246	254	206	246
Niacin	446	1547	720	1386
B_6	23	30	14	27
Biotin	-15	-11	-16	-3
Folates	16	20	13	16
B_{12}	102	79	78	60

r-values* (Schwab et al., 2005)

AS (mg/d) vs.	Thiamin	Riboflavin	Folic acid	B_{12}
OMI, kg/d	0.51	0.71	0.63	0.61
RDOMI, kg/d	0.40	0.49	0.50	0.54
Micr-N flow, g/d	0.65	0.79	0.77	0.44
Total VFA, m*M*	0.51	0.46	0.43	0.54

*($P < 0.05$)

Ruminal Apparent Synthesis

Santschi et al., 2005 & Schwab et al., 2005 vs. NRC-01

B-Vitamin	Schwab mg/d	Santschi mg/d	NRC-01* mg/d
Thiamin	44 to 61	26	127
Riboflavin	206 to 254	267	232
Niacin	446 to 1547	2213	1603
B_6	14 to 30	-14	85
Biotin	-3 to -16	-1	12
Folates	13 to 20	21	6
B_{12}	60 to 102	73	62

*Adjusted to similar DMI as reported in research trials

B-Vitamin Intestinal Absorption Coefficients

Santschi et al., 2005

B-Vitamin Absorption %	Santschi	Other Literature Estimates*
Thiamin	55 - 77	63 - 75
Riboflavin	35 - 37	23 - 24
Niacin	84 - 85	67 - 80
B_6	69 - 85	79
Biotin	28 - 46	0 - 50
Folates	0 - 16	79
B_{12}	11 - 16	5 – 48 (15)

*Miller et al., JAS, 1986; Zinn et al., JAS, 1987; Konings et al., BJN, 2002

Attempts to Define Requirements

- **NRC-01**
  - Total req. = tissue + milk
  - Tissue requirements derived from sows
  - Milk requirements based on milk secretion
  - Assumed 100% intestinal absorption

B-Vitamin (mg/d)	NRC-01 Total Req.	NRC-01 AS	Schwab-Santschi AS
Biotin	6	14	-9
Folic acid	35	7	17
Niacin	289	1804	1262
Panto.	425	38	--
Riboflavin	156	261	244
Thiamin	41	143	46
B_6	48	96	16
B_{12}	0.6	70	78

- **Dose response versus animal performance?**

Supplemental B-Vitamin Responses

Majee et al., 2003--Trial 1

Vitamin (mg/cow/d)	C	B	BBVIT1x	BBVIT2x
Biotin	0	20	20	40
Thiamin	0	0	150	300
Riboflavin	0	0	150	300
Pyridoxine	0	0	120	240
B12	0	0	0.5	1.0
Niacin	0	0	3000	6000
Panto.	0	0	475	950
Folic acid	0	0	100	200

Supplemental B-Vitamin Responses

Majee et al., 2003--Trial 1

Item	C	B	BBVIT1x	BBVIT2x
BW, lb	1456	1461	1452	1459
DMI, lb/d	55.0^{b}	56.5^{a}	55.0^{b}	53.7^{b}
Milk, lb/d	81.8^{b}	85.6^{a}	84.3^{ab}	82.5^{b}

Supplemental B-Vitamin Responses

Majee et al., 2003--Trial 1

Item	C	B	BBVIT1x	BBVIT2x
Fat, %	3.34	3.24	3.28	3.20
Fat, lb/d	2.71[ab]	2.75[a]	2.75[a]	2.62[b]
Protein, %	2.95	2.97	2.96	2.96
Protein, lb/d	2.40[b]	2.53[a]	2.49[ab]	2.44[b]

Supplemental B-Vitamin Responses

Majee et al., 2003--Trial 2

Vitamin (mg/cow/d)	B1x	B2x	BBVIT1x
Biotin	20	40	20
Thiamin	0	0	150
Riboflavin	0	0	150
Pyridoxine	0	0	120
B12	0	0	0.5
Niacin	0	0	3000
Panto.	0	0	475
Folic acid	0	0	100

Supplemental B-Vitamin Responses

Majee et al., 2003--Trial 2

Item	B1x	B2x	BBVIT1x
BW, lb	1474	1485	1487
DMI, lb/d	55.9	56.5	57.9
Milk, lb/d	90.4	89.8	90.4

Supplemental B-Vitamin Responses

Majee et al., 2003--Trial 2

Item	B1x	B2x	BBVIT1x
Fat, %	3.40	3.40	3.43
Fat, lb/d	3.06	3.06	3.08
Protein, %	2.80	2.79	2.83
Protein, lb/d	2.53	2.51	2.55

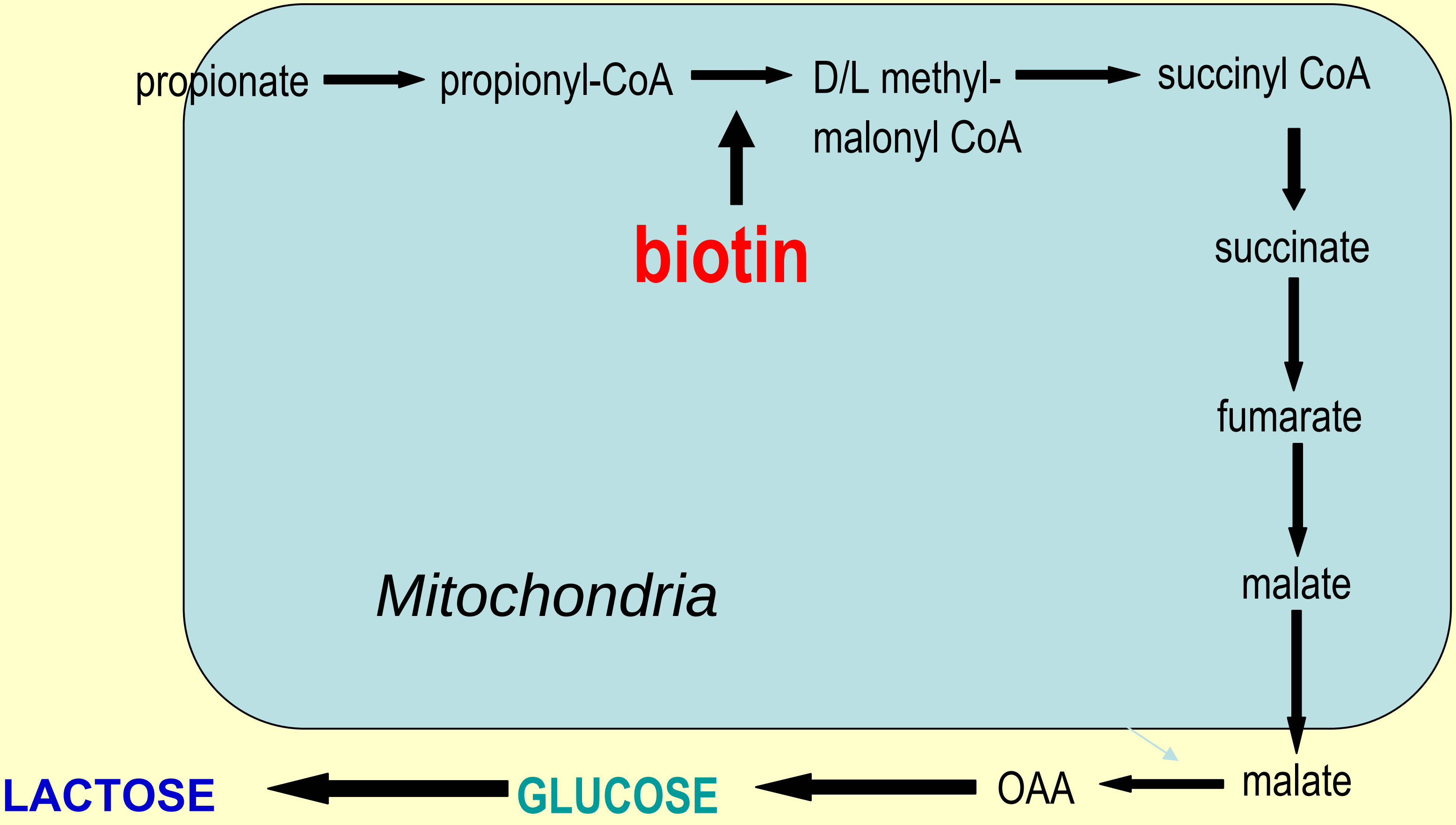
Supplemental B-Vitamin Responses

Biotin (ruminally-unprotected)

- **Improvements in hoof health at 20 mg/cow/d**
  - Reduced WLS (Midla et al., 1998; Hedges et al., 2001)
  - Improved locomotion scores (Fitzgerald et al., 2000)
  - Reduced sole ulcers (Bergsten et al., 2003)
- **Increased milk yield**
  - +6.2 lb/d early lactation (Zimmerly & Weiss, 2001)
  - +3.7 lb/d mid lactation (Majee et al., 2003)
  - +4.3 lbs/d average across all studies
- **Rumen-protection appears unnecessary**
- **Mode of action not well understood**

Metabolic Importance

- Role as enzymatic cofactors in the metabolism of CHO's, proteins, and lipids
- i.e.: production of glucose from propionate in liver



Supplemental B-Vitamin Responses

Biotin and hoof health

Reference	No. of Cows	Treatments	Response
Midla et al., 1998	100 1st Lactation	0 vs. 20 mg/d	< WLS
Fitzgerald et al., 2000	2705 on 20 Farms	0 vs. 20 mg/d	Improved Locomotion Scores
Hedges et al., 2001	900 on 5 Farms	0 vs. 20 mg/d	< WLS
Lischer at al., 2002	24 with sole ulcers	0 vs. 40 mg/d	Improved Histo. Horn Score
Bergsten et al., 2003	99, Mixed Parity	0 vs. 20 mg/d	< Sole Ulcers

Supplemental B-Vitamin Responses

Biotin and milk production

Reference	No. of Cows	Treatments	Response
Midla et al., 1998	1st Lac.--51C, 49 B	0 vs. 20 mg/d	+2.3 lb/d
Fitzgerald et al., 2000	2705 on 20 Farms	0 vs. 20 mg/d	+2.7 lb/d
Zimmerly&Weiss, 2001	Mixed Parity—18C, 18B	0, 10 or 20 mg/d	+6.2 lb/d
Margerison et al., 2002	Mature—18C, 18B	0 vs. 20 mg/d	+4.4 lb/d
Bergsten et al., 2003	Mixed Parity—49C, 50T	0 vs. 20 mg/d	+6.4 lb/d
Majee et al., 2003	Mature—28 in Latin sq.	0, 20 or 40 mg/d	+3.7 lb/d
Rosendo et al., 2004	Mature—18C, 20B	0 vs. 20 mg/d	0

Supplemental Biotin - Economics

	Gross Milk Revenues	Feed Cost
Early Lactation Zimmerly & Weiss, 2001	**+0.80/cow/d**	**+0.20/cow/d**
Mid Lactation Majee et al., 2003	**+0.50/cow/d**	**+0.15/cow/d**
Low Production Ferreira et al., 2005 JDS abstr	**+$0.20/cow/d**	**+$0.08/cow/d**

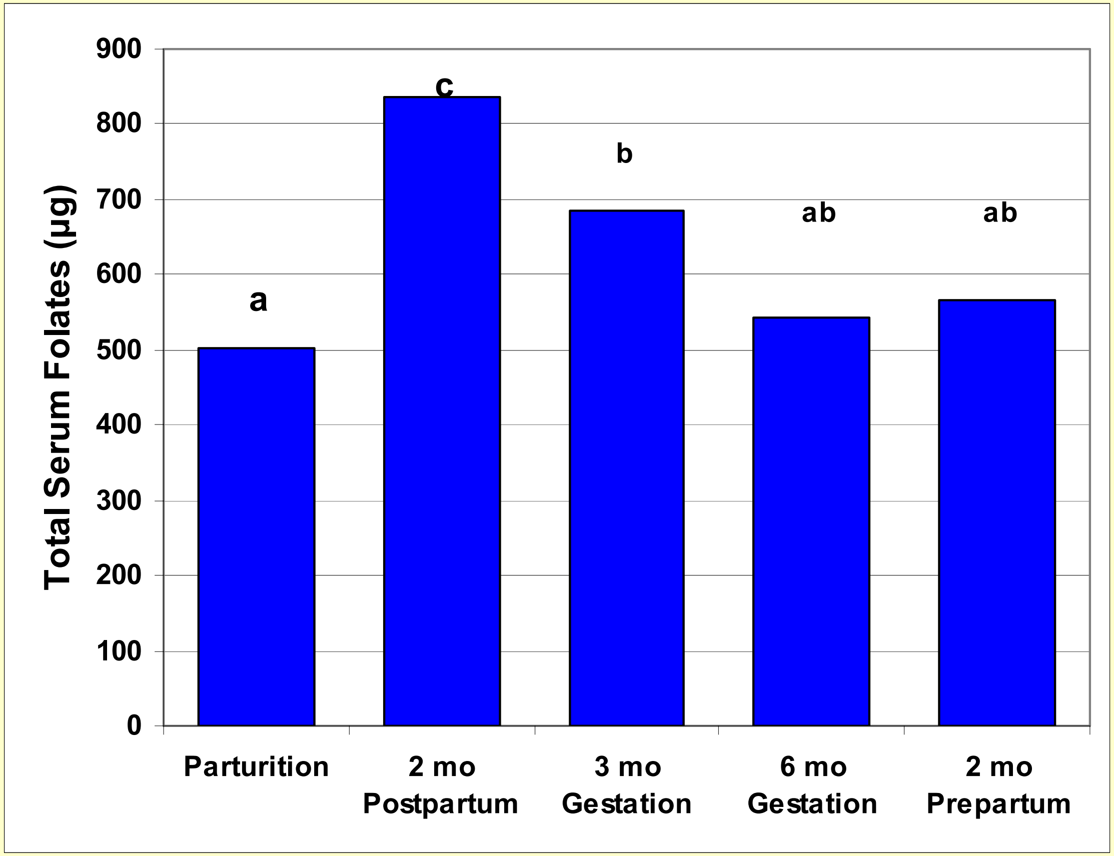
Better hoof health may be added benefit

- **Assumed $13/cwt milk price**
- **Feed cost included costs of biotin and increased DMI**

Folic Acid

Girard et al., 1989

- 70 multiparous cows--total serum folates measured from calving thru 2 months prepartum
- Levels follow feed intake (ruminal synthesis) or fetal requirement?



Supplemental B-Vitamin Responses

Folic Acid (Girard et al., 1995)

- **24 multiparous & 16 primiparous cows**
- **Injected weekly with 0 or 160 mg folic acid from pregnancy to 42 DIM in subsequent lactation**
- **Response**
  - Increased serum FA in primi- and multi-parous cows
  - Increased FA in milk and colostrum
  - Increased ($P = 0.09$) milk yield by 3.3 lb/d from pregnancy to dry off
  - Increased milk protein from 3.2 to 3.5% in multiparous cows

Supplemental B-Vitamin Responses

Folic Acid (Girard & Matte, 1998)

- **32 multi-, 31 primi-parous cows**
- **Fed ruminally-unprotected FA at 0, 1.5, 3.0 g/d for complete lactation**
- **Responses**
  - Decreased milk yield in primiparous cows
  - Increased milk yield in multiparous (0 vs. 3 g/d)
    - 5.0 lb/d (P = 0.06) complete lactation
    - 6.6 lb/d (P = 0.05) from 100 to 200 DIM
- **More research and likely rumen protection needed**

Supplemental B-Vitamin Responses

Niacin

- **Most widely researched B-vitamin in dairy cows**
- **Early research involved ketosis treatment at pharmacological doses**
- **Current use as feed additive (**6 to 12 g/d**) focused on reducing sub-clinical ketosis & increasing milk yield**
- **Four literature summaries**
  - Drackley (1992); Erdman (1992); Girard (1998); NRC (2001)
- **Recent Meta-Analysis (**Schwab et al., PAS, 2005**)**

Supplemental B-Vitamin Responses

Niacin

- **NRC, 2001** (statistical significance considered)
  - **NEFA**: 14 Treatment comparisons

    ⇧2, ⇔ 11, ⇩ 1
  - **Ketones**: 10 Treatment comparisons

    ⇔ 6, ⇩ 4
  - **Milk Yield**: 30 Treatment comparisons

    ⇧1, ⇔ 29
  - **Milk fat**: 30 Treatment comparisons

    ⇧3, ⇔ 26, ⇩ 1
  - **Milk protein**: 27 Treatment comparisons

    ⇧5, ⇔ 20, ⇩ 2

Supplemental B-Vitamin Responses

Niacin

- **Schwab et al., 2005.** *In* **Prof. Anim. Sci.**
  - Meta-analysis
  - Niacin-response data from 27 studies published from 1980 - 1998 with 6 -12 g/d ruminally-unprotected niacin supplemented
  - Evaluated DMI, milk yield, & milk composition
  - 6 g/d: No response
  - 12 g/d: 3.5% FCM (+1.1 lb/d, *P*=0.06), MPY (+25.8 g/d, *P*=0.01), MFY (+17.4 g/d, *P*=0.08)
  - Tenuous economic benefits
    - **Frequency of FCM response being greater than break-even was 54 to 57%**

Supplemental B-Vitamin Responses

Niacin

- **Schwab et al., 2005.** *In* **Prof. Anim. Sci.**
  - NS effects on plasma NEFA, BHBA, and glucose
  - Total tract nutrient digestibilities not improved in 6/6 trials
  - Ruminal nutrient digestibilities unaffected in 2/2 trials
  - Ruminal VFA affected in only 2/7 trials
  - Ruminal pH and ammonia unaffected in 6/6 trials
  - Microbial-N flow unaffected in 4/4 trials
  - Ruminal protozoa increased in 2/2 trials

Supplemental B-Vitamin Responses

Niacin

- French (2004 abstr.):
  - 48 g/d ruminally-unprotected niacin fed starting 30 d pre-partum
  - NEFA lower (*P*<0.01) day of & day after calving
  - Prepartum DMI decline reduced for supplemented cows

- More transition cow research needed with either high-dose ruminally-unprotected niacin or ruminally-protected niacin

Supplemental B-Vitamin Responses

Thiamin

- **Shaver and Bal (2000)**
  - 150 - 300 mg/d rumen-unprotected thiamin
  - Increased ($P = 0.01$) milk and component production in cows fed low fiber/high NFC diets
  - Trend for increased milk and milk protein yields in cows fed higher fiber/lower NFC diets
  - Positive response in 2 of 3 trials
  - More research needed

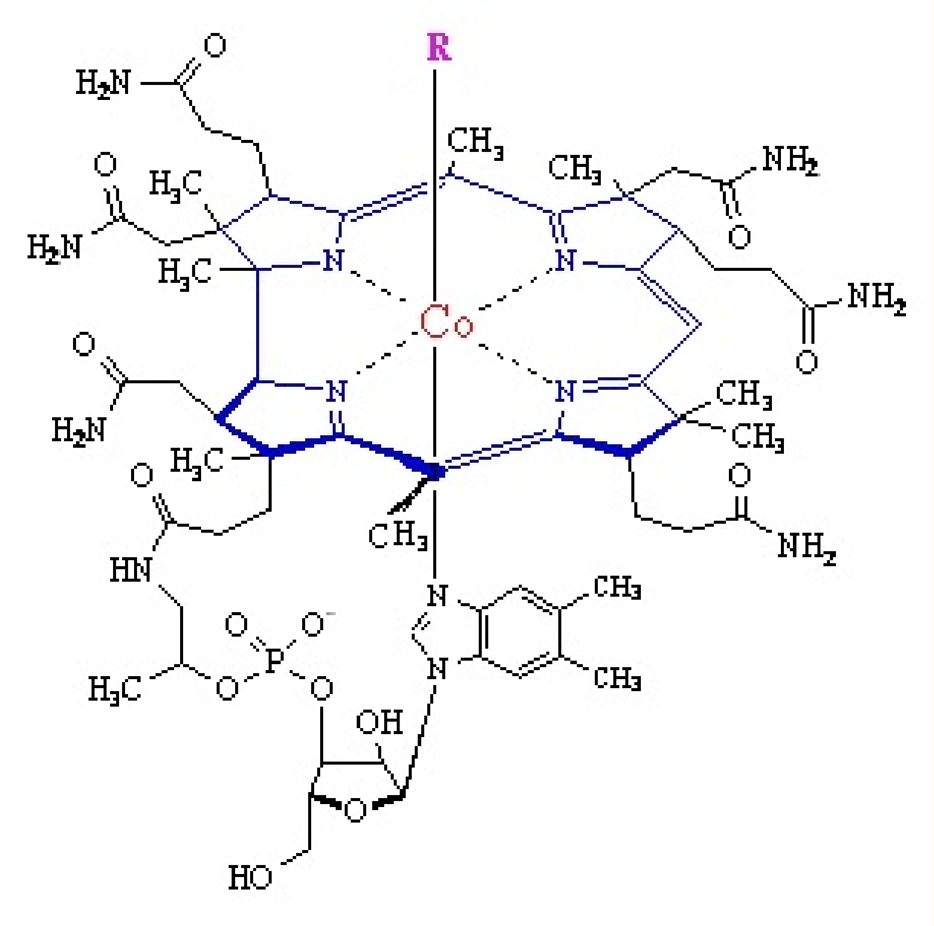
Supplemental B-Vitamin Responses

Vitamin B_{12} (injection studies only)

- **Elliot et al., 1977**→ 10 control, 12 B_{12} cows
  - 10 mg B_{12} twice weekly
  - Increased (*P* > 0.10) milk yield 8.4 lb/d
- **Croom et al., 1981**→ 15 control, 15 cows B_{12} cows
  - Three 150 mg B_{12} doses over 14 d
  - Increased (*P* > 0.10) milk yield 1.8 lb/d
- **Girard and Matte, 2005**
  - 14 early lactation, primiparous cows, fed 2 g/d FA
  - 0 or 10 mg B_{12} weekly
  - ECM yield increased (*P* = 0.03) 7.0 lb/d
- **More research needed**
- **Feed product not likely feasible** (high cost, poor availability)

Dietary factors influencing ruminal B-vit. synthesis

- **Cobalt and vitamin B_{12}**



Cobalt and vitamin B_{12}

- Kawashima et al. (1997; Nutr. Res.) – In vitro B_{12} production greater with Co-supplements and greater for higher Co level
- Stangl et al. (2000; BJN) – Increased dietary Co-sulfate in steers increased plasma and liver B_{12} concentrations
- Allen (1986; Univ. Minn Thesis) - In vitro B_{12} production and fiber digestion greater with higher Co and with Co-gluc

Cobalt and vitamin B_{12}

Kincaid et al., JDS, 2003

	Control TMR 0.37 ppm Co	TMR 0.68 ppm Co	TMR 1.26 ppm Co
Milk, kg/d	36.3	34.7	36.3
FCM, kg/d	35.4	35.6	38.8
Serum B_{12} (ng/ml)	1.89	2.23	1.46

- Diets fed 21d prepartum thru 120d postpartum
- Control unsupplemented with Co
- Treatments supplemented with Co-Gluc
- NS treatment differences
- Treatment x parity x week interaction for milk but not B_{12}

Supplemental B-Vitamin Responses

Riboflavin and B_6 alone

- Unaware of published reports

Supplemental B-Vitamin Responses

Pantothenic Acid alone

- Some work from Japan published in veterinary Journals suggesting beneficial effects on reproductive measurements
- An unpublished un-replicated pen trial suggesting milk yield responses in early lactation
- More controlled research warranted

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