Stress and Factors Altering Feedlot Animal Performance: The Role of Vitamins.

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Frontiers

The Last Frontier for Mankind – Space
The Last Frontier for Nutritionists – Vitamins

Why?

- Diverse compounds hard to assay.
- Variable intakes and deficiency symptoms.
- Marginal deficiencies are not readily apparent.
- Interactions & antagonisms.
- Synthesis & degradation within the gut.
- Supplementation can be expensive.
Needs for & Benefits from Vitamins for Ruminants

Primary Information Sources

3. Contact with specialists – Essi Evans
4. Research published in reviewed journals.
6. Personal unpublished observations.
Adult Ruminants

Supplements needed: Vitamin A (or carotenes), Vitamin D (with no access to sunlight); Vitamin E. Vitamin K and B-vitamins made by ruminal microbes appear sufficient for maintenance, but dietary supplements may improve performance under certain dietary, health, or production conditions. Ruminant organs make vitamin C.
All animals (as well as ruminants) make their own vitamin C except:
Large apes, humans
Guinea pigs
Red-vented bulbul.
As an antioxidant, is synthesis always adequate?
What Vitamins Do Ruminants Need?

Young (Pre-Ruminant) Calves

• When fed a diet deficient in a given vitamin, deficiency symptoms become obvious for thiamin, niacin, vitamin B12, choline, biotin, vitamin K within a week or a month. The vitamins MUST be included in milk replacers.

• The need for pre-ruminant calves indicates that ruminant TISSUES of adults ruminants ALSO require a supply of these same vitamins.
How do ruminants (cud-chewing animals including cattle, sheep, llama, deer) differ from non-ruminants (swine, poultry) in vitamin metabolism?
Vitamin Needs: Ruminants versus Non-ruminants

Research Goal: Measure the animal’s “response” to an increase in the supply of a vitamin. If “performance” is increased, the basal diet was “vitamin deficient.”

Animal class: 

<table>
<thead>
<tr>
<th>Animal class</th>
<th>Non-ruminant</th>
<th>Ruminant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>Amount from diet = X.</td>
<td>X – loss in rumen + ruminal synthesis. (both can vary).</td>
</tr>
<tr>
<td>Diet comp.</td>
<td>Usually consistent.</td>
<td>Highly variable.</td>
</tr>
<tr>
<td>Growth stage</td>
<td>High production level.</td>
<td>Slow relative growth.</td>
</tr>
</tbody>
</table>

Response: Growth, gain:feed. Growth, milk yield, alleviate specific health, maintenance, deficiency symptom, reproduction? Is animal’s response direct or indirect via microbes?

How can the supply of each vitamin for a ruminant be determined?
Ruminant Digestion: Assisted by microbes (bacteria, protozoa, fungi) in four-chambered stomach – Rumen, reticulum, omasum, abomasum.
Feeding both Microbes and the Ruminant

Needs for ruminal microbes (bacteria, protozoa, fungi)

Tissue needs. Met by the small intestinal supply = dietary vitamins that survive ruminal attack PLUS ruminally synthesized vitamins.
Consumed feed enters the rumen first. There, microbes partially DEGRADE & USE vitamins from the diet but will MAKE vitamins K and all B-vitamins.

For ruminants, the primary source of energy is Volatile Fatty Acids (VFA), not glucose or fat. So the need for vitamins used in glucose or fat metabolism is LESS, but the need for vitamins used in VFA metabolism is GREATER (e.g., biotin, B12).
Ruminal supply will vary with diet and feed intake.

Tissue vitamin supply varies due to microbial destruction of some and synthesis of others.

1. In vitro: Incubate vitamin with rumen fluid.
2. In animal: Intestinal cannulas (microbes adapt).

How can ruminal degradation & synthesis in the rumen of live animals be measured?
Intestinally Cannulated Ruminants
Allows microbes to adapt to vitamin supply.

Alter the dietary supply of the vitamin.

Measure the degree that small intestinal supply of the vitamin changes.

Rumen survival = Ratio of SI flow to intake.
Synthesis = Flow with no supplement divided by microbial energy supply (digested OM).
Materials and Methods

Three 194 kg steers calves in 3x3 Latin square. Diet: 44% flaked corn, 35% alfalfa hay, 10% sudan hay, 6% molasses, 4% fat, chromic oxide (marker).

Three levels of each B vitamin and vitamin C:
1. None.
2. Amounts required by 35-kg growing pigs (metabolic size adjusted) + choline + ascorbic acid.
3. 10 x pig requirements above.

10 d for adaptation, 4 d duodenal collection, 2X/d. Measured intake & duodenal flow of OM, ADF, N, thiamin, riboflavin, B6, B12, biotin, folic acid, niacin, pantothenate.

Extent of ruminal & total tract OM, ADF or N digestion were not altered by supplemental vitamins. Regressed flow against intake for each vitamin.
Pantothenic Acid Intake and Duodenal Flow

- Basal diet
- + 1X Pig’s Need
- + 10X Pig’s Need

Intake, mg/d

Duodenal flow, mg/d
Ruminal escape = 22%
Destruction = 78%

Pantothenic Acid Intake and Duodenal Flow

Duodenal flow, mg/d

Intake, mg/d

Basal diet

+ 1X Pig’s Need

1000 Ruminal escape = 22%
Destruction = 78%

+ 10X Pig’s Need
Ruminal escape = 22%
Destruction = 78%

1000 Ruminal escape = 22%
Destruction = 78%

5.5 mg/2.5 kg OMD
= 2.2 mg/kg OMD

Basal diet
+ 1X Pig’s Need
+ 10X Pig’s Need
If ruminal survival is low, ruminal protection is needed to increase post-ruminal supply.
Ruminal Synthesis of Vitamins

Ruminal vitamin synthesis depends on microbial growth. If ruminal survival of a vitamin is low, synthesis may compensate for SOME vitamins **IF** intake of digestible DM is sufficient.

How well is vitamin supply to the small intestine predicted by escape and DMI? Separate trial with 4 intake levels with 4 steers (200 kg).

Zinn et al. 1987
Responses to DM intake seem consistent. Precision of prediction appears reasonably good.
Quantitative B-Vitamin Requirements of Ruminants

- Supply at duodenum =
  1. Ruminal escape (of added) +
  2. Microbial synthesis
- Supply minus Requirement = surplus.

- Requirement
  1. Tissue needs (est. from swine?)
  2. Secretions (milk)
200 kg steer eating 5 kg feed/day versus its Requirement for Pigs
200 kg steer eating 5 kg feed/day

- Pantothenate: 190 mg/d, 22%
- Folate: 3%
- Choline: 9 mg/d, 5%?
With stressed calves, when feed intake is low, the likelihood of vitamin deficiencies increases.
Quantitative B-Vitamin Requirements of Ruminants

• Supply minus Requirement = surplus.

• Supply at duodenum =
  1. Ruminal escape (of added) +
  2. Microbial synthesis

• Requirement
  1. Tissue needs (est. from swine?)
  2. Secretions (milk)
600 kg cow, 40 kg milk, 20 kg feed/day
Are vitamins needed to replace those vitamins secreted with milk? Or do vitamins in milk reflect a spillover of excess?

600 kg cow, 40 kg milk, 20 kg feed/day
<table>
<thead>
<tr>
<th>Question</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Will intramuscular injection of B-vitamins alter a steer’s vitamin status?</td>
<td></td>
</tr>
<tr>
<td>Does a viral infection alter the B-vitamin status of steers?</td>
<td></td>
</tr>
<tr>
<td>Does B-vitamin status alter a steer’s response to a viral infection?</td>
<td></td>
</tr>
</tbody>
</table>
Dubeski 1996.  
Time sequence study using 12 calves, 6-8 months of age. Measured plasma B-vitamin concentrations.

1. While suckling versus weaned 30 d later.
Little impact of weaning on these plasma B-vitamins.

1. While suckling versus weaned 30 d later.
2. Before and after food deprivation for 3 days.
Little impact of fasting on these plasma B-vitamin concentrations.

1. While suckling versus weaned 30 d later.
2. Before and after food deprivation for 3 days.
3. 6 of the 12 calves given B-vitamin injections equal to swine requirements. Others had saline injections.
Huge impact of IM B-vitamin injections on plasma levels except ascorbate.
Dubeski 1996.
Time sequence study using 12 calves, 6-8 months of age. Measured plasma B-vitamin concentrations.

1. While suckling versus weaned 30 d later.
2. Before and after food deprivation for 3 days.
3. 6 of the 12 calves given B-vitamin injections equal to swine requirements. Others had saline injections.
4. All calves inoculated nasally with bovine herpesvirus-1. Maximum body temperature 5 d later. Compare before versus 5 d after virus inoculation both without and with vitamin injections.
Calves WITHOUT B-vitamin injections

Decreases in B12, pantothenic acid, & ascorbic acid, but not folic acid.
Huge decreases in folic acid, B12, pantothenic acid, & B6, but not ascorbate.
B-Vitamin Supplements for Stressed Calves

Cole et al. 1979. 275 steer calves; 220 kg, 28 days.
Cole et al. 1982. 186 steer calves; 188 kg, 28 days.
Leclerc et al., 2015. 998 calves; 261 kg, 21 days. 2g RP.

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Cole 1979</th>
<th>Cole 1982</th>
<th>Leclerc, Garza 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiamin, mg</td>
<td>0.35</td>
<td>0.35&amp;70</td>
<td>0</td>
</tr>
<tr>
<td>Riboflavin, mg</td>
<td>0.35</td>
<td>0.35&amp;70</td>
<td>0</td>
</tr>
<tr>
<td>Pyridoxine, mg</td>
<td>0.35</td>
<td>0.35&amp;70</td>
<td>0, R Protected</td>
</tr>
<tr>
<td>Pantothenate, mg</td>
<td>0.80</td>
<td>0.80&amp;160</td>
<td>0, R Protected</td>
</tr>
<tr>
<td>Niacin, mg</td>
<td>0.205</td>
<td>0.205&amp;410</td>
<td>0</td>
</tr>
<tr>
<td>Choline, mg</td>
<td>0.4600</td>
<td>0.4600&amp;9200</td>
<td>0</td>
</tr>
<tr>
<td>Folate</td>
<td>0</td>
<td>0</td>
<td>0, R Protected</td>
</tr>
<tr>
<td>Biotin</td>
<td>0</td>
<td>0</td>
<td>0, R Protected</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morbidity</td>
<td>62, 45%*</td>
<td>61, 50, 48%</td>
<td>?</td>
</tr>
<tr>
<td>Mortality</td>
<td>4, 3</td>
<td>0, 2, 0</td>
<td>?</td>
</tr>
<tr>
<td>ADG</td>
<td>1.14, 1.05</td>
<td>1.06, 0.99, 1.05</td>
<td>2.01, 2.20*</td>
</tr>
<tr>
<td>G:F</td>
<td>0.19, 0.19</td>
<td>0.17, 0.15, 0.16</td>
<td>0.23, 0.26*</td>
</tr>
</tbody>
</table>
Need for & Benefits from Vitamins for Ruminants

- Vitamins A – Carotenes
- Vitamin C – Ascorbic acid
- Vitamins D – The Sunshine vitamin
- Vitamins E – Tocopherols
- B-Vitamins – Diverse types

Ruminant’s requirements (mg/d or ppm).
Ruminal escape of dietary supplements.
Ruminal biosynthesis.
Likelihood of Deficiency.
### Vitamin A

<table>
<thead>
<tr>
<th></th>
<th>Vitamin A Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedlot cattle</td>
<td>2,200 IU/kg dry feed.</td>
</tr>
<tr>
<td>Pregnant cattle</td>
<td>2,800</td>
</tr>
<tr>
<td>Lactating cows</td>
<td>3,900</td>
</tr>
</tbody>
</table>

Injections of A, D, and E often given to starting feedlot cattle, but adjuvant and injection site concerns.

18 to 67% of A destroyed in rumen (forage vs concentrate diets).

6,000 to 11,000 IU A/kg depresses gain for 28 days.

Liver reserves last 2 to 4 months (biopsy to measure).

Sources:
- B-carotene (green plants)
- Yellow corn grain (cryptoxanthine)
- Corn silage – Poor source of vitamin A.

It’s not clear what Nitrate and Ferm. are referring to.

Carotene is an Antioxidant. Vitamin A is not.

Holsteins don’t but Guernsey do absorb carotene intact. Holsteins have more morbidity & mortality.
# Vitamin D

<table>
<thead>
<tr>
<th></th>
<th>Outdoors</th>
<th>Indoors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedlot cattle</td>
<td>0 (sunlight)</td>
<td>275 IU/kg diet</td>
</tr>
<tr>
<td>Dairy cattle</td>
<td>1,375</td>
<td></td>
</tr>
</tbody>
</table>

Injections of A, D, and E often given to starting feedlot cattle; adjuvant and injection site concerns.

Active in Ca absorption/resorption. Limited reserves. D2 more degraded in rumen than D3.

Very high D intakes may decrease shear force of meat cuts (make meat more tender) via elevated Ca and calpain activity, but high D intakes can depress intake. Rumen protected 1, 25- and 25-OH D3 may have potential.

Sources: Sunlight exposure.
<table>
<thead>
<tr>
<th>Situation</th>
<th>Vitamin E Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedlot cattle</td>
<td>15 to 60 IU/kg diet</td>
</tr>
<tr>
<td>Bovine respiratory disease</td>
<td>1,000 IU/day</td>
</tr>
<tr>
<td>Stressed calves</td>
<td>400-500 IU/day</td>
</tr>
<tr>
<td>Meat color stability</td>
<td>500-1000 IU/day</td>
</tr>
</tbody>
</table>

Injections of A, D, and E often given to starting feedlot cattle; adjuvant and injection site concerns. Antioxidant activity with vitamin C and Se. Reserves increased by grazing high quality forages. Gamma tocopherol also found in yellow corn grain. Fermentation (high moisture corn) destroys ALL gamma tocopherol. May reduce mastitis incidence of lactating dairy cows.
Vitamin E for Transport-Stressed Calves

ADG, kg/day

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>+Vit E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lee</td>
<td>1.22</td>
<td>1.18</td>
</tr>
<tr>
<td>Hays</td>
<td>0.95</td>
<td>0.97</td>
</tr>
<tr>
<td>Gill</td>
<td>0.78</td>
<td>0.80</td>
</tr>
<tr>
<td>Weighted Means</td>
<td>0.92</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Vitamin E doses (IU/d):
- 450 IU/d
- 700 IU/d
- 1400 IU/d

P-values:
- LEE: P=0.14
- HAYS: P=0.80
- GILL: P=0.92
Vitamin E for Feedlot Cattle

ADG, kg/day

11 increases: 3 decreases

P = 0.06

1.37 vs 1.32
Various tocopherols ($\alpha$, $\gamma$) differ in availability and tissue incorporation. Free tocopherols are readily oxidized. Acetate is stable.

Alderson et al. (1971) Abomasal measurements:
- 20% corn diet 8.4% ruminal loss
- 40% corn diet 22.2% ruminal loss
- 60% corn diet 25% ruminal loss
- 80% corn diet 42% ruminal loss.

Shin & Owens (1990) Duodenal measurements:
- Ruminal loss was 36-52% for various E forms.

Leedle et al. (1993) In vitro incubation:
- No destruction at 24 h (unadapted rumen fluid).

Extent of ruminal loss is not certain.
Roquet et al. (1992); Hidiroglou et al. (1990); Han et al. (1998)

- Nice plasma responses to fed tocopherol acetate or duodenally dosed free tocopherol.
- Only slight plasma response to duodenally administered tocopherol acetate.
- Acetate form is NOT absorbed?
- For intestines: Free tocopherol more useful than acetate.

Acetate form not adequately cleaved in the intestine. For pre-ruminant calves, the acetate form is useless. Must de-acetylation in the rumen precede intestinal absorption of tocopherol?

- Potential limited market for rumen protected (RP) alpha tocopherol (free, not the acetate).
All zoo rhinos were dying from anemia – fragile red blood cells. They can use E alcohol, but not acetate.
| Feedlot cattle | 0 need |

Synthesized in rumen. Anti-hemorrhagic vitamin, so often injected following castration & dehorning to aid blood clot formation. Sweet clover disease – Dicoumarol antagonist to K produced by fungus that grows on moist sweet clover. Dicoumarol used as a rat poison (WARFarin).
B-Vitamin Needs/Effects

**Pre-ruminants**
Deficiency symptoms develop if diet is devoid of thiamin, riboflavin, B6, choline, pantothenic acid, biotin, niacin, or B12.

**Functioning rumen**
Beneficial under SOME conditions.

- Ruminal biosynthesis by bacteria & protozoa.
- Monensin increases niacin, decreases thiamin.
- Ruminal escape varies among vitamins, diets?
- Plasma concentrations lowered with stress?
- Some rumen protected products tested (Choline).
- Need to consider B-vitamins individually.
- Specific dietary conditions.
- Bioavailability (antivitamin formation?) uncertain.
## Thiamin

<table>
<thead>
<tr>
<th>Pre-ruminant</th>
<th>Required at the tissue level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functioning rumen</td>
<td>Conditional supplement = 1 g/head/d</td>
</tr>
</tbody>
</table>

- Ruminal biosynthesis by bacteria & protozoa.
- Monensin decreases thiamin output from rumen.
- Plasma concentrations lowered with stress?
- Need less as carbohydrate intake decreases, so ruminal production of VFA should reduce its need.
- Plasma thiamin decreases with infection: competition?
- Used in glucose metabolism & brain function.
- S (>0.5%), amprolium (coccidiostat) increase need and can cause polioencephalomalacia (circling disease).
- 1 g/d soften supplemented when fed distiller’s grains (S).
- Avoid excess intake – thaminase 1 & 2 increase.
- KSU 1974 trial: 174 stressed calves (220 kg) fed 51d. 1g thiamin mononitrate/d = more sickness, lower DMI & ADG.
**Riboflavin**

<table>
<thead>
<tr>
<th>Status</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-ruminant</td>
<td>Required at the tissue level</td>
</tr>
<tr>
<td>Functioning rumen</td>
<td>No absolute requirement</td>
</tr>
</tbody>
</table>

- Higher in forage than concentrate diets (opposite to thiamin).
- Secretion in milk often exceeds 10 times riboflavin intake due to ruminal synthesis.
### B6 - Pyridoxals

<table>
<thead>
<tr>
<th>Pre-ruminant</th>
<th>Functioning rumen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required at the tissue level</td>
<td>No absolute requirement</td>
</tr>
</tbody>
</table>

- Required by pure cultures of some cellulose digesting bacteria but crossfeeding from other ruminal bacteria should meet this need.
- Reported to increase the lysine content of protozoa.
Pantothenic Acid

<table>
<thead>
<tr>
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<th>Required at the tissue level</th>
</tr>
</thead>
<tbody>
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<td>No absolute requirement</td>
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</tbody>
</table>

- Widespread in nature.
- Involved in fatty acid oxidation.
B12

<table>
<thead>
<tr>
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<th>Required at the tissue level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functioning rumen</td>
<td>No absolute requirement</td>
</tr>
</tbody>
</table>

- 4.5% cobalt; cobalt deficiency reduces B12 synthesis.
- Involved with nucleic acid metabolism and methyl transfer including propionate (VFA) metabolism.
- B12 and biotin increased in vitro cellulose digestion by rumen fluid (trials over 60 years ago).
- Various analogs (antivitamins?) of B12 are produced by ruminal microbes and appear in blood.
Niacin

<table>
<thead>
<tr>
<th>Pre-ruminant</th>
<th>Functioning rumen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required at the tissue level</td>
<td>No absolute requirement YET</td>
</tr>
</tbody>
</table>

- Can be synthesized by tissues from the amino acid tryptophan.
- Involved with detoxifying ammonia (urea toxicity).
- May increase protein synthesis by ruminal microbes.
- No benefit in milk yield from added niacin.
- 10 receiving and feedlot trials 30 years ago by John Brethour (Kansas State University at Hayes).
### Other Niacin Trials

<table>
<thead>
<tr>
<th>State</th>
<th>Year</th>
<th>Level</th>
<th>ADG</th>
<th>Gain:Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>1976</td>
<td>0.6 g/d</td>
<td>+4.5%</td>
<td>+8%</td>
</tr>
<tr>
<td>Indiana</td>
<td>1980</td>
<td>0.2 g/d</td>
<td>-1.0%</td>
<td>+5.7%</td>
</tr>
</tbody>
</table>
Folic Acid

<table>
<thead>
<tr>
<th>Pre-ruminant</th>
<th>Required at the tissue level</th>
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<tbody>
<tr>
<td>Functioning rumen</td>
<td>No absolute requirement</td>
</tr>
</tbody>
</table>

• Transfer of carbon units in DNA synthesis.
Biotin

<table>
<thead>
<tr>
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<th>Required at the tissue level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functioning rumen</td>
<td>No absolute requirement?</td>
</tr>
</tbody>
</table>

• Needed for tissue metabolism of propionic acid.
• Biotin is the **ONLY** B-vitamin required for cellulose digesting ruminal bacteria.
• In the absence of methionine, B12 and PABA often increase bacterial growth rates. Is crossfeeding supply from other rumen microbes adequate?
• Involved in hoof health and growth. Helps avoid lameness that reduces productivity.
• High ruminal survival avoids need for ruminally protected form.
Choline

<table>
<thead>
<tr>
<th>Pre-ruminant</th>
<th>Required at the tissue level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functioning rumen</td>
<td>Uncertain. Milk yield, ADG from RP choline</td>
</tr>
</tbody>
</table>

- Methyl transfer compound.
- Spares methionine as a methyl donor.
- Higher concentrations in protozoa than bacteria so greater supply with roughage diets than concentrate diets.
- 1998 Kansas State trial with 0 to 60 g RP choline for 318 heifers (300 kg fed 120 days).
Gain and efficiency for 318 heifers (342 kg) fed 120 days:
P (cubic) = 0.10
Best with 0% fat.

40% flaked corn
42% rolled corn
8% alfalfa
2% soy meal

Bindel 2000
Concern: High cost: Lactating cows = 30¢ per cow for 30 days before and after calving.

Gain and efficiency for 160 heifers (351 kg) fed 112-140 days: P (Cubic) = 0.10.

Bryant et al., 1999
Second Method to Assess Deficiencies:

Contrast ruminal concentrations with requirements (ppm) for chicks

• Determine concentration in rumen liquor
• Multiply by 60%? (flow/intake) ignoring ruminal absorption.
• Compare with poultry/swine needs (ppm) ignoring species differences.
• Ignore bioavailability differences.
Are All B-Vitamins Well Absorbed by Ruminants?

Net Absorption

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Input</th>
<th>Absorption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiamin</td>
<td>75</td>
<td>55-77%</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>25</td>
<td>35-36%</td>
</tr>
<tr>
<td>Niacin</td>
<td>79</td>
<td>84-85%</td>
</tr>
<tr>
<td>B6</td>
<td>79</td>
<td>69-85%</td>
</tr>
<tr>
<td>B12</td>
<td>48</td>
<td>11-16%</td>
</tr>
<tr>
<td>Biotin</td>
<td>-</td>
<td>28-46%</td>
</tr>
<tr>
<td>Folate</td>
<td>-</td>
<td>Neg-16%</td>
</tr>
</tbody>
</table>

Measure vitamin input to the small intestine.

Measure vitamin output from the small intestine.

Small intestinal digestion = Input minus output.
Fed 5 steers (600 kg) a concentrate diet (7 kg concentrate, 0.9 kg prairie hay/d). Removed 50 L ruminal contents daily. Strained through cheesecloth. Added rumen liquid to purified chick diets (55 g liquid:45 g purified diet). Purified diets were prepared that were deficient in EACH individual B- vitamin. Added rumen fluid to each diet. Measured responses in chick growth, feed intake, survival.
Ruminal Contents as a Source of B-Vitamins for Chicks

Primary study:
• 1,000 9-day old chicks fed 14 d
• 4 pens of 8 chicks fed each of 20 diets:
  1. Semipurified diet without B-vit (DEVOID)
  2. Diet 1 plus B-vitamins (COMPLETE)
  3. Diet 2 minus thiamin
  4. Diet 2 minus riboflavin
  5. Diet 2 minus niacin
  6. Diet 2 minus pyridoxine
  7. Diet 2 minus pantothenate
  8. Diet 2 minus folate
  9. Diet 2 minus B-12
 10. Diet 2 minus choline
11-20. 45% of diet 1-10 plus 55% rumen liquor
<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn starch</td>
<td>54.3</td>
</tr>
<tr>
<td>Vitamin-free casein</td>
<td>26.4</td>
</tr>
<tr>
<td>Glista salts</td>
<td>5.4</td>
</tr>
<tr>
<td>Corn oil</td>
<td>5.0</td>
</tr>
<tr>
<td>Cellulose</td>
<td>3.0</td>
</tr>
<tr>
<td>Citric acid</td>
<td>1.0</td>
</tr>
<tr>
<td>Arginine</td>
<td>1.2</td>
</tr>
<tr>
<td>DL Methionine</td>
<td>0.4</td>
</tr>
<tr>
<td>Gycine</td>
<td>0.2</td>
</tr>
<tr>
<td>Vit ADEK premix</td>
<td>0.1</td>
</tr>
<tr>
<td>B-vitamins</td>
<td>+/-</td>
</tr>
</tbody>
</table>

Ruminal fluid from steers fed concentrate diet filtered through 2 layers of cheesecloth had 10% DM. RF diets had only 12.4% of DM as rumen liquor.
100% of need

0% of need

Chick weight gain, g/day

-5 Complete, Devoid, Folate, Niacin, Choline, Riboflavin, Pyridoxine, Thiamin, B12, Pantothenate
Gain/Feed

- Complete
- Devoid
- Folate
- Niacin
- Choline
- Riboflavin
- Pyridoxine
- Thiamin
- B12
- Pantothenate

Basal
+ Rumen fluid

100% of need
0% of need
Bioavailability of B-Vitamins from Ruminal Contents - Conclusions

Ruminal fluid addition to purified diet usually increased DMI and ADG of chicks. (Unidentified growth factors?) ADG and gain/feed increases matched those expected from B-vitamin content of ruminal fluid, except for:

1. Pantothenate - at 39% of requirement, low intakes and gains. Low availability?
2. B-12 - At 1900% of requirement, low intakes and gains. (B-12 antivitamins may be formed in the rumen of cattle fed concentrate diets.) NM lamb study.

Poultry nutritionists don’t like the odor of rumen fluid! Yet consider the stink bird!
The Stink Bird is like Donald Trump’s worst fear: The Terrorist from the Mideast who attacks a restaurant and: “Eats, Shoots, and Leaves.”

The Only Ruminant that Flies: the Stink Bird
An enlarged crop ferments plant shoots & leaves to VFA. Bird burps CO2, methane, and odorous VFA.

Hoatzin in Peru (Wikipedia)
# Candidate Bypassable Vitamins

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Stressed calf</th>
<th>Typical steer</th>
<th>Lactating cow</th>
<th>Ruminal escape %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choline/betaine</td>
<td>?</td>
<td>Yes</td>
<td>Yes</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Folate</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>3</td>
</tr>
<tr>
<td>Pantothenate</td>
<td>Yes</td>
<td>Yes</td>
<td>?</td>
<td>22</td>
</tr>
<tr>
<td>Ascorbate</td>
<td>Yes</td>
<td>?</td>
<td>Yes</td>
<td>&lt;5</td>
</tr>
<tr>
<td>B-12</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>10</td>
</tr>
<tr>
<td>Formulated mix</td>
<td>Yes</td>
<td>No</td>
<td>?</td>
<td>varies</td>
</tr>
</tbody>
</table>

**Other vitamins:** Minimal market, responses unlikely or bypass adequate.
<table>
<thead>
<tr>
<th>Compound</th>
<th>Stressed calf</th>
<th>Typical steer</th>
<th>Lactating cow</th>
<th>Ruminal escape %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxytetracycline</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Piprazines,MOS</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>&lt;5?</td>
</tr>
<tr>
<td>Probiotics</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Varies</td>
</tr>
<tr>
<td>ZnO, Cu2SO4</td>
<td>No</td>
<td>Yes?</td>
<td>Yes?</td>
<td>100</td>
</tr>
<tr>
<td>Glucose</td>
<td>Yes</td>
<td>At times</td>
<td>At times</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Digel(Anti-froth)</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Lipase/Amylase</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Immotil</td>
<td>No</td>
<td>Yes</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Tranquilizers</td>
<td>Yes</td>
<td>No</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

*These or other compounds may prove worthwhile for certain animals at certain times or with certain conditions where bypass of a dietary therapeutic is low or release in the rumen may be detrimental.*
Vitamin Supply and Need (swine basis)

- **B12, mg**: Shortage = 0.2 mg/day or 0.3 mg/kg diet
- **B6 mg**: Shortage = 0.2 mg/day or 0.3 mg/kg diet
- **Biotin, mg**: Shortage = 0.17 g/day or 2 g/kg diet
- **Choline, g**: Shortage = 0.17 g/day or 2 g/kg diet
- **Folate, mg**: Shortage = 0.8 mg/day or 1.2 mg/kg diet
- **Niacin, mg**: Shortage = 30 mg/day or 45 mg/kg diet
- **Pantothenate, mg**: Shortage = 30 mg/day or 45 mg/kg diet
- **Riboflavin, mg**: Shortage = 0.8 mg/day or 1.2 mg/kg diet
- **Thiamin, mg**: Shortage = 0.8 mg/day or 1.2 mg/kg diet

Diagram showing the comparison between the concentration diet, need for 300 kg, and the daily deficit for each vitamin.
### Relative Vitamin Needs

<table>
<thead>
<tr>
<th>Vitamin &amp; rumen protection</th>
<th>Calc. steer reqt. ppm</th>
<th>Calc. cow’s reqt. ppm</th>
<th>Rumen fluid vs chick &amp; pig reqt ppm</th>
<th>Ruminal escape %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choline, RP</td>
<td>100</td>
<td>450</td>
<td>1600</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Folate, RP</td>
<td>0.9</td>
<td>0.9</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Pantothenate</td>
<td>19</td>
<td>26</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>0</td>
<td>0</td>
<td>1.7</td>
<td>101</td>
</tr>
<tr>
<td>Thiamin, RP?</td>
<td>0</td>
<td>0</td>
<td>1.2</td>
<td>52</td>
</tr>
<tr>
<td>Niacin</td>
<td>100</td>
<td>?</td>
<td>?</td>
<td>6</td>
</tr>
<tr>
<td>Ascorbate, RP</td>
<td>175</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Biotin</td>
<td>0.1</td>
<td>?</td>
<td>?</td>
<td>100</td>
</tr>
</tbody>
</table>

**Ruminally protected choline:** Texas Tech, KSU

**Folate:** Lactating cows (Canadian workers).

**Thiamin:** Only with excess sulfate (CO).
## Potential Vitamin Supplements

<table>
<thead>
<tr>
<th>Vitamin &amp; Rumen protect</th>
<th>Fed steer reqt. ppm</th>
<th>Stress Steer reqt. ppm</th>
<th>Material Cost Stressed steer/d Cents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choline, RP</td>
<td>2000</td>
<td>0</td>
<td>20.00-0</td>
</tr>
<tr>
<td>Folate, RP</td>
<td>0.9</td>
<td>0.9</td>
<td>0.14?</td>
</tr>
<tr>
<td>Pantothenate</td>
<td>0</td>
<td>19</td>
<td>0-1.65</td>
</tr>
<tr>
<td>Thiamin, RP</td>
<td>0</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0-13.00&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Niacin</td>
<td>100</td>
<td>100</td>
<td>5.70</td>
</tr>
<tr>
<td>Ascorbate,RP</td>
<td>0</td>
<td>175</td>
<td>0-3.40</td>
</tr>
<tr>
<td>Biotin</td>
<td>0.1</td>
<td>0.1</td>
<td>0.74</td>
</tr>
<tr>
<td>B12</td>
<td>0.01</td>
<td>0</td>
<td>0.45-0</td>
</tr>
<tr>
<td>Tocopherol, RP</td>
<td>0 IU</td>
<td>500 IU</td>
<td>0-89.00?</td>
</tr>
</tbody>
</table>

*Total, cents/d* 27.03 100.53

<sup>a</sup>Thiamin: Only with high sulfate diets (CSU). Ascorbate, Tocopherol, (and cysteine) are potential antioxidants. Tocopherol for immune stimulation. Niacin, biotin, B12 may stimulate ruminal fiber digestion.

Research needed to justify costs for certain vitamins.
<table>
<thead>
<tr>
<th>Vitamin or additive</th>
<th>Total need ppm</th>
<th>Rumen escape %</th>
<th>Rumen Protection Yes/No</th>
<th>Basis of level</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, D, E</td>
<td>Inject</td>
<td></td>
<td></td>
<td>NRC 2016</td>
</tr>
<tr>
<td>E alcohol</td>
<td>500</td>
<td>30</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Choline</td>
<td>400</td>
<td>&lt;5</td>
<td>Yes</td>
<td>TT, KSU trials</td>
</tr>
<tr>
<td>Folate</td>
<td>0.9</td>
<td>3</td>
<td>Yes</td>
<td>Immune function</td>
</tr>
<tr>
<td>Pantothenate</td>
<td>19</td>
<td>22</td>
<td>Yes</td>
<td>Low avail. (chicks)</td>
</tr>
<tr>
<td>Thiamin</td>
<td>100</td>
<td>5</td>
<td>Yes</td>
<td>S protection</td>
</tr>
<tr>
<td>Ascorbate</td>
<td>175</td>
<td>0</td>
<td>Yes</td>
<td>Antioxidant</td>
</tr>
<tr>
<td>Zn, Cu, Se</td>
<td>50</td>
<td>100</td>
<td>Yes</td>
<td>Bioavail? AB effects</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>10</td>
<td>100</td>
<td>No</td>
<td>Cellulose digestion</td>
</tr>
<tr>
<td>Niacin</td>
<td>100</td>
<td>6</td>
<td>No</td>
<td>Acts in rumen KSU</td>
</tr>
<tr>
<td>Biotin</td>
<td>0.1</td>
<td>100</td>
<td>No</td>
<td>Hoof health, Fiber dig.</td>
</tr>
<tr>
<td>B12</td>
<td>0.01</td>
<td>10</td>
<td>No</td>
<td>Fiber digestion</td>
</tr>
<tr>
<td>Cysteine</td>
<td>100</td>
<td>75?</td>
<td>No</td>
<td>Antioxidant (GSH)</td>
</tr>
<tr>
<td>Urea</td>
<td>5000</td>
<td>No</td>
<td>Retarded release</td>
<td>Rumen pH buffering</td>
</tr>
</tbody>
</table>
Supplementation for Ruminants - Overview

**Ruminal benefits:**

*Niacin, Biotin, B12.*

**Rumen Protection Needed:**

*Choline.* For stress: *Folate? vitamin E alcohol, vitamin C.*

**Meat tenderness:** *25OH vitamin D*

**Adequate bypass**

*Thiamin, Pyridoxine, Biotin*

**Injections:** *A, D, E.* Preferable to diet IF blemishes avoided and mild adjuvants.
Assessing a Ruminant’s Vitamin Status

1. Performance response to adding RP compound. Both bypass and intestinal availability must be known.
   (DuCoa - 90% choline escape claimed: we recovered 44% in bags in feces!)

Specific diets and feeding conditions.

2. Optimum level assessment:
   Plasma response (like amino acids?)

3. Tests used to estimate adequate status of nonruminants:
   Specific biochemical tests.
   Antioxidant levels.
   Tissue or plasma vitamin levels.

4. Employ slow-release injections or an “insulin pump” device to test performance responses to individual vitamins.
Thank you! /Obrigado!

Fred Owens