TRACE MINERALS LINK TO UDDER HEALTH

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SUMMARY

- BACKGROUND ON TRACE MINERALS
- TM COW AND CALF RELATIONSHIP
- FACTORS THAT INFLUENCE DIETARY TRACE MINERALS
- UDDER HEALTH
Co-factors that are incorporated into functional enzymes and proteins.

Crystallographic structure of bovine glutathione peroxidase
TRACE MINERALS: OF IMPORTANCE IN DAIRY

- Cobalt: Co
- B12
- Copper: Cu
- Iodine: I
  - Thyroid function
- Manganese: Mn
- Selenium: Se
- Zinc: Zn

TRACE MINERAL 101

- Essential for cellular energy metabolism and protein production.
  - Example: Mn, Se, Zn, Cobalt, I.

- Essential for structural components of the body.
  - Example: Mn, Zn

- Essential for reproduction and fertility.
  - Example: Mn, Cu, Se, Zn
TRACE MINERAL METABOLISM

TRANSPORT

EXCRETION

ENZYME

STRUCTURAL

STORAGE & RELEASE & EXCRETION
DEFICIENCIES

- **Primary**
  - Deficient area, Low levels in forage
  - No oral supplementation

- **Secondary**
  - Free choice minerals vs. supplemented feed
  - Mineral *“Tie up”*
    - Sulfur: DDG, CGF, water
    - Iron, Calcium
Influenced by stress or stage of production
Trace Mineral Status Not Static

Figure 3: Changes in liver and serum copper concentrations for beef cows
(Swenson, 1998).

<table>
<thead>
<tr>
<th>Time of Sampling</th>
<th>Serum Cu, ppm</th>
<th>Liver Cu, ppm (DM basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precalving</td>
<td>0.65</td>
<td>110</td>
</tr>
<tr>
<td>Calving</td>
<td>0.8</td>
<td>80</td>
</tr>
<tr>
<td>Breeding</td>
<td>0.7</td>
<td>85</td>
</tr>
<tr>
<td>Weaning</td>
<td>0.65</td>
<td>120</td>
</tr>
<tr>
<td>Precalving</td>
<td>0.68</td>
<td>115</td>
</tr>
</tbody>
</table>
PREGNANCY/TRACE MINERAL RELATIONSHIP

Complicated by deficiencies and antagonisms
PREGNANCY/TRACE MINERAL RELATIONSHIP

- **Zinc**
  - Liver: Zinc, Ppm DM
  - Days Relative to Calving

- **Manganese**
  - Liver Manganese, Ppm DM
  - Days Relative to Calving

- **Selenium**
  - Serum Selenium, μg/ML Whole Blood
  - Days Relative to Calving

- **Copper**
  - Liver Copper, Ppm DM
  - Days Relative to Calving
Calf liver status from Birth to Weaning
(Cow 20ppm Cu in diet)

IMPACT OF PRENATAL DIETARY COPPER LEVEL ON COPPER STATUS
AND IMMUNITY OF NEWBORN AND GROWING CALVES

JAY CHRISTOPHER BRANUM  May 1999
FACTORS THAT INFLUENCE DIETARY TRACE MINERALS

- **Intake**
  - Reduced DMI before calving
  - 30%-40% last 3 weeks (89% last week)

- **Absorption**
  - Bioavailability/Absorption
  - Organic

- **Antagonism**
  - Negative Interaction
Mineral Antagonism
COMPOUNDS FACTORS

- **Antagonism: Negative Interaction “tie up”**
  - **Calcium**: >.8% DM reduces Se absorption
  - **Sulfur (Water, DDG, molasses)**: reduces Se, Cu absorption.
  - **Iron (S)**: reduces Cu absorption or gut solubility.
  - **Cu-Mo-S**: Thiomolybdate: reduces copper bioavailability.

SYSTEMIC ANTAGONISM
## Measured Sulfur Concentrations (%) in DG’s from Various Ethanol Plants in the Midwest

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Avg</strong></td>
<td>0.71</td>
<td>0.72</td>
<td>0.83</td>
<td>1.06</td>
<td>0.81</td>
<td>0.90</td>
</tr>
<tr>
<td><strong>Min</strong></td>
<td>0.44</td>
<td>0.58</td>
<td>0.73</td>
<td>0.90</td>
<td>0.69</td>
<td>0.79</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>1.72</td>
<td>0.84</td>
<td>0.93</td>
<td>1.26</td>
<td>0.93</td>
<td>1.04</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Avg</strong></td>
<td>0.76</td>
<td>0.74</td>
<td>0.72</td>
<td>0.69</td>
<td>0.76</td>
<td>0.82</td>
</tr>
<tr>
<td><strong>Min</strong></td>
<td>0.61</td>
<td>0.64</td>
<td>0.60</td>
<td>0.61</td>
<td>0.69</td>
<td>0.73</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>0.95</td>
<td>0.82</td>
<td>0.80</td>
<td>0.83</td>
<td>0.82</td>
<td>0.89</td>
</tr>
</tbody>
</table>

*Erickson, 2007*
## Interactions Between Mo, S and Mo + S on Cu Absorption

<table>
<thead>
<tr>
<th>Basal Diet (0.1% S, 0.5 ppm Mo</th>
<th>% Reduction in Cu Absorption</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 4 ppm Mo</td>
<td>-0.5%</td>
</tr>
<tr>
<td>+ 0.3% S</td>
<td>-31%</td>
</tr>
<tr>
<td>+ 4 ppm Mo and 0.3% S</td>
<td>-62%</td>
</tr>
</tbody>
</table>

1) Cu and Mo – formation of cupric molybdate?  
2) Cu and S – formation of CuS  
3) Cu-S-Mo interaction – thiomolybdate formation  
   (mono, di, tri and tetra)

Adapted from:  
Gooneratne et al., 1989.  
Generalized Regional Pattern of Molybdenum Concentration in Legumes of the United States

- **Areas with background levels of 6-8 PPM of Molybdenum**
- **Areas with background levels of 2-4 PPM of Molybdenum**
- **Areas with background levels of 1 PPM or LESS of Molybdenum**
- General location of naturally occurring Molybdenum-Toxic areas
- General location of Industrial Molybdenosis

Generalized regional pattern of molybdenum concentrations in Legumes of the United States (ppm = 1 μg/g). From Kubota, 1977, by courtesy Marcel Dekker, Inc.
Effect of Sulfur Content of Supplemental Feeds On Liver Copper Accumulation in Heifers

Arthington (2004)
IMPORTANCE OF TRACE MINERALS: IMMUNE SYSTEM

- **Reactive Oxygen Free Radical** $O_2^-$
- **SOD**
- **Hydrogen Peroxide** $H_2O_2$
- **Catalase**
- **GPx**
- **Water** $H_2O$

Balanced Oxygen $O_2$
TRACE MINERALS LINK TO UDDER HEALTH

- **Zn, Cu, Se**
  - Cu Zn (SOD), Se (GPX)

- **Response to infection**
  - Innate (Non-Specific)
    - Epithelium
    - Indiscriminate killing by immune system
  - Acquired (Specific)
    - Antibody Formation
Zinc: Epithelial Integrity

Zinc. Zinc has been identified as a key mineral in the processes of keratinization (Smart and Cymbaluk, 1997; Mulling et al., 1999; Mulling, 2000b). The ubiquitous distribution of Zn among cells, coupled with Zn being the most abundant intracellular trace element, points to very basic functions. Whereas Zn is a component of over 200 enzyme systems, it has a role in 3 key functions in the keratinization process—catalytic, structural, and regulatory (Cousins, 1996). Catalytic roles are found in enzymes such as RNA nucleotide transferases, RNA polymerase, alkaline phosphatase, carboxypeptidase, alcohol dehydrogenase, and the carbonic anhydrases (Cousins, 1996; NRC, 2001). As indicated earlier, the presence of ribonucleic and deoxyribonucleic acid, ascorbic acid, free aldehyde groups, and alkaline phosphatase in keratinizing cells serves as a positive indicator of intense cellular activity (Frazer and MacRae, 1980; Hendry et al., 1997). These catalytic enzymes are Zn metalloenzymes and, as such, are dependent upon Zn as an activator, and thus an integral component in the differentiation of keratinocytes.

J. Dairy Sci. 87:797–809

Invited Review: Formation of Keratins in the Bovine Claw: Roles of Hormones, Minerals, and Vitamins in Functional Claw Integrity

D. J. Tomlinson,1 C. H. Mulling,2 and T. M. Fakler2
1Zinpro Corporation, Eden Prairie, MN 55344
2Freie Universität Berlin, Institute for Veterinary Anatomy, Koserstra 20, Berlin, Germany 14195
Manganese. In general, manganese is an activator of enzyme systems in the metabolism of carbohydrates, fats, proteins and nucleic acids (52). It is also essential for normal brain function, and plays a role in collagen formation, bone growth, urea formation, synthesis of fatty acids and cholesterol and digestion of protein (30, 33).
Neutrophil and Macrophage Driven Response to Pathogens

**Steps to Deal with Pathogen**

**Neutrophil Movement to Site of Infection**
- Selenium status determines how many neutrophils move to the site of infection.

**Phagocytosis of Pathogen**
- Copper status impacts the amount of pathogen phagocytosed.

**Respiratory Burst to Destroy Pathogen**
- Copper and Zinc are part of Cu & Zn-Superoxide Dismutase (SOD) enzyme, which converts superoxide radicals to hydrogen peroxide.
- Both these enzymes are critical in controlling the respiratory burst and preventing white blood cell destruction.
- Selenium is part of Glutathione Peroxidase enzyme, which converts hydrogen peroxide to water.

**References:**
OXIDANTS (REACTIVE OXYGEN MOLECULES) ROM

ORIGIN:

Aerobic exercise
Pregnancy
Stress
Tissue injury
Infection
Detoxification of compounds

DNA DAMAGE
PROTEIN DESTRUCTION
LIPOPEROXIDATION OF CELL MEMBRANES

ENZYMES

GSH-PX Activity/mg Hemoglobin in Erythrocytes

Days Post Injection ** (P<0.05)

- Multimin 90
  - Additional enzymes available due to MM90 Supplementation
- Control
  - Enzymes derived from oral feed & forage

- Reactive Oxygen Free Radical O₂
- SOD
- Hydrogen Peroxide Free Radical H₂O₂
- Catalase
- Water H₂O
- Balanced Oxygen O₂
- GPx
Supplemented cows

- Greater intracellular killing of Staph and E-coli.
- Se and Vit E: greater affect on Staph aureus killing
- Vit. E only: greater affect on E-coli killing
- Se and Vit. E: did not result in greater killing over Se and Vit. E alone
Copper Supplemented First Calf Heifers

- Clinical response was reduced after experimental infection
  - Lower SCC
  - Lower Rectal Temp
  - Lower Bacterial Count

Role of Dietary Copper in Enhancing Resistance to *Escherichia coli* Mastitis¹

R. W. Scaletti,* D. S. Trammell†, B. A. Smith*, and R. J. Harmon*

*Department of Animal Science
University of Kentucky, Lexington 40546
†Department of Animal and Dairy Science
University of Georgia, Tifton 31793
TRADITIONAL USES: INJECTABLE

- Treat clinical disease associated with deficiency.
  + RP’s
  + White Muscle Disease (STD Syndrome)
    - Se, Vit. E
In the face of potential antagonism and reduced DMI

How do we effectively manage this?
Effect of an injectable trace mineral supplement containing selenium, copper, zinc, and manganese on the health and production of lactating Holstein cows


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Department of Clinical Sciences, College of Veterinary Medicine, Cornell University, Ithaca, NY 14853, United States
STUDY DESIGN

1410 cows
Randomly allocated:
- TMS
- Control

Clinical endometritis
Uterine Lavage

230 days of pregnancy
1st injection 5 ml

260 days of pregnancy
2nd injection 5 ml

Calving

35 DIM
3rd injection 5 ml

Data collection based on farm database: metritis, mastitis, SCC, RP, DA, Stillbirth, reproductive performance, culling
Chemical composition (mineral and vitamins) of pre-fresh and lactating cows diets for study farms 1, 2, and 3. Pre-fresh diets were fed from 3 week prepartum through parturition and lactation diets were fed from parturition through week 35 postpartum.

<table>
<thead>
<tr>
<th>NRC 2001 recommendations</th>
<th>Farm 1</th>
<th>Farm 2</th>
<th>Farm 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-fresh</td>
<td>Lactation</td>
<td>Pre-fresh</td>
</tr>
<tr>
<td>Copper ppm</td>
<td>13.0</td>
<td>11.0</td>
<td>19.25</td>
</tr>
<tr>
<td>Manganese ppm</td>
<td>18.0</td>
<td>13.0</td>
<td>108.59</td>
</tr>
<tr>
<td>Selenium ppm</td>
<td>0.30</td>
<td>0.30</td>
<td>0.38</td>
</tr>
<tr>
<td>Zinc ppm</td>
<td>22.0</td>
<td>52.0</td>
<td>63.77</td>
</tr>
</tbody>
</table>
Multimin®90 injected cows had reduced somatic cell counts

SCC - PRIMIPAROUS COWS:

Least square means of linear scores

Month of lactation

CONTROL

MM90
SCC – SECOND LACTATION COWS:

Least square means of linear scores

Month of lactation

CONTROL

MM90
SSC - > 2 LACTATION COWS:
RESULTS

**Subclinical Mastitis**

- **Control**
  - Incidence (%): 12
- **TMS**
  - Incidence (%): 8

*P-value = 0.005*
RESULTS

<table>
<thead>
<tr>
<th>Condition</th>
<th>Incidence (%) Control</th>
<th>Incidence (%) TMS</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endometritis</td>
<td>35</td>
<td>30</td>
<td>0.03</td>
</tr>
<tr>
<td>Metritis</td>
<td>10</td>
<td>10</td>
<td>0.83</td>
</tr>
<tr>
<td>RP</td>
<td>5</td>
<td>5</td>
<td>0.99</td>
</tr>
<tr>
<td>DA</td>
<td>2</td>
<td>1</td>
<td>0.19</td>
</tr>
</tbody>
</table>

**P-values**
- Stillbirth: 0.04
- Endometritis: 0.03
- Metritis: 0.83
- RP: 0.99
- DA: 0.19
SOMATIC CELL COUNTS

REDUCED FROM 299,660 TO 218,964.

A SIGNIFICANT BENEFIT!
ECONOMICAL BENEFIT OF USING MULTIMIN90 IN DAIRIES:

UNIVERSITY OF FLORIDA COMPILED A REPORT USING THE CORNELL DATA
Table 2. List of prices and production measure that were different among states.

<table>
<thead>
<tr>
<th>Item</th>
<th>California</th>
<th>Idaho</th>
<th>New York</th>
<th>Pennsylvania</th>
<th>Wisconsin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield, lbs/d(^1)</td>
<td>62</td>
<td>64</td>
<td>57</td>
<td>53</td>
<td>56</td>
</tr>
<tr>
<td>Milk yield, kg/d(^1)</td>
<td>28.1</td>
<td>29.1</td>
<td>25.9</td>
<td>24.1</td>
<td>25.4</td>
</tr>
<tr>
<td>Milk price, cwt(^2)</td>
<td>$18.5</td>
<td>$17.5</td>
<td>$23.1</td>
<td>$23.6</td>
<td>$20.9</td>
</tr>
<tr>
<td>Milk price, kg(^2)</td>
<td>$0.407</td>
<td>$0.385</td>
<td>0.508</td>
<td>0.519</td>
<td>0.460</td>
</tr>
<tr>
<td>Springer heifer price, $(^2)</td>
<td>1400</td>
<td>1500</td>
<td>1450</td>
<td>1550</td>
<td>1570</td>
</tr>
</tbody>
</table>
Table 3. Economic comparison ($/cow/yr; mean ± SD) among states on the benefit from using Multimin TMS.

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Control profit</td>
<td>$680</td>
<td>$594</td>
<td>$1384</td>
<td>$1215</td>
<td>$904</td>
</tr>
<tr>
<td>TMS profit</td>
<td>$722</td>
<td>$634</td>
<td>$1420</td>
<td>$1247</td>
<td>$938</td>
</tr>
<tr>
<td>Net gain</td>
<td>$42</td>
<td>$40</td>
<td>$36</td>
<td>$32</td>
<td>$34</td>
</tr>
</tbody>
</table>