Nutrient Profiling – Mineral Supplementation
Pre- and Postnatal Trace Mineral Supplement Source on Heifer and Bull Performance and Sexual Development

Deborah Price, Matt Hersom, Joel Yelich, Max Irsik, Owen Rae
Introduction

• Trace minerals (TM) are essential nutrients involved in physiological & biochemical processes
  • Metabolism, immunity, growth, & reproduction (Hidiroglou, 1979; Spears, 2000; Suttle, 2010)

• TM source of either organic or inorganic, affects mineral bioavailability (Spears, 1996)

• Maternal nutrition during gestation may impact the developing fetus & can potentially affect postnatal animal (Ashworth and Antipatis, 2001; Hostetler et al., 2003)
Influence of Trace Minerals on Cow-Calf Production Cycle

Maternal TM status

- Growth, immunity, performance, & sexual development
- In utero TM transfer & fetal development
- Postnatal Calf nutrition (colostrum/milk)
- Reproduction-Pregnancy establishment
- Placental growth & development

Maternal TM Supplementation
Experiment Rationale

• Examination of long-term effects of prenatal and postnatal TM source & cattle breed on neonatal and growing calves, and heifer & bull sexual development are warranted
Objectives

1. Investigate effects of TM source over 2 production cycles on cow TM status, performance, & reproduction

2. Examine effects of prenatal & postnatal cow TM source on
   1. Neonatal & growing calf TM status, performance, & immunity
   2. Weaning calf TM status, performance, & acute phase response (APR) to a weaning stressor

3. Study effects of prenatal & postnatal TM source on
   1. Heifer sexual development
   2. Bull sexual development
Experimental Design

- Starting $82 \pm 2$ d pre-calving in yr 1
- **Breed**: pregnant Angus (AN) & Brangus (BN) cows
- **TM source**
  - Inorganic (ING, Na selenite & salt sulfates)
  - Organic (ORG, Se-yeast & proteinates)
- TM supplement (Co, Cu, Mn, Se, Zn) fed 3x/wk
  - Pre-calving to breeding: *Pellet* (0.4 kg/454 kg BW/d)
  - Breeding to weaning: *Loose mineral* (0.09 kg/cow/d)
Experimental Design

- **2 Production cycles:** cows remained same TM treatments assigned in Yr 1
  - Yr 1 cows, $n = 199$
    - ING-AN = 49, ING-BN = 51, ORG-AN = 50, ORG-BN = 49
  - Yr 2 cows; $n = 161$
    - ING-AN = 41, ING-BN = 44, ORG-AN = 38, ORG-BN = 38
- Resultant calves used additional experiments
  - Neonatal & growing calf performance & immunity
  - Heifer sexual development
  - Bull sexual development
• Study effects of prenatal & postnatal TM source on heifer sexual development
  • Puberty
  • Pregnancy
Materials & Methods

• Yr 1: \( n = 80 \); 20 heifers/treatment
• Yr 2: \( n = 61 \); ING-AN = 16, ING-BN = 15, ORG-AN = 14, & ORG-BN = 16
• 28 d intervals
  • BW, BCS (scale 1-9), & hip height (HH)
• 84 d intervals
  • Liver biopsy for TM analysis (Co, Cu, Fe, Mn, Mo, Se, & Zn)
    • Yr 1 = 6 heifers/treatment
    • Yr 2 = 5 heifers/treatment
Materials & Methods

• Weekly blood samples
  • Progesterone (PROG) determination by RIA

• Pregnancy confirmed by transrectal ultrasonography
  • Days 51, 72, & 107 from start of natural service breeding season (yr 1 = 71 d; yr 2 = 72 d)

• Definitions
  • **Puberty** = date when PROG ≥ 1.5 ng/mL with one of next two weekly blood samples with PROG ≥ 1.5 ng/mL
  • **Pregnancy** = first date of three consecutive weekly blood samples with PROG ≥ 1.5 ng/mL and confirmed by estimated age based on ultrasound pregnancy diagnosis
Year 1 Heifers
# Year 1 Physical Characteristics of Heifers at Start of 168 d Development Period

<table>
<thead>
<tr>
<th>Variable</th>
<th>Trace mineral (TM) × Breed (B)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AN-ING</td>
<td>BN-ING</td>
</tr>
<tr>
<td><strong>n</strong></td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>233</td>
<td>233</td>
</tr>
<tr>
<td><strong>BW, lb</strong></td>
<td>472</td>
<td>485</td>
</tr>
<tr>
<td><strong>BCS</strong></td>
<td>4.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>HH, cm</strong></td>
<td>106.6</td>
<td>110.8</td>
</tr>
</tbody>
</table>

<sup>a, b</sup> = Means within a row differed, \( P \leq 0.05 \)
Physical Characteristics of Year 1 Heifers at End of 168 d Development Period

<table>
<thead>
<tr>
<th>Variable</th>
<th>AN-ING</th>
<th>BN-ING</th>
<th>AN-ORG</th>
<th>BN-ORG</th>
<th>SEM</th>
<th>TM</th>
<th>B</th>
<th>TM × B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heifers, n</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, d</td>
<td>401</td>
<td>401</td>
<td>402</td>
<td>407</td>
<td>5</td>
<td>0.45</td>
<td>0.60</td>
<td>0.54</td>
</tr>
<tr>
<td>BW, lb</td>
<td>714</td>
<td>730</td>
<td>737</td>
<td>759</td>
<td>15</td>
<td>0.13</td>
<td>0.26</td>
<td>0.83</td>
</tr>
<tr>
<td>Development ADG, lb/d</td>
<td>1.43</td>
<td>1.43</td>
<td>1.41</td>
<td>1.52</td>
<td>0.07</td>
<td>0.49</td>
<td>0.31</td>
<td>0.48</td>
</tr>
<tr>
<td>BCS</td>
<td>5.4</td>
<td>5.4</td>
<td>5.4</td>
<td>5.5</td>
<td>0.1</td>
<td>0.38</td>
<td>0.56</td>
<td>0.77</td>
</tr>
<tr>
<td>HH, cm</td>
<td>115.3</td>
<td>119.2</td>
<td>116.1</td>
<td>120.0</td>
<td>0.9</td>
<td>0.39</td>
<td>&lt; 0.01</td>
<td>1.00</td>
</tr>
</tbody>
</table>
## Physical Characteristics of Year 1 Heifers at Initiation 72 d Breeding Season

<table>
<thead>
<tr>
<th>Variable</th>
<th>Trace mineral (TM) × Breed (B)</th>
<th>$P$-value</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>AN-ING</td>
<td>BN-ING</td>
</tr>
<tr>
<td>Heifers, $n$</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>RTS, (1-5)</td>
<td>2.8</td>
<td>3.2</td>
</tr>
<tr>
<td>Pelvic Area, cm²</td>
<td>353</td>
<td>375</td>
</tr>
<tr>
<td>Pubertal, $n$ (%)</td>
<td>4/20 (20)</td>
<td>4/20 (20)</td>
</tr>
</tbody>
</table>
Year 1 Effect of TM source × Breed on Age to Puberty

Non-pubertal heifers, %

Age to Puberty
ING-AN = 424 ± 8 d
ING-BN = 428 ± 9 d
ORG-AN = 433 ± 9 d
ORG-BN = 431 ± 7 d

$P$-value
TM = 0.82
Breed = 0.11
TM*breed = 0.36
Effect of TM Source on Year 1 Interval to Pregnancy

Average Interval to PG
ING = 42 ± 3 d
ORG = 34 ± 3 d
HR: ORG vs ING = 1.60

P-value
TM = 0.02
Breed = 0.05
TM*breed = 0.19
Effect of TM Source on Year 1 Age to Pregnancy

Average Age to PG
ING = 450 ± 5 d
ORG = 446 ± 5 d
HR: ORG vs ING = 1.32

P-value
TM = 0.20
Breed = 0.45
TM*breed = 0.53
Effect of TM Source × Breed on Heifer Final Pregnancy Rate

$P$-value
TM = 0.27
Breed = 0.79
TM*Breed = 0.79

Pregnancy Rate, %

<table>
<thead>
<tr>
<th>Breed</th>
<th>ING-AN</th>
<th>ING-BN</th>
<th>ORG-AN</th>
<th>ORG-BN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pregnancy Rate (%)</td>
<td>90</td>
<td>85</td>
<td>95</td>
<td>95</td>
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</tbody>
</table>
Year 2 Heifers
## Physical Characteristics of Year 2 Heifers at Initiation of 168 d Development Period

<table>
<thead>
<tr>
<th>Variable</th>
<th>TM × breed (B)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ING-AN</td>
<td>ING-BN</td>
</tr>
<tr>
<td>n</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>Age, d</td>
<td>245</td>
<td>243</td>
</tr>
<tr>
<td>BW, lb</td>
<td>476</td>
<td>525</td>
</tr>
<tr>
<td>BCS</td>
<td>4.4</td>
<td>4.7</td>
</tr>
<tr>
<td>HH, cm</td>
<td>106.1</td>
<td>112.9</td>
</tr>
</tbody>
</table>
### Physical Characteristics of Year 2 Heifers at End of 168 d Development Period

<table>
<thead>
<tr>
<th>Variable</th>
<th>Trace mineral (TM) × breed (B)</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ING-AN</td>
<td>ING-BN</td>
</tr>
<tr>
<td>Heifers, $n$</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>Age, d</td>
<td>413</td>
<td>411</td>
</tr>
<tr>
<td>BW, lb</td>
<td>675</td>
<td>770</td>
</tr>
<tr>
<td>Development ADG, lb/d</td>
<td>1.19</td>
<td>1.46</td>
</tr>
<tr>
<td>BCS</td>
<td>5.0</td>
<td>5.6</td>
</tr>
<tr>
<td>HH, cm</td>
<td>117.4</td>
<td>124.2</td>
</tr>
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</table>
# Physical Characteristics of Year 2 Heifers at Initiation of 71 d Breeding Season

<table>
<thead>
<tr>
<th>Variable</th>
<th>Trace mineral (TM) × breed (B)</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ING-AN</td>
<td>ING-BN</td>
</tr>
<tr>
<td>Heifers, n</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>RTS(^1), (1-5)</td>
<td>2.9</td>
<td>3.4</td>
</tr>
<tr>
<td>Pelvic Area, cm</td>
<td>444</td>
<td>481</td>
</tr>
<tr>
<td>Pubertal, n (%)</td>
<td>2/16 (26)</td>
<td>5/15 (33)</td>
</tr>
</tbody>
</table>

\(^1\)RTS (1-5); 1 = no palpable structures; 3 = slight uterine tone, 8-10 mm follicles present; 5 = good uterine tone, CL present (Anderson et al., 1991. Agri-Practice)
Effect of TM source × Breed on Age to Puberty

Average Age to Puberty
- ING-AN = 432 ± 12 d
- ING-BN = 435 ± 12 d
- ORG-AN = 418 ± 6 d
- ORG-BN = 394 ± 11 d

HR: ORG-BN vs ORG-AN = 2.01
HR: ORG-BN vs ING-BN = 6.17

P-value
- TM < 0.0001
- Breed = 0.07
- TM*breed = 0.03
Effect of TM source on Age to Pregnancy

Average Age to Pregnancy
ING = 459 ± 4 d
ORG = 441 ± 4 d
HR: ORG vs ING = 1.56

P-value
TM = 0.18
Breed = 0.65
TM*breed = 0.73
Effect of TM Source × Breed on Heifer Final Pregnancy Rate

$P$-value
TM = 0.51
Breed = 0.83
TM*breed = 0.73

Pregnancy Rate, %

<table>
<thead>
<tr>
<th>Breed Type</th>
<th>Pregnancy Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>ING-AN</td>
<td>75</td>
</tr>
<tr>
<td>ING-BN</td>
<td>80</td>
</tr>
<tr>
<td>ORG-AN</td>
<td>71</td>
</tr>
<tr>
<td>ORG-BN</td>
<td>69</td>
</tr>
</tbody>
</table>
Summary

• **TM Source × Breed**: decreased age to puberty
  - ORG-BN pubertal 24 d earlier ORG-AN & 41 d earlier ING-BN

• **TM Source**
  - ORG greater ING
    - More heifers pubertal at start of breeding
  - No effect final pregnancy rate
  - Decreased age to puberty & pregnancy
    - ORG pubertal 29 d younger than ING
    - ORG pregnant 18 d younger than ING (not significant)
Summary

• Breed
  • Brangus greater Angus
    • Pelvic area at start of breeding
    • BW & BCS all of breeding
  • No effect final pregnancy rate
• Decreased age to puberty
  • Brangus pubertal 13 d younger than Angus
Conclusions

• TM source has variable/inconsistent effects on performance

• Breed consistently influences performance traits
  Brangus greater BW, BCS, & Pelvic area

• Decreased age to puberty in ORG heifers may hasten the time to pregnancy

• More research needed with larger sample sizes
  • Confirm effect on performance & reproduction
  • Compare timing of supplementation initiation
• Study effects of prenatal & postnatal TM source on bull sexual development
  • Puberty
  • Sexual maturity
Methods & Materials

• Total of 32 bulls; \( n = 8 \) bulls/treatment

• Every 2 weeks
  • BW, BCS, & scrotal circumference (SC) measured
  • BSE conducted once SC \( \geq 26 \) cm

• Semen evaluated
  • Concentration – Hemocytometer
  • Gross motility (0 - 4, 0 = none, 1 = poor, 2 = fair, 3 = good, 4 = very good)
  • Individual motility
  • Morphology – normal, primary, & secondary abnormalities

• Liver biopsy \((n = 4 \) bulls/treatment\) for TM analysis every 56 d
Methods & Materials

• Puberty = ejaculate $\geq 50 \times 10^6$ cells/mL & $\geq 10\%$ motility

• Sexual Maturity = based on *Theriogenology* guidelines
  • $\geq 70\%$ normal sperm
  • $\geq 30\%$ motility
  • SC passed for age
  • Passed 2 consecutive BSE
# Bull Physical Characteristics at Experiment Initiation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Trace mineral (TM) × breed (B)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ING-AN</td>
<td>ING-BN</td>
</tr>
<tr>
<td>$n$</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Age, d</td>
<td>252</td>
<td>241</td>
</tr>
<tr>
<td>BW, lb</td>
<td>516</td>
<td>573</td>
</tr>
<tr>
<td>BCS</td>
<td>4.7</td>
<td>4.6</td>
</tr>
<tr>
<td>HH, cm</td>
<td>110.2</td>
<td>117.0</td>
</tr>
<tr>
<td>SC, cm</td>
<td>22.9</td>
<td>23.8</td>
</tr>
</tbody>
</table>
Effect of TM Source & Breed on Bull BW

- **P-value**
  - TM = 0.89
  - B = 0.03
  - Day < 0.001
  - TM*Day < 0.001
  - B*Day = 0.07

- ***= Means within day differ, \( P \leq 0.05 \)
- **†= Means within day differ, \( P \leq 0.10 \)
**Effect of TM Source & Breed on Bull BCS**

- **P-value**
  - TM = 0.01
  - B < 0.01
  - Day < 0.001
  - TM*Day = 0.03
  - B*Day = 0.01

- **Means**
  - * = Means within day differ, $P \leq 0.05$
  - † = Means within day differ, $P \leq 0.10$
Effect of TM Source & Breed on Bull Age at Puberty

$P$-value
TM = 0.52
B = 0.34
TM*B = 0.23

$\begin{align*}
\text{ING-AN} & : n = 8, 338 \\
\text{ING-BN} & : n = 6, 342 \\
\text{ORG-AN} & : n = 8, 346 \\
\text{ORG-BN} & : n = 5, 313
\end{align*}$
**Effect of TM Source & Day Relative to Puberty on Bull SC & Sperm Concentration**

**SC**
- TM = 0.15
- B = 0.17
- Day < 0.001
- TM*Day = 0.09

**Concentration**
- TM = 0.53
- B = 0.10
- Day < 0.001

* = Means within day differ, $P \leq 0.05$
† = Means within day differ, $P \leq 0.10$
Effect of Breed & Day Relative to Puberty on Sperm Motility

Individual

P-value
TM = 0.17
B = 0.64
Day < 0.001

Gross

P-value
TM = 0.71
B = 0.03
Day < 0.001
B*Day = 0.001

*= Means within day differ, $P \leq 0.05$
†= Means within day differ, $P \leq 0.10$

Gross motility measured from 0 to 4
Effect of Breed & Day Relative to Puberty on Bull Sperm Morphology

Normal
SEM = 5.8%
P-value
TM = 0.07
B = 0.29
Day < 0.001
B*Day = 0.05

Primary
SEM = 2.9%
P-value
TM = 0.24
B = 0.38
Day = 0.07

Secondary
SEM = 5.7
P-value
TM = 0.19
B = 0.07
Day < 0.001
B*Day = 0.02

*= Means within day differ, \( P \leq 0.05 \)
† = Means within day differ, \( P \leq 0.10 \)
Effect of TM Source & Breed on Bull Age at Sexual Maturity

Age, d

<table>
<thead>
<tr>
<th>Breed</th>
<th>ING</th>
<th>ORG</th>
<th>AN</th>
<th>BN</th>
<th>ING-AN</th>
<th>ING-BN</th>
<th>ORG-AN</th>
<th>ORG-BN</th>
</tr>
</thead>
<tbody>
<tr>
<td>391</td>
<td>351</td>
<td>391</td>
<td>351</td>
<td>391</td>
<td>412</td>
<td>370</td>
<td>371</td>
<td>332</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

P-value
TM = 0.14
B = 0.13
TM*B = 0.94
## Bull Seminal Characteristics at Experimental Endpoint

<table>
<thead>
<tr>
<th>Variable</th>
<th>Trace mineral (TM) × breed (B)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ING-AN</td>
<td>ING-BN</td>
</tr>
<tr>
<td>SC, cm</td>
<td>34.9</td>
<td>36.4</td>
</tr>
<tr>
<td>Sperm, 10⁶ cells/mL</td>
<td>156.0</td>
<td>540.3</td>
</tr>
<tr>
<td>Gross motility², units</td>
<td>2.3</td>
<td>2.5</td>
</tr>
<tr>
<td>Individual motility, %</td>
<td>37.5</td>
<td>32.9</td>
</tr>
<tr>
<td>Normal sperm, %</td>
<td>66.1</td>
<td>60.0</td>
</tr>
<tr>
<td>Primary abnormalities, %</td>
<td>16.0</td>
<td>19.2</td>
</tr>
<tr>
<td>Secondary abnormalities, %</td>
<td>17.9</td>
<td>20.8</td>
</tr>
</tbody>
</table>

¹Experimental endpoint defined as sexual maturity (if bull reached) or d 196 of experiment
²Gross motility measured on scale of 0-4.
Summary

• TM source × breed
  • Tended affect endpoint sperm concentration
    • ING-BN greatest concentration – due to 1 bull

• TM Source
  • No effect bull performance
  • ING greater SC post puberty
  • No effect seminal traits relative to puberty & sexual maturity
  • ORG tended greater individual motility at experimental endpoint
  • No effect age at puberty
  • Numerically decreased age at sexual maturity in ORG bulls by 40 d
Summary

• **Breed**
  - Affected endpoint performance: BN > AN for BW, BCS, & HH
  - Liver TM concentrations: BN > AN for Cu, Mn, & Se
  - Seminal traits prior to puberty
    - BN > AN Normal sperm
    - AN > BN Secondary abnormalities
  - Post-puberty gross motility: BN > AN
Discussion

• Larger sample sizes to confirm effect of TM source on age at sexual maturity
  - ORG TM source may aid development of earlier maturing bulls

• More research needed to determine if fertility differences exist between TM sources
Overall Conclusions

• ORG TM may hasten onset of
  • Puberty & age to pregnancy in heifers
  • Age at sexual maturity in bulls

• Studies are needed to determine if timing of TM supplementation affects calf growth and sexual development

• Additional investigations into effects of TM source on endocrine and hormonal parameters could elucidate mechanisms behind differences in sexual development based on TM source
Questions