Novel physiological responses in phosphorus deficient beef cows

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Phosphorus is a key challenge

Nutritional Phosphorus deficiency is important in cattle grazing rangelands in Northern Australia
Our challenge

Better understand the physiological mechanisms controlling mobilization and deposition of body P reserves in breeder beef cattle

Develop diagnostic tools of P status (talk Tuesday)
Design & Methods

40 heifers calving at 3 years age, placed in pens

Balanced diet: straw, flour, sugar, oil, and urea based
+/- Calcium Phosphate “low” P or adequate “high” P diet

Three phases:
1. Late pregnancy: last 4 months
2. Lactation: 3 months
3. Weaning & P repletion: 6 weeks

Treatments HH, HL, LH and LL, cross-over at calving

Measurements: LW, feed intake, faecal, milk, blood samples and bone biopsies (rib & hip)
Results: Blood Phosphorus

Cows placed on low P diet 2 weeks prior to start
Results: Blood Calcium

- Ca is increased in P deficiency

**Normocalcemia**

- Low P
- High P

Months from calving

Total Ca (mmol/L)
Phosphorus & Calcium

Inverse relationship between blood P and Ca (& Mg)
- P deficiency towards hypercalcaemic
- Adequate P diet towards hypocalcemic

Likely due to more bone mobilisation in P deficiency
Results: Parathyroid Hormone

PTH is suppressed in P deficiency

![Graph showing PTH levels over months from calving]

- ** PTH levels in Low P condition
- High P condition

** PTH is suppressed in P deficiency
Results: PTH versus Calcium

PTH levels correspond (in large part) to plasma Ca

\[ r^2 = 0.47 \]
Results: CTX-1 bone resorption

CTX-1 is increased in P deficiency
Increase in CTX-1 towards term
Results: Osteocalcin

Bone deposition

OCN is decreased in P deficiency
Marked decrease OCN at calving
Results: Bone turnover

P deficiency characterised by increased bone turnover
Adequate diet P decreased bone turnover
Cortical (rib) bone Thickness

Biopsy at start diets versus at calving

On both diets there was a substantial increase in rib cortical bone (growing)
Results: 1,25 Dihydroxy Vitamin D3

Vitamin D3 is increased by P deficiency

Also Vit D3 increased last weeks pregnancy in adequate (high) P diet
Results: production responses

<table>
<thead>
<tr>
<th></th>
<th>Change Maternal LW (kg)</th>
<th>Feed Intake (kg DM /day)</th>
<th>Calf Birth Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High P diet</td>
<td>+37</td>
<td>7.0</td>
<td>32.5</td>
</tr>
<tr>
<td>Low P Diet</td>
<td>-12</td>
<td>5.4</td>
<td>31.4</td>
</tr>
<tr>
<td>s.e.d</td>
<td>6.3</td>
<td>0.21</td>
<td>1.37</td>
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<tr>
<td>P value</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>n.s.</td>
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</tbody>
</table>
Summary: Late Pregnancy

P Deficiency
Hypophosphatemia
Normocalcemia, but significant increase

Increased CTX-1 (bone resorption)
Decreased Osteocalcin (bone deposition)

Suppressed PTH
Increased 1,25 diOH Vitamin D3

So to maintain P homeostasis pregnant heifers
1. mobilise bone
2. activate 1,25diOH Vitamin D3
Results: Phosphorus

![Graph showing PIP (mmol/L) over months from calving]

- **Lactation** and **Wean & P repletion** periods are marked.
- **HH**, **HL**, **LH**, and **LL** categories are represented with different symbols.
- Not full repletion is highlighted in red.

**PIP (mmol/L)**

- **Months from calving**: 0, 1, 2, 3, 4, 5

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**HH**

**HL**

**LH**

**LL**

Not full repletion
Results: Calcium

Ca is increased in P deficiency (LL and HL)
Results: Parathyroid Hormone

PTH is suppressed in P deficiency (LL and HL groups)
Results: CTX-1

Bone resorption

CTX-1 is increased in P deficiency
Major increase in CTX-1 early lactation
Results: Osteocalcin  Bone deposition

OCN is increased in lactation
P supplementation (LH) marked increase
Results: Cortical Bone Thickness

During lactation all diets utilised cortical bone reserves, albeit LL major loss.
Results: 1,25 Dihydroxy Vitamin D3

Vitamin D3 is increased early lactation
Low P diet increased Vit D
Summary

P deficiency in lactation

Is similar to late pregnancy.....
Hypophosphatemia
Increased Calcium
Suppressed PTH

Except....
Substantial increase CTX-1
High maintained Osteocalcin (growing animal)
Further increase 1,25 diOH Vitamin D3
Conclusions

Cows ingesting severely P deficient diets attempt to achieve homeostasis through pronounced bone resorption, together with activation of 1,25diOH Vitamin D3.

Both processes appear to be independent of PTH.

In contrast, homeostasis with adequate dietary P intake appears to be regulated by PTH, in response to blood Ca.

Ongoing work is examining responses in mature cows.
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