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Breeding Herd Education Series

Vitamin D for Sows

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What is Vitamin D?
• "Sunshine" and "Fat-soluble" vitamin
• Functions
  – Ca-P homeostasis, bone mineralization
  – Immune regulation
• Metabolites
  – 7-dehydrocholesterol: Converted to cholecalciferol (Vit D3) in skin under ultraviolet irradiation
  – Cholecalciferol: Found in animal (ergocalciferol: in plant)
  – 25-hydroxyvitamin D (25-OH D): Hydroxylated in liver
  – 1, 25-dihydroxyvitamin D: Hydroxylated in kidney
  – 24, 25-dihydroxyvitamin D: In the breakdown pathway

Introduc;on
Vitamin D Metabolites for Pigs
• Hydroxylated vitamin D metabolites are distributed in pig plasma and tissues (liver, kidney and adipose tissue).
  – 1,25-(OH)2D3: Tissues > Plasma (Stored or active form)
  – 25-OH D3: Tissues < Plasma (Circulating form)
  – 25-OH D1: Lower concentration in animal tissues
• Vitamin D3: 5-7 days of plasma half-life
• 25-OH D3: 20-30 days of plasma half-life
• 1,25-(OH)2D3: 4-8 hours of plasma half life

McDowell, 2000

The Impetus for Current Concern for Vitamin D
• Rising issues for vitamin D status...WHY??
  – Increasing metabolic bone disease and PFTS
  – Low [vitamin D] at birth (Hurst and Littledoe, 1982)?
  – Low [vitamin D] of pigs and sows in confinement housing?

McDowell et al, 2012

Vitamin D Deficiency
• Vitamin D deficiency results in severe bone disease.
• Rickets: A failure in adequate bone mineralization
• Osteomalacia: A demineralization of formed bone
• Osteoporosis: A diminished bone mineral content and mass

Rickets

The children, six years of age, three were rachitic and two were not, the former being in good condition with the normally grown child of the same age in the center.

Osteomalacia

A years case of Adolescent rickets is depicted.
NRC Requirement Estimates for Vitamin D for Swine

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin D, IU/kg</td>
<td>110</td>
<td>110</td>
<td>110</td>
<td>110</td>
<td>110</td>
<td>110</td>
<td>110</td>
<td>110</td>
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<td>110</td>
</tr>
</tbody>
</table>

Strategies for enhancing Vit. D status

- **For sows**
  - Vit. D injection to sow before farrowing (Exp. 1)
  - Vit. D supplementation in maternal diets for gestation and lactation (Exp. 2)
  - Vit. D requirement study (level and sources; Exp. 3)

- **For piglets**
  - Vit. D administration orally or by injection at birth of piglets (Exp. 4 and 5)

- **Vit. D effect under disease conditions (PRRS; Exp. 6)**

Effect of Vitamin D Supplementation to Sows on Its Status for Sows and Offspring

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>Vitamin D Injection</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sows, ng/ml</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>42.07</td>
<td>37.10</td>
<td>0.192</td>
</tr>
<tr>
<td>At farrowing</td>
<td>43.10</td>
<td>58.60</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Change</td>
<td>1.03</td>
<td>21.50</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Piglets, ng/ml</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At birth</td>
<td>4.00</td>
<td>6.15</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>At weaning</td>
<td>9.67</td>
<td>12.05</td>
<td>0.050</td>
</tr>
<tr>
<td>Change</td>
<td>5.67</td>
<td>5.53</td>
<td>0.903</td>
</tr>
</tbody>
</table>

Sources: Kim and Lindemann (2007); NRC (2012)

The Relationship of Vit. D Status between Sows and Piglets

- Intramuscular injection of vitamin D to sows at 20 day pre-partum resulted in the enhancement of its status in sows.
- Vitamin D status of sows is closely correlated to that of neonatal piglets.
- The improvement of maternal vitamin D status could be effective to enhance status of offspring if needed.

Effect of Vitamin D Injection to Sows before Farrowing (Exp. 1)

- A total of 24 sows (Avg. parity: 5.2)
- Vit D3 administration at 2 weeks pre-partum

**Treatments**
- Control: no administration
- 5 ml injection of Vit. D3 (100,000 IU of Vit. D3, 100 IU of Vit. E, and 200,000 IU of Vit. A per ml)

- All sows consumed the same gestation diet supplemented with 2,750 IU/kg of Vit. D3.

**Blood collection**
- Sows: Prior to injection and at farrowing
- Piglets: At birth (2 pigs of each litter) and at weaning (1 of the 2 piglets measured at birth)

Experimental Results

Jang and Lindemann, 2013
Vitamin D3 in Maternal Diets (Exp. 2)

- A total of 84 sows after breeding
- 3 treatments (starting after breeding)
  - 1,500, 3,000, or 6,000 IU/kg of gestation and lactation diets
  - Feed: 2.0 kg/d in gestation, ad libitum access in lactation

Measurements
- Sow
  - Blood on d 0 and 100 in gestation, at farrowing and weaning
  - Milk at farrowing, on d 10 and at weaning (d 21)
- Piglet
  - Blood at birth, on d 10 and at weaning (d 21)

Adapted from Flohr et al., 2013

Vitamin D Status of Sows (Exp. 2)

Effects of Maternal Vit. D3 on Milk and Pig Serum 25(OH)D3 (Exp. 2)

Comparison between Maternal Administration Methods (Exp. 1 vs. Exp. 2)

Vitamin D Dose-Response in Gilts and Sows (Exp. 3; Requirement Study)

- A total of 160 gilts and 160 multiparous sows
- 8 treatments (2 x 4 factorial)
  - Feeding level: 200, 800, 1,400, 2,000 IU/kg Vit. D
  - Vit. D source: Vit. D3 or 25-OH D3
- Measurements
  - Gilts: Blood 25-OH D3 bone characteristics (harvested on d 28 of gestation)
  - Sows: Blood 25-OH D3 reproductive performance

Adapted from Lauridsen et al., 2010
• 25-OH D$_3$ concentrations in plasma of gilts and sows were linearly increased by increasing level of Vit D$_3$.
• 25-OH D$_3$ supplementation was more efficient than Vit D$_3$ to increase its plasma status.

• No significant differences in the number of total born/litter
• But numerically lower number of total born in high doses of Vit D (1,400 and 2,000 IU)

* Higher doses of Vit D supplementation (1,400 or 2,000 IU) decreased still birth compared with lower doses (200 or 800 IU); P<0.05.

* No significant differences on the number of live born/litter

* High dose of Vit D$_3$ supplementation (1,400 or 2,000 IU) had lower litter size at weaning compared with low dose (200 or 800 IU); P<0.05.
Vitamin D Status of Pigs from Birth to Weaning as Administered Orally or by Injection (Exp. 4)

- A total of 32 pigs (Yorkshire × Duroc) from 4 litters (8 pigs/sow).
  - Within each litter, 2 pigs were assigned to each treatment.
  - All sows consumed common gestation and lactation diets supplemented with 880 IU/kg of Vit. D3.

- 4 treatments
  - Control: no administration
  - Oral administration of vitamin D3 (40,000 IU)
  - Oral administration of vitamin A, D3, and E
  - Injectable administration of vitamin A, D3, and E

- Measurements
  - Body weight of sows and piglets
  - Serum 25-OH D3, retinol, α-tocopherol concentration of sows and piglets

Vitamin D Status of Pigs from Birth to Weaning as Administered Orally or by Injection (Exp. 5)

- A total of 45 pigs (Yorkshire × Duroc) from 4 litters of pigs
  - Within each litter, pigs were assigned to 7 treatments
  - All sows consumed common gestation and lactation diets supplemented with 880 IU/kg of Vit. D3.

- 7 treatments
  - Control: no administration
  - Injectable administration of vitamin complex (50,000 IU)
  - 5 of oral administration of vitamin D3 and variable vitamin A and E

- Measurements
  - Body weight of sows and piglets
  - Serum 25-OH D3, retinol, α-tocopherol concentration of sows and piglets

Effect of Vitamin D Administration to Pigs on Serum 25-OH D3 Concentration (Exp. 5)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sow</th>
<th>Control</th>
<th>Oral D3 (1)</th>
<th>Oral D3 (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-OH D3, ng/ml</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth</td>
<td>26.45</td>
<td>4.41</td>
<td>4.67</td>
<td>4.33</td>
</tr>
<tr>
<td>8 wk</td>
<td>86.25*</td>
<td>110.74*</td>
<td>91.43*</td>
<td>86.30*</td>
</tr>
<tr>
<td>Weaning</td>
<td>32.65</td>
<td>5.00*</td>
<td>40.29*</td>
<td>26.50*</td>
</tr>
</tbody>
</table>

* Means without a common superscript differ (P<0.05).

- Piglets receiving Vit. D had significantly higher serum 25-OH D3 concentrations than those in the control.
- The injectable route had the numerical highest serum 25-OH D3 concentrations compared to the oral route.

Jang and Lindemann, 2013
Effect of Vitamin D<sub>3</sub> Administration to Pigs on Growth Performance (Exps. 4 and 5)

### Experimental Results

<table>
<thead>
<tr>
<th>Exp. 4</th>
<th>Oral Vit. D&lt;sub&gt;3&lt;/sub&gt;</th>
<th>Control</th>
<th>Oral Vit. D&lt;sub&gt;3&lt;/sub&gt;</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight, kg</td>
<td>331.3</td>
<td>314.1</td>
<td>330.2</td>
<td>314.2</td>
</tr>
<tr>
<td>d 10</td>
<td>331.3</td>
<td>314.1</td>
<td>330.2</td>
<td>314.2</td>
</tr>
<tr>
<td>Weaning</td>
<td>242.0</td>
<td>242.0</td>
<td>242.0</td>
<td>242.0</td>
</tr>
</tbody>
</table>

No effects on the growth performance of piglets.

### Experimental Results

Effect of Oral Vit. D on Serum 25-OHD under PRRSv Infection (Exp. 6)

**Vitamin D under Disease Conditions (PRRS; Exp. 6)**

- A total of 40 barrows from a herd negative for PRRS
- 4 treatments (2 x 2 factorial)
  - Oral Vit. D (40,000 IU) to piglets at 2 day of age and at weaning
  - Inoculation of PRRSv MN-184 (1 x 10<sup>5</sup> TCID<sub>50</sub>/ml) at weaning
- Measurements
  - Serum 25-OH<sub>D</sub> concentration
  - PRRS ELISA s/p value

**Experimental Results**

Vitamin D Publications in Humans


Reference Range of Serum Vitamin D Concentration (ng/ml) of Pigs

<table>
<thead>
<tr>
<th>Phase of production</th>
<th>Reference range</th>
<th>Jan Inside</th>
<th>June Inside</th>
<th>Outdoor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td>5-15</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10 day old pig</td>
<td>8-23</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2-4 weeks old</td>
<td>25-30</td>
<td>8.4 (2.1-56.2)</td>
<td>13.7 (1.0-63.4)</td>
<td>-</td>
</tr>
<tr>
<td>Grower</td>
<td>30-35</td>
<td>21.8 (3.4-54.1)</td>
<td>18.0 (5.5-50.5)</td>
<td>61.03</td>
</tr>
<tr>
<td>Finisher</td>
<td>30-35</td>
<td>27.6 (1.7-77.9)</td>
<td>28.1 (6.6-68.5)</td>
<td>85.98</td>
</tr>
<tr>
<td>Mature animals</td>
<td>35-70</td>
<td>35.7 (8.6-83.4)</td>
<td>36.3 (4.7-94.5)</td>
<td>-</td>
</tr>
<tr>
<td>Pregnant sows</td>
<td>35-100</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Abbod and Madson, 2012

Low concentration of Vit. D in all groups even though all samples came from herds with no reported clinical history of lameness or metabolic disease.
Conclusion

- Vitamin D₃ supplementation to sows in gestation (either dietary supplementation or injection) can improve 25-OH D₃ status for both sows and their progeny.
- Vitamin D₃ administration to piglets can improve its serum status regardless of administration routes.
  - Injection method is more efficient to enhance vitamin status than oral or dietary administrations.
- Vitamin D administration has potential to boost immune response under disease-challenge conditions.