The effects of maternal dietary supplementation of cholecalciferol (vitamin D₃) in conjunction with 25(OH)D₃ on sow and pig performance

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Introduction

Vitamin D₃

25(OH)D₃

Hy·D®

DSM Nutritional Products, Parsippany, NJ
Kitson and Roberts, 2012

24-hydroxylation

CYP24A1

25-Hydroxyvitamin D

D_{25}

D_{3}

D_{4}

Absorption in small intestine
- Packaging into chylomicrons
- Lymphatic drainage

UV-B radiation
(290-315 nm)

Sun

Epidermis

Pre Vitamin D

DHC7

Liver

CYP27A1

25-Hydroxyvitamin D

CYP2R1

24,25(OH)_{2}D

24,25(OH)_{2}D

1a, 25(OH)_{2}D

1α-hydroxylation

CYP27B1

Bound to DBP

Cell

Adipocytes

K-RXR VDRE

Binding to VDRE

Regulation of gene expression

K-State

Research and Extension

Knowledge for Life
Kitson and Roberts, 2012; Bar et al., 1980

**Non-genomic mechanism**
- Intestinal Ca absorption
- Opening of gated Ca channels
- Ca uptake by osteoblasts
- Ca uptake by muscle fibers
### Metabolites of Vitamin D₃

<table>
<thead>
<tr>
<th>Vitamin D₃ (Cholecalciferol)</th>
<th>1,25(OH)₂D₃ (Calcitriol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Formed in the skin from sunlight</td>
<td>- Formed in the kidney</td>
</tr>
<tr>
<td>- Absorbed in the small intestine from the diet</td>
<td>- Active hormone form</td>
</tr>
<tr>
<td></td>
<td>- Regulate Ca and P levels in the blood</td>
</tr>
<tr>
<td></td>
<td>- Key role during bone mineralization</td>
</tr>
<tr>
<td>25(OH)D₃ (Calcidiol)</td>
<td>- Effects cell differentiation, proliferation, and growth in many tissues</td>
</tr>
<tr>
<td>- Formed in the liver</td>
<td></td>
</tr>
<tr>
<td>- Main circulating form</td>
<td></td>
</tr>
<tr>
<td>- Reflects vitamin D status of the animal</td>
<td></td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>24,25(OH)₂D₃ (24,25-dihydroxyvitamin D₃)</td>
<td></td>
</tr>
<tr>
<td>- Development of bone integrity</td>
<td></td>
</tr>
<tr>
<td>- Healing of bone fractures</td>
<td></td>
</tr>
</tbody>
</table>

Dittmer and Thompson, 2011; Gropper et al., 2004; Seo et al., 1997
## Vitamin D$_3$

### NRC Recommendations

<table>
<thead>
<tr>
<th>Stage</th>
<th>Requirement (IU/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sows</td>
<td>800</td>
</tr>
<tr>
<td>Nursery</td>
<td>220</td>
</tr>
<tr>
<td>Finishing</td>
<td>150</td>
</tr>
</tbody>
</table>
2016 Feeding Regimen Survey

- A survey of current feeding regimens for vitamins and trace minerals in the US swine industry

- Journal of Swine Health and Production
- 18 producers with approximately 40% of US sow herd participated

- Vitamin D survey (IU/kg)
  - Gestation/lactation: 1,762
  - Nursery: 1,744
  - Early/mid finishing: 935
  - Late finishing: 770

Vitamin D controls selected (IU/kg)
- Gestation/Lactation: 1,500
- Nursery: 1,500
- Early/mid finishing: 1,000
- Late finishing: 800

Flohr et al., 2016b
Impacts on Skeletal Muscle

- Increase in muscle fiber number of the LM of d 90 fetuses (Hines et al., 2013) and pigs at birth and weaning (Zhou et al., 2016) when the maternal diet contained 25(OH)D₃
Objective

To determine if feeding a combination of vitamin D₃ (Rovimix D3, 500,000 IU/g; DSM Nutritional Products, Parsippany, NJ) and its more available metabolite, 25(OH)D₃ (Hy-D, DSM Nutritional Products, Parsippany, NJ), influences sow performance, sow and piglet vitamin D₃ status, muscle development of the piglets, and subsequent growth performance.
<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VitaminD₃, IU</td>
<td>Hy-D, µg</td>
<td>VitaminD₃, IU</td>
</tr>
<tr>
<td>Gestation</td>
<td>1500</td>
<td>---</td>
<td>500</td>
</tr>
<tr>
<td>Lactation</td>
<td>1500</td>
<td>---</td>
<td>500</td>
</tr>
<tr>
<td>Nursery 1</td>
<td>1500</td>
<td>---</td>
<td>500</td>
</tr>
<tr>
<td>Nursery 2</td>
<td>1500</td>
<td>---</td>
<td>500</td>
</tr>
<tr>
<td>Total vitamin D₃ activity, IU</td>
<td>1500</td>
<td>1500</td>
<td>3500</td>
</tr>
<tr>
<td>Finisher 1</td>
<td>1000</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Finisher 2</td>
<td>1000</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Total vitamin D₃ activity, IU</td>
<td>1000</td>
<td>1000</td>
<td>2000</td>
</tr>
<tr>
<td>Finisher 3</td>
<td>800</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Total vitamin D₃ activity, IU</td>
<td>800</td>
<td>800</td>
<td>1600</td>
</tr>
</tbody>
</table>
## Litter Characteristics

<table>
<thead>
<tr>
<th>Litter characteristics</th>
<th>Diet</th>
<th>SEM</th>
<th>Probability, P &lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total born, n</td>
<td>1,500 IU D₃</td>
<td>500 IU D₃ + 25 μg 25(OH)D₃</td>
<td>1,500 IU D₃ + 50 μg 25(OH)D₃</td>
</tr>
<tr>
<td>Born alive, %</td>
<td>17.28</td>
<td>16.73</td>
<td>17.86</td>
</tr>
<tr>
<td>Stillborn, %</td>
<td>87.80</td>
<td>92.13</td>
<td>89.67</td>
</tr>
<tr>
<td>Mummies, %</td>
<td>9.53</td>
<td>6.93</td>
<td>9.42</td>
</tr>
<tr>
<td>Standardized liter size, n</td>
<td>14.00</td>
<td>13.83</td>
<td>13.96</td>
</tr>
<tr>
<td>Weaning liter size, n</td>
<td>13.00</td>
<td>13.09</td>
<td>13.00</td>
</tr>
<tr>
<td>Survivability, %</td>
<td>93.08</td>
<td>95.07</td>
<td>93.57</td>
</tr>
</tbody>
</table>
Immunohistochemistry
Birth
Immunohistochemistry
Weaning
Primary Muscle Fiber Number
Birth

\[ P = 0.007 \]
\[ SEM = 22,206 \]

\begin{align*}
&1,500 \text{ IU D}_3 \quad 96,957^b \\
&500 \text{ IU D}_3 + 25 \mu g 25(\text{OH})\text{D}_3 \quad 111,124^b \\
&1,500 \text{ IU D}_3 + 50 \mu g 25(\text{OH})\text{D}_3 \quad 174,054^a
\end{align*}

\text{abMeans with different superscripts differ (}P < 0.05\text{)}
Secondary Muscle Fiber Number

Birth

\[ \begin{align*}
1,749,488 & \quad 1,882,926 \\
1,694,981 &
\end{align*} \]

\( P > 0.05 \)

\( \text{SEM} = 169,975 \)

\( ab \)Means with different superscripts differ \((P < 0.05)\)
Piglet Serum 25(OH)D$_3$

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Birth</th>
<th>Weaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,500 IU D3</td>
<td>2.0$^{bx}$</td>
<td>4.7$^{by}$</td>
</tr>
<tr>
<td>500 IU D3 + 25 μg 25(OH)D3</td>
<td>3.6$^{cy}$</td>
<td>7.6$^{ay}$</td>
</tr>
<tr>
<td>1,500 IU D3 + 50 μg 25(OH)D3</td>
<td>2.1$^{abx}$</td>
<td></td>
</tr>
</tbody>
</table>

Trt × Time, $P < 0.001$
Trt, $P < 0.001$
Time, $P < 0.001$

SEM = 0.27

Indicates an effect of time within treatment ($P < 0.05$)
Indicates an effect of treatment at that time point ($P < 0.05$)
Pig Serum 25(OH)D₃

Trt × Time, $P < 0.001$
Trt, $P < 0.001$
Time, $P < 0.001$
SEM = 1.76

1,500 IU D3 500 IU D3 + 25 μg 25(OH)D3 1,500 IU D3 + 50 μg 25(OH)D3

16.6cx 36.4bx 17.8cx

61.3ax 30.0by 17.8cx

53.4ay

xyz Indicates an effect of time within treatment ($P < 0.05$)
abc Indicates an effect of treatment at that time point ($P < 0.05$)
Colostrum/Milk 25(OH)D$_3$

- 1,500 IU D3
- 500 IU D3 + 25 μg 25(OH)D3
- 1,500 IU D3 + 50 μg 25(OH)D3

Trt × Time, $P = 0.518$
Trt, $P < 0.001$
Time, $P = 0.001$
SEM = 0.09

Indicates an effect of time within treatment ($P < 0.05$)
Indicates an effect of treatment at that time point ($P < 0.05$)
Discussion

- No effect on sow and litter performance due to vitamin D

- Primary muscle fiber number in piglets at birth from sows fed 1,500 IU D₃ + 50 μg 25(OH)D₃ compared to others
  - longer prenatal period of primary myogenesis which delayed the onset of secondary myogenesis
Discussion

- Milk concentrations of $25(\text{OH})D_3$ above the colostrum $25(\text{OH})D_3$
  - $25(\text{OH})D_3$ concentrations consumed by the piglets contributed to the increase in progeny vitamin $D_3$ status from birth to weaning
Conclusion

- Combining vitamin D₃ + 25(OH)D₃ in the maternal diet:
  - Improves vitamin D₃ status of the dam and progeny
  - Increases primary muscle fibers at birth
  - Does not change growth performance to market

- To our knowledge, this is the first study investigating the effect of improving maternal vitamin D status on serum 24,25(OH)₂D₃ of the piglets
Implications

- Feeding combinations of vitamin D₃ and 25(OH)D₃ may eliminate the practice of orally dosing newborn piglets and could potentially improve carcass characteristics