The Role of Vitamin D in the Antioxidant Status of Pigs

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Swine Nutrition & Health
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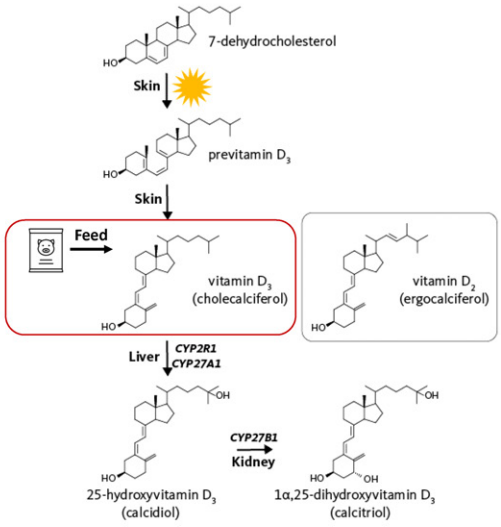
Chemical Structures of Vitamin D



- One of the fat-soluble vitamins / Secosteroid hormones
- Synthesized in skin via UV-B exposure / Ingested through diet
- Vitamin D_3 (cholecalciferol): animal-derived or UV-synthesized
- Vitamin D_2 (ergocalciferol): plant/fungal-derived

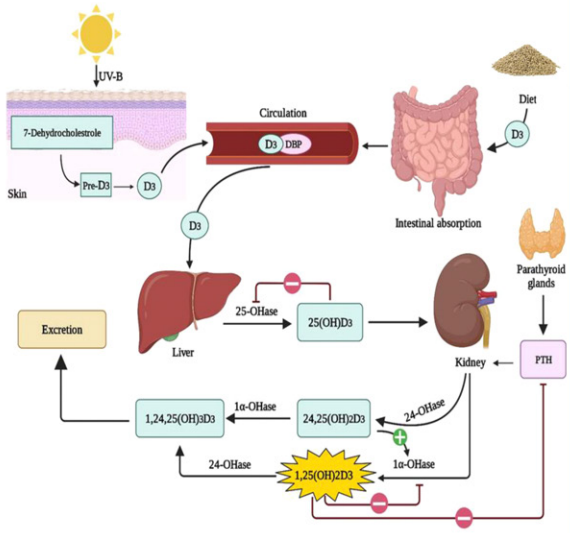
Vitamin D in the body

Intestinal Absorption

- Micelle formation
- Packaged into chylomicrons
- Transported in blood (vitamin D binding protein)

Activation

- Two-step hydroxylation in liver and kidney
- Liver: Vitamin D -> 25-OHD_3
- Kidney: 25-OHD_3 -> 1,25$(OH)_2D_3$



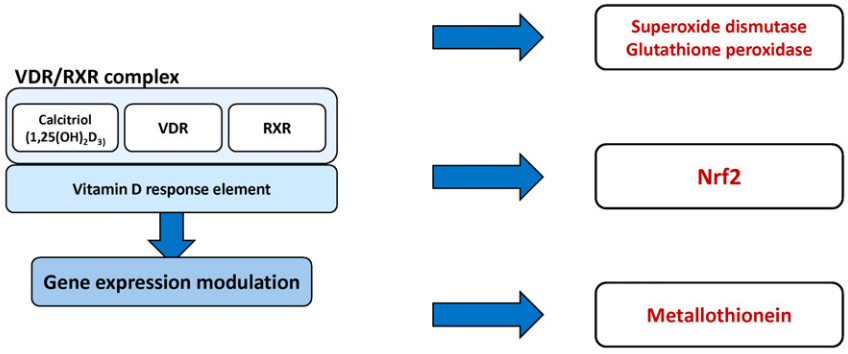
Function of Vitamin D in animal body

- Intestinal Ca/P absorption
- Osteoblast activity -> bone mineralization

- ↓ Pro-inflammatory cytokines
- ↑ Antimicrobial peptides

- ↑ Antioxidant enzyme expressions
- ↓ Oxidative stress marker

Antioxidant potential of Vitamin D



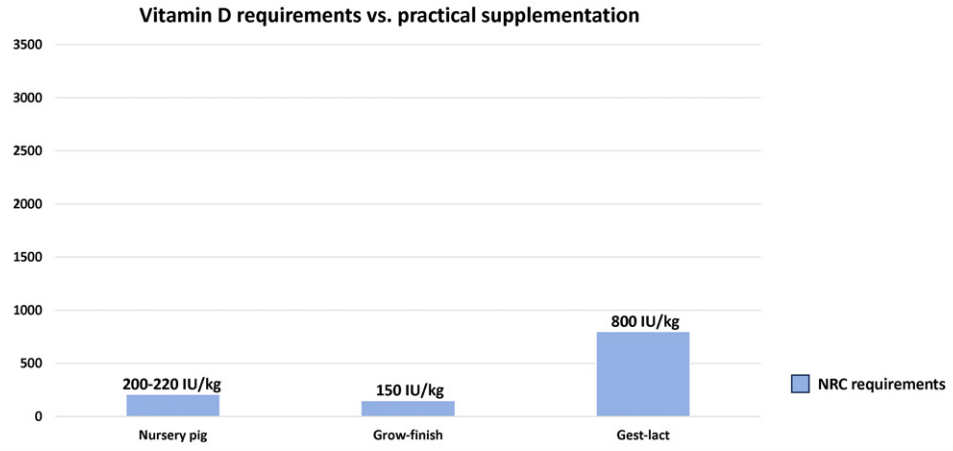
Antioxidant potential of Vitamin D

Superoxide dismutase Glutathione peroxidase	• Remove ROS directly • Decrease lipid peroxidation
Nrf2	• Binds antioxidant response element • Promoting antioxidant system
Metallothionein	• Vitamin D receptor directly binds on metallothionein gene receptor • Directly neutralizes hydroxyl radicals

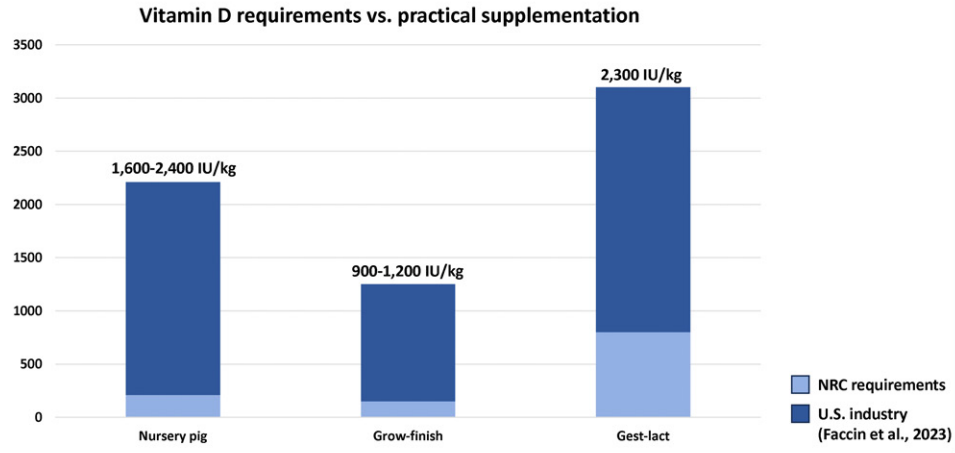
Improve antioxidant status

- ↑ Glutathione
- ↑ Glutathione peroxidase
- ↑ Superoxide dismutase
- ↑ Total antioxidant capacity
- ↓ Reactive oxygen species
- ↓ Malondialdehyde

The use of Vitamin D in swine diets



The use of Vitamin D in swine diets



Objectives

To evaluate the effects of dietary VD_3 supplementation on blood **vitamin D status** and **antioxidant capacity** in weaning pigs.

Vitamin D in nursery pigs

Study 1

- 40 newly weaned pigs (6.02 kg; 17.2 d of age)
- 5 replicates with 4 pigs per pen
- Treatments:
  1. NRC-VD_3: 220 (Phase 1) and 200 (Phase 2) IU/kg of VD_3
  2. High-VD_3: 2,000 IU/kg of VD_3 for both Phase 1 and Phase 2

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Effects of dietary vitamin D_3 supplementation on growth performance, blood vitamin D status, and antioxidant capacity in weaning pigs

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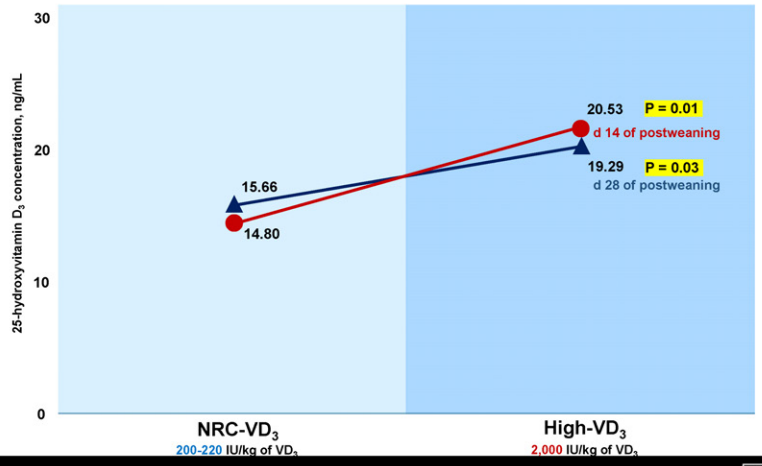
Objective: This study evaluated the effects of dietary vitamin D_3 (VD_3) supplementation on growth performance, blood vitamin D_3 and antioxidant status in weaning pigs.
Methods: Forty newly weaned piglets (6.02±1.17 kg) were assigned to two treatments with five replicates over a 28-d period. Treatments were 1) NRC-VD_3; NRC recommended levels (220 IU/kg in Phase 1 [d 0–14 postweaning] and 200 IU/kg in Phase 2 [d 14–28 postweaning]), and 2) High-VD_3; a high level of VD_3 (2,000 IU/kg in Phase 1 and 2). Body weight, average daily gain, average daily feed intake, and gain-to-feed ratio were measured weekly. Blood samples were collected at d 14 and 28 postweaning for the analyses of plasma 25-hydroxycholecalciferol (25-OHD_3), total antioxidant capacity (T-AOC), superoxide dismutase (SOD) activity, and malondialdehyde (MDA) levels. Pearson correlation coefficients between plasma 25-OHD_3 and SOD, MDA, or T-AOC were determined.
Results: Growth performance did not differ in overall nursery period although feed intake was lower in the High-VD_3 group than the NRC-VD_3 group in d 14–28 postweaning ($p<0.05$). Pigs fed High-VD_3 diets showed greater plasma 25-OHD_3 at d 14 and 28 postweaning ($p<0.05$), tended to have reduced plasma MDA ($p = 0.06$), and increased plasma SOD activity ($p = 0.10$) at d 14 postweaning compared with those fed NRC-VD_3 diets with no effect in plasma T-AOC. At d 14 postweaning, plasma 25-OHD_3 was positively correlated with plasma SOD activity ($r = 0.532$; $p<0.05$) and tended to be negatively correlated with plasma MDA levels ($r = -0.491$; $p = 0.06$).
Conclusion: High VD_3 supplementation at 2,000 IU/kg did not enhance growth performance, while improving plasma vitamin D and antioxidant status in weaning pigs compared to NRC-level supplementation. Therefore, supplementing weaning pigs with higher-than-recommended levels of VD_3 could be beneficial to enhance their antioxidant status and overall health.

Keywords: Antioxidant Status; Growth Performance; Oxidative Stress; Vitamin D_3; Weaning Pig

High-VD_3 increased plasma 25-OHD_3 levels



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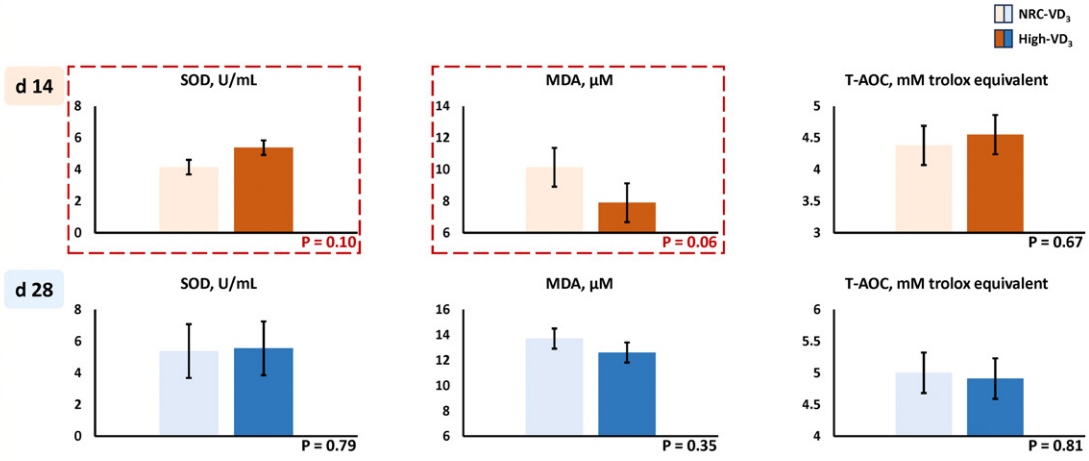
High-VD_3 increased SOD activity and decreased MDA levels



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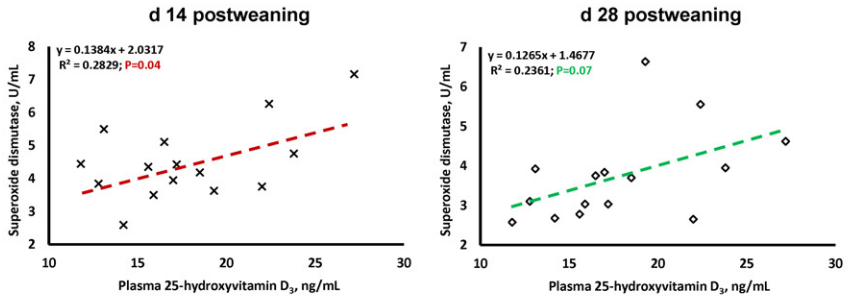
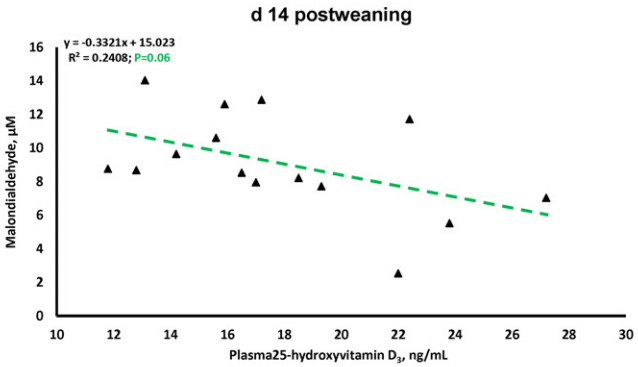
SOD activity is positively correlated with vitamin D status



Plasma 25-OHD$_3$ levels are correlated with SOD activity in nursery pigs

MDA level is negatively correlated with vitamin D status



Plasma 25-OHD$_3$ levels are negatively correlated with MDA concentrations

Vitamin D_3

- NRC levels vs. 2,000 IU/kg VD_3 supplementation
  - ↑ Plasma 25-OHD_3 levels
  - ↑ Antioxidant status & ↓ oxidative stress
- Recommend exceeding VD_3 supplementation over NRC requirements for health benefits

Plasma 25-OHD_3 levels were correlated with SOD activity and MDA levels

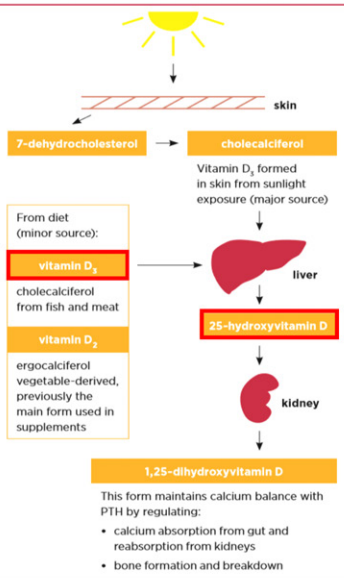
↓

What if we could elevate plasma 25-OHD_3 levels further?

25-OHD_3

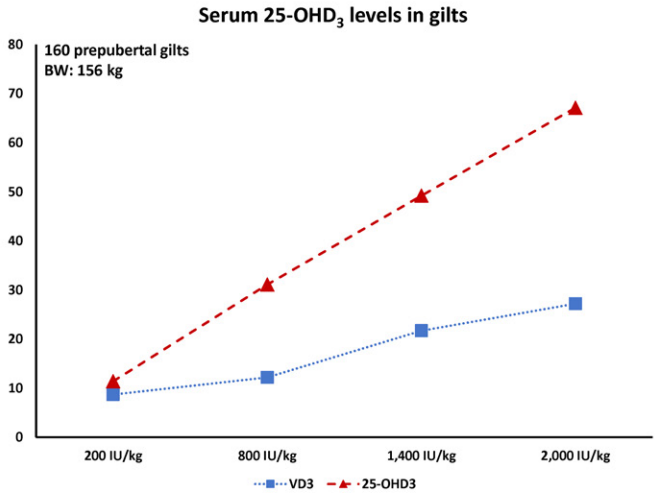
Metabolized form of VD_3

- Major circulating form of Vitamin D
- Hydroxylated in the liver after absorption
- Bypass the metabolic process of VD_3 in liver



VD_3 vs. 25-OHD_3

$25\text{-}OHD_3$ supplementation can further increase blood $25\text{-}OHD_3$ levels compared with VD_3



(Burild et al., 2016)

Objectives

To evaluate the effects of dietary $25\text{-}OHD_3$ on blood vitamin D status and antioxidant capacity in weaned pigs

25-OHD$_3$ in nursery pigs

Study 2

- 48 newly weaned pigs (5.27 kg; 18.7 d of age)
- 4 replicates with 4 pigs per pen
- Treatments:
  1. VD$_3$ 2,000 IU/kg
  2. 25-OHD$_3$ 1,000 IU/kg
  3. 25-OHD$_3$ 2,000 IU/kg

Study 3

- 60 newly weaned pigs (5.63 kg; 17.9 d of age)
- 5 replicates with 4 pigs per pen
- Treatments:
  1. VD$_3$ 2,000 IU/kg
  2. VD$_3$ 1,000 IU/kg + 25-OHD$_3$ 1,000 IU/kg
  3. 25-OHD$_3$ 2,000 IU/kg

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Effects of dietary 25-hydroxycholecalciferol supplementation on growth performance, blood vitamin D and antioxidant status in nursery pigs

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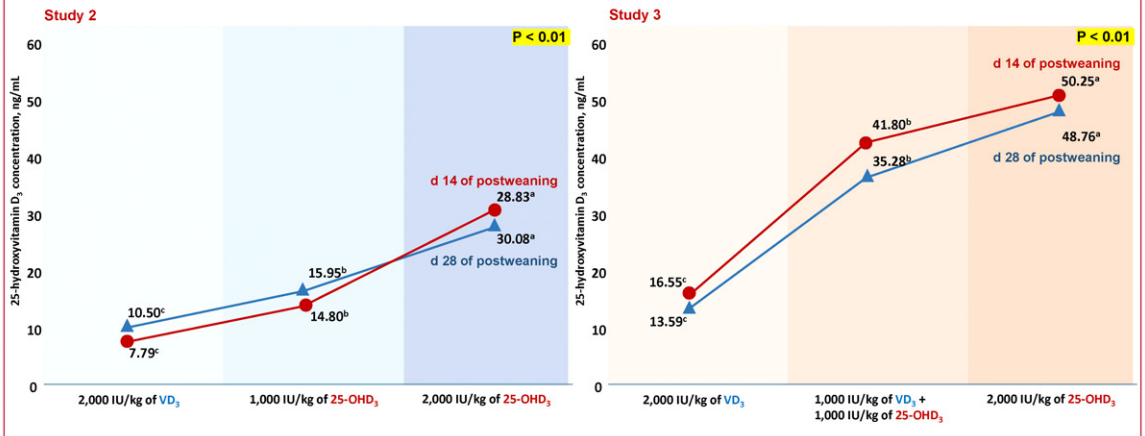
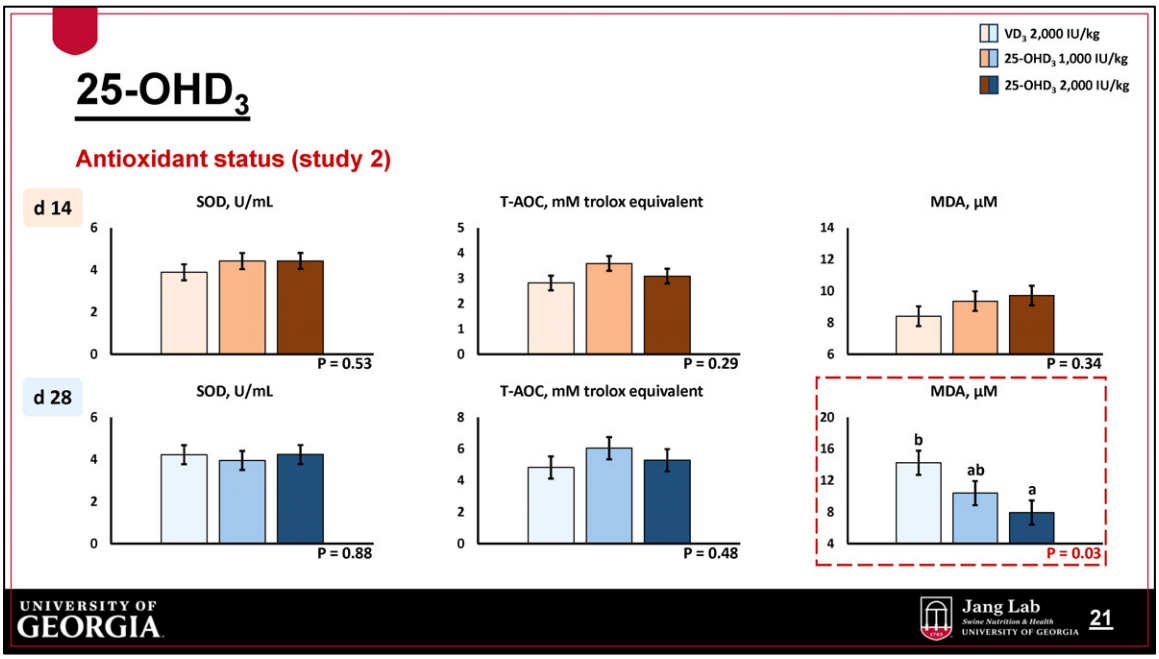
animals
MDPI
Article

Effects of Dietary 25-Hydroxycholecalciferol Alone or in Combination with Vitamin D$_3$ on Growth Performance, Blood Vitamin D Status, Immune Response, Bone Integrity, and Antioxidant Capacity of Nursery Pigs

Chan Ho Kwon [1], Eva S. Safaie [1], Jannell A. Torres [1], Zhaohui Yang [2], Xi Chen [2], Pengcheng Xue [2] and Young Dal Jang [1,*]

25-OHD$_3$




VD3 2,000 IU/kg
25-OHD3 1,000 IU/kg
25-OHD3 2,000 IU/kg
25-OHD3
Antioxidant status (study 2)
d 14
SOD, U/mL
P = 0.53
T-AOC, mM trolox equivalent
P = 0.29
MDA, µM
P = 0.34
d 28
SOD, U/mL
P = 0.88
T-AOC, mM trolox equivalent
P = 0.48
MDA, µM
b
ab
a
P = 0.03
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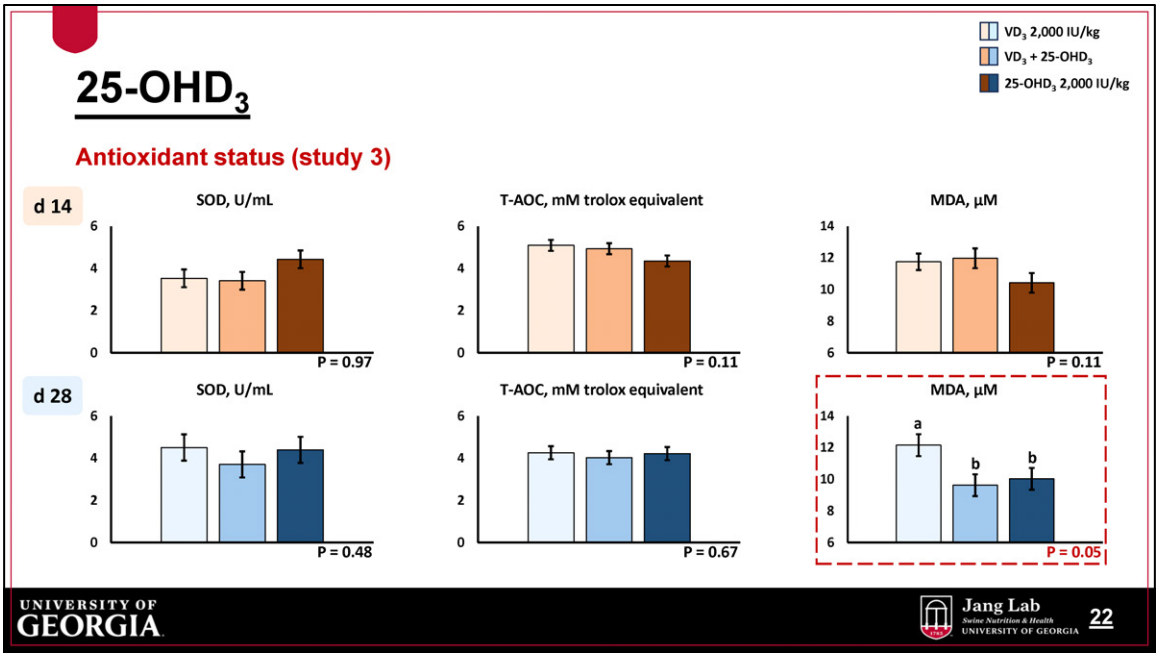
VD3 2,000 IU/kg
VD3 + 25-OHD3
25-OHD3 2,000 IU/kg
25-OHD3
Antioxidant status (study 3)
d 14
SOD, U/mL
P = 0.97
T-AOC, mM trolox equivalent
P = 0.11
MDA, µM
P = 0.11
d 28
SOD, U/mL
P = 0.48
T-AOC, mM trolox equivalent
P = 0.67
MDA, µM
a
b
b
P = 0.05
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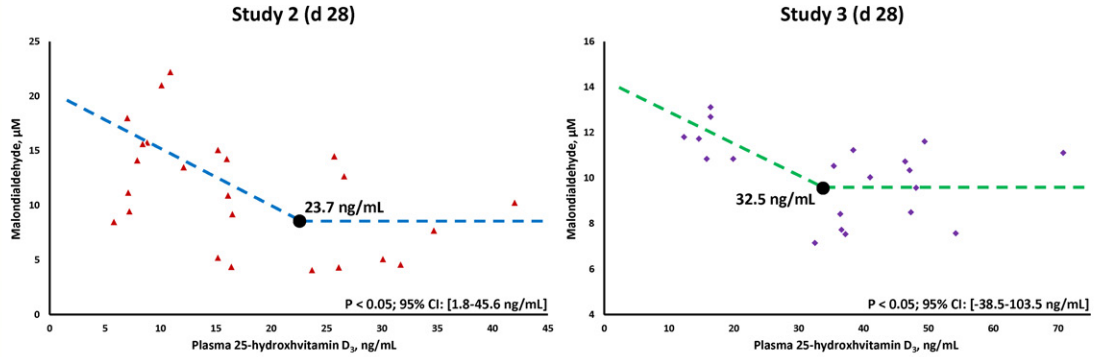
25-OHD$_3$

The plasma MDA level was minimized when plasma 25-OHD$_3$ levels reached 23.7 (study 1) and 32.5 (study 2) ng/mL at d 28 postweaning

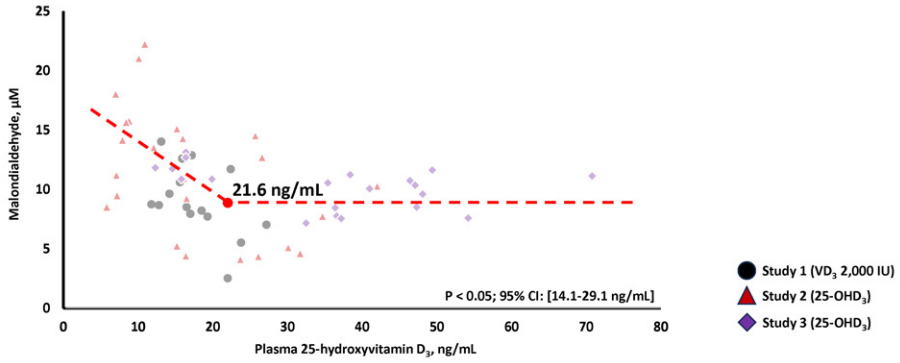
Broken-line analysis



Overall

Based on our studies, we concluded that 21.6 ng/mL is the minimum plasma 25-OHD$_3$ level to minimize MDA concentrations

Broken-line analysis



25-OHD_3

- 25-OHD_3 supplementation vs. VD_3 supplementation
  - ↑ Plasma 25-OHD_3 levels
  - ↑ Antioxidant status and ↓ oxidative stress
- Increase in plasma 25-OHD_3 levels by 25-OHD_3 supplementation further reduce oxidative stress

Plasma 25-OHD_3 levels were correlated with MDA levels

↓

What about 25-OHD_3 supplementation in sow diets?

Objectives

To evaluate the effects of dietary 25-OHD_3 supplementation during late gestation and lactation on vitamin D status, milk composition, antioxidant capacity, and immune responses in sows and their progeny during the suckling period.

25-OHD$_3$ in sow diets

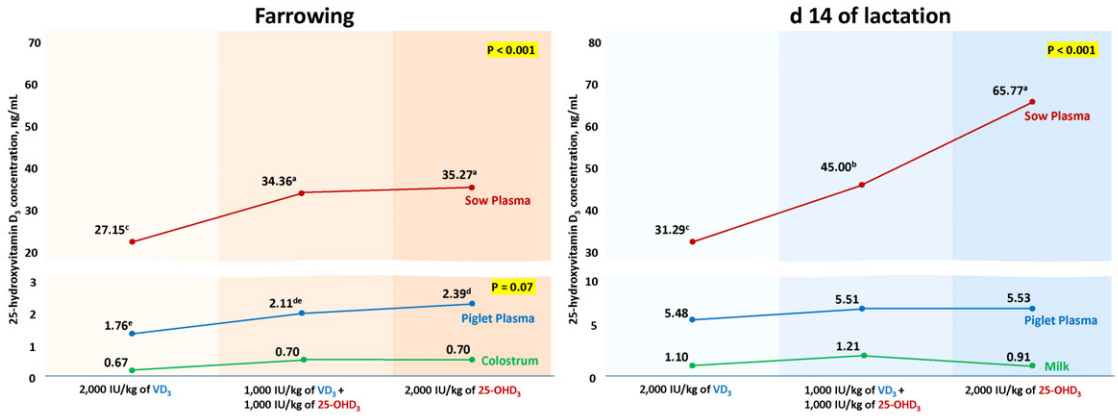
Study 4

- 30 sows in d 105-108 of gestation
- 3 treatments with 10 replicates each
- Same diets were fed in late gestation and lactation periods
- Blood and milk samples were collected
- Treatments:
  1. VD$_3$ 2,000 IU/kg
  2. VD3 2,000 IU/kg + 25-OHD$_3$ 1,000 IU/kg
  3. 25-OHD$_3$ 2,000 IU/kg

Sample analysis

- Vitamin D status (plasma and milk)
- Milk compositions
- Antioxidant parameters (plasma and milk)
  - Superoxide dismutase
  - Total antioxidant capacity
  - Malondialdehyde
- Immunoglobulin G (plasma and milk)

25-OHD$_3$ in sow diets




VD3 2,000 IU/kg
VD3 + 25-OHD3
25-OHD3 2,000 IU/kg
25-OHD3 in sow diets
Superoxide dismutase, U/mL
Farrowing
Sow
P = 0.045
Colostrum
P = 0.06
Piglet
P = 0.99
d 14 of lactation
Sow
P = 0.40
Milk
P = 0.19
Piglet
P = 0.87
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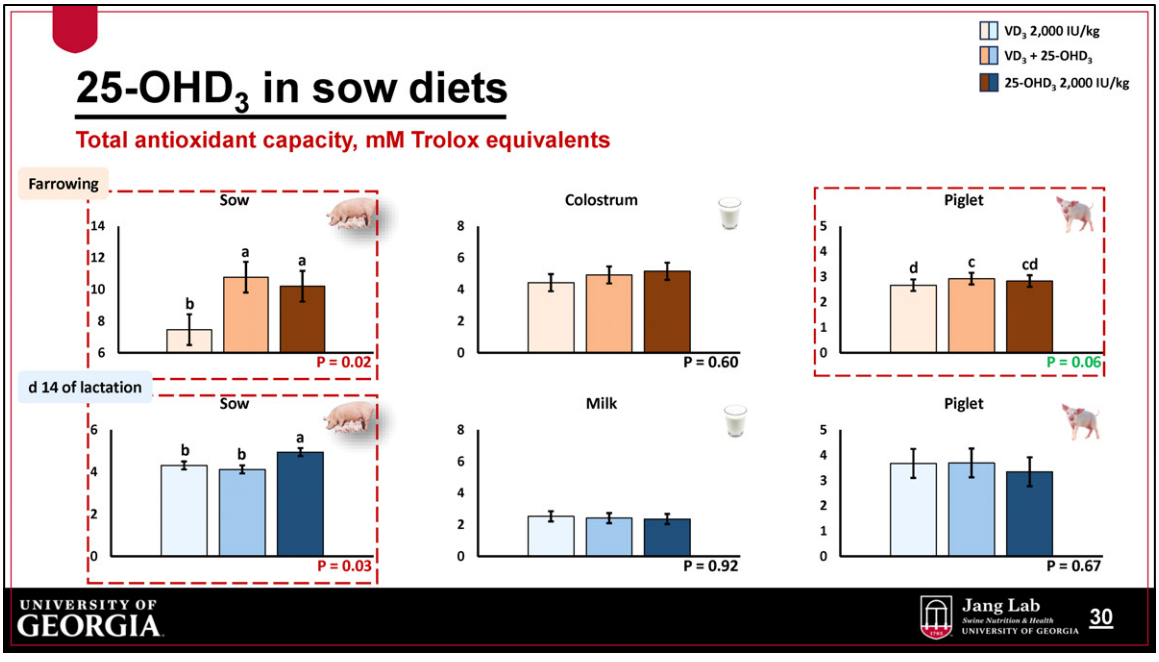
VD3 2,000 IU/kg
VD3 + 25-OHD3
25-OHD3 2,000 IU/kg
25-OHD3 in sow diets
Total antioxidant capacity, mM Trolox equivalents
Farrowing
Sow
P = 0.02
Colostrum
P = 0.60
Piglet
P = 0.06
d 14 of lactation
Sow
P = 0.03
Milk
P = 0.92
Piglet
P = 0.67
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VD3 2,000 IU/kg
VD3 + 25-OHD3
25-OHD3 2,000 IU/kg
25-OHD3 in sow diets
Malondialdehyde, μM
Farrowing
Sow
P = 0.39
Colostrum
P = 0.96
Piglet
c
d
c
P = 0.09
d 14 of lactation
Sow
P = 0.88
Milk
P = 0.55
Piglet
P = 0.67
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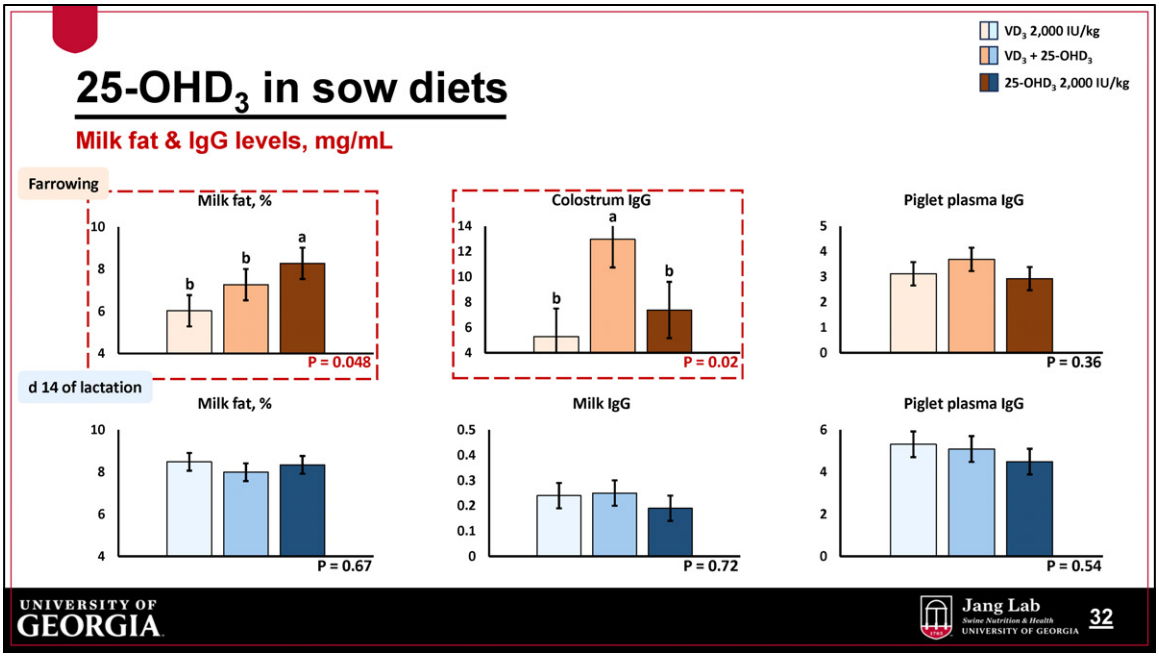
VD3 2,000 IU/kg
VD3 + 25-OHD3
25-OHD3 2,000 IU/kg
25-OHD3 in sow diets
Milk fat & IgG levels, mg/mL
Farrowing
Milk fat, %
b
b
a
P = 0.048
Colostrum IgG
b
a
b
P = 0.02
Piglet plasma IgG
P = 0.36
d 14 of lactation
Milk fat, %
P = 0.67
Milk IgG
P = 0.72
Piglet plasma IgG
P = 0.54
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추가했습니다

25-OHD$_3$ in sow diets

- 25-OHD$_3$ supplementation vs. VD$_3$ supplementation in sow diets
  - ↑ Plasma 25-OHD$_3$ levels in sows and their progeny
  - ↑ Antioxidant status in sows
  - ↓ Oxidative stress in piglets
  - ↑ Colostrum fat and IgG contents

25-OHD$_3$ improved the health status of sows and milk

↓

Their progeny also improved their early health

Summary

Nursery pig

- High-VD$_3$ supplementation: ↑ Vitamin D status ↑ Antioxidant status
- 25-OHD$_3$ supplementation: ↑ Vitamin D status ↑ Antioxidant status
- Vitamin D status and oxidative stress are negatively correlated

Sow

- 2,000 IU/kg of 25-OHD$_3$ supplementation enhanced…
  - ➢ Vitamin D status, superoxide dismutase, total antioxidant capacity, milk fat contents, and colostrum IgG levels

Suckling pig

- 25-OHD$_3$ supplementation in sow diets…
  - ➢ Increased vitamin D status and antioxidant capacity
  - ➢ Decreased oxidative stress

Take home messages

High vitamin D_3 can increase vitamin D status and antioxidant capacity, while 25-OHD_3 is more efficient

In nursery pigs, vitamin D requirement should be determined based on plasma 25-OHD_3 levels

The use of vitamin D_3 may be insufficient for enhanced vitamin D status compared to 25-OHD_3

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Jannell Torres (M.S.)
Madison Mejia (Undergraduate student)
Shelby Greer (Undergraduate student)

Devenish LLC
Edward Yang (PhD)
Allen Xue (PhD)
Xixi Chen (PhD)
Kristy Dorton (PhD)