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Not so micro: Vitamins and Mycotoxins Impact on Production

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Vitamins

Sara Hough, DVM

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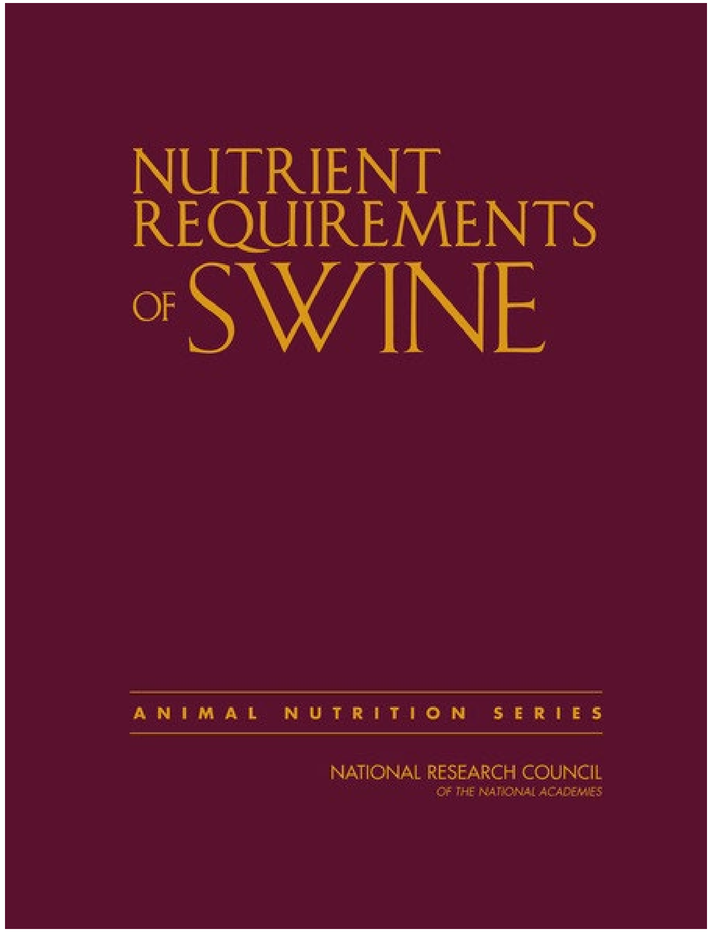
Vitamins are essential

- Do we feed NRC levels?
- Why do they need to be supplemented?



Vitamins and Minerals-
Micro-nutrients with macro-responsibilities

100% necessary for metabolic functions!

Functions of Vitamins & Deficiency Symptoms

Vitamin	Basic function(s)	Deficiency disorders/diseases
Vitamin A	Retinal pigments, epithelial cell differentiation, gene transcription	blindness, xerophthalmia, keratomalacia, impaired growth
Vitamin D	Intestinal Ca absorption, bone Ca mobilization, renal Ca resorption, regulation of PTH secretion, possible function in muscle	Rickets, Osteomalacia
Vitamin E	antioxidant protector for membranes	nerve, muscle degeneration
Vitamin K	Clotting factors and their Ca-binding proteins	impaired blood clotting
Vitamin B_1	coenzyme for various energy metabolism enzymes	Beriberi, polyneuritis, Wernicke-Korsakoff syndrome
Vitamin B_2	coenzyme for numerous flavoproteins that catalyze redox reactions in fatty acid synthesis/degradation, TCA cycle	dermatitis
Vitamin B_6	coenzyme for amino acid metabolism	symptoms vary by species
Vitamin B_{12}	coenzyme for conversion of methylmalonyl-CoA to succinyl-CoA, methyl group transfer from 5-CH3-FH4 to homocysteine in methionine synthesis	megaloblastic anemia, impaired growth
Pantothenic Acid	co-substrate for activation/transfer of acyl groups to form esters, amides, citrate, triglycerides, etc.	symptoms vary by species
Niacin	co-substrate for many dehydrogenases, e.g. TCA cycle respiratory chain	Pellagra
Folic Acid	coenzyme for transfer of single-carbon units	megaloblastic anemia
Biotin	coenzyme for carboxylations	dermatitis, cracked hooves
Choline	component of acetylcholine and the membrane structural component phosphatidylcholine	Perosis (deformity of leg bones in young birds), fatty liver
Vitamin C	co-substrate for hydroxylations in collagen synthesis, steroid metabolism	Scurvy

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Non Ruminant Nutrition

OXFORD

AMERICAN SOCIETY OF ANIMAL SCIENCE

Industry survey of added vitamins and trace minerals in U.S. swine diets

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Table 9. Added vitamin and trace mineral concentrations in gestation diets

	Count, N [1]	Weighted average[2]	Average	Ratio to NRC	Standard deviation	Low	25%	Median	75%	High
Vitamins										
A, IU/kg	36	10,511	9,646	2.41	1,549	5,511	8,821	9,920	10,856	12,472
D, IU/kg	36	2,276	2,367	2.96	805.9	1,500	1,733	2,204	2,537	4,499
E, IU/kg	35	95.5	84.4	1.92	22.9	44.1	66.1	79.4	94.5	132.3
K, mg/kg	36	3.87	3.96	7.92	2.10	1.41	3.00	3.75	4.42	14.5
Thiamin, mg/kg	28	2.57	2.74	2.74	1.94	0.25	2.04	2.21	3.00	9.92
Riboflavin, mg/kg	36	9.01	8.58	2.29	1.26	5.51	7.88	8.27	9.92	10.8
Niacin, mg/kg	36	44.9	45.3	4.53	9.34	22.0	39.9	44.1	49.6	82.7
Pantothenic acid, mg/kg	36	31.8	29.8	2.49	5.47	20.0	26.4	28.1	33.0	45.2
Pyridoxine, mg/kg	36	4.08	3.11	3.11	1.65	0.25	1.98	3.31	4.00	8.17
B_{12}, µg/kg	36	37.9	36.5	2.44	5.70	20.0	33.1	37.4	39.7	55.1
Biotin, mg/kg	36	0.37	0.29	1.43	0.10	0.09	0.22	0.25	0.33	0.65
Folic acid, mg/kg	35	2.65	2.11	1.62	1.32	0.88	1.32	1.74	2.21	8.27
Choline, mg/kg	33	533.3	576.3	0.46	115.3	300.0	515.0	584.3	661.2	778.4
★ C,[3] mg/kg	1	209.5	209.5	–	–	–	–	–	–	–
Trace minerals										
Copper, mg/kg	36	16.6	17.6	1.76	2.83	11.6	15.0	16.5	20.0	25.0
			43.4	1.74	9.57	20.0	35.3	50.0	50.0	60.0
			0.30	2.00	0.01	0.27	0.30	0.30	0.30	0.30
			127.8	1.28	34.9	60.0	111.9	125.0	125.2	302.0
			0.52	3.73	0.26	0.23	0.35	0.50	0.63	1.26
			109.7	1.37	20.5	45.0	100.0	105.0	118.5	165.0
			0.19	–	0.03	0.08	0.20	0.20	0.20	0.20
			0.39	–	–	–	–	–	–	–
Carnitine, mg/kg	1	19.8	19.8	–	–	–	–	–	–	–

Chad…or whatever his Polynesian name is?

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Stability

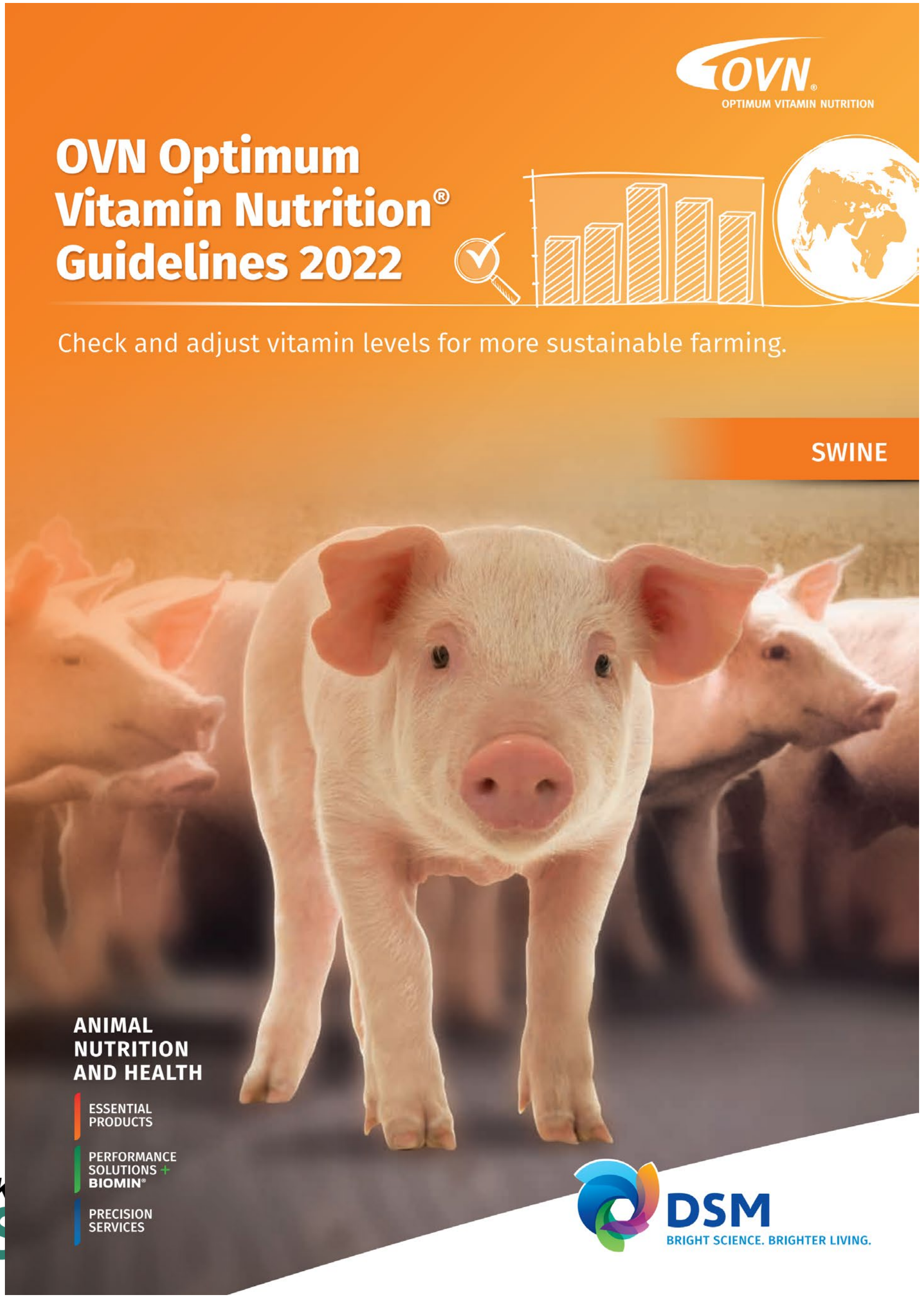
Table 1. Susceptibility of vitamins to factors affecting stability

Vitamin	Abbreviation	Temperature	Humidity	Light	Oxygen	Acid pH	Alkaline pH
Vitamin A	A	Very sensitive	Sensitive	Very sensitive	Very sensitive	Sensitive	Stable
Vitamin D	D	Sensitive	Sensitive	Sensitive	Very sensitive	Sensitive	Stable
Vitamin E	E	Stable	Stable	Sensitive	Sensitive	Sensitive	Sensitive
Vitamin K	K	Sensitive	Very sensitive	Stable	Sensitive	Very sensitive	Stable
Riboflavin	B_2	Stable	Sensitive	Sensitive	Stable	Stable	Stable
Niacin	B_3	Stable	Stable	Stable	Stable	Stable	Stable
Pantothenic acid	B_5	Sensitive	Sensitive	Stable	Stable	Stable	Stable
Vitamin B_{12}	B_{12}	Very sensitive	Sensitive	Sensitive	Sensitive	Stable	Stable
Pyridoxine	B_6	Very sensitive	Sensitive	Sensitive	Stable	Sensitive	Stable
Biotin	H	Sensitive	Stable	Stable	Stable	Stable	Stable
Folic acid	B_c	Very sensitive	Sensitive	Very sensitive	Stable	Very sensitive	Stable

Adapted from DSM Vitamin Nutrition Compendium and Shurson et al. (2011).

Considerations:

- Choline Chloride
- Inorganic Trace Minerals
- Processing
- Storage


OVN
OPTIMUM VITAMIN NUTRITION
OVN Optimum Vitamin Nutrition® Guidelines 2022
Check and adjust vitamin levels for more sustainable farming.
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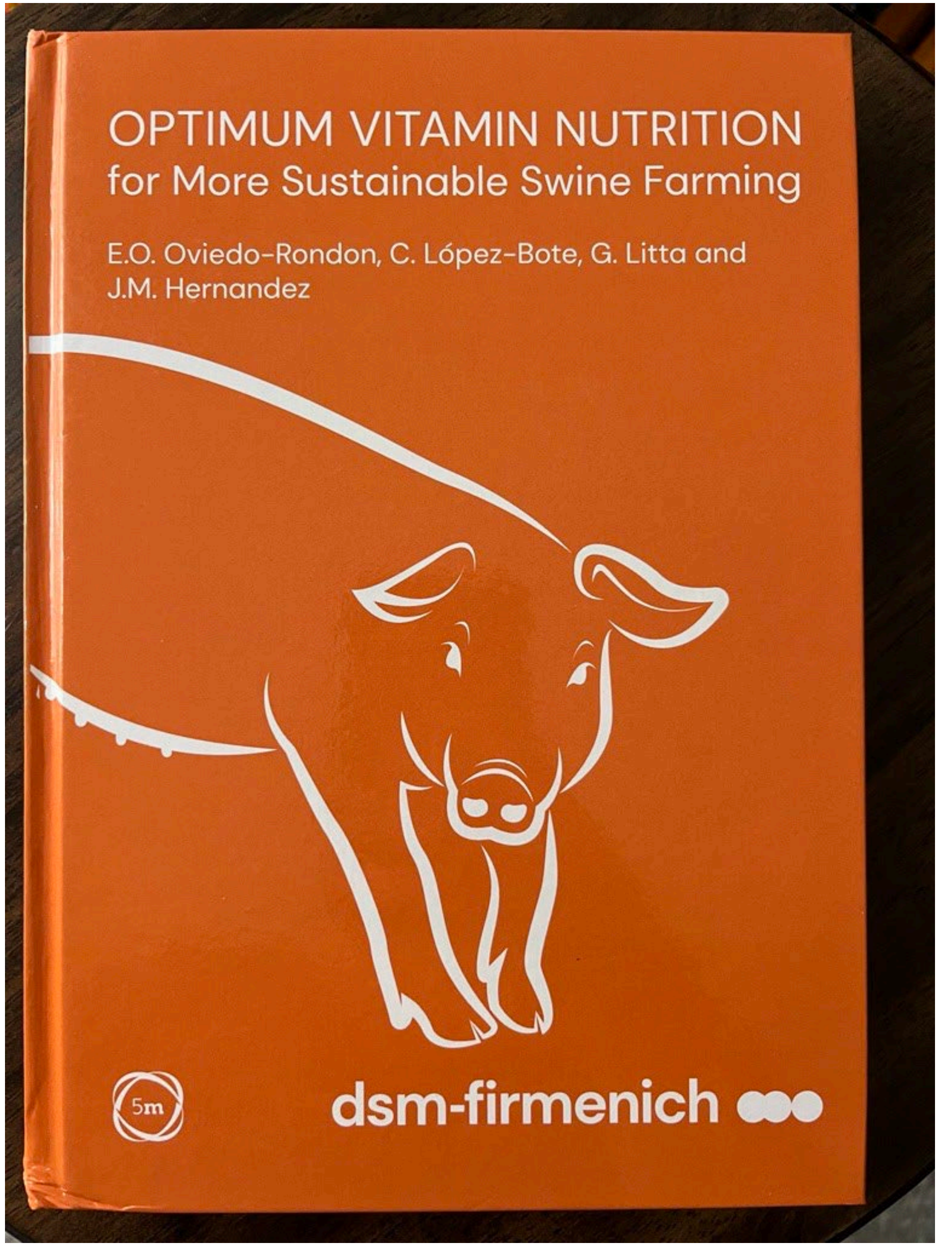
OPTIMUM VITAMIN NUTRITION
for More Sustainable Swine Farming
E.O. Oviedo-Rondon, C. López-Bote, G. Litta and J.M. Hernandez
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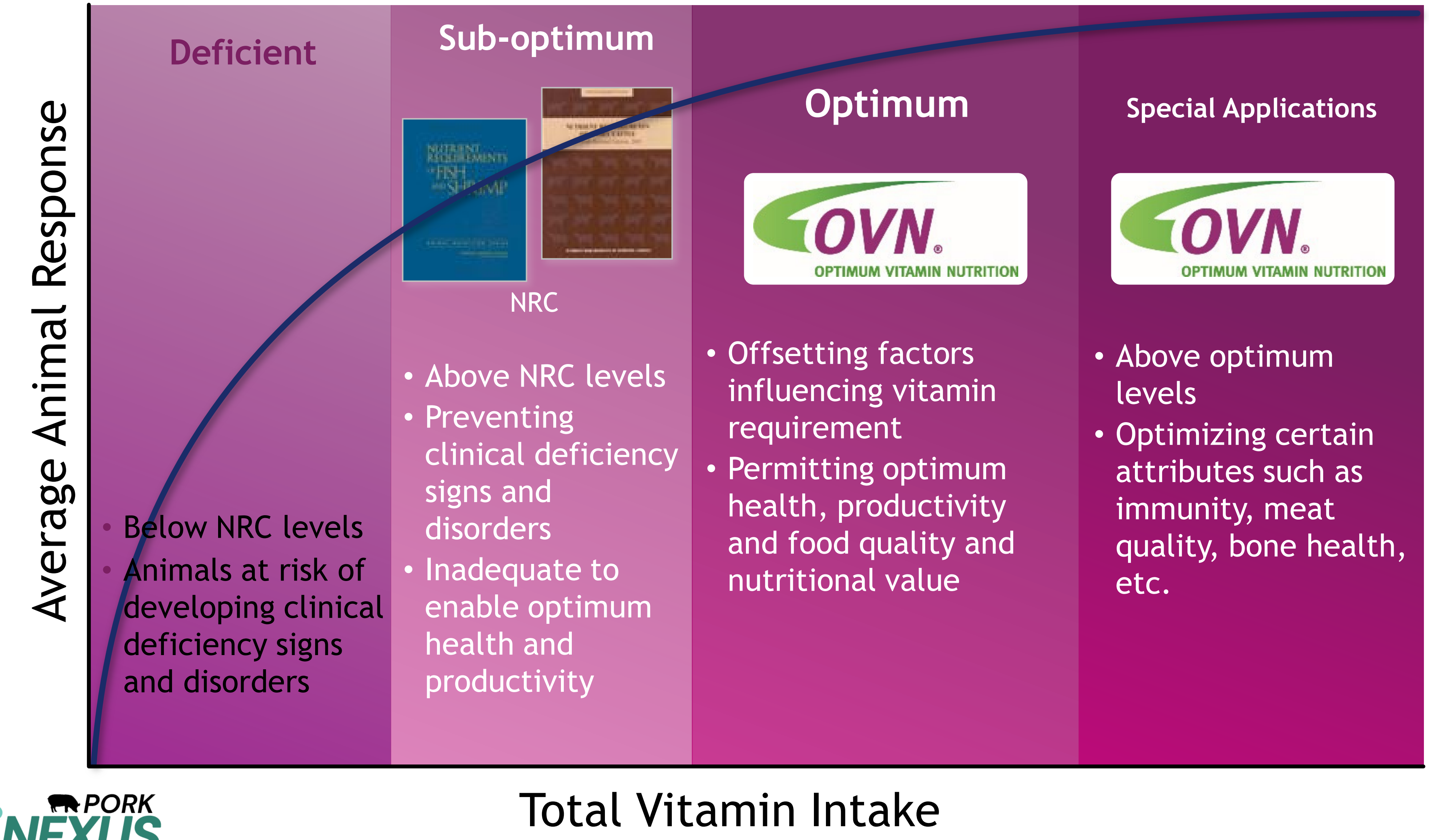
Optimum Vitamin Nutrition (OVN®)



Optimum Vitamin Nutrition® (OVN) Guidelines

SWINE[1]

OVN Optimum Vitamin Nutrition®

Category/phase	Duration	Vitamin A	Vitamin D_3	25OHD$_3$ (Hy-D)	Vitamin E[2]	Vitamin K	Vitamin B_1	Vitamin B_2	Vitamin B_6	Vitamin B_{12}[6]	Niacin	Biotin	d-Pantothenic acid	Folic acid	Vitamin C[7]	Choline	β-carotene
UNITS		IU	IU	mg	mg	mg	mg	mg	mg	mg	mg	mg	mg	mg	mg	mg	mg
Fattening pigs																	
Pre-starter	< 5 kg	10,500 – 22,500	1,890 – 2,100	0,05	105 – 160[3]	8.5 – 11	3.8 – 5.8	10.5 – 16	6.4 – 8.4	0.052 – 0.072	63 – 84	0.32 – 0.52	32 – 52	1.6 – 3.3	210 – 260	525 – 420	-
Starter	5 – 30 kg	10,500 – 16,000	1,890 – 2,100	0,05	105 – 160[3]	5.2 – 6.4	3.2 – 5.2	10.5 – 16	6.4 – 8.4	0.042 – 0.062	38 – 58	0.32 – 0.52	26 – 46	1.6 – 2.6	105 – 210	260 – 420	-
Grower	30 – 70 kg	7,350 – 10,500	1,570 – 2,100	0,05	64 – 105[4]	2.1 – 4.2	2.1 – 3.1	7.3 – 10.5	2.6 – 4.7	0.032 – 0.052	21 – 50	0.2 – 0.4	26 – 47	1.1 – 1.16	-	157 – 315	-
Finisher	70 kg to market	5,250 – 8,400	1,050 – 1,570	0,05	64 – 105[4]	2.1 – 4.2	1.1 – 2.1	6.3 – 10.5	2.1 – 3.7	0.032 – 0.052	21 – 42	0.105 – 0.21	26 – 47	0.52 – 1.05	-	105 – 210	-
Breeders																	
Replacement gilts	-	10,500 – 13,100	1,900 – 2,100	0,05	84 – 105	2.5 – 4.4	1.05 – 2.2	6.3 – 10.5	5.3 – 8.4	0.032 – 0.052	30 – 50	0.32 – 0.52	16 – 33	3.7 – 5.7	210 – 315	270 – 525	-
Sows	Gestation	10,500 – 15,700	1,570 – 2,100	0,05	105 – 160[5]	4.7 – 5.2	2.1 – 2.6	6.3 – 10.5	3.7 – 5.7	0.032 – 0.052	32 – 47	0.52 – 0.84	37 – 42	3.7 – 5.7	210 – 315	525 – 840	-
	Lactation	10,500 – 15,700	1,570 – 2,100	0,05	105 – 190[5]	4.7 – 5.2	2.1 – 3	6.3 – 10.5	3.7 – 5.7	0.032 – 0.052	40 – 100	0.52 – 0.84	37 – 42	3.7 – 5.7	210 – 315	525 – 840	300[8]
Boars	-	10,500 – 15,700	1,570 – 2,100	0,05	105 – 160	4.7 – 5.2	1.05 – 2.2	6.3 – 10.5	3.7 – 5.7	0.032 – 0.052	32 – 47	0.52 – 0.84	21 – 33	3.7 – 5.7	210 – 525	525 – 840	-

[1] Added per kg air-dried feed. Local limits need to be observed. OVN® levels are ranges for consideration, depending on several factors, such as husbandry conditions and health status.
[2] When dietary fat is higher than 3% then add 5 mg/kg feed for each 1% dietary fat
[3] For optimum immune function increase level up to 250 mg/kg
[4] For optimum meat quality increase level up to 250 mg/kg for 90 to 120 days before slaughter
[5] For optimum piglet health increase level up to 250 mg/kg during late pregnancy and lactation
[6] Use upper level as reference for animal protein free diets and when cobalt is supplemented at very low levels or removed
[7] Recommended under heat stress condition and to enhance reproductive performance in breeders. Use ROVIMIX® STAY-C35 for reducing loss during feed processing
[8] For improved sow fertility the suggested level must be fed **per animal per day** immediately after weaning until confirmed conception

OVN website: https://www.dsm.com/anh/products-and-services/tools/ovn.html#swine

Swine OVN brochure: https://dsm-animal-nutrition-health.scaura.com/s/ba6b13d4

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Optimum Vitamin Nutrition® vs Genetic Supplier Recommendations

Nutrient	Gilts/Sows					
	NRC, 2012	Topigs		PIC	DNA	OVN
		Min	Max			
Vitamin A, IU/kg	***4,000 Gestation 2,000 Lactaction***	***10,000***	***12,000***	***9,920***	***8,950***	***10,000 – 15,000***
Vitamin D_3, IU/kg	800	1,800	2,000	1,985	1,650	1,500 – 2,000
Vitamin E, IU/kg	44	80	150	66	88	100 – 150
Vitamin K, mg/kg	0.5	2	4.5	4.4	4.4	4.5 – 5.0

Vitamin fortification of the sows’ diets

Hinson et al. (2022, JSHAP)

T1: US **Industry** vitamin levels

T2: **Reduced** vitamin levels: A, D, E and K at NRC requirements for gestation and water-soluble at approximately half the inclusion rate of the industry

Vitamin levels of gestation and lactation sow feed

	Gestation		Lactation	
	Industry	Reduced	Industry	Reduced
Total vitamin content				
Vitamin A, IU/kg	11,332	4173	11,316	4156
Vitamin D, IU/kg	2213	794	2213	794
Vitamin E, IU/kg	75.6	56.2	74.4	51.9
Vitamin K, mg/kg	1.4	0.51	1.4	0.51
Riboflavin, mg/kg	8.0	3.7	8.2	4.0
Niacin, mg/kg	66.0	37.7	65.4	37.1
Pantothenic acid, mg/kg	30.4	15.3	31.4	16.2
Biotin, mg/kg	0.53	0.25	0.56	0.27
Vitamin B_{12}, µg/kg	30.9	11.0	30.9	11.0
Vitamin B_6, mg/kg	6.17	6.01	7.16	7.01
Thiamin, mg/kg	3.43	3.28	3.34	3.19
Folic acid, mg/kg	1.9	0.89	2.1	1.0
Choline, mg/kg	1526	1528	1765	1766

T1: US **Industry** vitamin levels

T2: **Reduced** vitamin levels: A, D, E and K at NRC requirements

Vitamin levels of nursery diets fed to weaned pigs for 40 days

Diet: Feed budget:	Phase 1 0.91 kg/pig		Phase 2 1.81 kg/pig		Phase 3 3.63 kg/pig		Phase 4 until week 6	
	Industry	Reduced	Industry	Reduced	Industry	Reduced	Industry	Reduced
Total vitamin content								
Vitamin A, IU/kg	11,462	2553	11,222	2313	11,226	2315	4134	1881
Vitamin D, IU/kg	2800	220	2800	220	2800	220	946	201
Vitamin E, IU/kg	135.6	19.3	137.0	20.7	137.1	20.8	32.4	16.7
Vitamin K, mg/kg	1.25	0.50	1.25	0.50	1.25	0.50	0.51	0.50
Riboflavin, mg/kg	8.2	2.0	8.3	2.1	8.2	2.1	6.0	2.5
Niacin, mg/kg	102.4	20.5	107.0	25.0	106.7	24.8	53.4	26.5
Pantothenic acid, mg/kg	61.0	10.3	62.7	12.0	62.5	11.8	26.8	11.8
Biotin, mg/kg	0.08	0.08	0.11	0.11	0.11	0.11	0.11	0.11
Vitamin B_{12}, µg/kg	33.1	2.2	33.1	2.2	33.1	2.2	22.0	4.4
Vitamin B_6, mg/kg	7.3	4.1	10.0	6.8	10.1	6.9	7.1	7.1
Thiamin, mg/kg	5.0	2.8	6.3	4.0	6.2	4.0	4.0	4.0
Folic acid, mg/kg	0.85	0.37	1.04	0.56	1.04	0.56	0.54	0.52
Choline, mg/kg	1286	1287	1427	1427	1392	1392	1316	1316

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Source: Hinson et al., 2022

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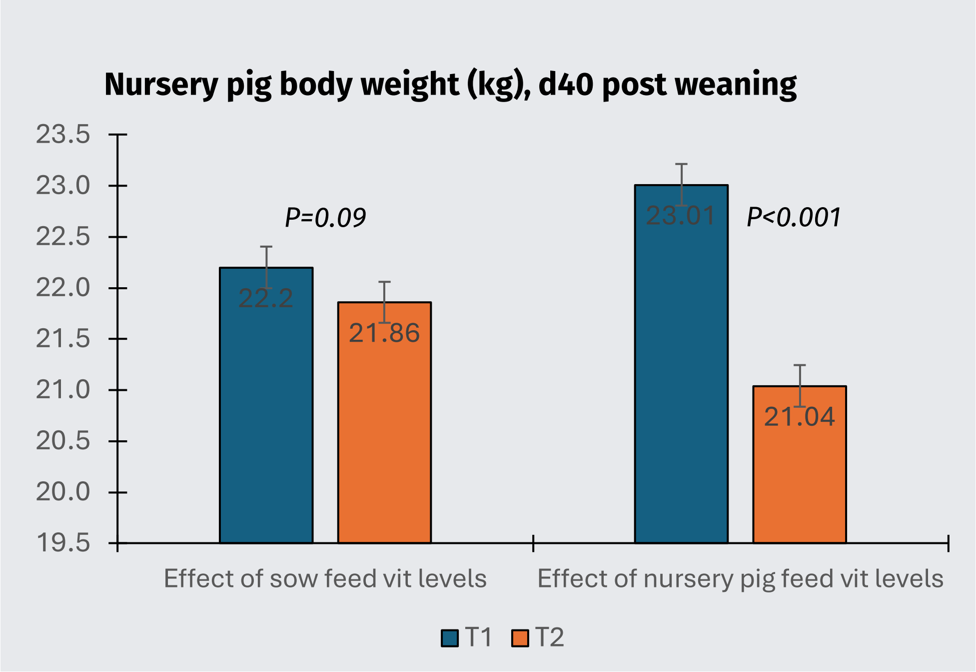
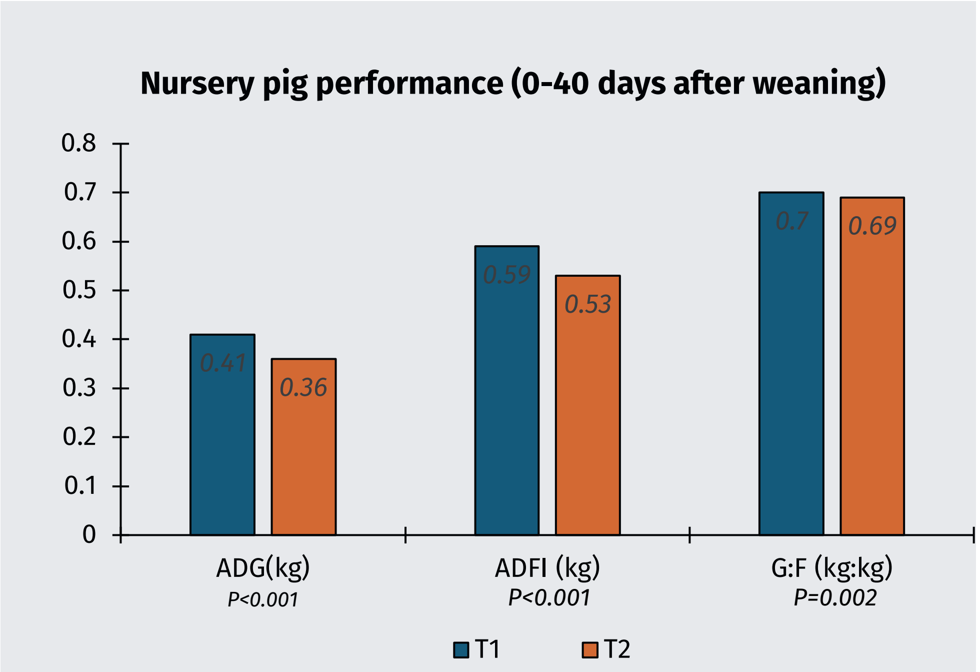
Vitamin fortification of the sows' diets
Hinson et al. (2022, JSHAP)

Reduced Vitamin supplementation in sows (gestation and lactation) and nursery pigs resulted in significantly lower nursery pig performance





T1: US industry vitamin levels
T2: Reduced vitamin levels:

Source: Hinson et al., 2022

Vitamin fortification of the sows' diets
Estimated ROI based on *Hinson et al. (2022, JSHAP)*

The use of a higher vitamin levels provided a ROI of >6:1 when compared to a reduced vitamin supplementation in sow and nursery feed

ROI VITAMIN LEVEL / PIGLET WEIGHT		Sow Feed	
pig price, $/kg BW:	**1.52**	**Reduced Vit**	**Industry Vit**
D 0 Body Weight, kg		6.33	6.43
D 40 Body Weight, kg		21.86	22.20
G:F		0.69	0.70
Per Pig			
Total gain, kg		15.53	15.77
Value of gain, $		23.60	23.97
Net value (deducting vitamin cost), $		23.46	23.78
"ROI" of Industry Vitamins vs. reduced levels		**>6:1**	

CONCLUSION
Reducing vitamin levels with the aim of saving feed costs may jeopardize animal performance, potentially increasing meat production cost and ultimately reduce farmers´ profit

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Source: Hinson et al., 2022

T1: US industry vitamin levels
T2: Reduced vitamin levels:

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Commercial Experiment – Winter 2020-2021

"Effects of varying strategies of dietary micronutrient supplementation additive on nursery pig performance and serum vitamin levels"*

- A total of 1,056 pigs (average initial BW = 14.3 lb) were initially used in a growth study with the experimental treatments below, 22 pigs per pen and 12 replicate pens per treatment. Serial blood samples from 2 pigs/pen – d 1, 21, and 42.

	Control	+Vitamin E +Se	+ Vitamin A +25(OH)D_3 + Vitamin E + Vitamin C
Vitamin A, IU/kg	10,410	10,410	22,420
Vitamin D_3, IU/kg	550	550	550
25(OH)D_3, µg/kg	44	44	55
Vitamin E, IU/kg	70	195	295
Vitamin C, mg/kg	250	250	298
Se, mg/kg	0.30	0.45	0.30

First week (P1) only

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*System experiencing severe PRRSv symptoms and effects on health and performance.

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Commercial Experiment – Winter 2020-2021

	Control	E, Se	A, HyD, E, C		SEM	*P* ≤
Overall, D 0 to 42						
ADG, lb	0.53	0.53	*0.59*		0.025	0.139
ADFI, lb	0.82	0.84	0.88		0.028	0.414
F/G	1.56[ab]	1.60[a]	*1.50[ab]*		0.029	0.007
Final BW, lb	41.1	41.9	*42.6*		0.82	0.373
Recorded Injections, %	61.4	62.5	*54.2*		5.05	0.184
Removals (Dead+Cull), %	27.4	30.5	*21.4*		≤3.02	0.056

	Control	E, Se	A, HyD, E, C		SEM	*P* ≤
Economics, $						
Revenue/pen	477.12	460.80	*530.76*		26.98	0.152
Feed (+ water) cost/pen	137.91	138.69	148.62		4.04	0.042
Feed cost/lb of gain	0.48	0.50	*0.37*		0.054	0.222
MOFC/PEN at the end	339.21	322.11	*382.14*		23.20	0.183
MOFC/PIG at the end	20.90	20.93	*22.00*		0.62	0.392

Vitamins and Immunity

Langel *et al. Vet Res* (2019) 50:101
https://doi.org/10.1186/s13567-019-0719-y

VETERINARY RESEARCH

RESEARCH ARTICLE Open Access

Oral vitamin A supplementation of porcine epidemic diarrhea virus infected gilts enhances IgA and lactogenic immune protection of nursing piglets

Stephanie N. Langel[1], Francine Chimelo Paim[1], Moyasar A. Alhamo[1], Kelly M. Lager[2], Anastasia N. Vlasova[1*] and Linda J. Saif[1*]

Vitamins and Immunity

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RESEARCH ARTICLE

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and Linda J. Saif[1*]

Journal of Dairy Research (2017) **84** 8–13. *© Proprietors of Journal of Dairy Research 2016* 8
doi:10.1017/S0022029916000650

High concentration of vitamin E supplementation in sow diet during the last week of gestation and lactation affects the immunological variables and antioxidative parameters in piglets

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Vitamins and Immunity

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Veterinary Immunology and Immunopathology

journal homepage: www.elsevier.com/locate/vetimm

Research paper

Modulation of weanling pig cellular immunity in response to diet supplementation with 25-hydroxyvitamin D_3

Jeffrey D. Konowalchuk [a], Aja M. Rieger [a], Moira D. Kiemele [b], Diana C. Ayres [b], Daniel R. Barreda [a,b,*]

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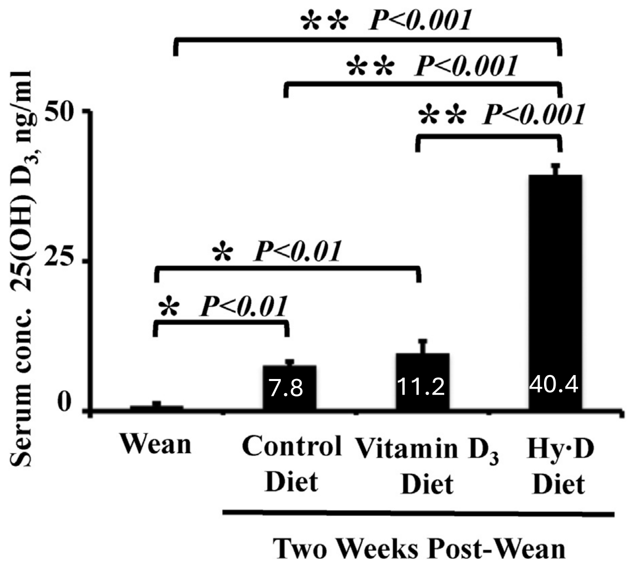


Immunity

and stressors – SINS – ear & tail necrosis, pathogens, mortalities

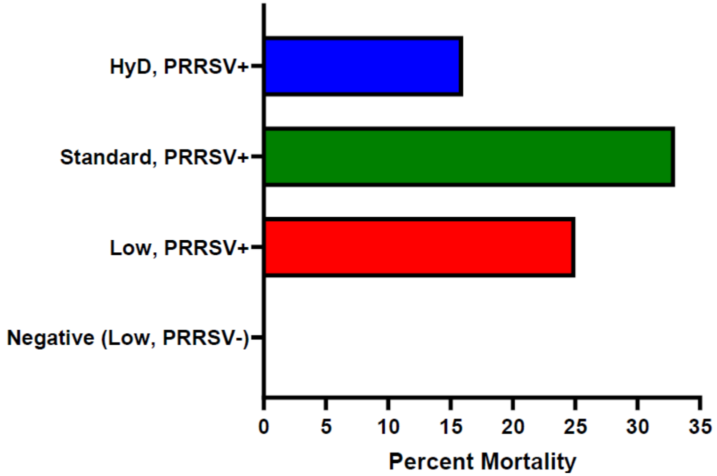
Effects of Dietary Vitamin D Levels on PRRSv Disease Outcomes in Nursery Pigs – preliminary data

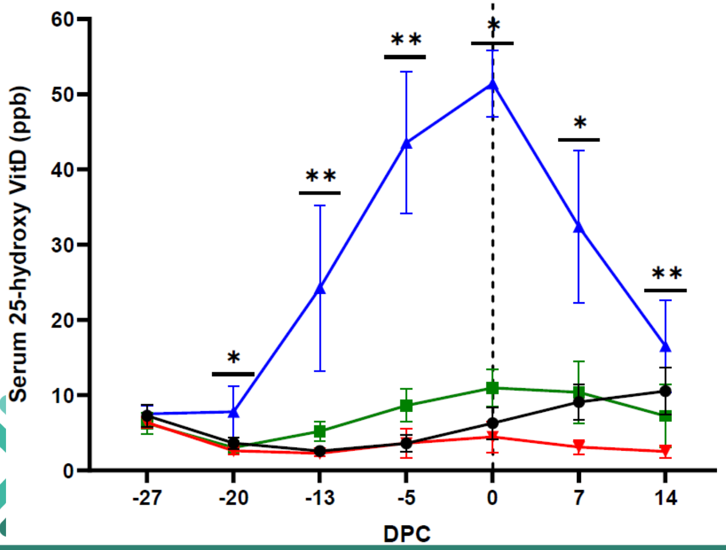
NC STATE UNIVERSITY - Dr. Rahe Lab

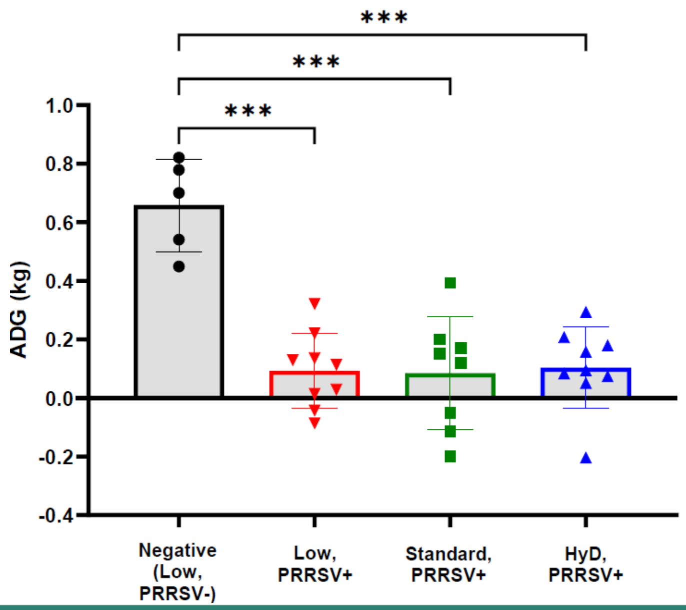
Keen et al., (2024) Unpublished

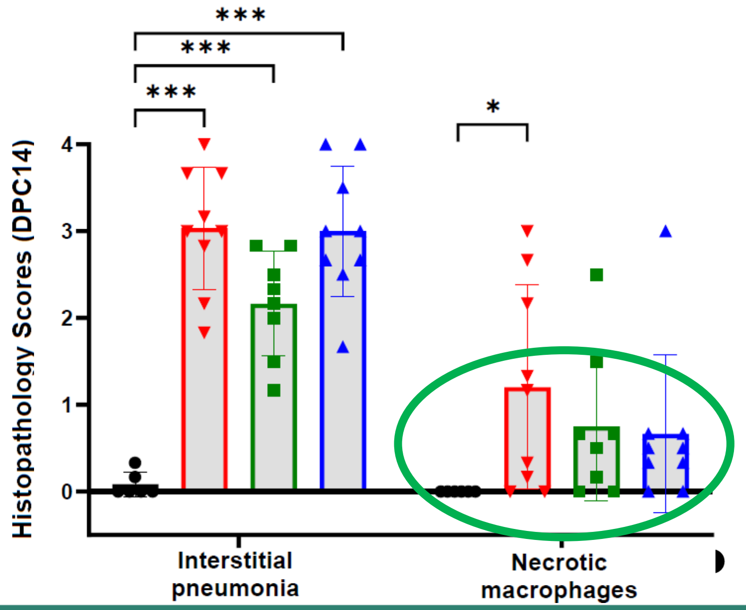
Treatment	Diet	PRRSV challenge
Negative (n=6)	Marginal (200IU/kg VD_3)	No
Low (n=12)	Marginal	Yes
Standard (n=12)	Industry (1,500IU/kg VD_3)	Yes
HyD (n=12)	Industry + HyD supplementation (3,500IU/kg total VD_3)	Yes

Negative (Low, PRRSV-)
Low, PRRSV+
Standard, PRRSV+
HyD, PRRSV+

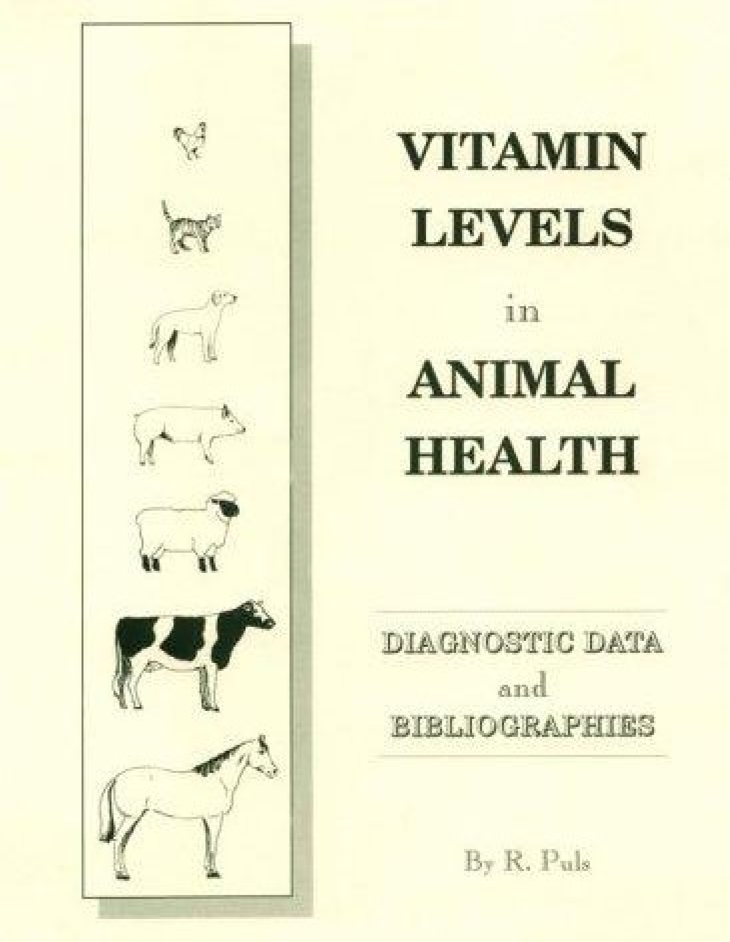








Vitamin Diagnostics



Serum Vitamin Levels

Normal values for adult animals

Species	Vitamin A (retinol)	Vitamin E (α-tocopherol)	β-carotene	Vitamin C	Vitamin D ($25\text{-OH-}D_3$)
Cattle	250-800	300-1,000	300-1,200	0.4-1.70	20-60
Cats	200-1,600	800-2,000	<3	0.1-0.5	
Deer - fallow	130-280	70-180			
Deer - red (elk)	130-390	100-220	<10		
Dogs	300-4,500	500-4,000	<4-50	0.20-0.60	28-38
Elephants	38-45	60-120			
Emus	780-970	239			
Ferrets	400-700				
Foxes	300-400	200-350			
Goats	200-400	70-125	<20	0.50	10-20
Horses	200-350	200-500	1-150	0.50-1.70	2-7
Kangaroo/wallaby	100-200	100-250	<20		
Llamas	450-1000	150-600	<10		
Mink	350-450	700-2,000			
Ostrich	300-760	100-400	<10		
Pigs	50-400	180-300	<10	0.70-2.60	20-100
Poultry	300-800	100-1,400	<10-50	1.00-2.00	5-30
Rabbits	460			0.40	
Reindeer	200-450	200-600	<10		
Seals	160-200	400-600			
Sheep	300-600	150-400	<20	4.0-14.0	10-60
Skunk	770	175			
Tiger	160-220	1,200-1,700			
Wolf	200-900	1,800-2,400			
	µg/L	µg/dl	µg/dl	mg/dl	ng/ml

Vitamin A

Pigs

Diet		Age		Serum/plasma	Liver
Deficient		Adult		<150	<60
Adequate		Fetus	<1	100-200	70-100
		Suckling	1-30	400-500	125-200
	1,200	Weanling	31-70	400-500	125-200
	1,800-10,000	Growing	71-180	400-500	200-400
	2,100-25,000	Adult	>180	250-400	200-1,000
Toxic	>400,000	Adult		>2,900	12,000-120,000
	IU/kg diet		days	µg retinol/L	µg/g dry wt

TISSUE LEVELS:
Colostrum: adequate 2,000-2,400 µg/l
Milk: adequate 700- 800 µg/l (mainly as palmitate).
Plasma vitamin A is approximately 76% retinol.
Beta-carotene is not normally absorbed intact or present in serum.

DIET:
Vitamin A needs can be met by either carotene or vitamin A.
Leafy green plants are a good source, grains contain little carotene.
Adequate: 7,000 IU/day. or 1,500-1,800 IU/kg body wt/day
Deficient: 18 µg/kg body wt/day
Toxic: 19,824 µg/kg body wt/day or 440,000-888,000 IU/kg diet.
Adequate levels for growth are also adequate for maximum immune response.
220,000 IU/kg diet for 8 weeks did not produce signs of toxicity.
1 mg β-carotene has a potency of 123-500 IU vitamin A depending on level in diet. Higher dietary levels are utilized less efficiently.

DEFICIENCY SIGNS:
Symptoms in growing pigs include incoordination, back weakness, paralysis, night or total blindness, and paresis. Cerebrospinal fluid pressure increases and plasma vitamin A levels drop.
Sows may fail to show oestrus, have poor conception rates, early embryonic death, reabsorb fetuses, or produce weak, dead or deformed piglets.
Sterility may occur in boars.

TOXICITY:
Signs of toxicity include roughened hair coat, scaly skin, hyperirritability, sensitivity to touch, bleeding from cracks in skin and above hooves, blood in urine and faeces, loss of control of legs with inability to rise, periodic tremors, reduced CSF pressure, dwarfism, skeletal abnormalities and death.

INTERACTIONS:
Nitrate and nitrite may affect vitamin A requirement in pigs (controversial).
10,000 IU vitamin A/kg feed has no effect on vitamin E levels in plasma or liver.
Injection of beta-carotene appears to improve reproductive performance.

ORIGINAL RESEARCH

PEER REVIEWED

A survey of vitamin and trace mineral ranges for diagnostic lab reporting from conventionally raised swine

Laura Greiner, PhD; Sarah Elefson, MS; Scott Radke, DVM; Chloe Hagen, BS; Dalton Humphrey, MS; Spenser Becker, MS

Summary

Objective: The purpose of this study was to survey the vitamin and mineral levels in various pig tissues at different phases of the life cycle.

Materials and methods: Forty-eight healthy pigs of different stages of production were used for sampling of different tissues. Seven sows and a minimum of 10 animals from each phase of production (suckling, nursery, and finishing) were selected for sampling. A blood sample was collected via sterile venipuncture for serum vitamin and mineral analysis. After euthanasia, the diaphragm and liver were collected. Samples were submitted to the Iowa State University Veterinary Diagnostic Laboratory for analysis. Data were analyzed using SAS (version 9.4; SAS Institute Inc) and presented as minimum and maximum concentrations with standard error. The experimental unit was the animal.

Results: Levels of vitamin A, vitamin E, copper, zinc, selenium, iron, and manganese were higher in liver tissues than in serum and diaphragm tissues. Diaphragm muscle had similar levels of phosphorus as the liver tissue. Serum had similar levels of calcium as the liver tissue.

Implications: These data provide a sampling of vitamin and mineral levels present in tissues and serum of commercial pigs and suggest that vitamin and mineral levels differ between sampling sites.

Keywords: swine, vitamin, mineral, tissue

Received: September 14, 2021
Accepted: March 10, 2022

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Table 1: Preferred sampling sites for common vitamins and minerals tested in swine*

Nutrient	Preferred biological sample
Vitamin A	Liver
Vitamin E	Serum
Vitamin D3	Serum
Calcium	Serum
Cobalt	Liver
Copper	Liver
Iron	Liver
Magnesium	Serum
Manganese	Liver
Molybdenum	Liver
Phosphorus	Serum
Potassium	Serum
Selenium	Liver/Serum/Blood
Sodium	Serum
Zinc	Liver

* Preferred sample sites such as serum may not reflect true nutrient status. Sampl should be collected from locations of vitamin and mineral storage to best assess status.

Age	Vit E ppm	Vit A ppm
Fetus	1.2-3.0	0.1-0.2
Neonate	1.5-2.5	0.4-0.5
Nursing	1.5-2.5	0.4-0.5
Grow/Finish	2.0-2.5	0.4-0.5
Adult	2.0-3.0	0.25-0.4

Table 7: Median vitamin and mineral concentrations in the serum of suckling, nursery, and finisher pigs and lactating sows

Nutrient, unit†	Suckling piglet*	Nursery*	Finisher*	Lactating sow*
Vitamin A, ppm‡§	0.12	0.30	0.17	0.08
Vitamin E, ppm§	2.8	0.70	1.6	2.3
Vitamin D2, ng/mL§	0.75	0.75	0.75	0.750
Vitamin D3, ng/mL§¶	3.1	18.3	31.3	35.5
Calcium, ppm	106.0	82.7	94.8	94.7
Copper, ppm	1.8	1.1	2.0	1.9
Iron, ppm	2.9	2.0	1.4	1.4
Magnesium, ppm	32.1	20.1	18.3	32.9
Manganese, ppm§	0.015	0.003	0.002	0.003
Molybdenum, ppm§	0.002	0.012	0.004	0.011
Phosphorus, ppm§	85.3	50.3	46.3	63.1
Potassium, ppm	479.1	331.3	248.0	402.5
Selenium, ppm	0.123	0.109	0.235	0.273
Zinc, ppm	0.9	0.7	0.7	0.7

* Suckling piglets were 1-21 days of age (n = 17); Nursery pigs were 22-64 days of age (n = 13); Finisher pigs were 65-165 days of age (n = 11); and Lactating sows (n = 7).

† Values presented per unit of wet tissue weight.

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Bone
health & reduced lameness issues

Assessing Vitamin D Status - One of the Essentials in Metabolic Bone Disease Diagnosis

Serum vitamin D reference ranges considered "normal"

Age of animal	25-OH-D_3 ng/ml
Neonate	5-15
10 days	8-23
3-4 weeks old	25-30
Finishing pigs	30-35
Mature	35-70
Parturition	35-100

Darin Madson (ISU–VDL)

"This is more of general guide"

Survey of Data from the ISU–VDL

Hough, S., 2021. American Assoc. of Swine Vet. Annual Meeting

Data from **2016 - 2020**	**Serum 25-OH-D_3 (ng/ml)**		
Age	Mean	Median	**June Outdoor - Mean**
Nursery	15.3	7.4	**58.6**
Grower	14.6	12.4	**61.1**
Finishing	31.5	26.6	**86.0**
Mature/Sow	40.23	33.5	**57.2**
			(Arnold et al., 2015)

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Vitamin D status in swine: what should you be aiming for?

dsm-firmenich recommendation range for growing pigs & sows

$25\text{-}OH\text{-}D_3$ level (ng/ml)	Status
>60	Optimum level that could trigger positive effects on: – immune competence – muscle growth (daily weight gain) – gilts selection rate, farrowing time, milk secretion, piglet livability and performance
30-60	Adequate level for Ca and P metabolism and bone health
21-29	Insufficient level for: – Ca and P metabolism and bone health-> pigs at risk for bone disorders (e.g., lameness) – reduced selection rate in gilts – prolonged farrowing time and milk release in sows. – immune competence and muscle growth
<20	Deficient level for: – Ca and P metabolism – higher probability of bone disorders e.g., rickets, osteomalacia, osteochondrosis – immune competence and muscle growth

Literature references:

<u>Pig performance and muscle growth</u>

Hines et al., 2013; Starkey et al., 2014; Zhou et al., 2016; Thayer et al., 2019; Upadhaya et al., 2022

<u>Piglets livability and performance</u>

Weber et al., 2014; Zhou et al., 2016; Planchenault et al., 2018; Zhang et al., 2019; Zhao et al., 2022

<u>Immune response</u>

Konowalchuk et al., 2013; Meuter et al., 2016; Yang et al., 2018; Yang et al., 2019; Zhang et al., 2019; Zhang et al., 2022

<u>Bone and skeletal health</u>

O'Doherty et al., 2010; Sugiyama et al., 2013; Weber et al., 2014; Cogo et al., 2016; Zhou et al., 2017; Zhang et al., 2019; Zhang et al., 2022

<u>Sows' performance</u>

Lauridsen et al., 2010; Coffey et al., 2012; Meuter et al., 2016; Planchenault et al., 2018; Zhou et al., 2017;
Wang et al., 2020; Zhang and Piao, 2021

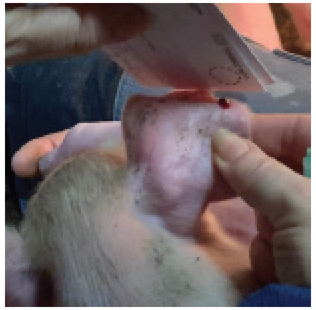
Verax™ DBS Analytics

Sampling Guidelines

- Puncture the blood vessel by holding the lancet needle at a 90° angle to the blood vessel. A new lancet needle should be used for each animal

- Allow a droplet of blood to form

- Carefully and without too much pressure hold the pre-printed circle of the DBS card onto the blood drop to collect the sample (more details on the DBS quality acceptance criteria on step 3)

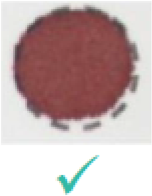


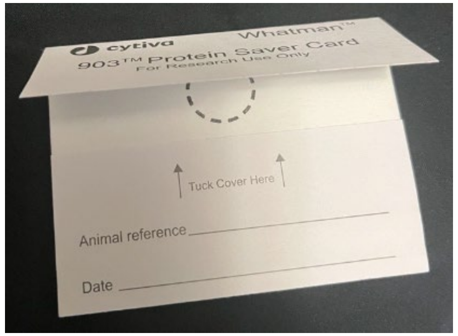
- Make sure the bleeding has stopped by applying some pressure to the skin puncture if needed
- Place the open DBS card on a dry surface, not in direct sunlight and allow the drop of blood to dry completely before closing the flap of the card

STEP 3: Check the quality of the sample

DBS samples are only suitable for analysis if they meet the following criteria;

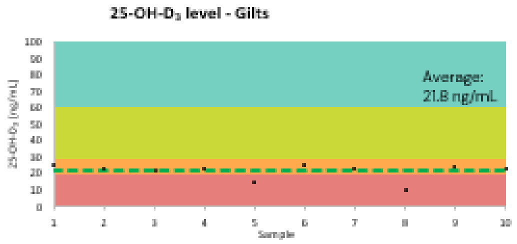
- **Acceptable sample:** The circle is filled as much as possible with a single drop of blood

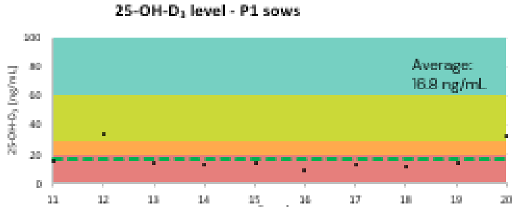


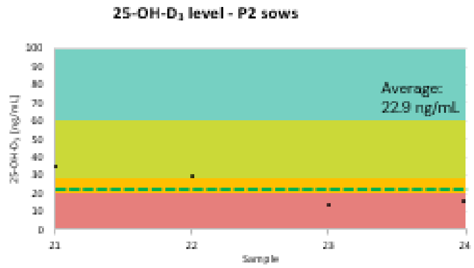


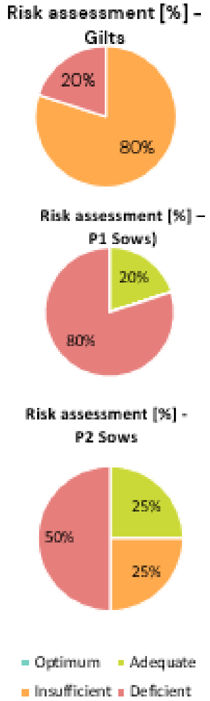
25-OH-D$_3$ blood levels in gilts & sows

Country: USA
Date: June 2024









> 60 ng/ml	Optimum level that could trigger positive effects on: – Immune competence – Muscle growth (daily weight gain) – Gilts selection rate, farrowing time, milk secretion, piglet livability and performance
30–60 ng/ml	Adequate level for calcium and phosphorus metabolism and bone health Sub-optimum level for: – Immune competence and muscle growth – Gilts selection rate, farrowing time, milk secretion, piglet livability and performance
21–29 ng/ml	Insufficient level for: –Calcium and phosphorus metabolism and bone health –> pigs at risk for bone disorders (e.g. lameness) – Reduced selection rate in gilts – prolonged farrowing time and milk release in sows. – Immune competence and muscle growth
<20 ng/ml	Deficient level for: – Calcium and phosphorus metabolism – high probability of bone disorders e.g., rickets, osteomalacia, osteochondrosis – Reduced selection rate in gilts – prolonged farrowing time and milk release in sows. – Immune competence and muscle growth

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Conclusions

- Vitamins are essential and higher levels are needed for optimum performance and immunity
- Reference ranges for various metabolites are from 30 years ago, consider diagnostics within context
- Reach out to dsm-firmenich for 25OHD3 testing and resources

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Mycotoxins

Lan Zheng, PhD

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Economic loss

- Economic impact of dampness and mold-related infections in U.S.:
  - **$22.4 billion**[1]
    - Allergic rhinitis
    - Acute bronchitis
    - Asthma morbidity
    - Asthma mortality

- Economic impact of mycotoxins in U.S.:
  - **>$1.5 billion**[2]
    - Crop costs
    - Mitigation costs
    - Livestock costs
  - PRRS: $664 million[3]

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[1]Mudarri et al., 2016; [2]CAST, 2003; [3]Holtkamp et al 2011

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Common sources of mycotoxins

Corn

DDGS, Corn Gluten

Afla, DON, ZEN, FUM

Wheat Midds, Small Grains

DON, ZEN, Ergot, Ochratoxin A

Soybean

DON, ZEN

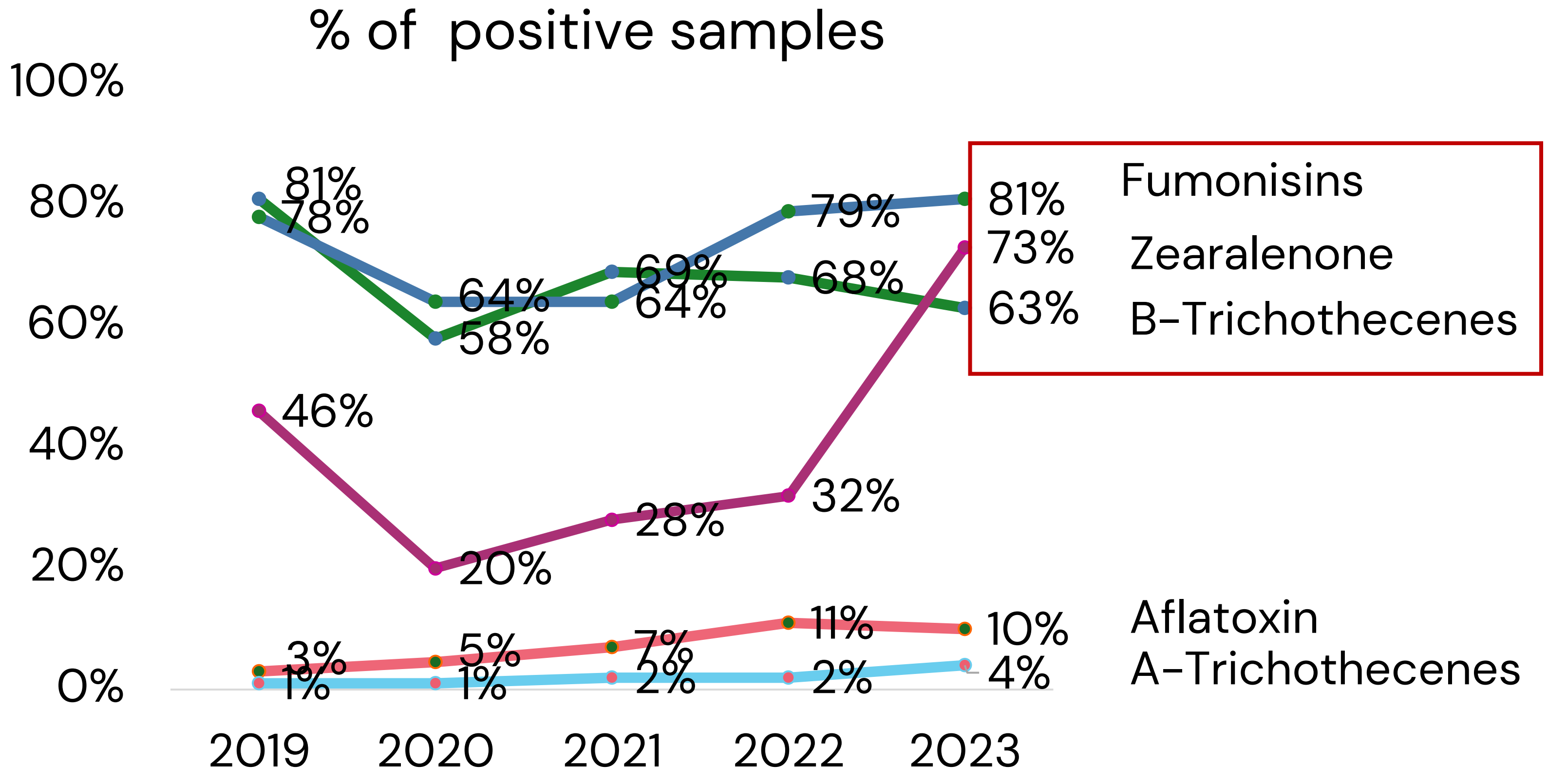
Oil: Corn, Soy...

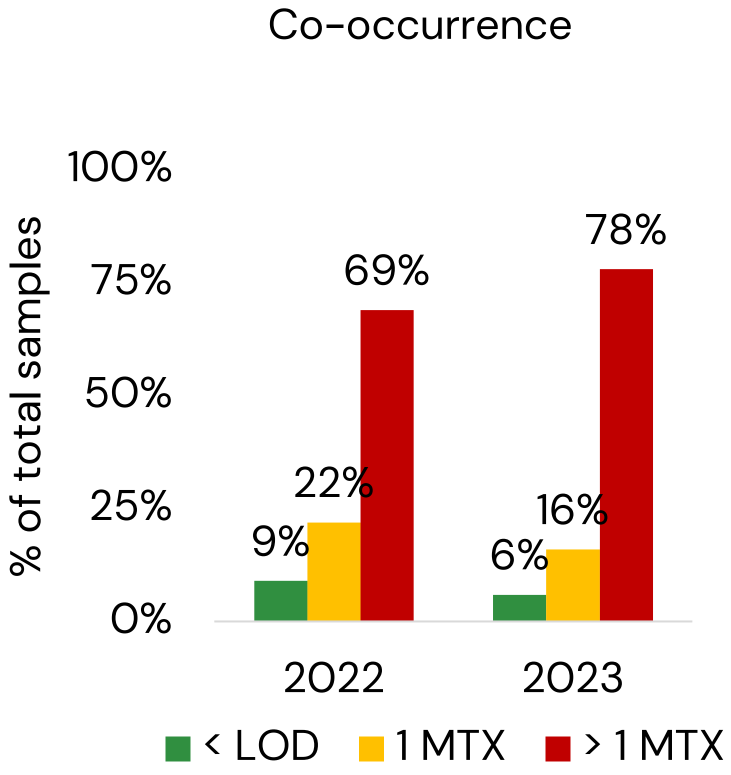
ZEN, Afla → Fat soluble

FUM and DON → Water and fat soluble

Aflatoxin (Afla); Deoxynivalenol (DON); Zearalenone (ZEN); Fumonisins (FUM)

Occurrence trend: 2019-2023 corn crop





Effects of major mycotoxins

DON & T2/HT-2	Zearalenone	Fumonisins	Ergot alkaloids
• Vomiting • Diarrhea • Reduced feed intake • Poor immunity • Tail and ear necrosis • Ulcers • Reproduction (reduced litter size / fertility / abortions)	• False estrus • Poor reproduction • Reduced fertility • Reduced litter size • Enlarged uterus, small ovaries, cysts in ovary • Rectal or uterus prolapse • Spray legs	• Pulmonary edema • Diarrhea • Reduced feed intake • Ulcers • Poor performance • Poor immunity • Heart failure • Folate deficiency • Udder edema • ↑Serum Sa:So* ratios	• Neurotoxicity • Reproductive disorders • Necrosis • Immune modulation

*sphinganine:sphingosine

Combined mycotoxin challenges

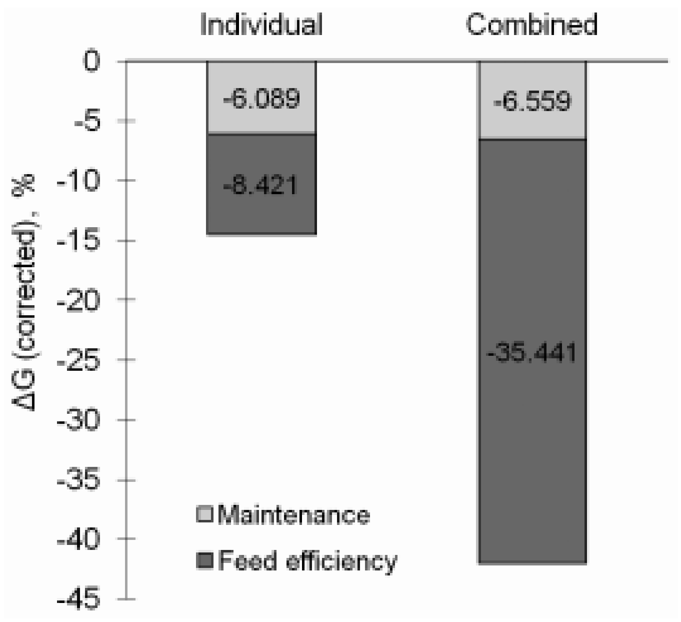


Figure 2 – Partitioning of the weight gain variation (corrected ΔG, comparison between control and challenged pigs) between the fraction due to the change in maintenance requirement or due to the change in feed efficiency of growing pigs fed diets containing mycotoxins in individual or combined challenges.

- Feed intake: Single (14%)
  Combined (42%)
- Weight gain: Single (17%)
  Combined (45%)

The average dietary concentration of mycotoxins were 0.485 ppm for aflatoxins (maximum of 4 ppm), 3.63 ppm for deoxynivalenol (maximum of 72 ppm), 1.14 ppm for zearalenone (maximum of 9 ppm), and 23.2 ppm for fumonisins (maximum of 120 ppm).

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85 published papers, 1,012 treatments and 13,196 animals

Andrestta et al, 2016

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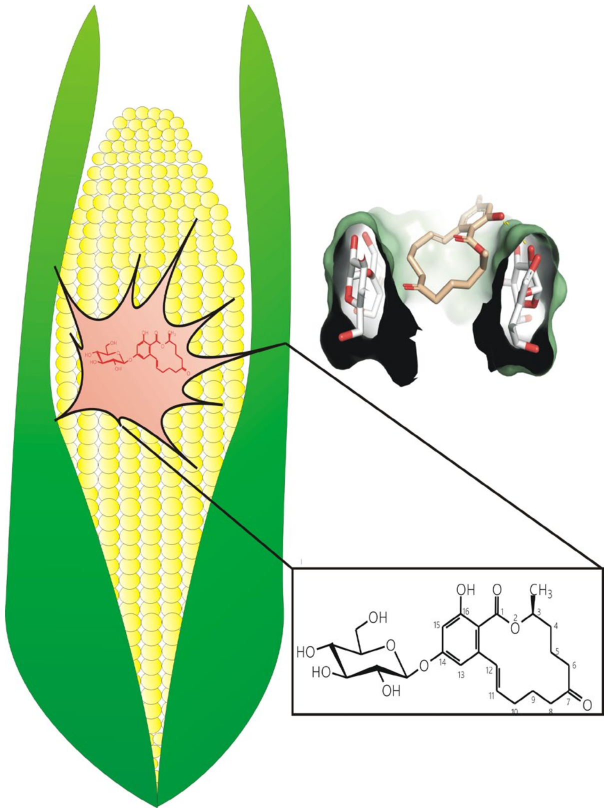
Modified mycotoxins

- Masked trichothecenes
  - **82%** samples positive for Don-3-glucoside[1]
- Masked fumonisins
  - **60%** for risk assessment[2]
    - 10 ppm → 16 ppm
- Masked zearaleone
  - **100%** for risk assessment[2]
    - 100 ppb → 200 ppb



[1]Berthiller et al., 2013; [2]EFSA, 2014

Impact on nutritional value of grains

- Discounted protein, amino acids, and vitamins:
    - Mold spore count of 1-5 million cfu/g can have discounted nutrient value by 5-10%[1].
-

Corn type	Metabolizable energy (kcal/kg)	Crude protein (%)	Crude fat (%)
Normal	3,410	8.9	4.0
Moldy	3,252	8.3	1.5

Tindall (1983)

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[1] https://extension.umn.edu/

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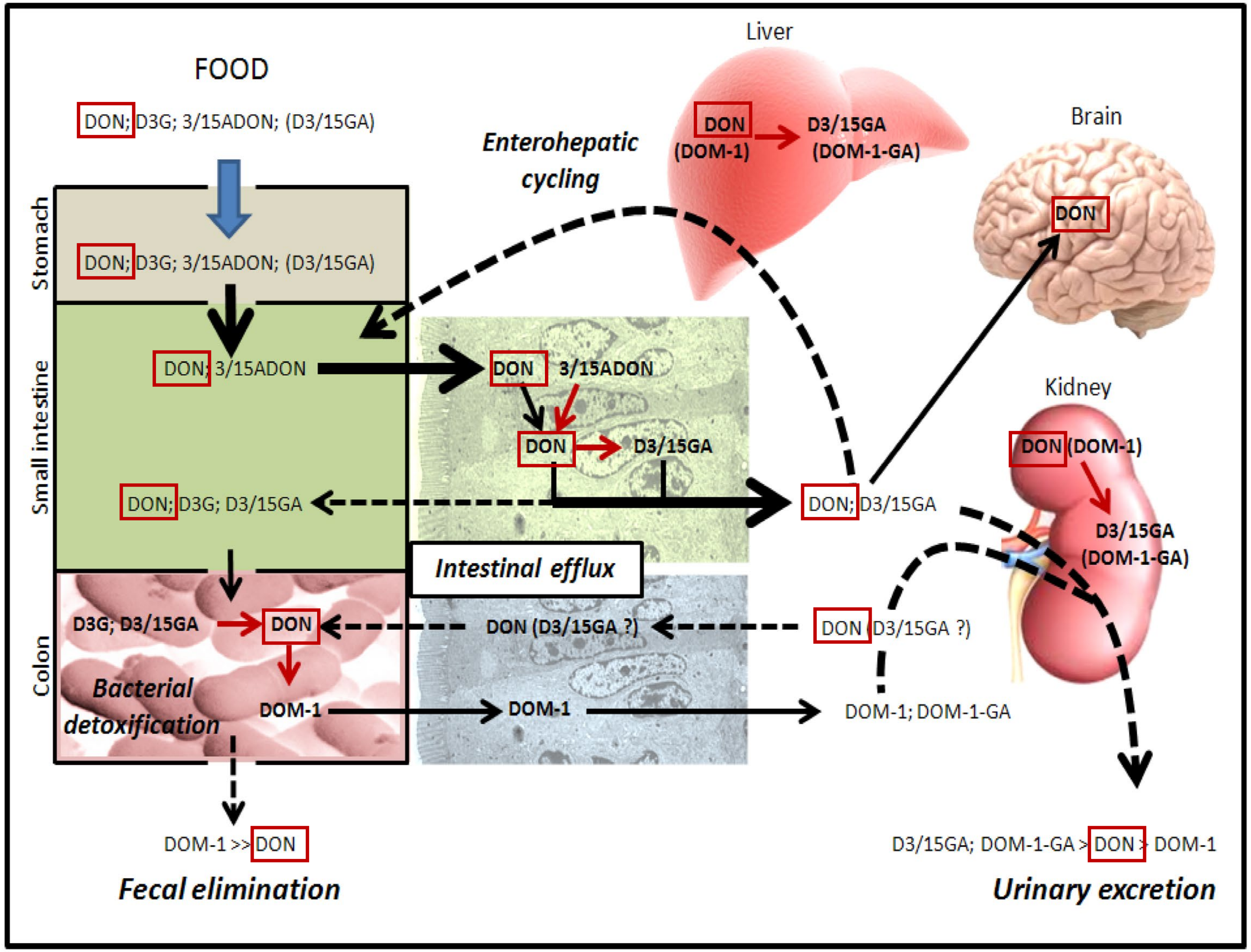
Impact on nutrient digestibility

Mycotoxins (ppm)	Phase	DM	Energy	Fat	CP	Reference
AFB1 (0.28)	38 kg, 102 d	↓ 2.1%	↓ 2.5%	↓ 4.7%	No change	Pu et al., 2020
DON (5)	10 kg, 5 d	↓ 7.6%	↓ 9.5%	- -	↓ 15.7%	Mwaniki et al., 2019
DON (4.6)	6 kg, 14 d	↓ 3.4%	↓ 4.8%	↓ 25.6%	- -	Van Le Thanh et al., 2015
FUM (15)	13 kg, 21 d	- -	↓ 1.2%	No change	- -	Zeebone et al., 2020

Gastrointestinal tract: First target

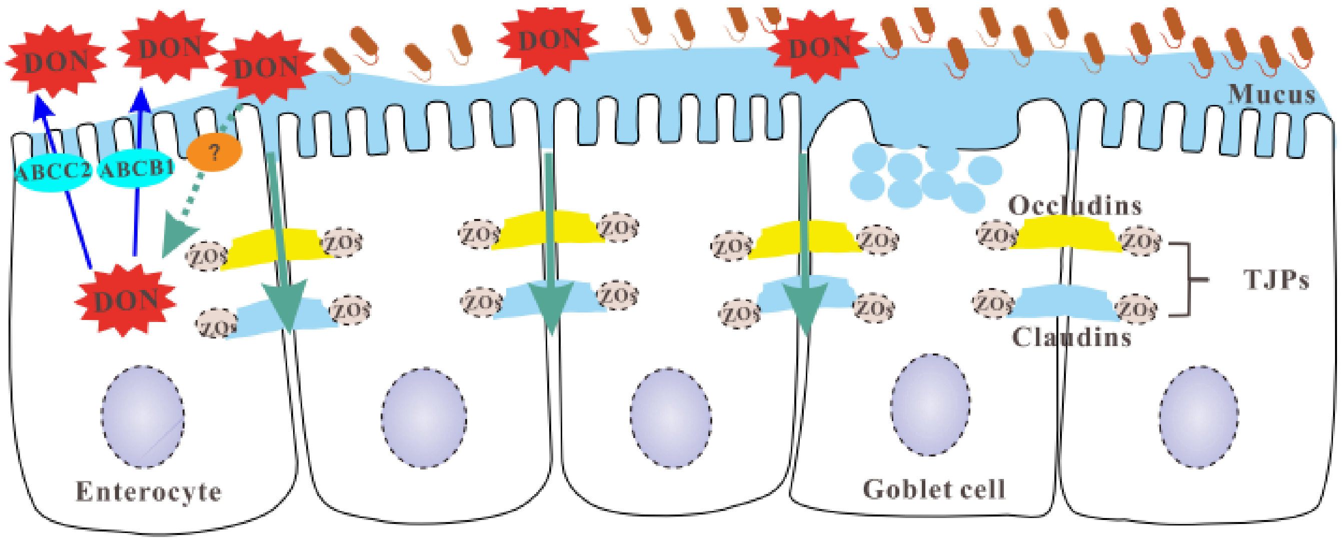


- Enterohepatic circulation may increase the exposure all along the GIT. DON and FUM are slowly absorbed in the lower GIT.
- Neurotoxic effect: 25% to 30% of the plasmatic DON is found in the cerebrospinal fluid
- Oxidative stress

Maresca, 2013

Impact on physical barrier function

Transcellular transport



Paracellular transport

↓ Tight junctions
↓ Integrity of intestinal barrier

- Chronic exposure
  - Absorption rate of DON: chronic (89%) > acute (54%)[1]
  - Paracellular diffusion may massively increase and become predominant.

[1] Goyarts et al., 2006

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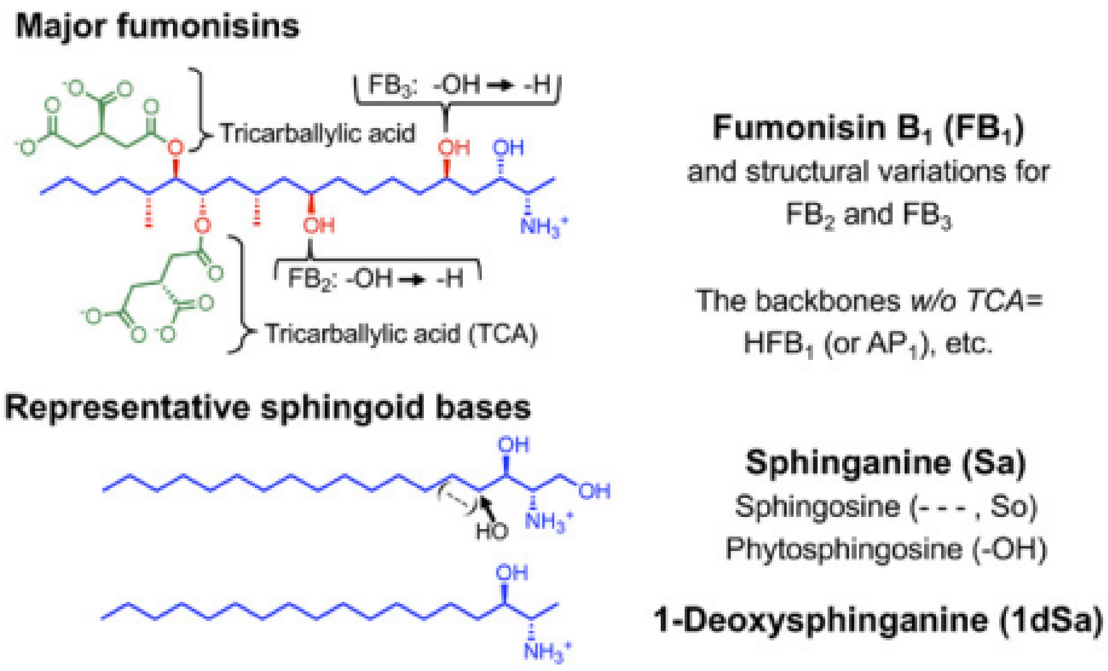
Impact on physical barrier function



Riley and Merrill, 2019

- Fumonisins disrupt intestinal barrier
  - Inhibits ceramide synthase by epithelial cells.
  - Promote cytokine production
    - Upregulate expression of TNF-α

Sphingolipids: cell membranes, nervous tissue, brain, skin, liver, and kidney.

Li et al., 2022

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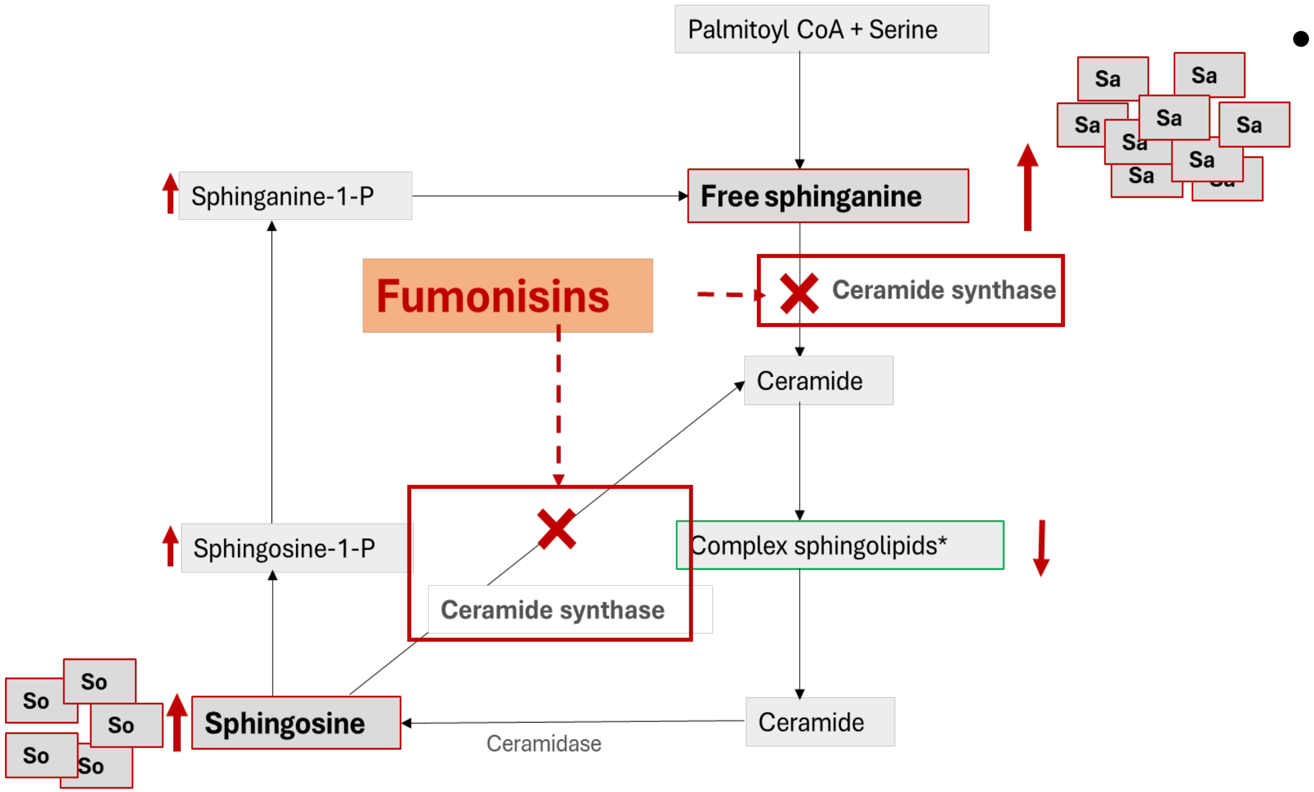
Impact on physical barrier function



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Sphingolipids: cell membranes, nervous tissue, brain, skin, liver, and kidney.

Li et al., 2022

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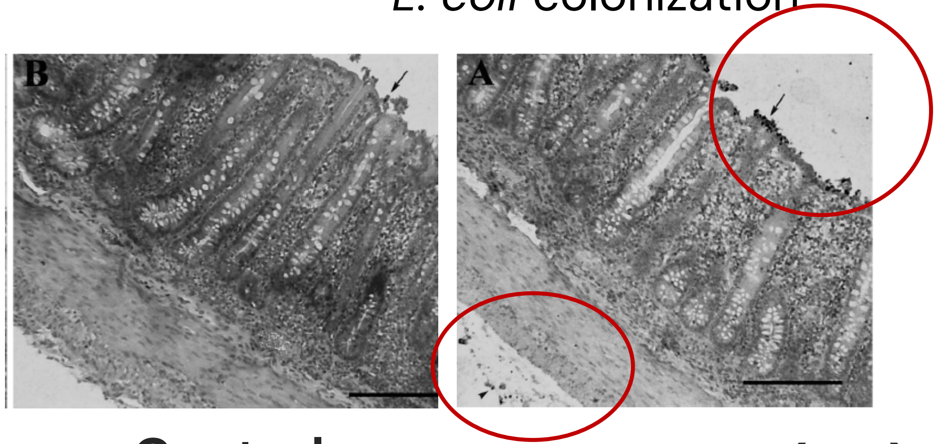
Increase susceptibility to diseases

E. coli colonization

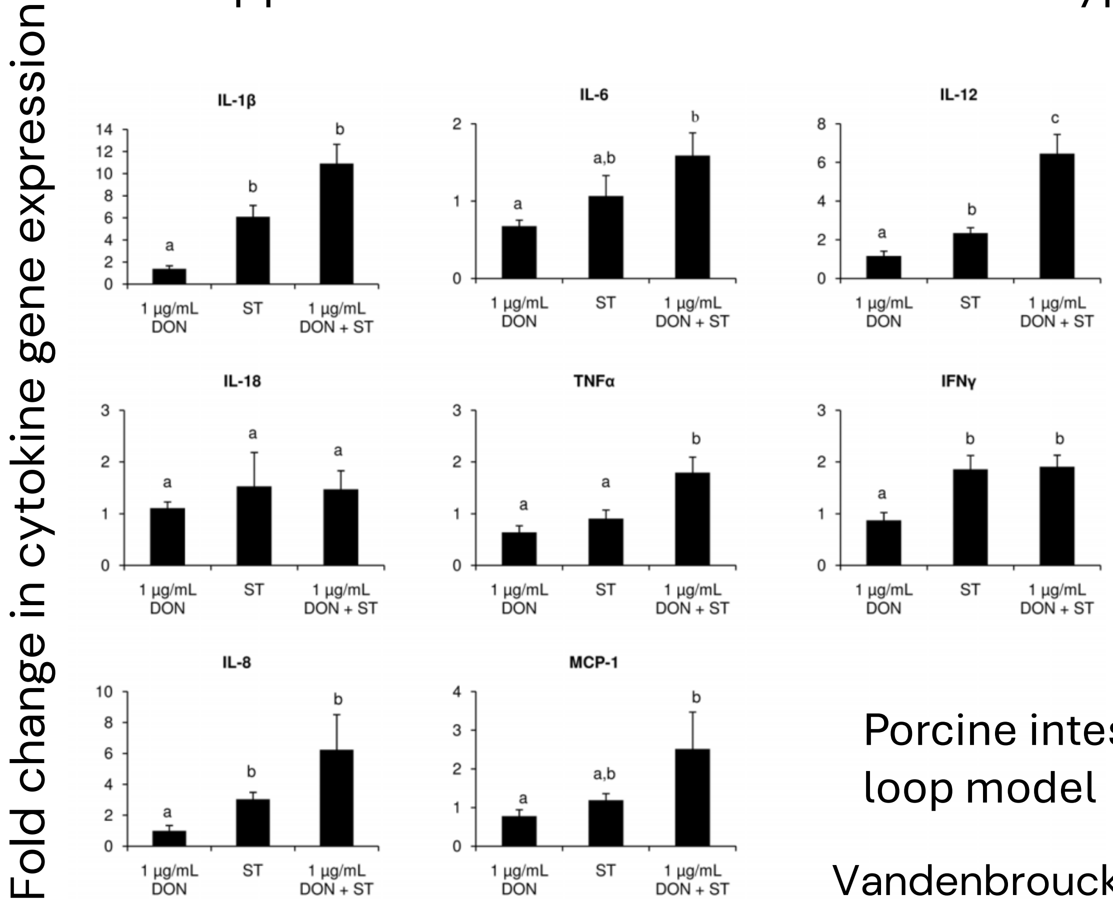


Control **Fumonisin (FB1)**

Feeding 6.5 ppm FUM for 7 days significantly increased intestinal colonization by *E. coli*.

Oswald et al., 2013

900 ppb DON with or without *Salmonella* Typhimurium



Porcine intestinal ileal loop model

Vandenbroucke et al., 2011

↑Salmonella invasion in and translocation

↑Inflammatory response in the gut

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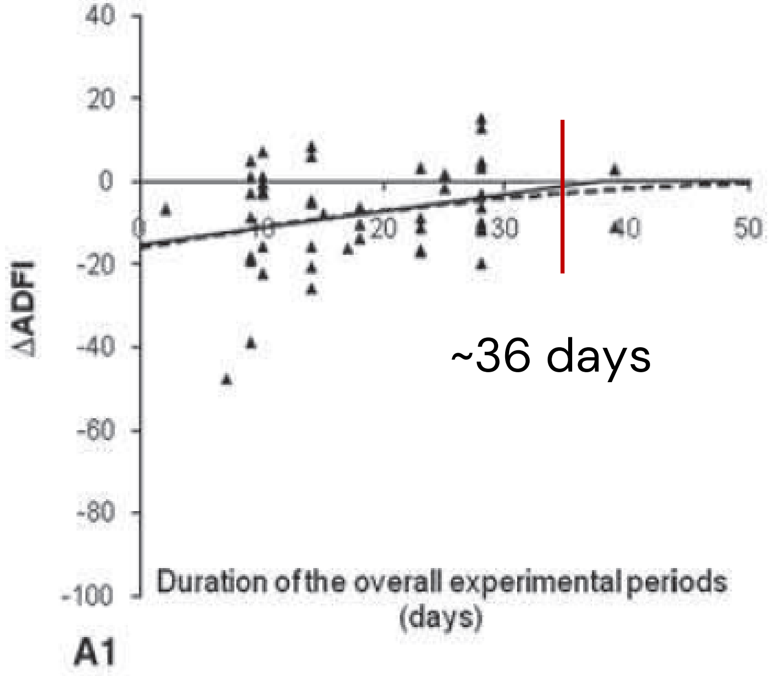
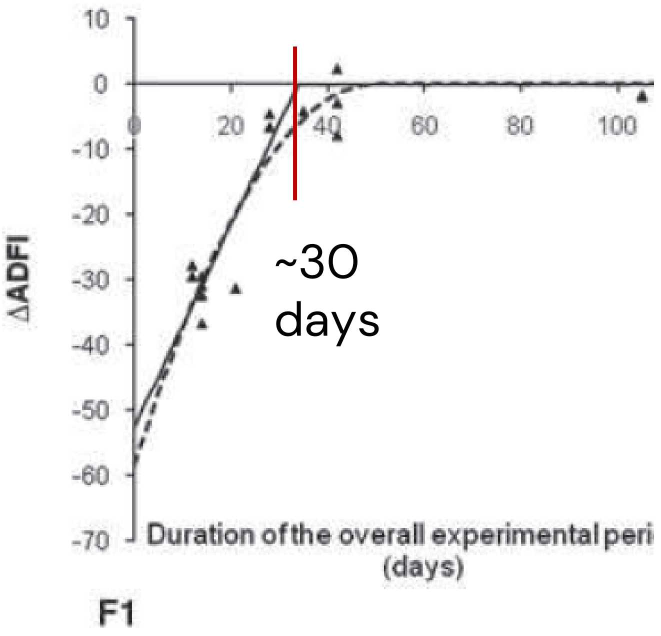
Impact on feed intake

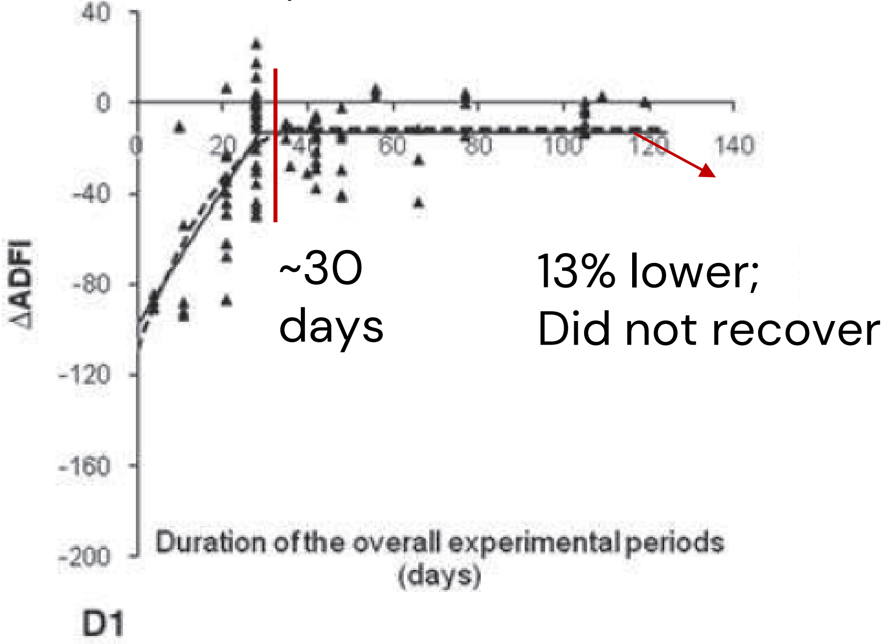
Digestive *E. coli* challenge



Respiratory disease



Mycotoxicoses *



*single, 2 or 3 mycotoxins (aflatoxin, deoxynivalenol, fumonisin and/or zearalenone)

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Pastorelli et al., 2012

dsm-firmenich

Nutrient utilization

toxins MDPI

Article

Vitamin D Supplementation Impacts Calcium and Phosphorus Metabolism in Piglets Fed a Diet Contaminated with Deoxynivalenol and Challenged with Lipopolysaccharides

Béatrice Sauvé [1], Younes Chorfi [2], Marie-Pierre Létourneau Montminy [1] and Frédéric Guay [1,*]

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https://doi.org/10.1093/jas/skae099
Advance access publication 13 April 2024
Non Ruminant Nutrition

OXFORD
AMERICAN SOCIETY OF ANIMAL SCIENCE

Impact of deoxynivalenol in a calcium depletion and repletion nutritional strategy in piglets

Béatrice Sauvé[†,1], Frédéric Guay[†], Marie-Pierre Létourneau Montminy[†]
[†]Department of Animal Sciences, Université Laval, Québec (QC), Canada, G1V 0A6.
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toxins MDPI

Article

Vitamin 25(OH)D₃, E, and C Supplementation Impact the Inflammatory and Antioxidant Responses in Piglets Fed a Deoxynivalenol-Contaminated Diet and Challenged with Lipopolysaccharides

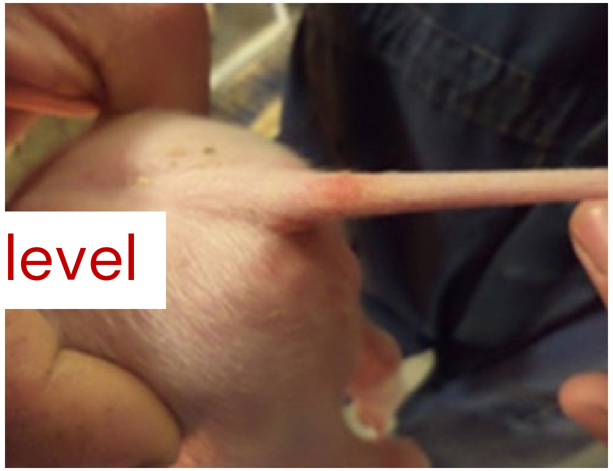
Béatrice Sauvé [1,*], Younes Chorfi [2], Marie-Pierre Létourneau-Montminy [1] and Frédéric Guay [1]

- ↑Intestinal permeability
- ↓ Intestinal absorption of Ca and P
- ↓ Vitamin D status
- ↓ Bone recovery following Ca and P depletion
- <u>Adding vitamins E and C and 25-OH-D_3</u> reduced inflammation and improved antioxidant status after the LPS immune stimulation.

Sauvé et al., 2023; Sauvé et al., 2023; Sauvé et al., 2024

Transfer from sows to piglets

Acceptable level ≠ Safe level



Neonatal tail necrosis in a 1-day-old piglet

- No clinical signs were shown in sows
- 30% pre-weaning mortality
- Splay legs, swollen and reddened vulva in newborn piglets

<u>Mycotoxin levels in the feed:</u>

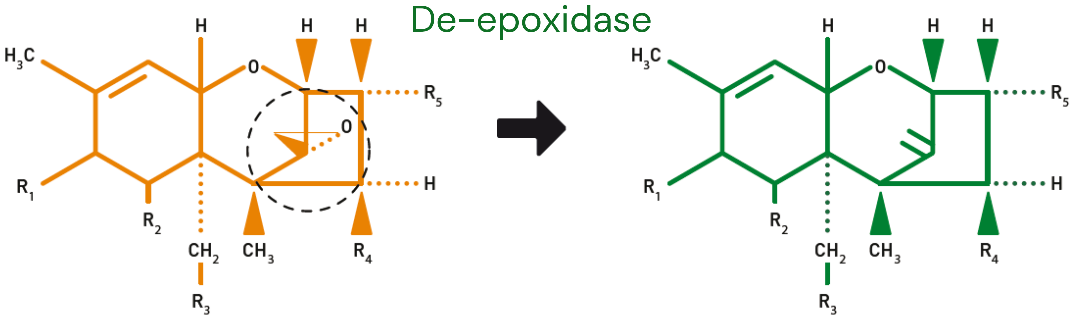
- Gestation: **72.6 ppb** ZEN and metabolites
- Lactation: **51.9 ppb** ZEN and metabolites

Hennig-Pauka et al., 2018

- <u>Mycotoxin levels in sow feed:</u>
  - **484 vs. 257 ppb of DON** in Clinical vs. Control
- DON in sow plasma were significantly different
- Swine inflammation & necrosis syndrome

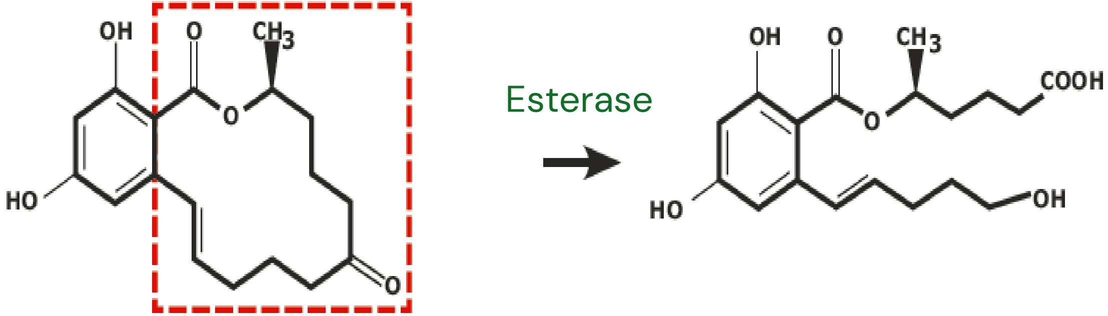
Van Limbergen et al., 2017

Mitigation strategies: biotransformation



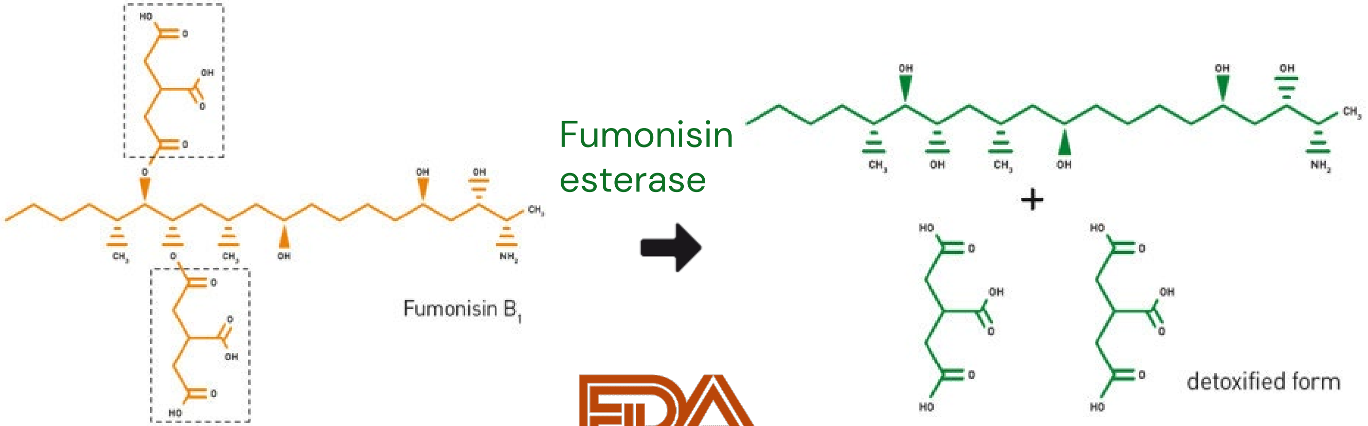
Trichothecenes

Detoxified form



ZEN

ZOM-1



Fumonisin B_1

FDA
APPROVED

Detoxified form

Schatzmayr, et. al, Mycotoxin Research, 2003

Molnar, et al; Syst. Appl. Microbiology, 2004

Politis, et al; British Poultry Science, 2005

Schatzmayr, et al; Molecular Nutrition and Food Research, 2006

Vekiru et al, Applied and Environmental Microbiology, 2011

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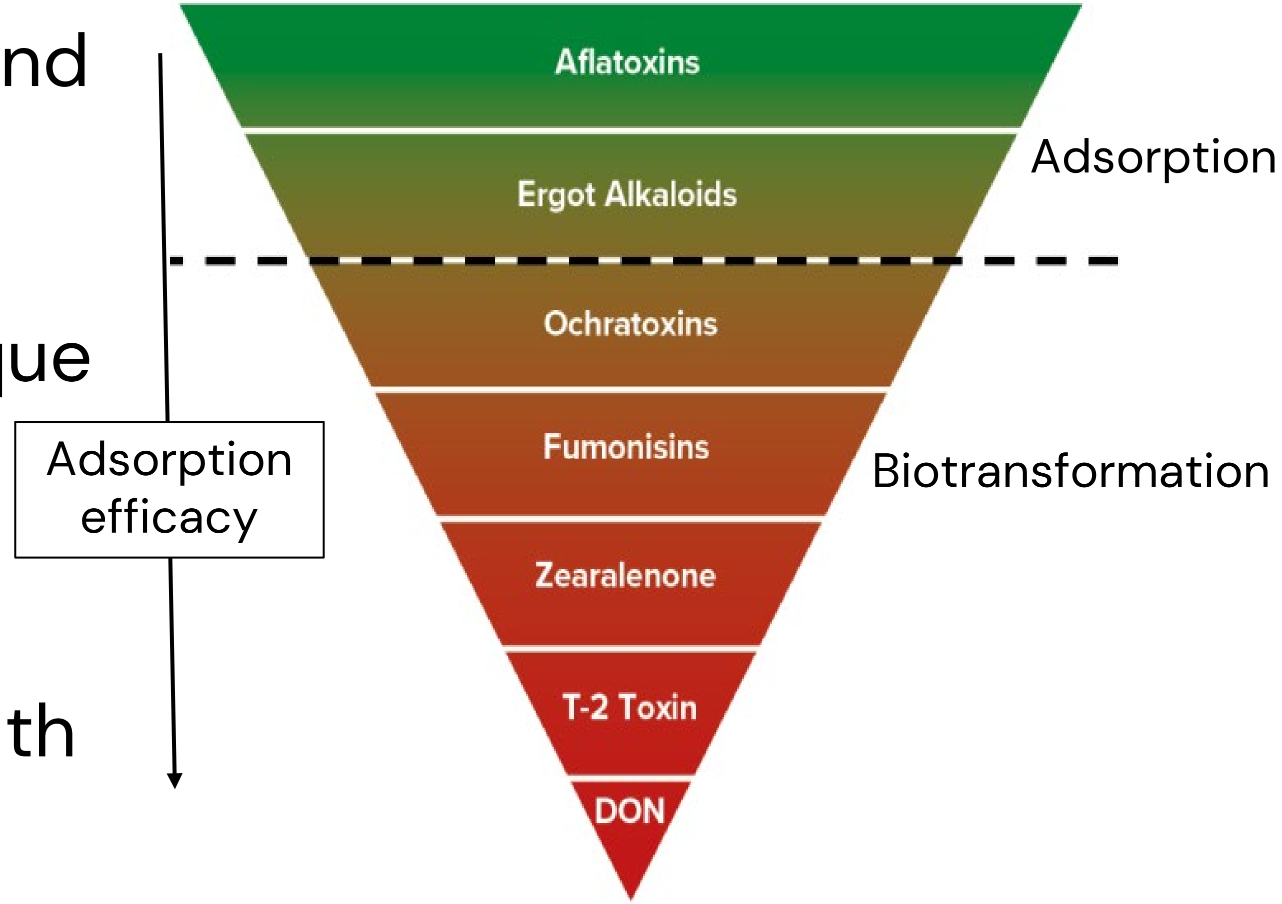
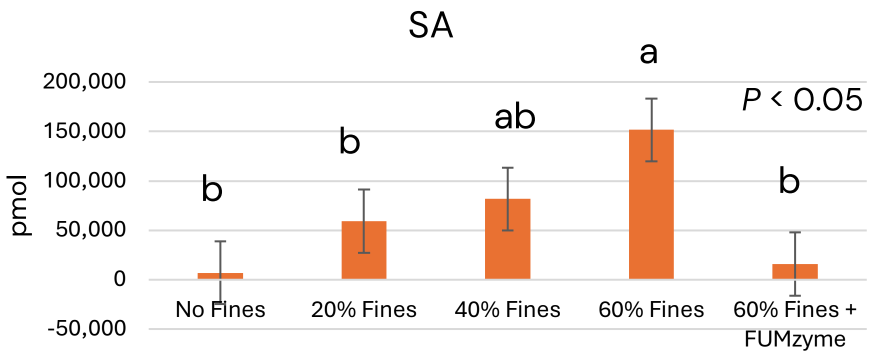
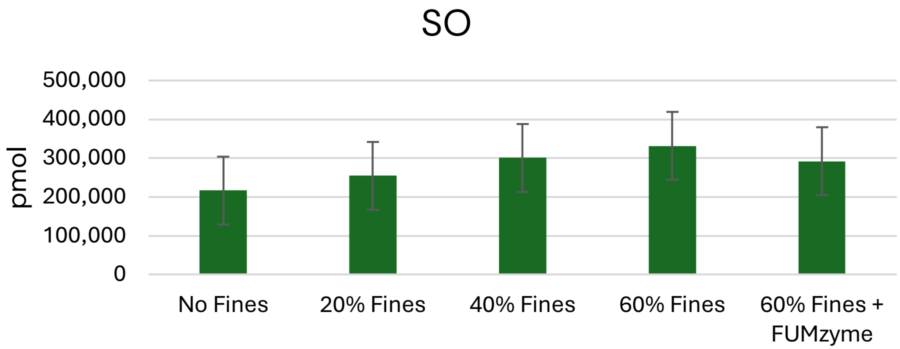
Mitigation strategies

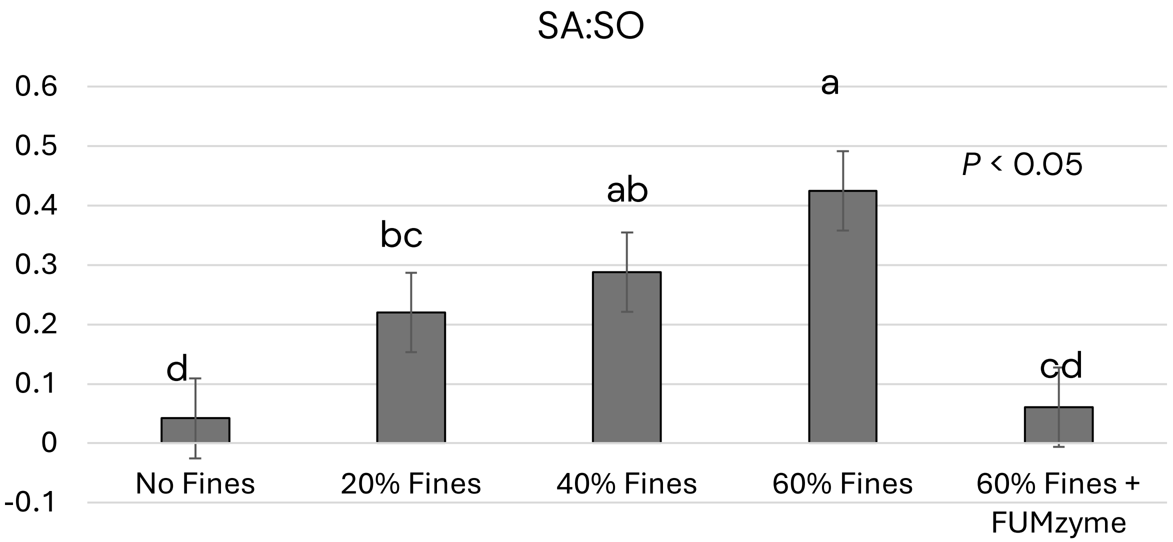
- 1. Adsorption a synergistic blend of minerals
- 2. Biotransformation with unique enzymatic degradation
- 3. Bioprotection for immunity support and liver and gut health



Mitigation strategies







Biofix Plus with FUMzyme ameliorated 93% of the increased sphinganine and 95% of SA:SO caused by fumonisins.

Blood was collected at the end of wk 6 for SA:SO measurement

Paczosa, 2023

Conclusions

- Mycotoxins:
  - Affect intestinal integrity
  - Impair immunity → prolonged recovery
  - Decrease nutrient utilization (i.e., vitamin D status)
- Microbial and enzymatic technologies are innovative strategies to detoxify non-adsorbable mycotoxins.