FUNCTIONAL AMINO ACIDS: IMPACT BEYOND GROWTH IN SWINE

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Leman China Swine Conference
October 2024

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Sick Pigs Grow Slowly and Cost More

- Pigs in a 'dirty' environment 10-20% slower (Pluske et al., 2018; Cornelison et al., 2018)
- Sub-clinical disease reduces lean gain by 20-35% and feed efficiency by 10-20% (Le Floc'h et al., 2009)
- ~$8-30 USD financial loss/market pig and increased mortality (up to 20%) (Pluske et al., 2018; Cornelison et al., 2018)
- Increased antibiotic usage, diagnostic fees, etc

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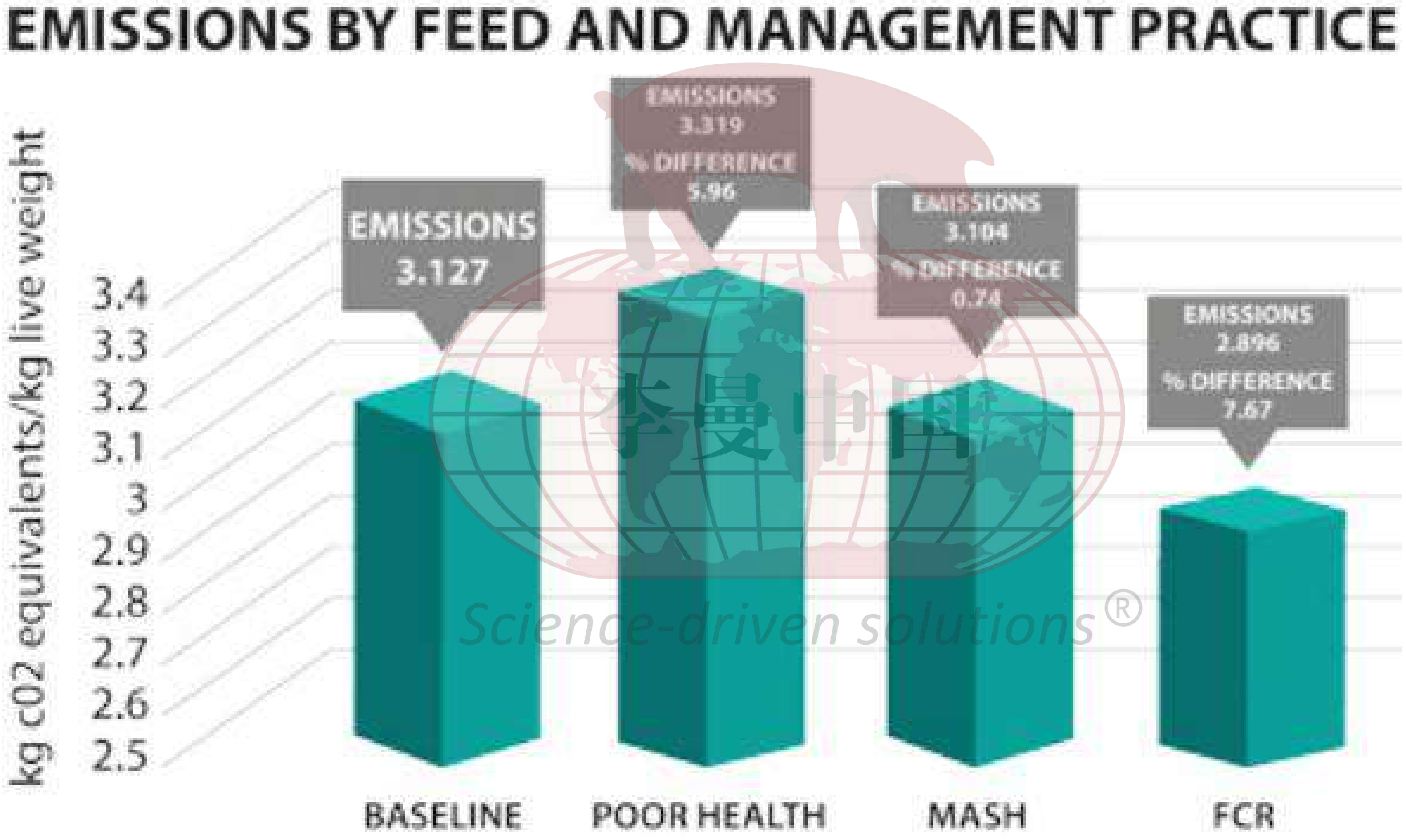
Healthy Pigs are More Efficient



Woods, 2023

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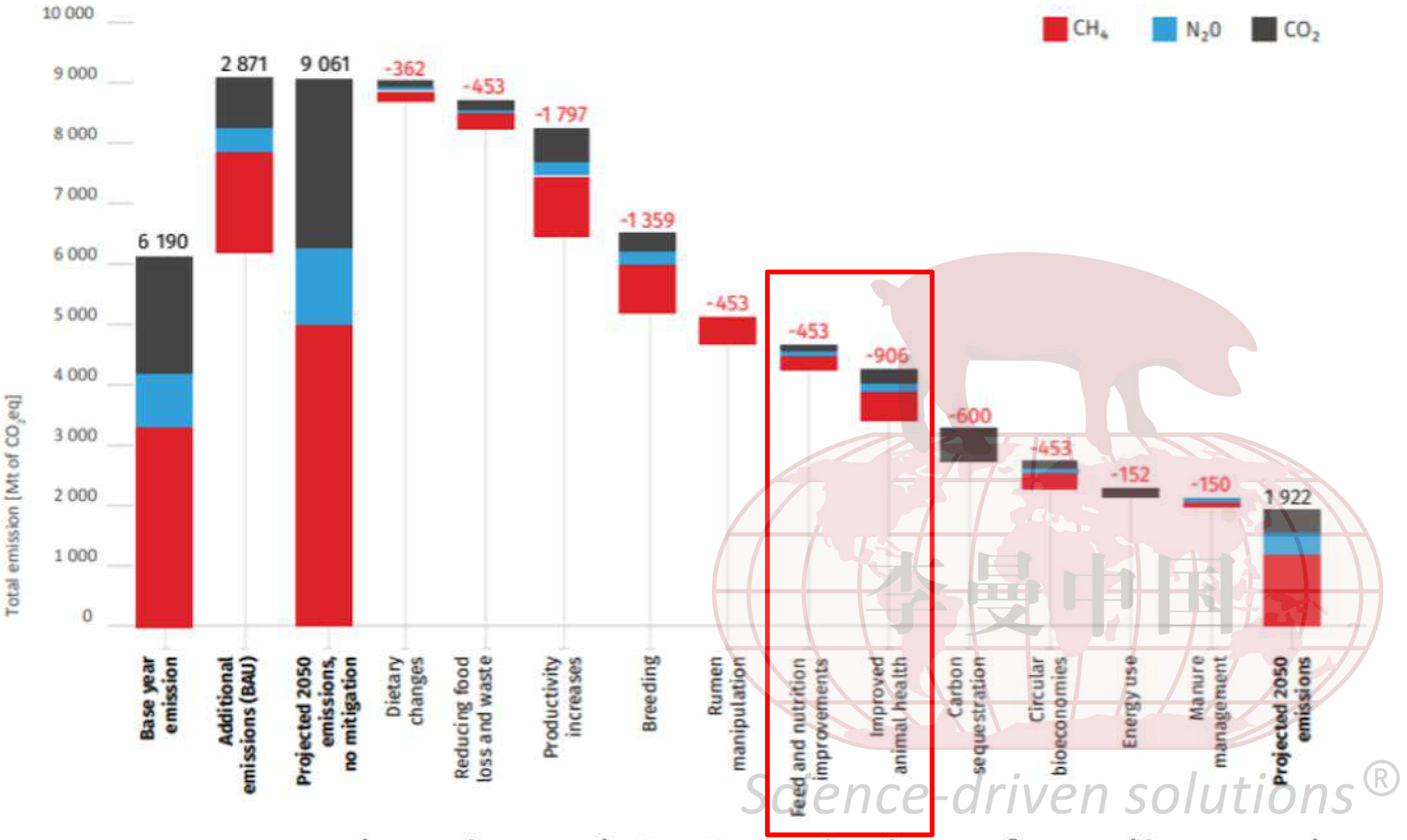
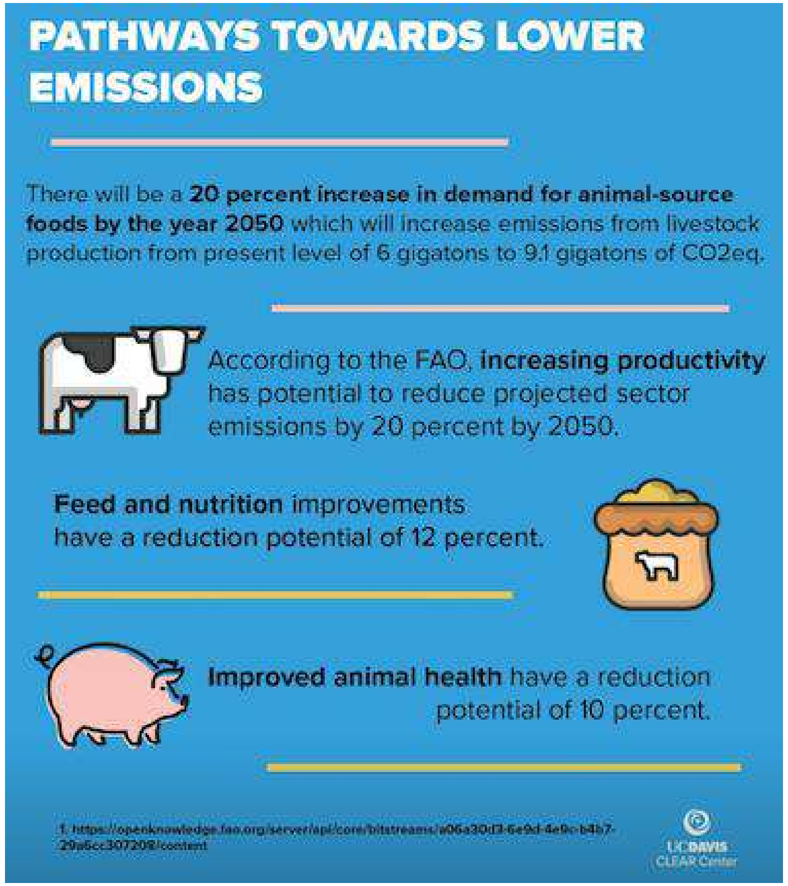


Base year and projected GHG emissions from livestock systems as a waterfall chart with a range of mitigation measures applied to 2025 with their technical potential.



FAO, 2023

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Alternatives to Antibiotics?

Spray-dried plasma	Alternate cereals	Fructo-oligosaccharides
Conventional egg products	Low protein diets	Other oligosaccharides
Immune egg products	Nucleosides	Bacteriocins
Milk protein products	Direct-fed microbials	Bacteriophage
Acids	Essential oils	Yeast and yeast products
Lactose	Fermented liquid feed	Enzymes
Mannan oligosaccharide		Competitive inhibition
Zinc		Limit feeding
Copper		

Pettigrew, 2006

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"As our industry moves away from the use of antibiotic growth promoters and heavy metals (e.g. copper and zinc) the **functional value of nutritional ingredients** has become increasingly more important to understand. In our search to create **gut friendly diets** we see new nutrients being added to the specifications like; **glutamine, omega 3, undigested protein, soluble, insoluble and inert fibre** to name a few." (Edwards, 2021; pig333.com)

The amino acid requirements of disease

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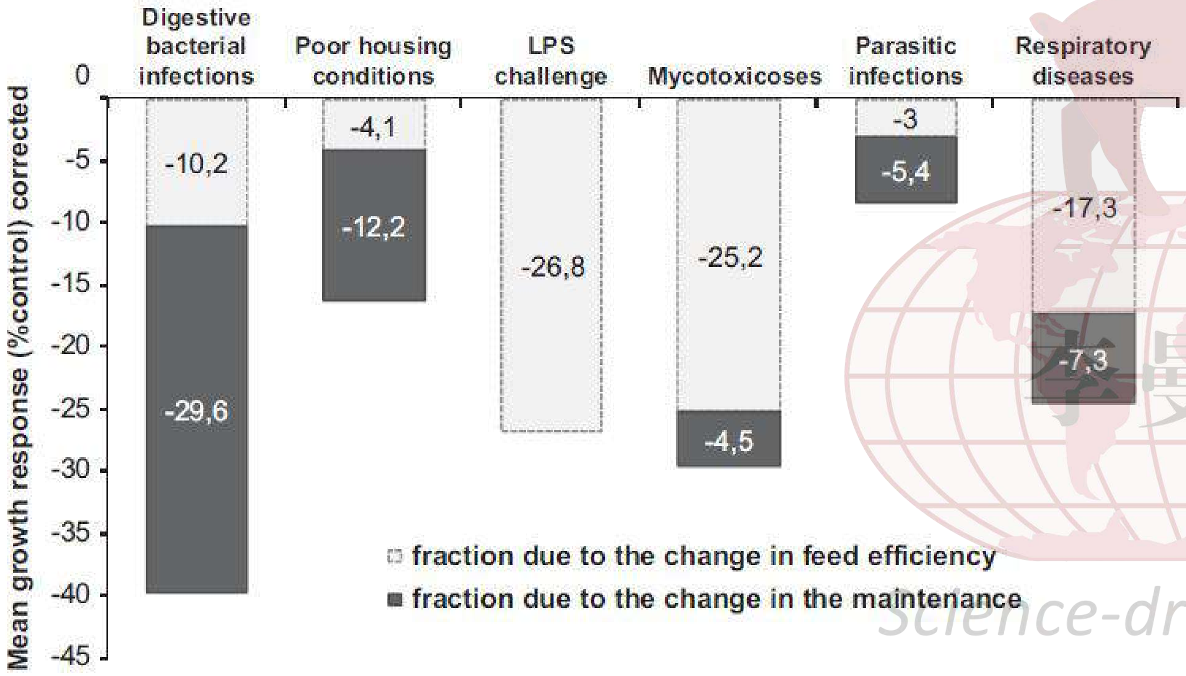
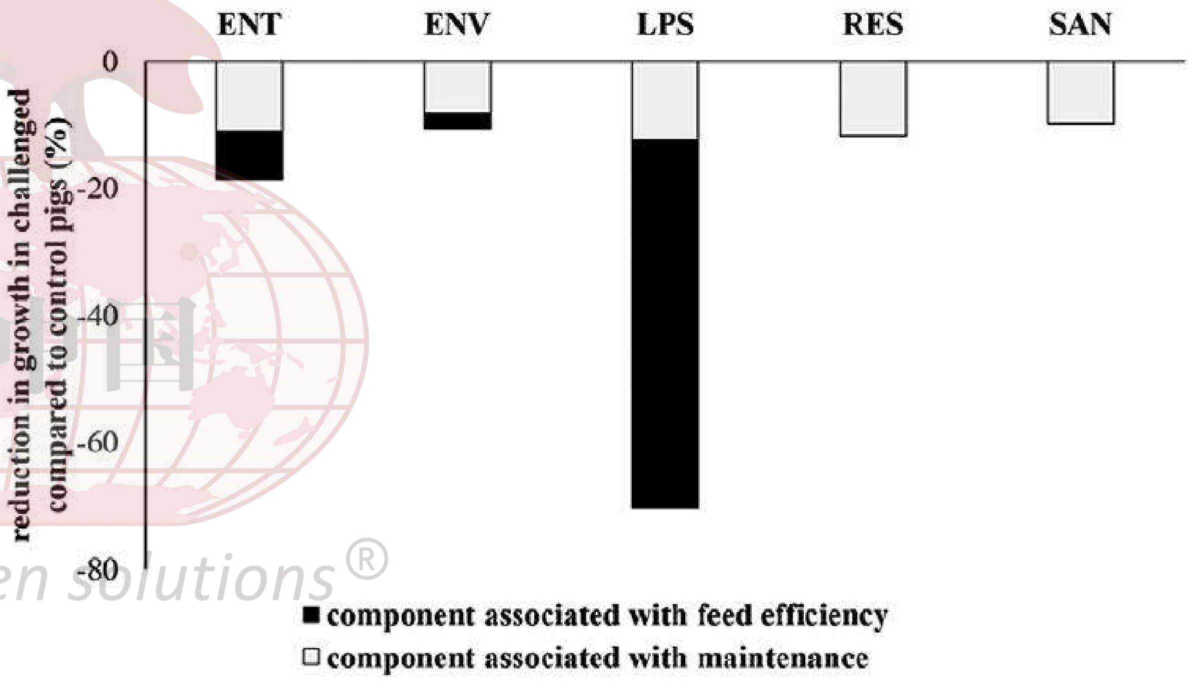
We feed pigs for growth

- Current requirements based on growth performance
  - Average daily gain, feed efficiency

- Developed under high health conditions, fast growing animals, appropriate feed intake

Feed Intake (efficiency) vs. Maintenance (requirements)



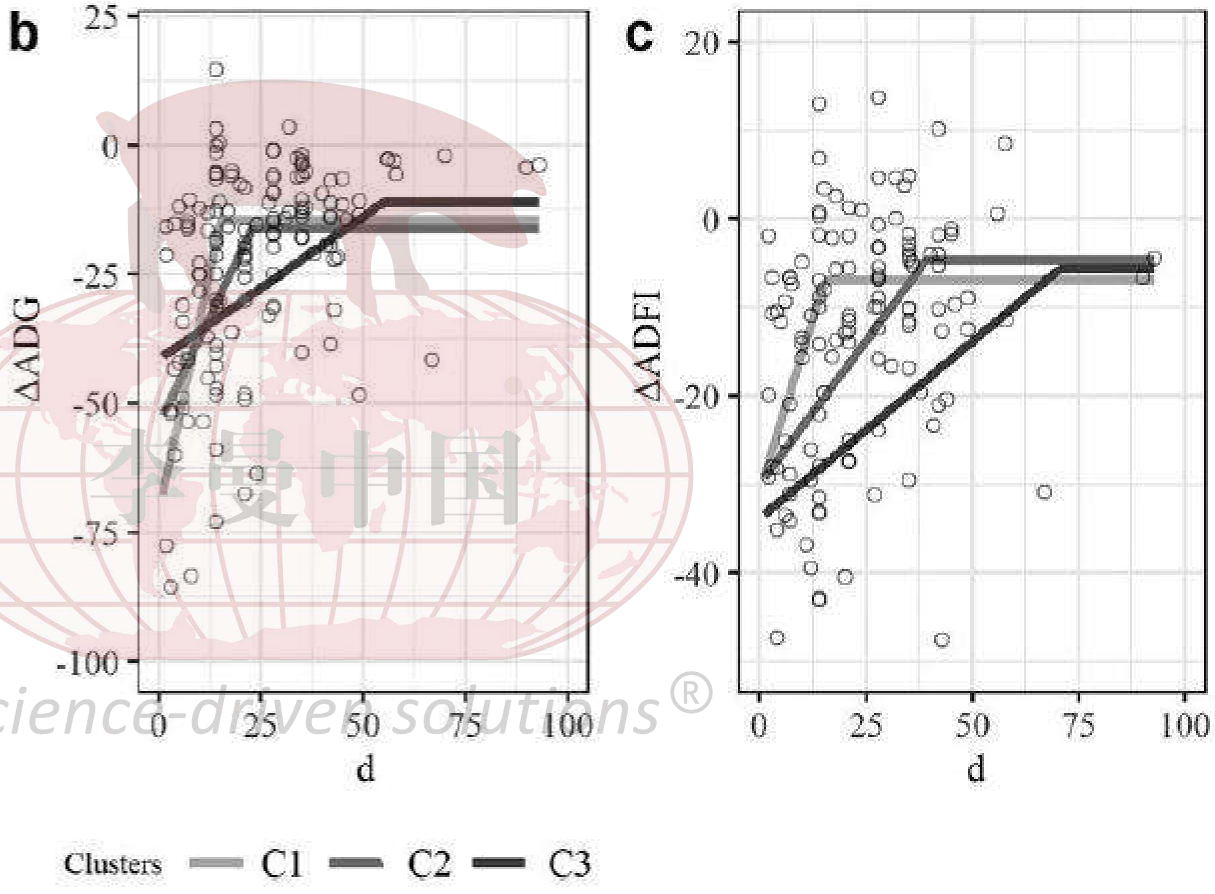


Pastorelli et al., 2012

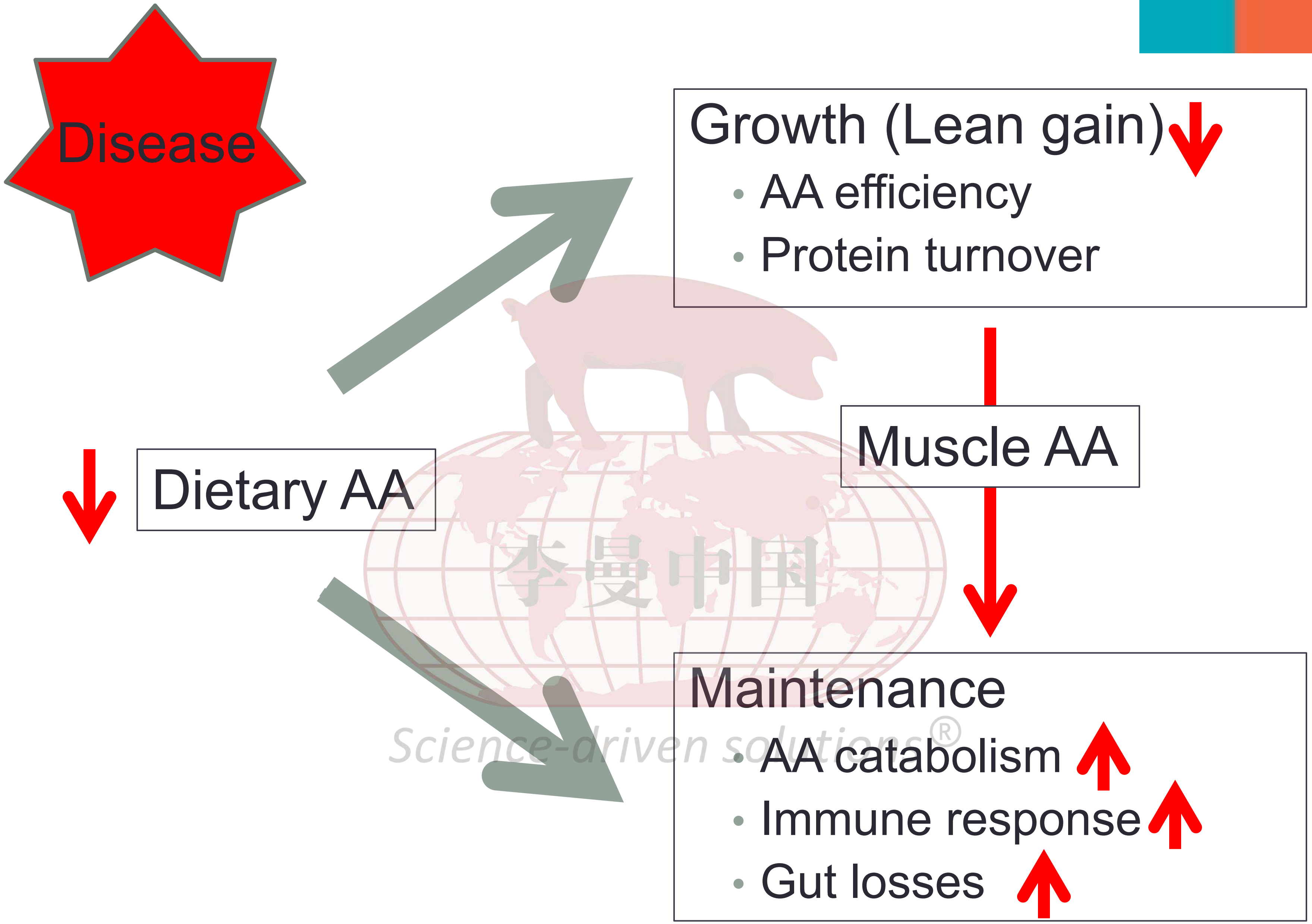
Rodrigues et al., 2021

- Younger animals have more drastic initial response but recover faster

- Females have more drastic initial response than males (not shown)

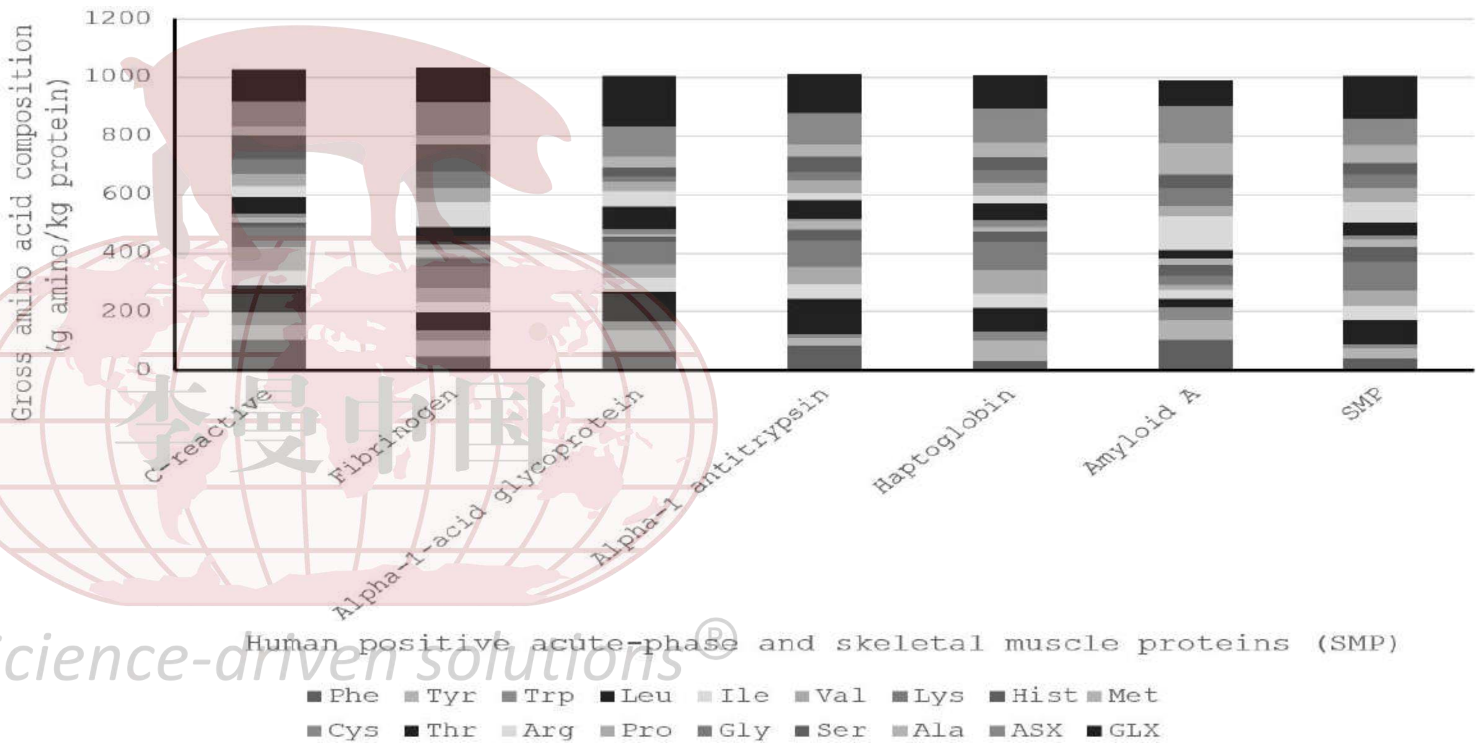


Rodrigues et al., 2021


Disease
Growth (Lean gain)
AA efficiency
Protein turnover
Dietary AA
Muscle AA
Maintenance
AA catabolism
Immune response
Gut losses

Feeding the Immune System

- During the immune response, amino acids are redirected from growth to support the immune response (Reeds et al., 1994)



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Mismatch Between Immune System and Skeletal Muscle Amino Acids

Ratios of amino acids in immune system to skeletal muscle

	24 h	5 d
Arginine	0.81	0.94
Cysteine	1.88	1.62
Glycine	1.53	1.62
Histidine	0.76	0.79
Isoleuci	[illegible]	[illegible]
Leucine	[illegible]	[illegible]
Lysine	[illegible]	[illegible]
Methior	[illegible]	[illegible]
Phenylalanine	0.82	0.90
Proline	0.99	1.04
Valine	1.09	1.18
Threonine	1.40	1.29

Synthesis of 1 g of albumin would require degradation of 6 g of muscle

Klasing, 2016

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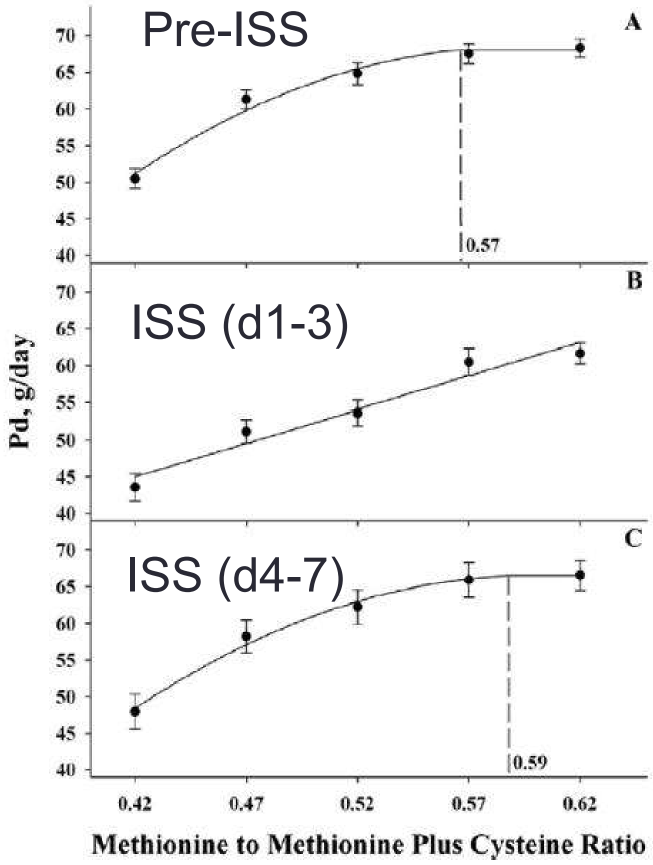
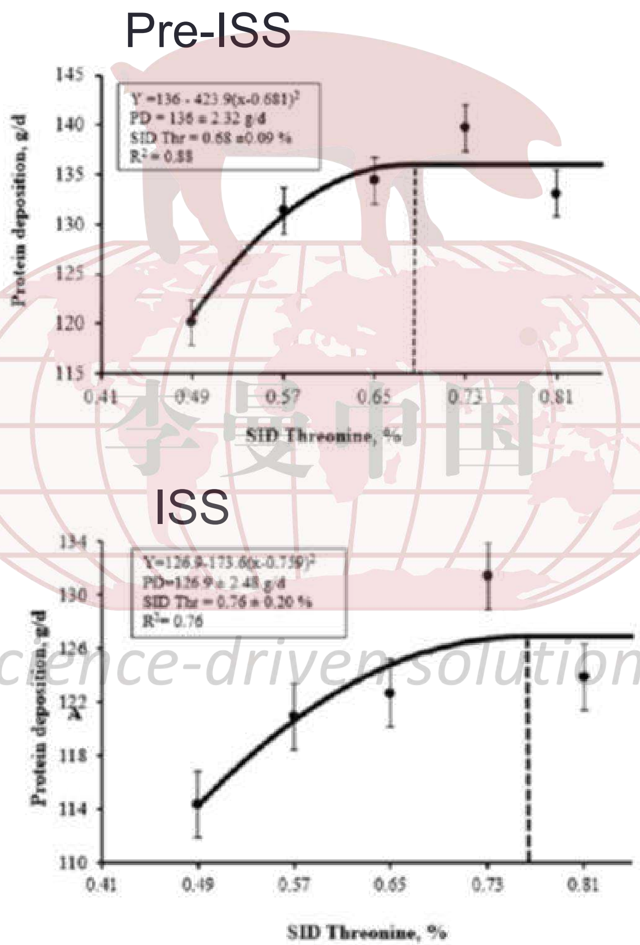
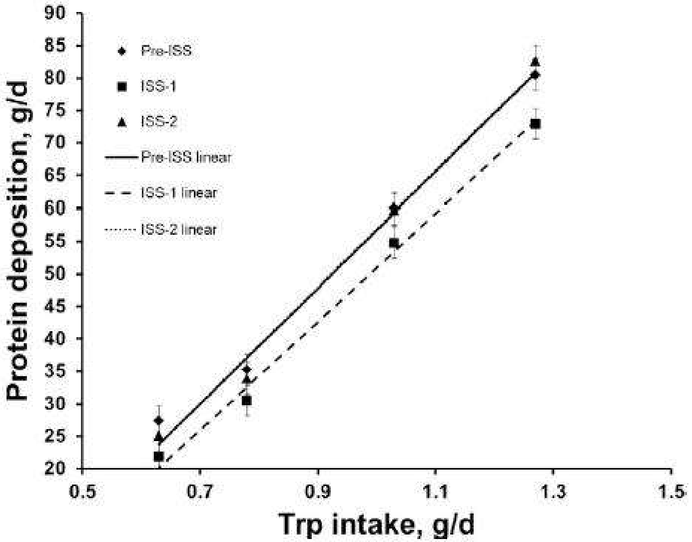
Evidence for Increased Amino Acid Requirement with Immune Stimulation







Litvak et al., 2013; Wellington et al., 2018; de Ridder et al., 20

Amino acid	Effect[b]	Status	References
SAA	↑ intestinal epithelial growth	Healthy	Bauchart-Thevret et al. (2009)
	↑ efficiency of AA utilization	LPS	Kim et al. (2012b)

METHIONINE (SAA) –

MULTIPLE ANTIOXIDANT SYSTEMS

	↓ ear biting	LSC	van der Meer et al. (2017)
Trp	↓ plasma haptoglobin levels, IDO activity, and lung weight	CFA	Le Floc'h et al. (2008)
	↑ plasma levels of Trp	LSC	Le Floc'h et al. (2009)
	↑ feed intake	ETEC	Trevisi et al. (2009)

TRYPTOPHAN –

ANTIOXIDANT/IMMUNE SUPPRESENT

	↓ ear biting	LSC	van der Meer et al. (2017)
Thr	↑ serum IgG concentration	Healthy	Wang et al. (2006)
	↑ production of mucus	Healthy	Law et al. (2007)
	↑ protein synthesis in muscle and intestine, and mucins	Healthy	Wang et al. (2007)
	↑ gut barrier function	Healthy	Wang et al. (2010)

THREONINE –

GUT HEALTH (MUCIN PRODUCTION)

	↑ growth performance	ST	Wellington et al. (2019)
	↑ mucin production	LPS/ST	Wellington et

Rodrigues et al, 2023

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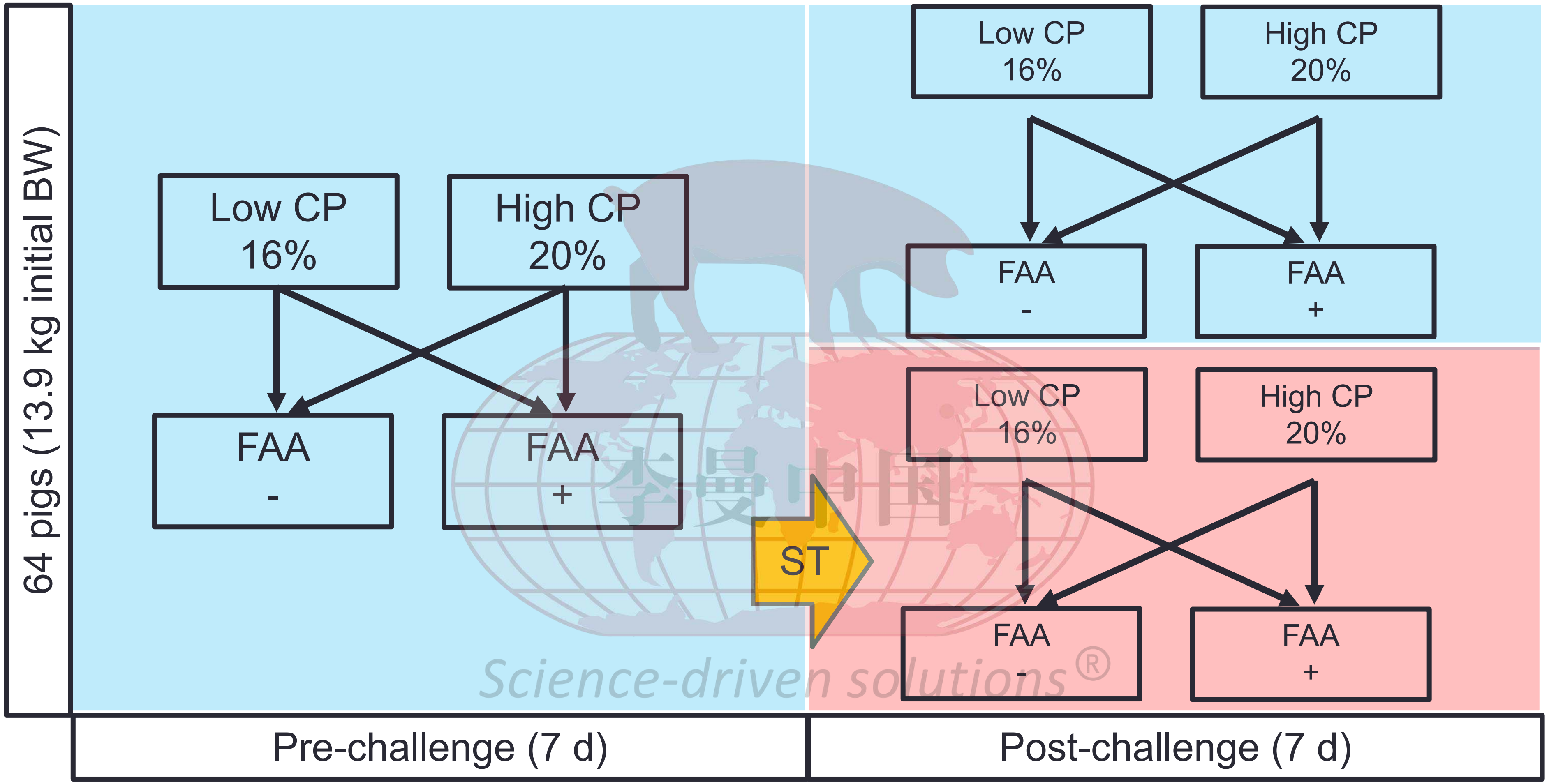
Does a blend of functional amino acids improve growth performance in Salmonella-challenged pigs?

What is the effect of dietary protein content?



*FAA+ = Met, Trp, and Thr at 120% of NRC (2012)

Rodrigues et al., 2021

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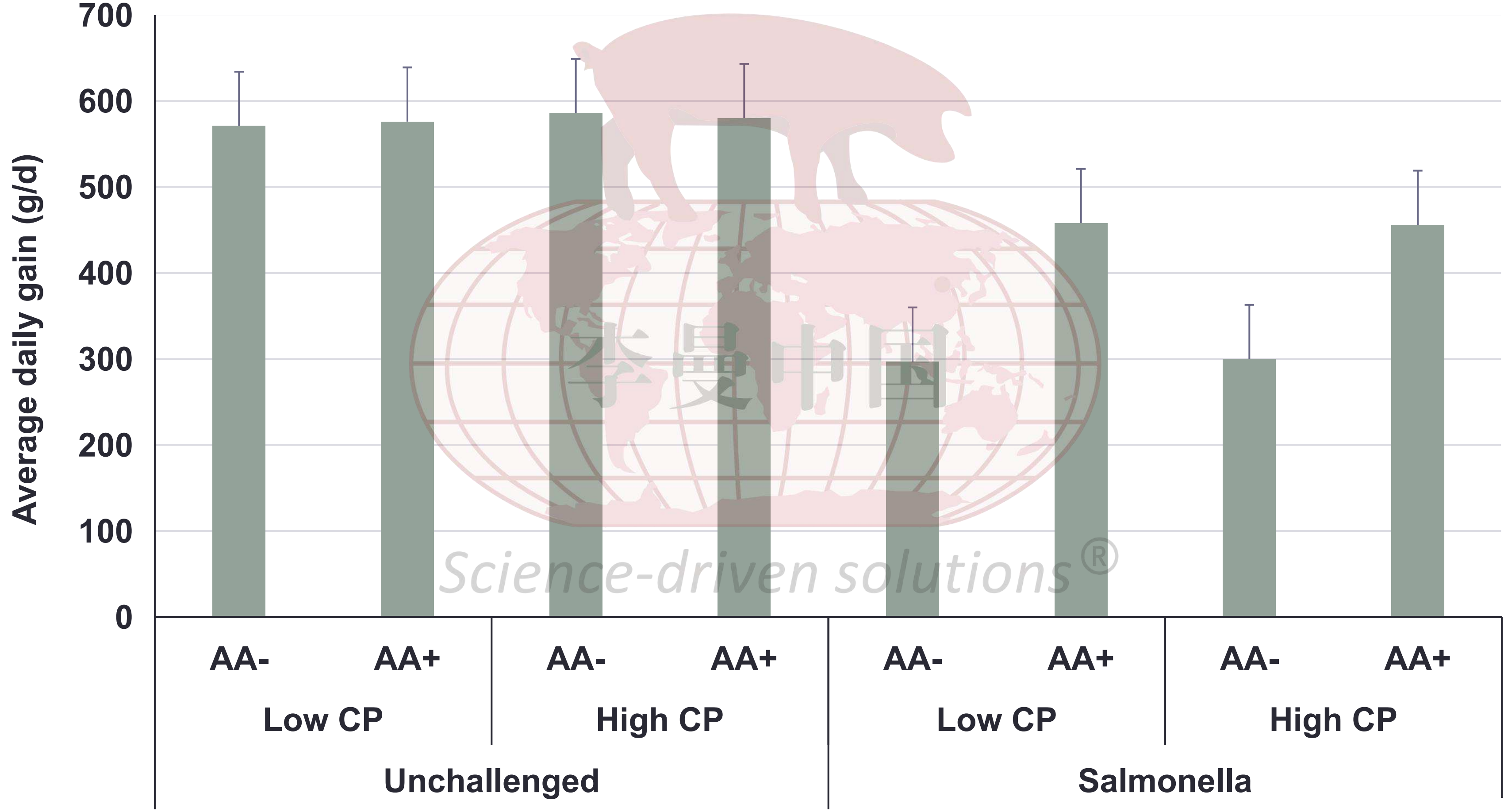
Amino acid supplementation increased growth performance



Rodrigues et al., 2021

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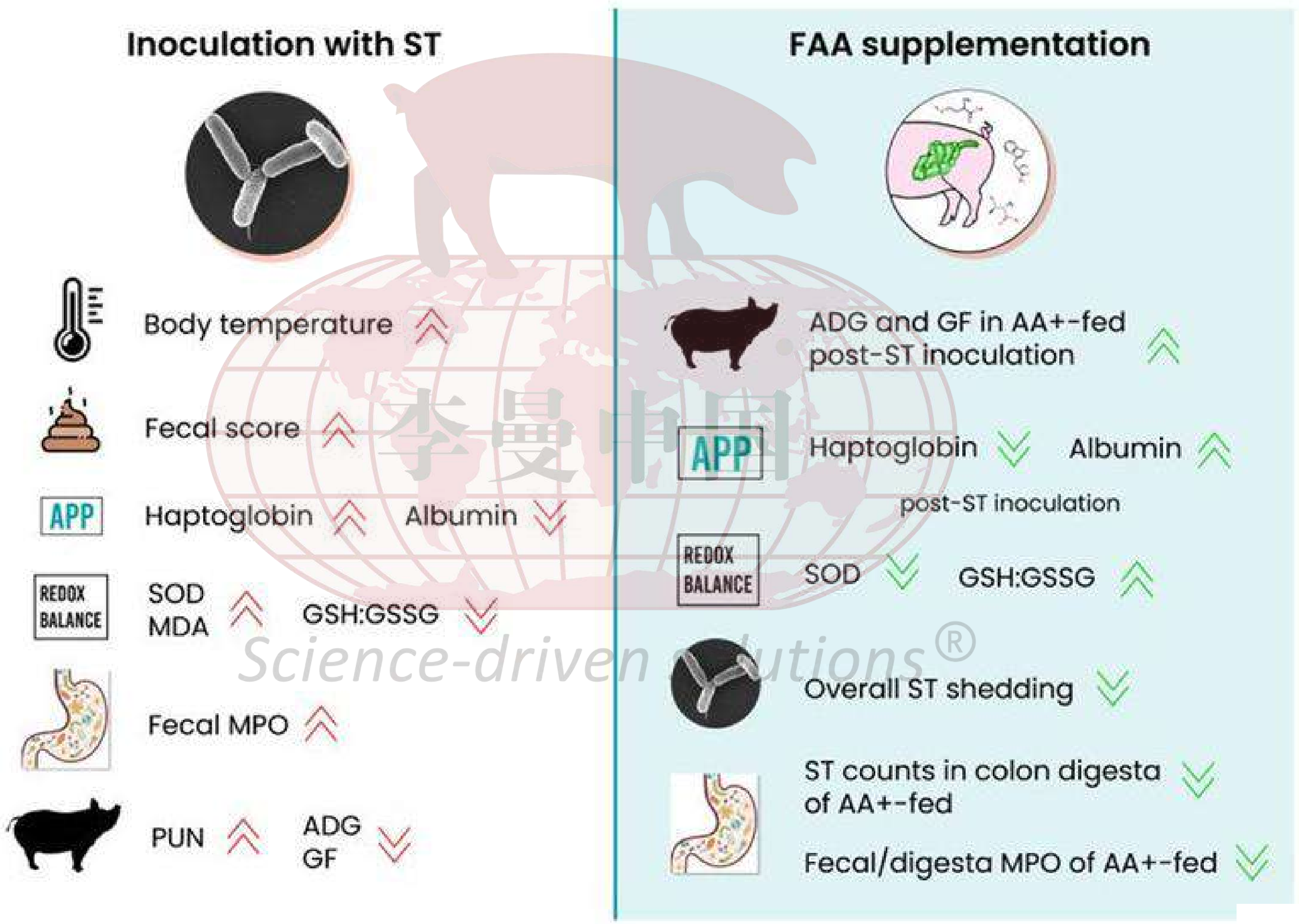
FAA attenuated the immune response



Rodrigues et al., 2021

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Similar response in grower pigs

	GOOD		POOR		P-value		
	CN	AA+	CN	AA+	SC	D	SC*D
ADG, kg	0.81^{a}	0.80^{a}	0.60^{c}	0.70^{b}	<0.01	0.04	0.03
ADFI, kg	1.45^{a}	1.38^{ab}	1.24^{c}	1.29^{bc}	<0.01	0.81	0.08
G:F, kg/kg	0.55^{b}	0.58^{a}	0.47^{c}	0.54^{b}	<0.01	<0.01	0.06
Protein Deposition, g/d	137^{a}	139^{a}	109^{b}	127^{a}	<0.01	0.03	0.07
Lipid Deposition, g/d	87	84	57	70	<0.01	0.32	0.10
N retention efficiency, %	60^{a}	60^{a}	55^{b}	59^{a}	<0.01	0.03	0.03

AA+, amino acid supplemented (120% Met, Thr, Trp); ADG, average daily gain; ADFI, average daily feed intake; CN, control diet; D, diet; G:F, gain:feed; SC, sanitary conditions

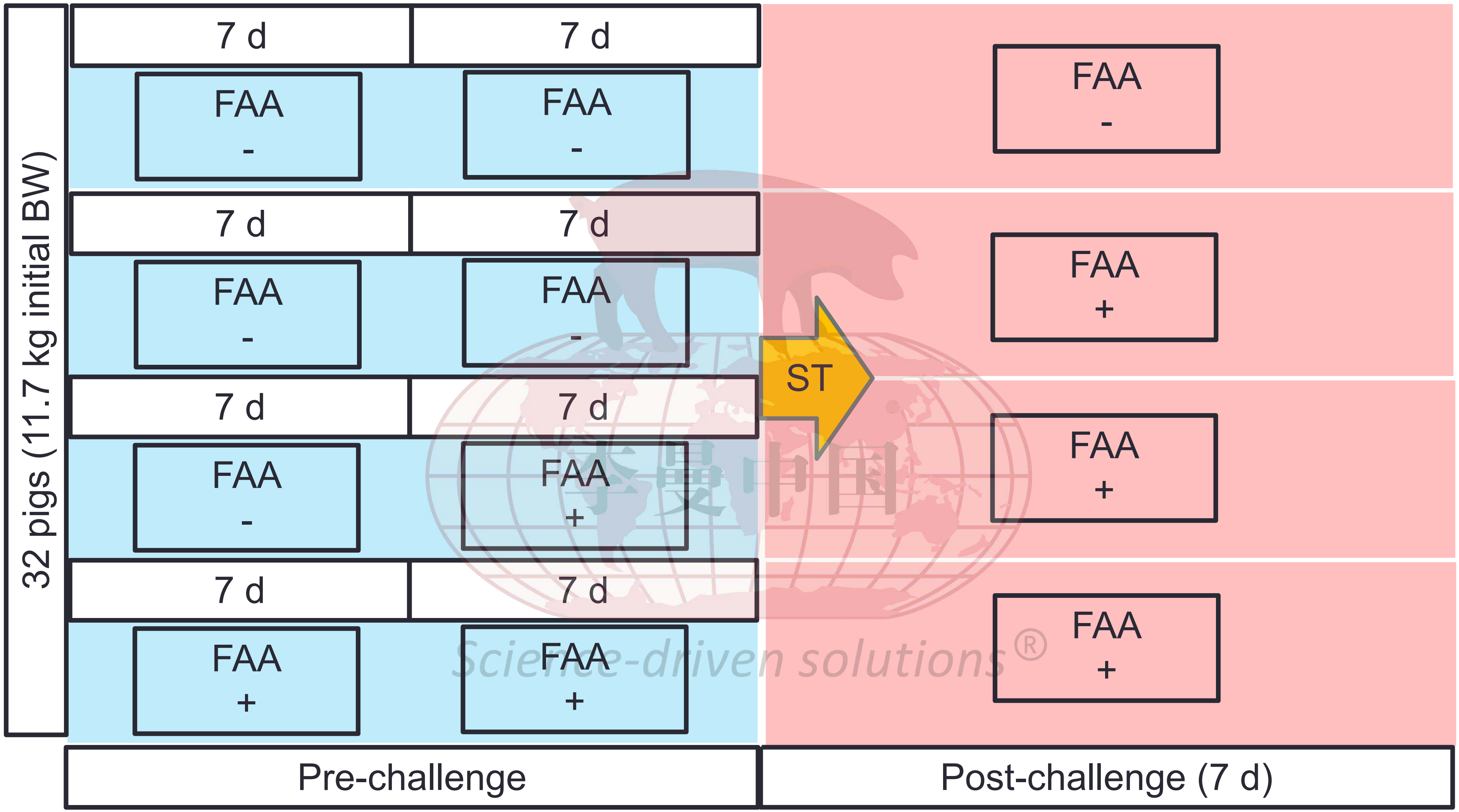
Cunha Valini et al., 2023

Item	GOOD[1]		ST + POOR		RSD[2]	*P*-value		
	CN	AA+	CN	AA+		SC	D	SC × D
7 d post-challenge								
Haptoglobin, g/L	0.27	0.40	0.86	0.89	0.13	<0.01	0.31	0.50
Total protein, g/dL	6.60	6.65	6.15	6.31	0.26	<0.01	0.48	0.70
Albumin, g/L	41.63	43.13	35.77	38.44	1.87	<0.01	0.05	0.57
Urea, mg/dL	17.05	17.11	21.63	18.23	2.03	0.03	0.08	0.20
Creatinine, mg/dL	0.83	0.88	0.95	0.88	0.18	0.56	0.90	0.52
28 d post-challenge								
Haptoglobin, g/L	0.22	0.24	0.35	0.39	0.07	<0.01	0.50	0.78
Total protein, g/dL	5.76	5.71	5.73	5.85	0.14	0.47	0.63	0.31
Albumin, g/L	34.54	35.70	31.36	34.49	1.54	0.01	0.01	0.26
Urea, mg/dL	17.03	16.78	20.08	16.63	1.83	0.15	0.09	0.12
Creatinine, mg/dL	1.28	1.31	1.29	1.32	0.05	0.80	0.28	0.83

[1]GOOD, good sanitary condition; ST + POOR, salmonella challenge and poor housing condition; CN, control diet (basal AA profile); AA+, supplemented diet (supplemented AA profile containing 20% above Trp, Thr, and Met + Cys:Lys ratio).

Cunha Valini et al., 2023

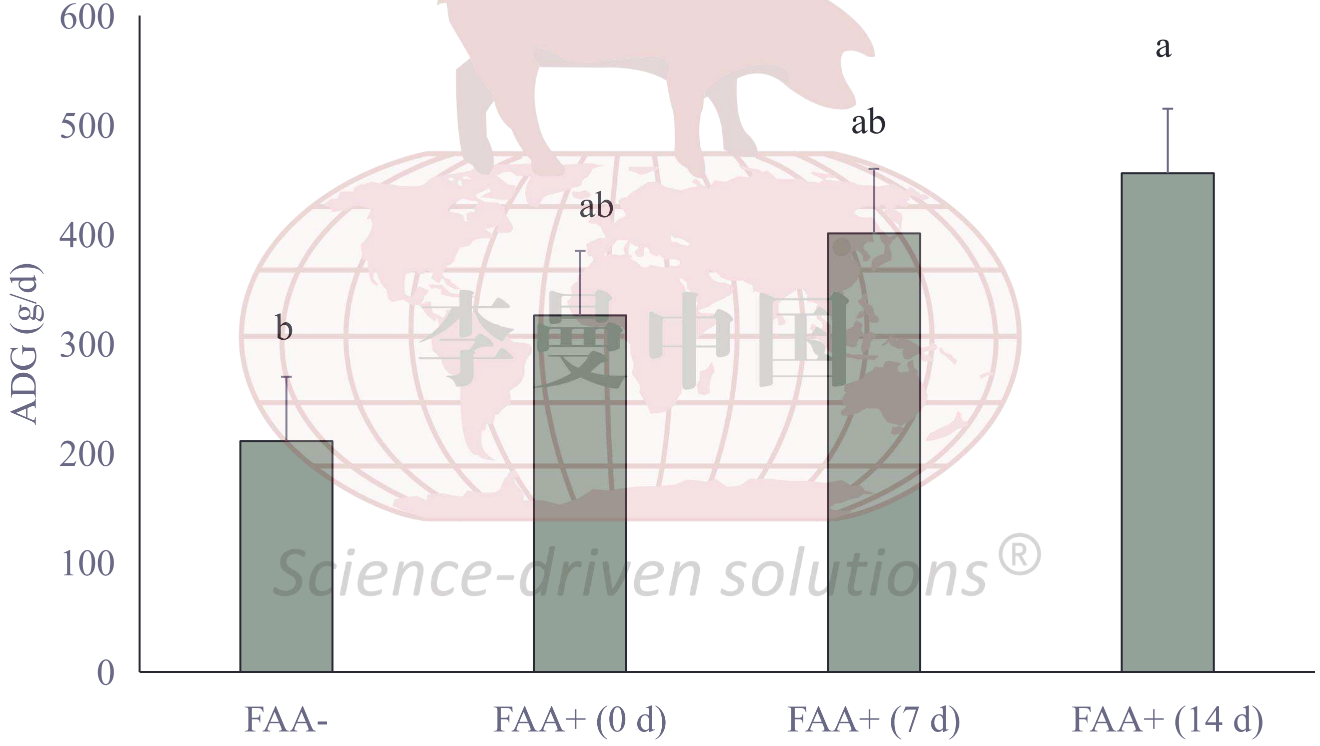
Does increased adaptation time improve response to a blend of functional amino acids?



*FAA+ = Met, Trp, and Thr at 120% of NRC (2012)

Rodrigues et al., 2021

Amino acid supplementation and a longer adaptation period improves performance



Rodrigues et al., 2021

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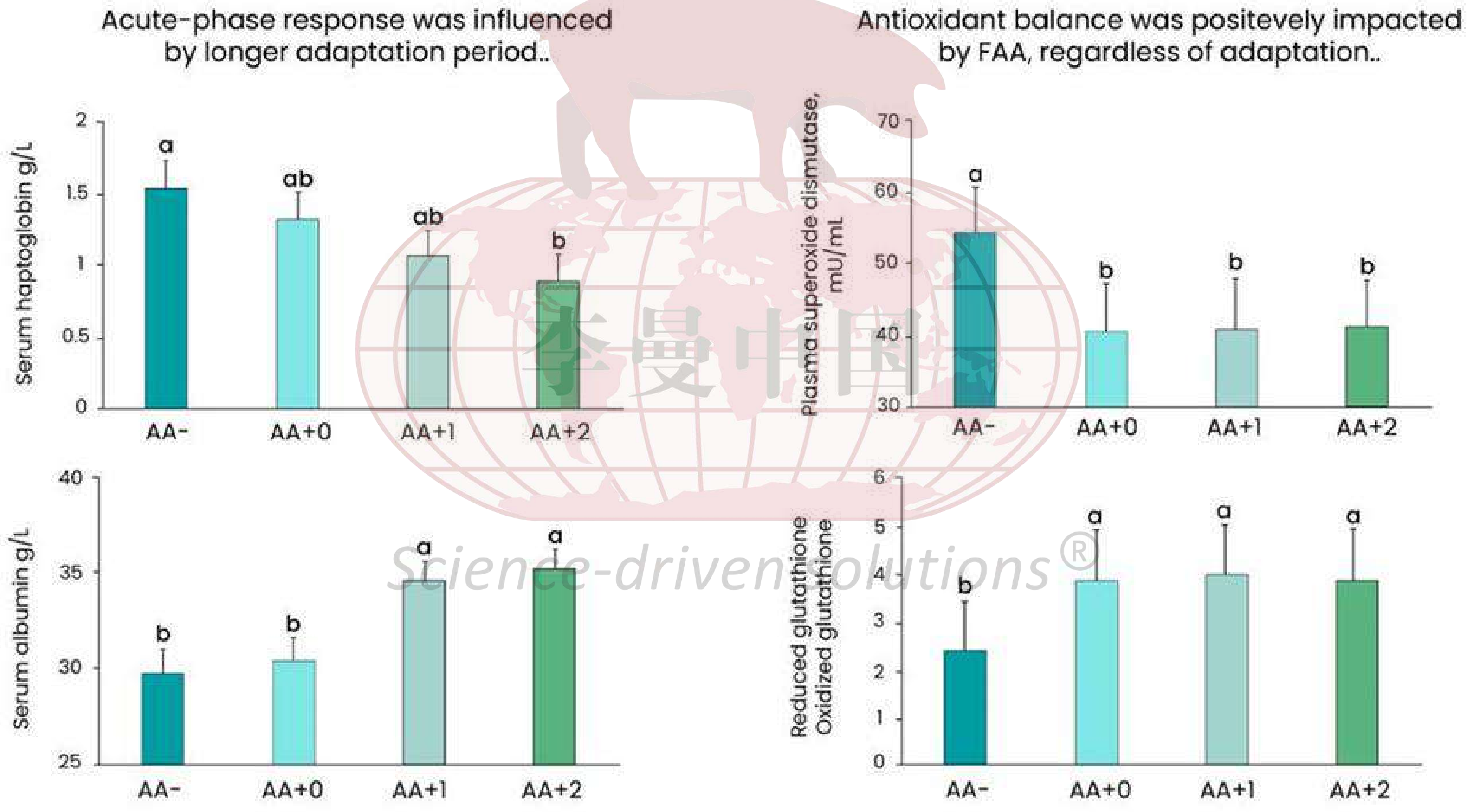
FAA and adaptation time altered acute-phase response and oxidant/antioxidant balance



Rodrigues et al., 2021

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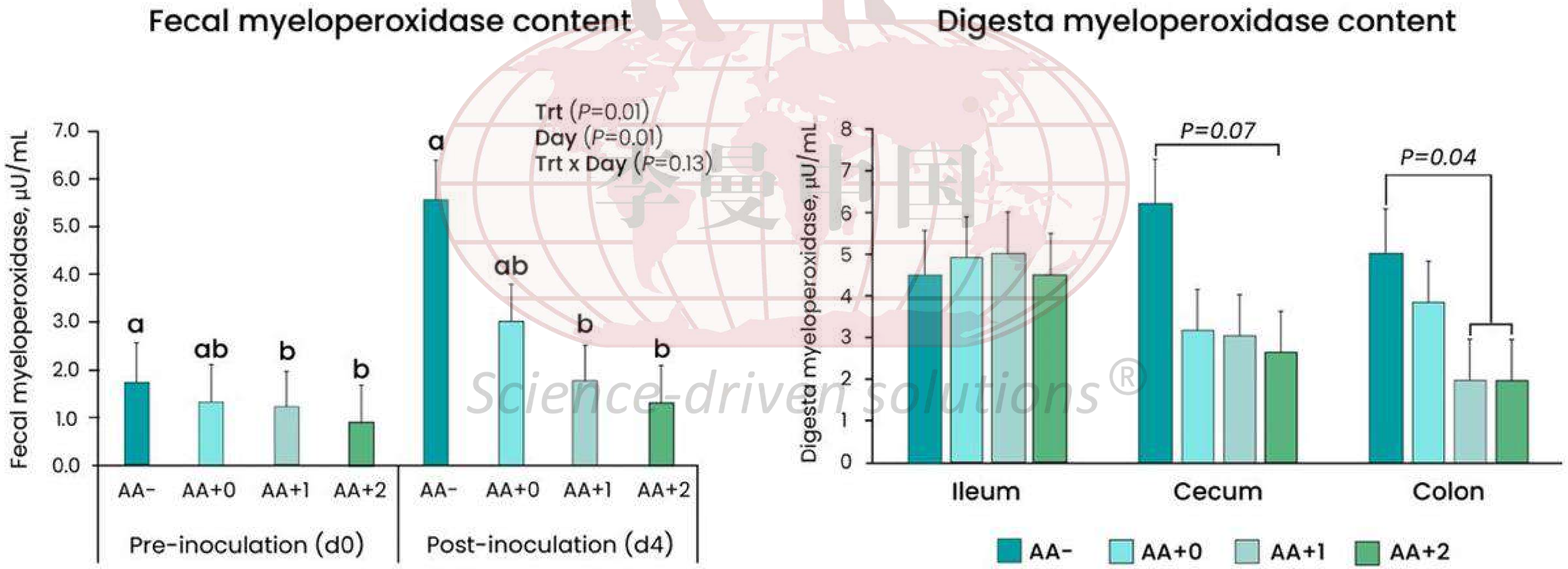
FAA and adaptation time improved intestinal health



Rodrigues et al., 2021

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Timing & stage of production important

- Increased Lys:energy content improved growth performance of PRRS-challenged pigs at the time of challenge, however, no improvement was observed if the adjusted diet was provided post-challenge (i.e., peak infection) (Schweer et al.; 2019; Jasper et al., 2020; Miller et al., 2022)

- Growth performance improved only in nursery period and feed efficiency improved only in finisher period in pigs housed in unsanitary conditions (van der Meer et al.; 2016)

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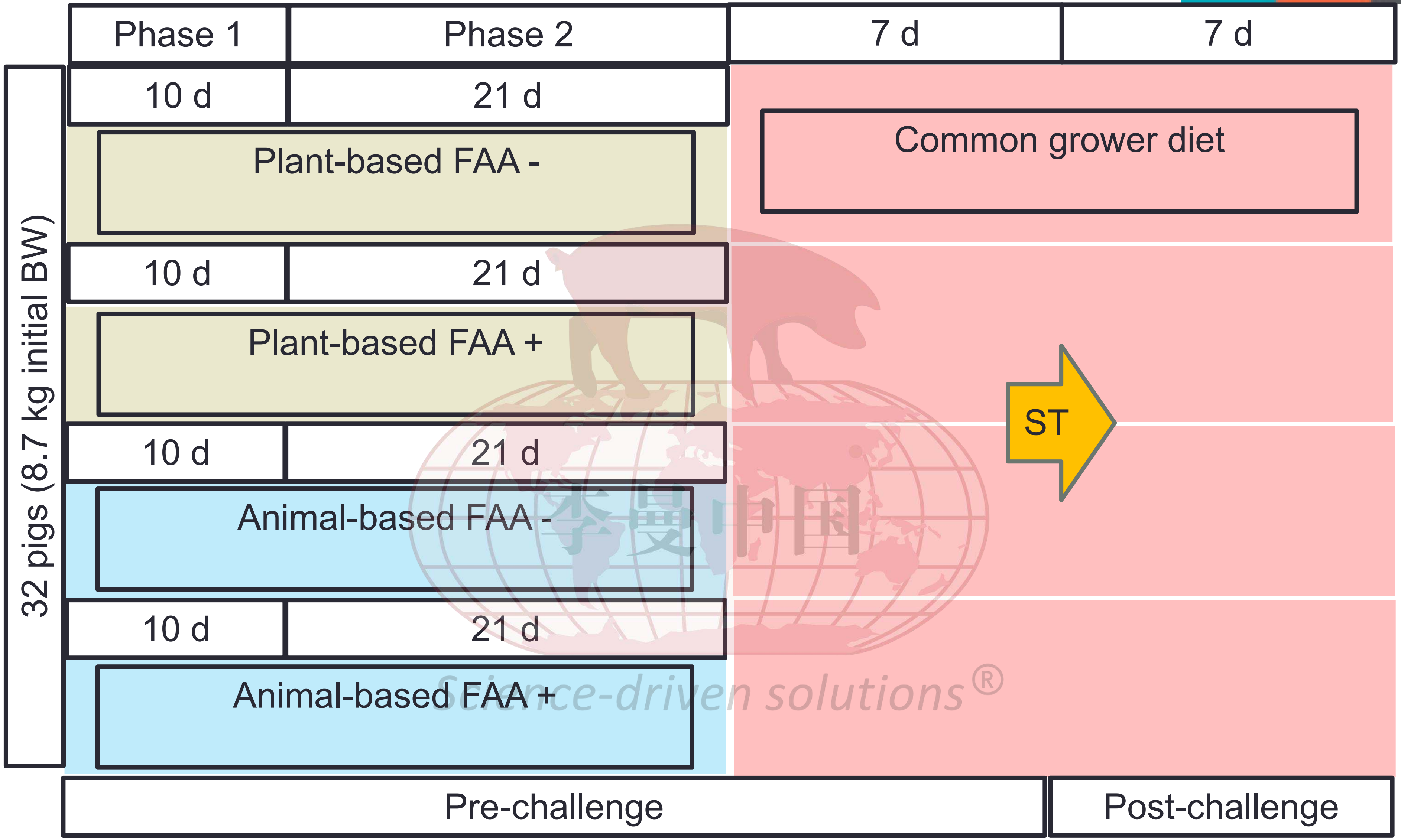
What is the impact of functional amino acids in newly-weaned pigs fed nursery diets containing plant-based vs. animal-based protein sources during subsequent Salmonella challenge?



*FAA+ = Met, Trp, and Thr at 120% of NRC (2012)

Rodrigues et al., 2022

	Phase I (d 0-10 post-weaning)				Phase II (d 10-31 post-weaning)				Grower (d 31-45 post-weaning)
	Plant based		Animal based		Plant based		Animal based		
	FAA-	FAA+	FAA-	FAA+	FAA-	FAA+	FAA-	FAA+	
Corn	27.67	27.31	61.27	60.92	34.94	34.59	71.58	71.22	48.95
Wheat	13.00	13.00	-	-	15.00	15.00	-	-	15.00
Barley	13.00	13.00	-	-	15.00	15.00	-	-	15.00
Canola meal	10.00	10.00	-	-	10.00	10.00	-	-	-
Meat meal	-	-	4.00	4.00	-	-	3.00	3.00	-
Fish meal	-	-	5.00	5.00	-	-	4.00	4.00	-
Blood meal	-	-	1.00	1.00	-	-	1.00	1.00	-
Whey protein	10.00	10.00	10.00	10.00	-	-	-	-	-
Soybean oil	7.50	7.50	-	-	7.50	7.50	-	-	1.00
Soybean meal, 46% CP	20.00	20.00	17.00	17.00	18.50	18.50	18.00	18.00	16.00
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Limestone	1.12	1.12	0.02	0.02	1.22	1.22	0.42	0.42	1.20
Monocalcium phosphate	1.00	1.00	-	-	1.10	1.10	0.30	0.30	1.10
Vitamin/Mineral Premix[2]	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.20
L-Lys HCl	0.57	0.57	0.49	0.49	0.61	0.61	0.52	0.52	0.62
DL-Met	0.14	0.30	0.18	0.33	0.12	0.27	0.16	0.31	0.16
L-Thr	0.17	0.33	0.16	0.32	0.18	0.34	0.17	0.33	0.21
L-Trp	-	0.04	0.03	0.07	0.01	0.05	0.03	0.08	0.03
L-Val	0.08	0.08	0.05	0.05	0.07	0.07	0.05	0.05	0.11
L-Arg	-	-	0.01	0.01	-	-	-	-	-
L-Iso	-	-	0.03	0.03	-	-	0.02	0.02	0.05
L-His	-	-	0.01	0.01	-	-	-	-	0.02

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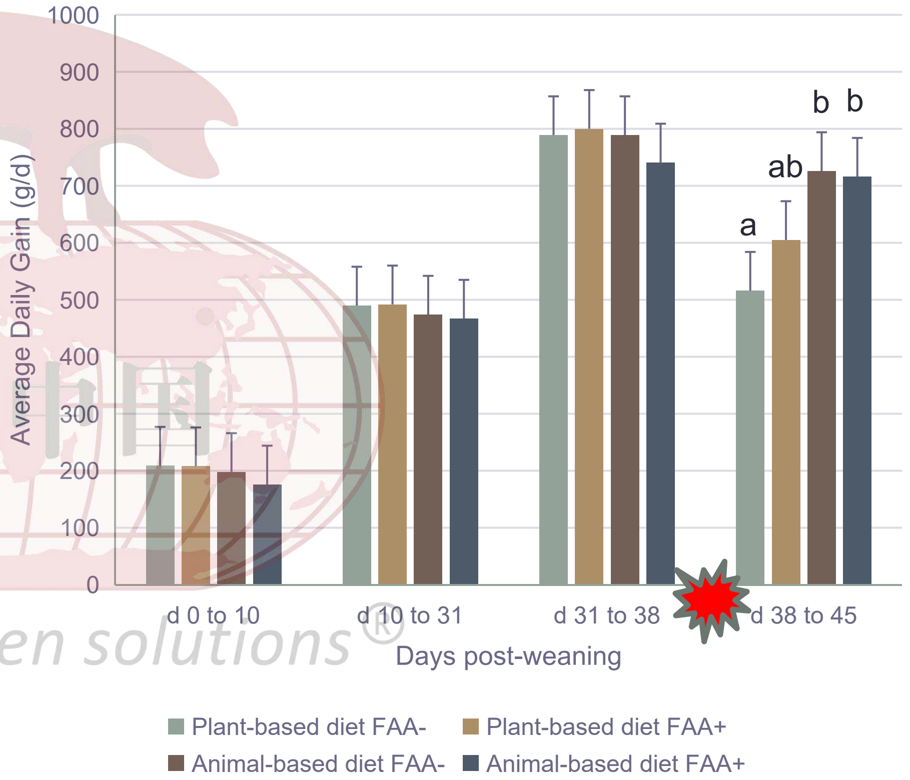
- Plant-based diets may reduce performance and health status and increase mortality (Skinner et al., 2014)

- Use of animal-based nursery diets or FAA supplementation may improve performance during disease challenge



Rodrigues et al., 2022

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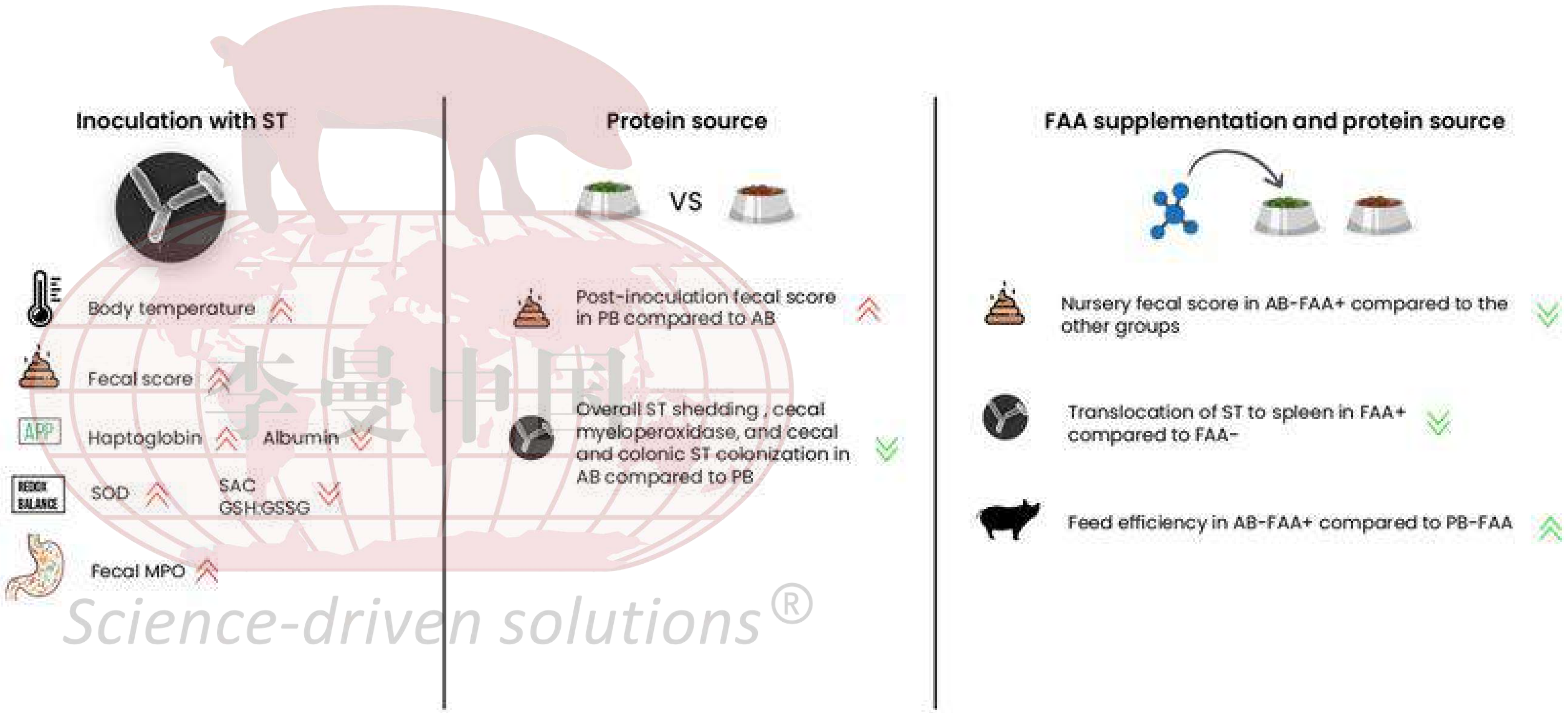
- Animal-based/FAA+ improved fecal score
- FAA reduced post-challenge body temperature and ST translocation
- Plant-based decreased fecal score and increased ST shedding and ST colonization in digesta



Rodrigues et al., 2022

SUMMARY

- Nutrient requirements to support development and the immune response vs. growth performance
- Protein can impact gut health
  - Consider protein source/digestibility
- Pig response to challenge affected by age, sex, and challenge type
- Adjusting dietary amino acid content can improve growth performance, development, immune response
  - Influenced by supplementation time, protein source

Acknowledgements

- Nutrition research group

- Staff at the CFRC, WCVM-ACU, and Prairie Swine Centre

Government of Saskatchewan
EVONIK INDUSTRIES
NSERC CRSNG
Mitacs
Swine Innovation Porc
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