Altering diet composition as alternative to zinc oxide and to reduce post-weaning diarrhea

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Wageningen Livestock Research

Zero Zinc Summit, Copenhagen June 2019

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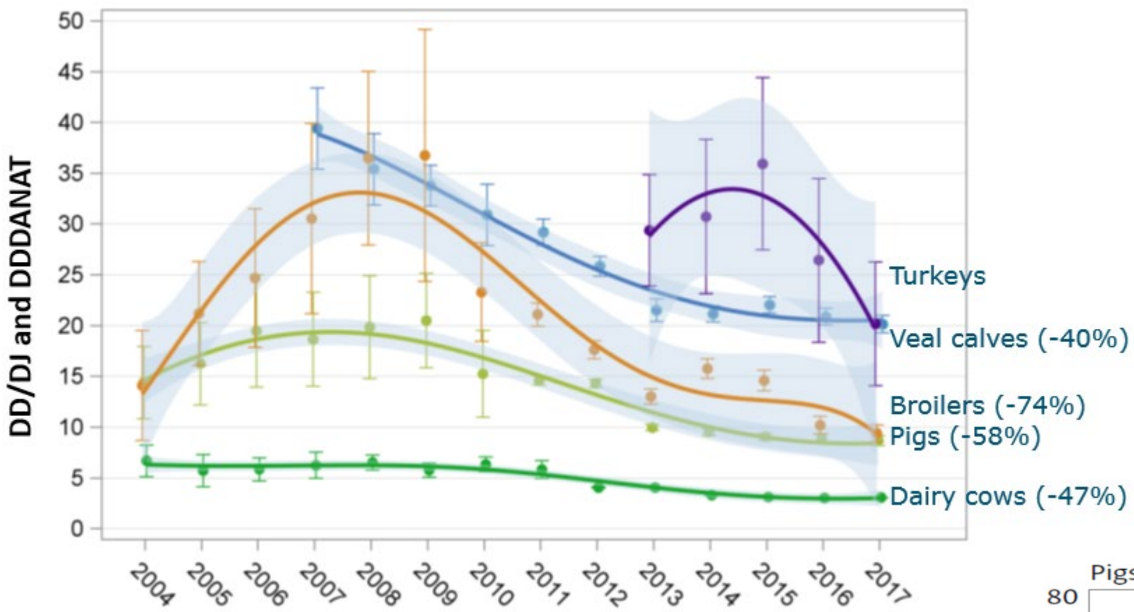
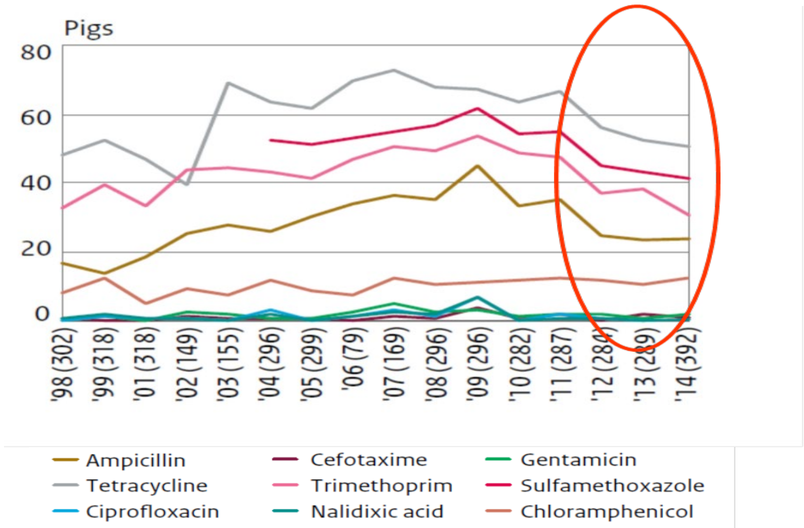
Introduction

- The importance of gut health and reduction of post-weaning diarrhoea
- Health risks around weaning and options for control (ban on ZnO and reduction AB use)
- Effects of ingredient and nutrient composition on gut health and function in the post-weaning phase
- Conclusions

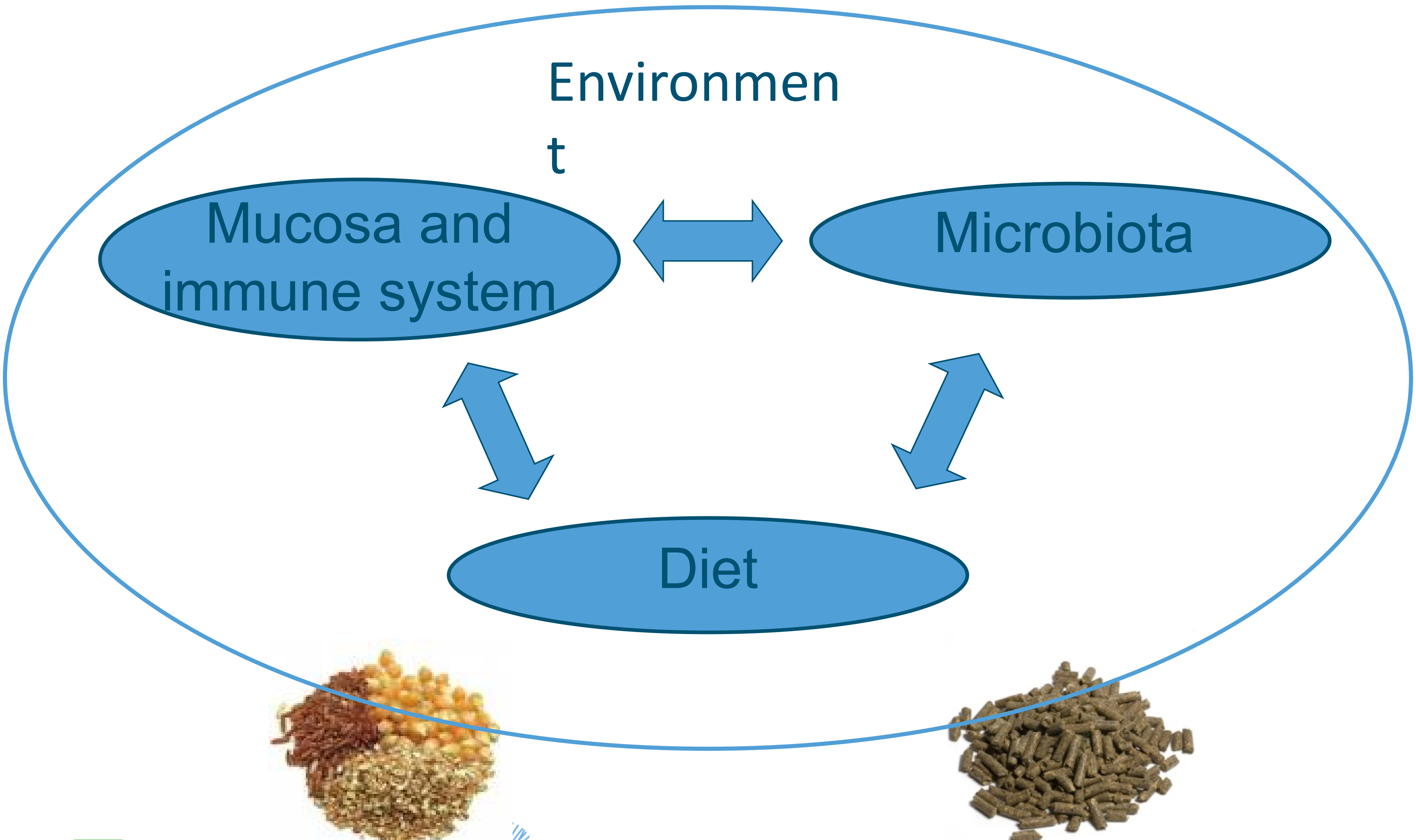
Reduction in antibiotic use and resistance in NL





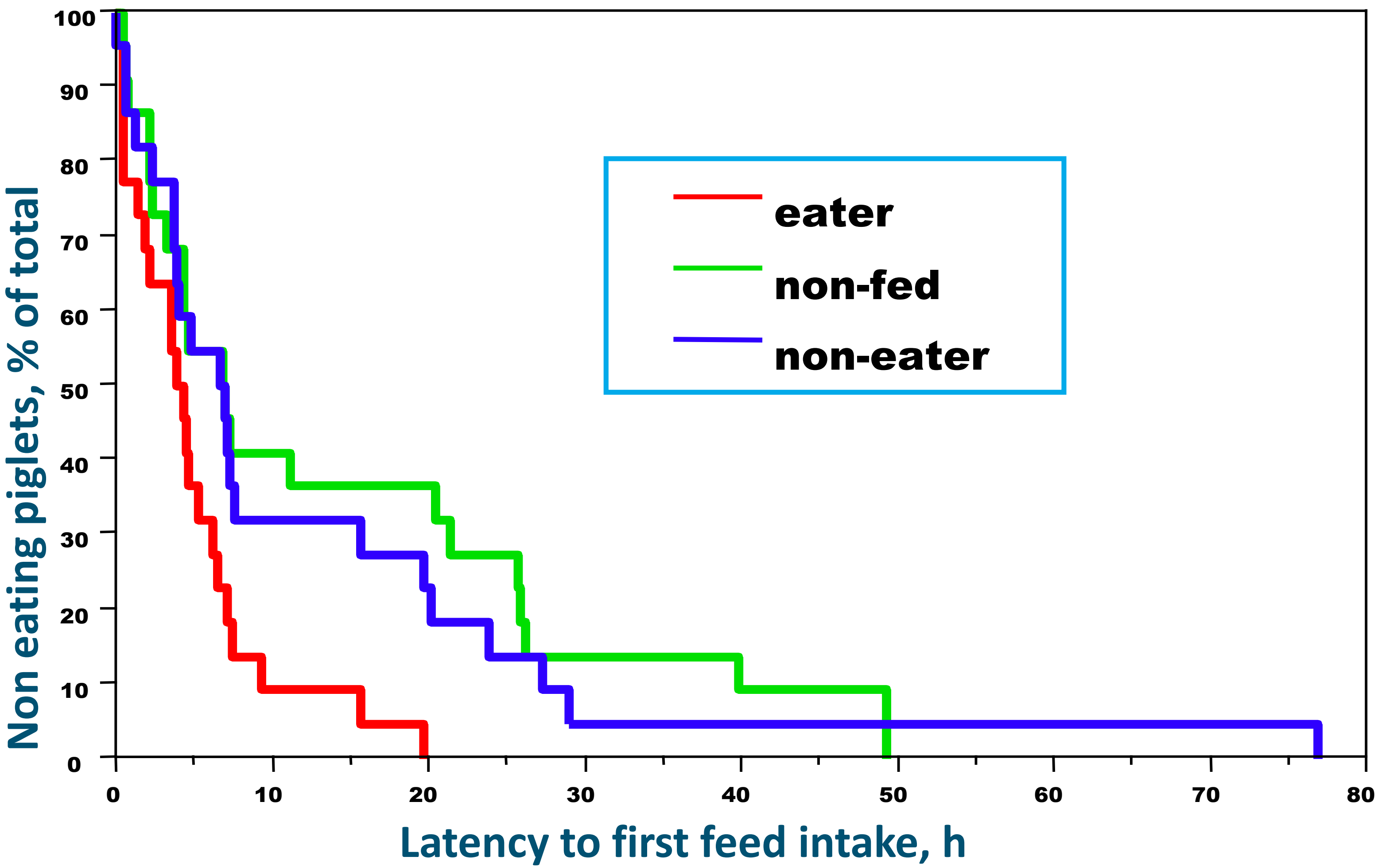
SDA (2018)

Intestinal health



Pre-weaning feed intake:

effect on the development of post-weaning feed intake



Bruininx, 2002

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Options for diet optimization

- Pre-weaning feeding (shaping the microbiota and gut development)
- Selection of protein sources (digestibility and functionality)
- Optimization of dietary protein level and AA profile
- Selection of (processed) starch source
- Selection of fibre source
- Inclusion of selected feed additives (e.g. organic acids, enzymes, pre- and probiotics)
- Diet form, structure and palatability

Intestinal response in piglets to neonatal and maternal interventions

- Gene expression in intestinal scrapings of offspring piglets using whole genome microarrays

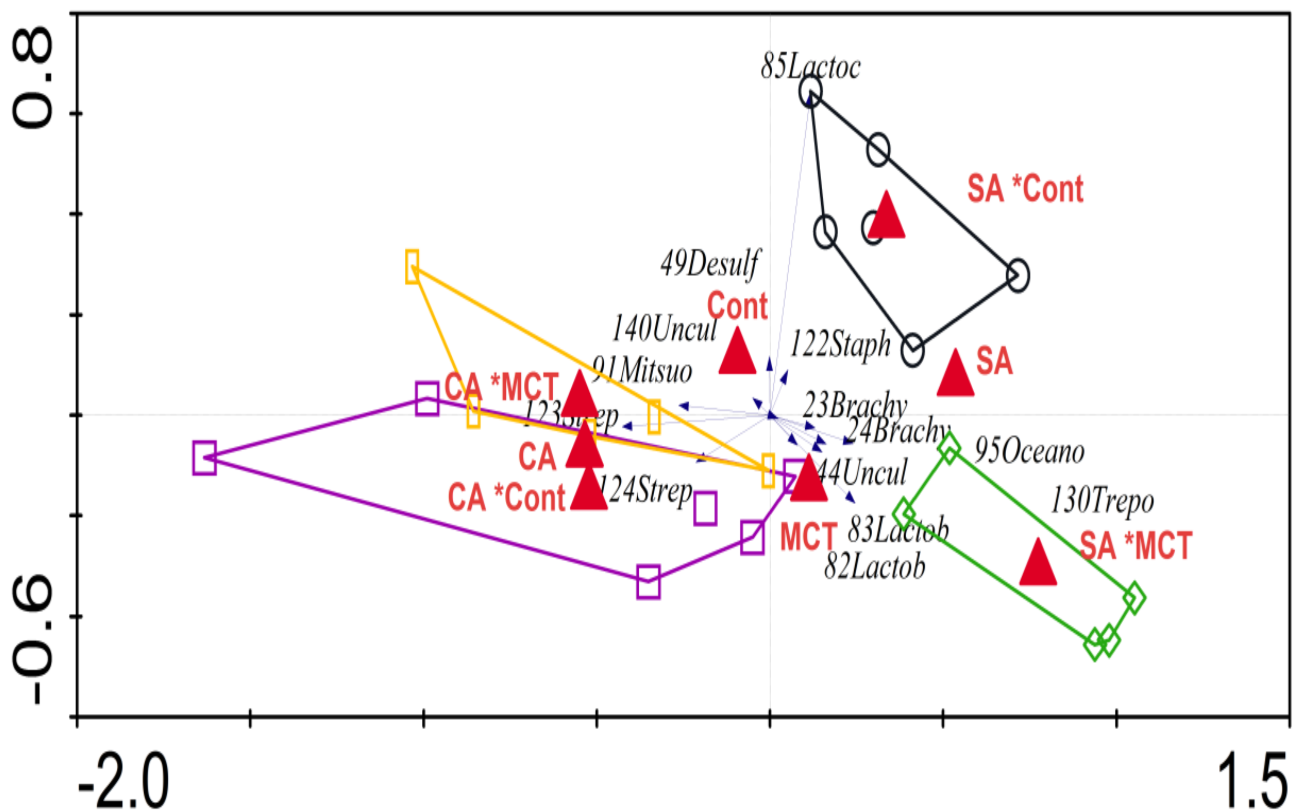
Intervention	Day	Neonatal	Maternal
MCFA (jejunum)	1	-	3
	31	293	203
β-glucan (ileum)	1	-	0
	31	31	302
GOS (colon)	1	-	2721
	31	42	878

* FC>2; P≤0.05

- All dietary interventions strongly affect intestinal gene expression in offspring piglets related to processes involved in tissue metabolism and immune development (effects being intervention specific!).
- GOS has large effect on Day 1; β-glucans and MCFAs have main effect on Day 31

de Greeff et al. (2016)

Jejunal microbiota composition as affected by oral association and dietary fat composition in piglets (d20 and 21 of age)



A mix of soya oil (50 g/kg) and palm oil (30 g/kg) was exchanged with coconut oil (70 g/kg + 10 g/kg other fat sources)

Jansman et al. (2014)

Protein in diets for weaned piglets

- Sources with a high CP content and highly digestible (e.g. whey protein, soya concentrate, potato protein, fishmeal)
- Low levels of antinutritional factors allowing good intake and digestion
- Balanced AA profile
- Low levels of enzymatically non-digestible protein inducing potential protein fermentation in distal part GI tract
- Protein sources with functional properties

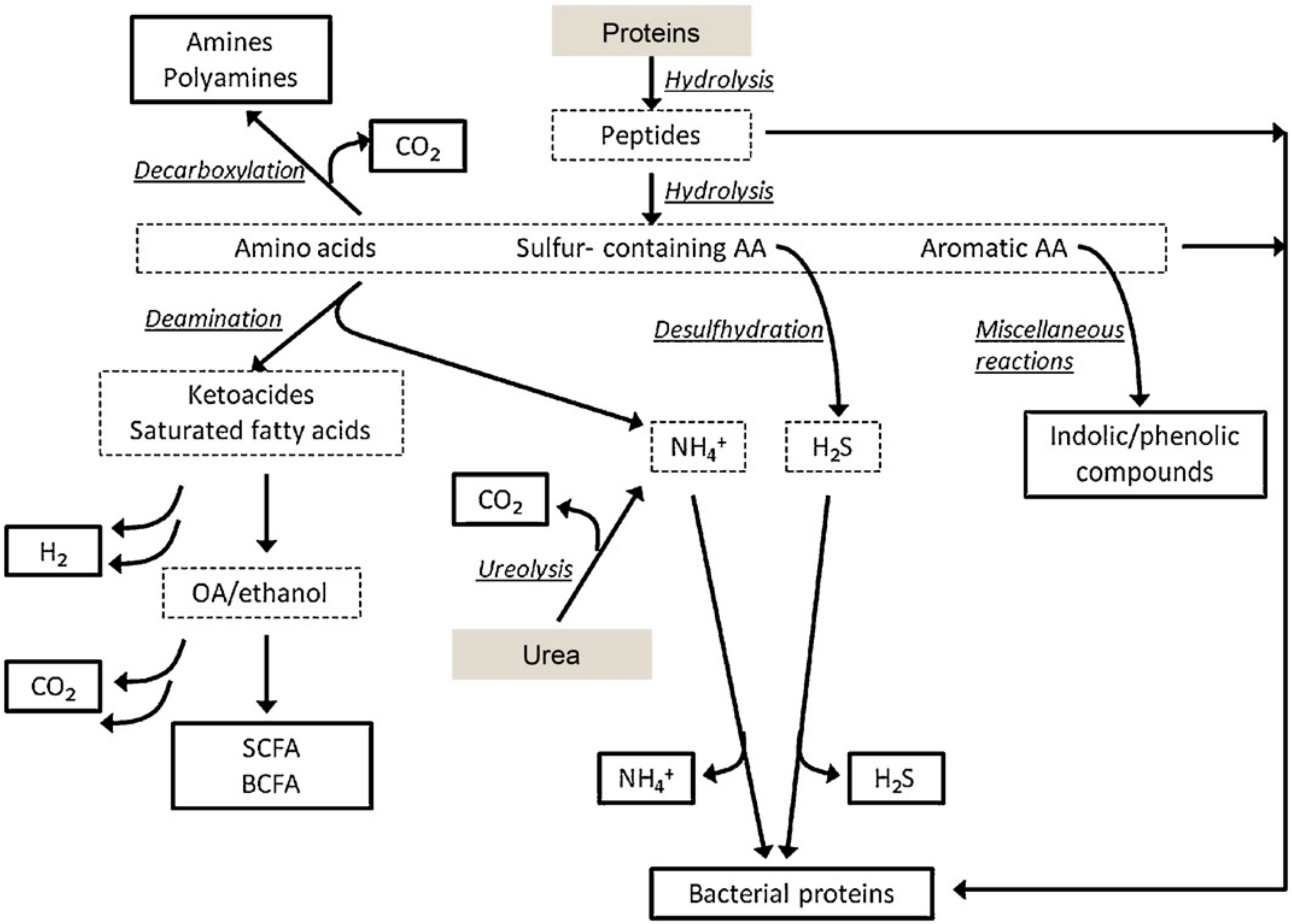
Effect of dietary protein level on performance and health in piglets

CP[1]	23%	21%	19%	17%	Sign. Diet
Intake, g/d	528	522	464	414	*
BWG, g/d	353	340	288	232	*
Water intake, l/d	3.83	3.01	3.24	3.22	NS
Faecal consistency score (0-3)	0.36	0.20	0.18	0.29	NS
pH, ileum	6.7	6.0	6.1	6.3	*
Ammonium, jejunum, mg/l	35	34	27	22	*
Ammonium, ileum, mg/l	72	49	42	38	*

[1]Diets balanced for Lys, M+C, Thr and Trp (but not for Val, Ile and other AA)

Nyachoti et al. (2006)

Protein fermentation in the GIT



Davilaa et al. (2013)

Plasma proteins in post-weaning diets

Treatment	Week 1-2	Week 3-4	Week 5
T1	control	control	control
T2	2500 ppm ZnO	control	control
T3	5.0% plasma	control	control
T4	2.5% plasma	control	control
T5	5.0% plasma	2.5% plasma	1% plasma
T6	2.5% plasma	1.25% plasma	0.5% plasma

Day 1-14	T 1	T 2	T 3	T 4	T 5	T 6	SEM[1]	P-value[2]
Body gain, g/d	203[a]	261[c]	230[b]	220[ab]	231[b]	209[a]	7.1	<0.001
Feed intake, g/d	250[a]	308[c]	278[b]	266[ab]	276[b]	253[a]	6.9	<0.001
FCR	1.24	1.18	1.21	1.22	1.20	1.21	0.018	0.354
Day 1-35								
Body gain, g/d	383[a]	412[b]	395[ab]	395[ab]	411[b]	382[a]	9.1	0.092
Feed intake, g/d	531[a]	565[c]	547[abc]	557[abc]	562[bc]	534[ab]	10.5	0.111[2)]
FCR	1.39	1.37	1.39	1.42	1.37	1.40	0.014	0.157

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Bikker et al (2018)

Plasma proteins in post-weaning diets

	T 1	T 2	T 3	T 4	T 5	T 6	SEM[1]	P-value[2]
Week 1	a	b	a	ab	ab	ab		
Normal faeces, %	90.7	95.8	92.6	94.0	92.8	93.0		<0.001
Soft faeces, %	8.6	4.2	6.0	5.6	6.7	6.8		
Watery diarrhoea, %	0.7	0.0	1.4	0.5	0.5	0.2		
Week 2	a	b	a	a	a	a		<0.001
Normal faeces, %	93.2	98.6	93.0	91.7	92.8	93.0		
Soft faeces, %	6.5	1.4	7.0	8.3	7.2	6.7		
Watery diarrhoea, %	0.2	0.0	0.0	0.0	0.0	0.2		

Bikker et al (2018)

Plasma proteins in piglet diets

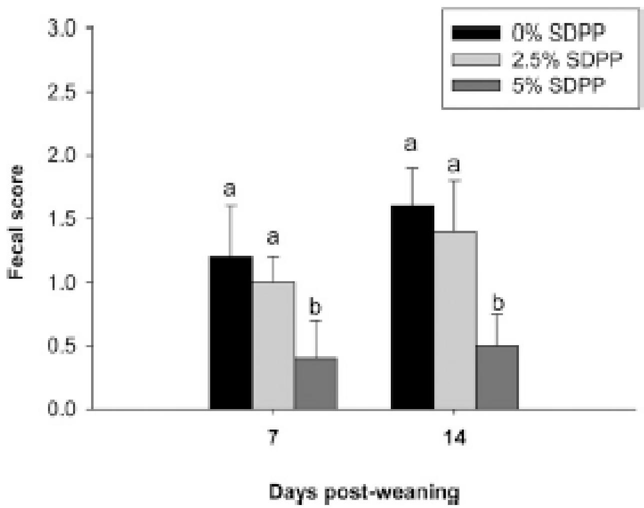

FIGURE 1 Fecal scores in weaned pigs fed different dietary levels of spray-dried porcine plasma (SDPP) for 7 or 14 d. Values are mean ± SE, n = 8. Means at a time without a common letter differ, $P < 0.05$. *Different from d 7, $P < 0.05$.

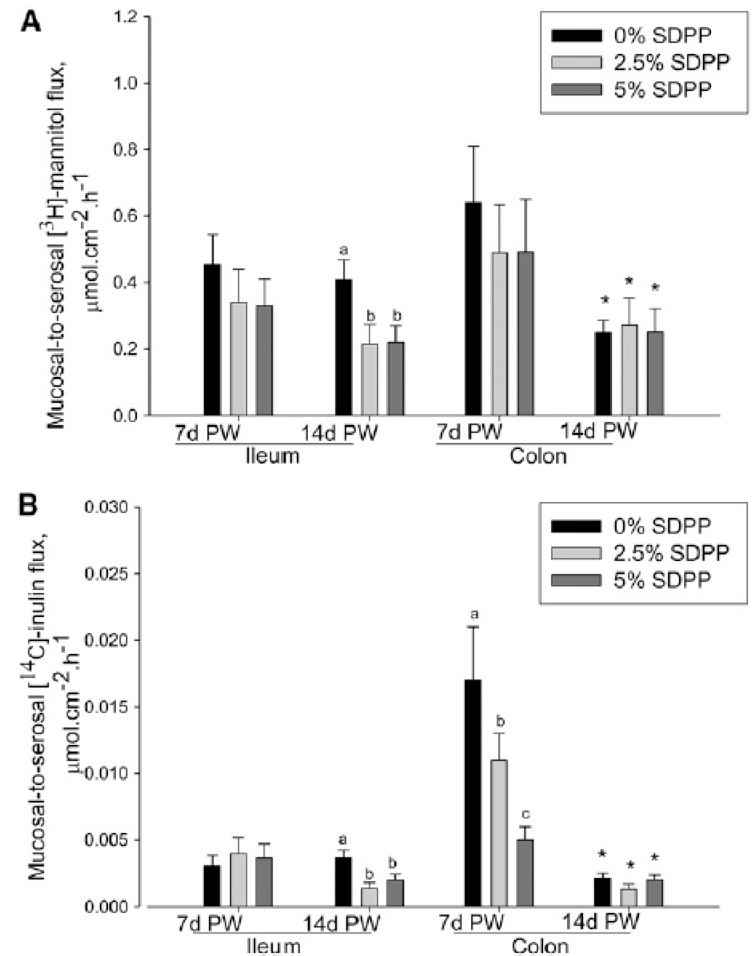

FIGURE 3 Effects of spray-dried porcine plasma (SDPP) on mucosal-to-serosal ^{3}H-mannitol (*A*) and ^{14}C-inulin (*B*) flux in the ileum and colon of weaned pigs fed different dietary levels of SDPP for 7 or 14 d. Values are mean ± SE, n = 8. Means at a time without a common letter differ, $P < 0.05$. *Different from d 7, $P < 0.05$.

Peace et al. (2011)

Role of AA in gut tissue and GALT

<u>Glutamine</u>

- Oxidative substrate for immune cells and IECs
- Precursor for glutamate/GSH
- Intestinal growth, structure and function (young animals and disease states)
- Supports proliferative rates and reduces apoptosis of IECs
- Protects against E.coli/LPS-induced damage to intestinal structure and barrier function
- Lowers inflammatory and increases immune regulatory cytokine production

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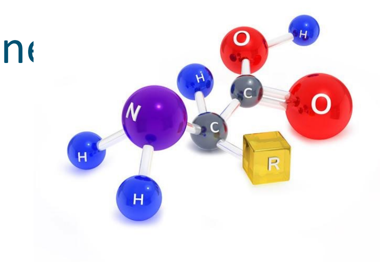
<u>Glutamate</u>

- Oxidative substrate for immune cells and IECs
- Precursor for GSH and other amino acids (i.e. arginine)
- Intestinal growth, structure and function
- Acts as immune transmitter between dendritic cells and T-cells
- Facilitates T-cell proliferation and Th1 and pro-inflammatory cytokin



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Modified from Ruth and Field (2013)

Role of AA in gut tissue and GALT

Arginine

- Precursor for NO and glutamate in IECs and immune cells
- Intestinal growth, structure and function
- Increases expression of HSP70 to protect intestinal mucosa
- Protects against E.coli/LPS-induced damage to intestinal structure and barrier function
- Facilitates neutrophil and macrophage killing through iNOS-mediated NO production

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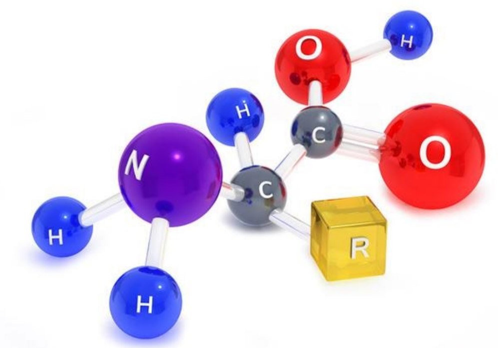
Methionine & cysteine

- Precursor for GSH, taurine and cysteine
- Reduces intestinal oxidative stress
- Increases goblet cells and proliferating crypt cells

Threonine

- Mucin synthesis
- Intestinal structure and function
- Intestinal IgA levels



Modified from Ruth and Field (2013)

Glutamine supplementation and gut function

Gene Expression Is Altered in Piglet Small Intestine by Weaning and Dietary Glutamine Supplementation[1–3]

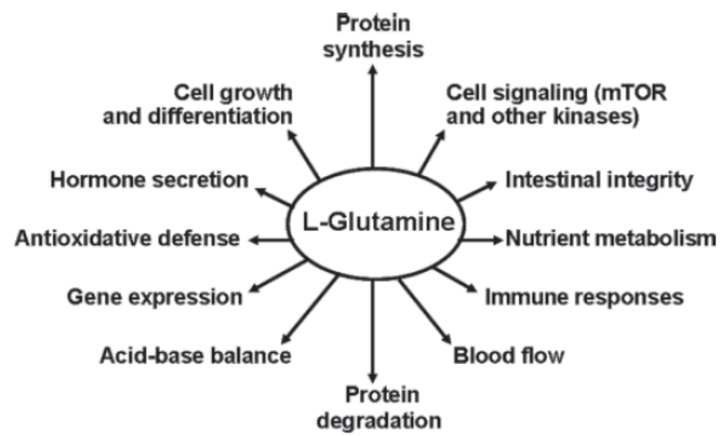
Junjun Wang,[4,5] Lixiang Chen,[5–7] Peng Li,[5] Xilong Li,[5] Huaijun Zhou,[5] Fenglai Wang,[4]* Defa Li,[4] Yulong Yin,[5,6]* and Guoyao Wu[4–6]*

[4]State Key Laboratory of Animal Nutrition, China Agricultural University, Beijing, China 100094; [5]Texas Agricultural Experiment Station, The Texas A&M University System, College Station, TX 77843; [6]Institute of Subtropical Agriculture, Chinese Academy of Sciences, Changsha, Hunan, China 410128; and [7]College of Animal Science and Technology, Hunan Agricultural University, Changsha, Hunan, China 410128

TABLE 3 Jejunal morphology in 28-d-old piglets[1]

Treatment	Villus height	Crypt depth	Lamina propria
Expt. 1		μm	
Suckling	468 ± 8.5	204 ± 8.1	205 ± 8.2
Weaned	265 ± 7.0*	223 ± 8.7	224 ± 8.8
Expt. 2			
W+Ala	269 ± 7.5	228 ± 7.9	229 ± 8.0
W+Gln	371 ± 9.2†	246 ± 7.7	248 ± 7.8

[1] Values are means ± SEM, $n = 12$. *$P < 0.01$ vs. age-matched suckling piglets; †$P < 0.01$ vs. the W+Ala group. W+Ala, Weaned pigs receiving dietary supplementation with isonitrogenous L-alanine (1.22%, wt:wt; control); W+Gln, Weaned pigs receiving dietary supplementation with L-glutamine (1%, wt:wt).



Wang et al. (2008)

Wu et al. (2011)

NSP in cereals and grain legumes (g/kg DM)

Ingredient	Soluble NSP	Insoluble NSP	Total NSP	Major NSP
Wheat[a]	25	94	119	Arabinoxylan
Barley (hulled)[b]	45	122	167	β-Glucan
Barley (hull-less)[a]	50	74	124	
Rye[a]	42	110	152	Arabinoxylan
Oat (hulled)[a]	40	192	232	β-Glucan
Oat (hull-less)[a]	55	63	116	
Soybean[c]	27	165	192	Galacturonans, arabinans and galactose
Pea[c]	25	322	347	Rhamnogalacturonan, glucan
Lupin[c]	46	320	366	Rhamnogalacturonan, arabinose and galactose
Lupin kernel[d]	27	218	245	

[a]Bach Knudsen (1997); [b]Englyst (1989); [c]Choct (1997); [d]Annison *et al.* (1996).

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Pluske et al. (2001)

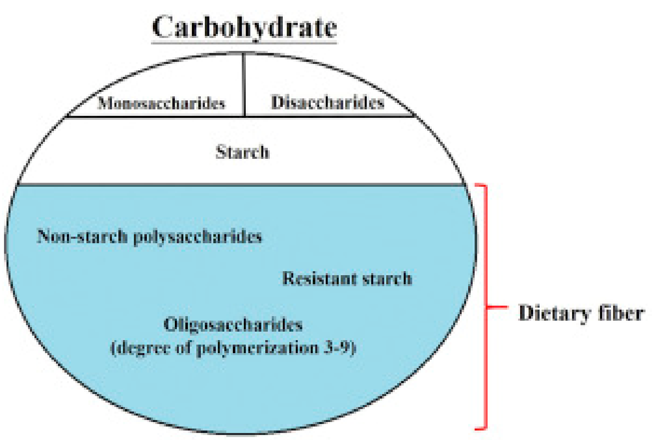
Rice vs barley in diets for weaned piglets

	Incorporation of pearl barley (g/kg)		
	0	500	500 + enzyme†
Viable CFU/g mucosal scraping ($\log_{10}$)			
Mid-small intestine	0·98[a]	4·14[b]	3·48[b]
Proximal colon	2·29[a]	5·21[b]	6·00[b]
ETEC from intestinal swabs at post mortem (%)			
Duodenum	7·5	22·1	26·5
Ileum	11·0[a]	47·6[b]	21·4[ab]
Caecum	16·5[a]	53·2[b]	53·0[b]
Faeces	27·9	44·5	38·8
Mean daily faecal swab score post-infection‡	1·9	2·1	1·6
Faecal DM (g/kg)			
Average over 6 d post-weaning	304	295	299
Average post-infection	301	292	277
Mean faecal consistency score§			
Pre-infection	1·5	1·8	1·7
Post-infection	2·9[a]	3·6[b]	3·7[b]

Hopwood et al. (2004)

NSP (dietary fibre) in diets

- Carbohydrates with large variation in chemical nature
- Functional properties (water holding, swelling, bulk density, viscosity and their solubility) in relation to behaviour in GIT
- Extent and location of fermentation
- Prebiotic activity (microbiota composition)



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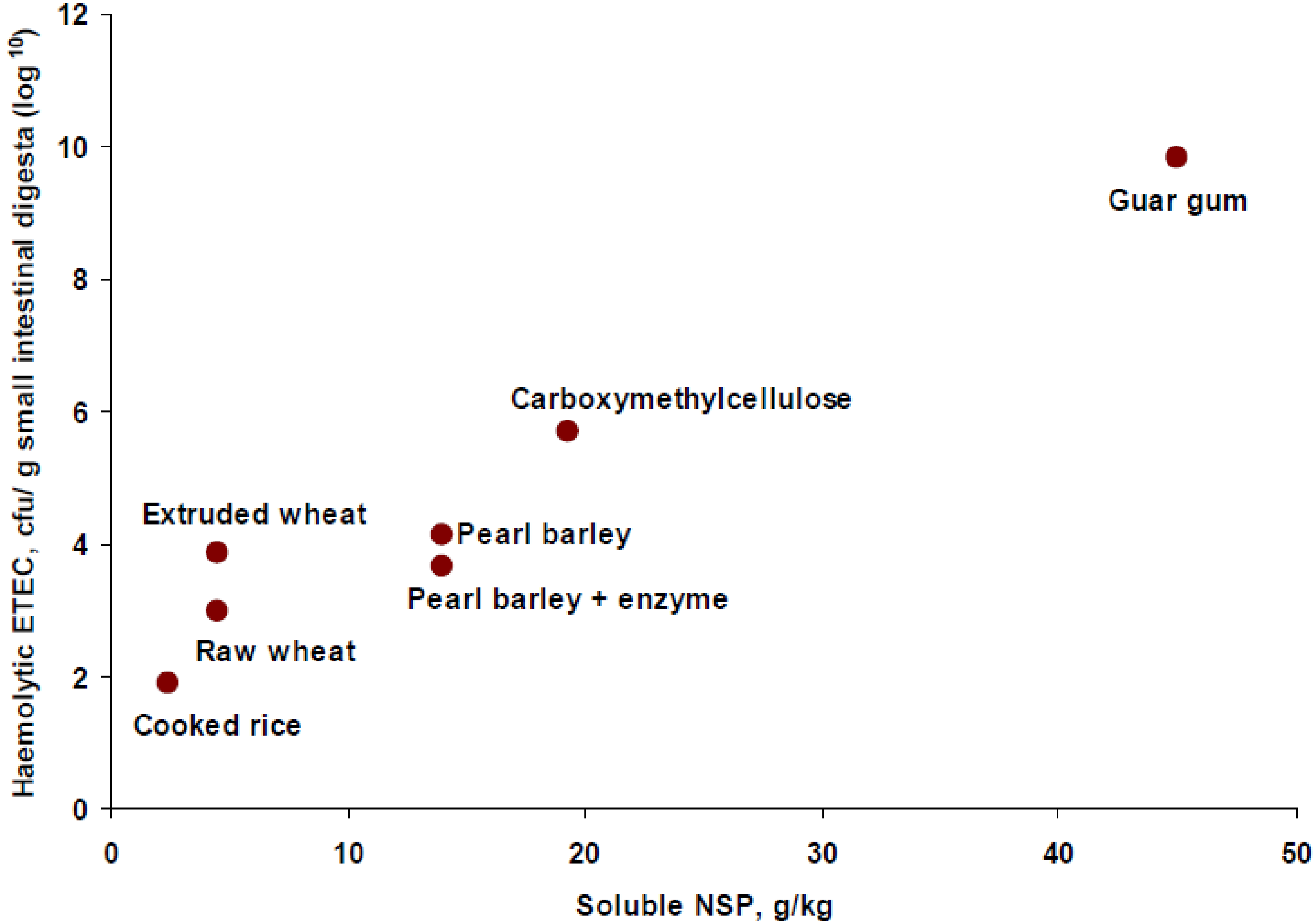
Soluble NSP and small intestinal ETEC in piglets



Kim et al. (2012)

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Dietary NSP and gut health and performance

Animal type	Challenge model	Basal diet	Type of NSP[a]	Response		Reference
				Performance	Intestinal health	
Weanling pigs	*E. coli*	Rice	Soluble	↓ Daily gain	↑ Infection, PWD incidence, proliferation, pH	[85]
Weanling pigs	*E. coli*	Rice	Soluble	No effect	↑ Infection, PWD incidence, proliferation; ↕ pH	[84]
Growing pigs	*Lawsonia intracellularis*	Corn-SBM	Insoluble	No effect	↕ Lesion length, diarrhea prevalence, proliferation	[94,95]
Growing pigs	Swine dysentery	Triticale, barley	Soluble	No effect	↓ Infection, PWD incidence; ↕ gut pH, SCFA	[88]
Weanling pigs	Non	Rice, animal protein	Insoluble	No effect	↓ PWD incidence; firmer stool	[91]
Weanling pigs	*E. coli*	Porridge oats, wheat, animal protein	Soluble	No effect	↓ Infection, PWD incidence, pH; ↑ *Lactobacillus*: coliform	[93]
Weanling pigs	Non	Corn, barley, soy protein concentrate	Insoluble	No effect	↕ PWD incidence, lactobacilli; ↑ SCFA; ↓ *E. coli*, coliforms	[89]
Weanling pigs	*E. coli*	Corn, wheat, barley, SBM	Insoluble	No effect	↕ SCFA; ↓ PWD incidence, *E. coli*; ↑ microbial diversity	[96]
Growing pigs	Non	Wheat, SBM	Soluble	No effect	↕ Immune response, bifidobacteria, lactobacilli, VFA; ↓ Enterobacteriaceae	[97]

E. coli: *Escherichia coli*; PWD: post-weaning diarrhea; SBM: soybean meal; SCFA: short-chain fatty acids; VFA: volatile fatty acids. The symbol ↑ indicates an increase in response criteria, ↓ indicates a decrease in response criteria, and ↕ indicates no effect on response criteria.
[a] NSP: non-starch polysaccharides; NSP-containing diets are compared with non-antibiotic control diets for the entire experimental period; significance is defined as $P < 0.05$.

Agyekum and Nyachoti (2017)

Conclusions

- Weaning of piglets is a very critical period in the life of a pig in relation to the functional development of the gut and the sensitivity for gut health problems, affecting actual zootechnical performance and possibly performance in later life.
- Diet composition and nutrition strategies can help to reduce gut health problems in the period around weaning and support the functional development of the gut.
- Protein source and concentration, starch source, and levels of soluble (fermentable) and insoluble NSP are critical factors to consider, beside the use of targeted feed additives.
- Functional properties of feed ingredients in relation to gut function and health have to be considered more in depth and have to become a more integral part of diet formulation.

Thank you for your attention!