Advances in weaning pig nutrition

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Introduction

- Weaning - most stressful period in pig's life
  - abruptly removed from the sow, where
  - access to ~20 small meals of milk each day
  - removed to unfamiliar surroundings, mixed with unfamiliar pigs and fed a dry diet predominantly of vegetable origin
- Post-weaning 'growth check'
- Always challenged to minimise this growth check
- 2.34 more live born pigs per litter now than 10 yrs. ago
- Large litters = lighter piglets born/weaned and more variable litters

Introduction

- Even Greater challenges lay ahead
  - Continued selection for increased litter-size
  - Pressure to reduce antibiotic usage
  - Removal of medicinal zinc after 2022
- There is no one simple or "off the shelf" solution but
- In many cases this will simply mean strictly adhering to good management practices, where this is not currently the case
- Tweaking feeding programs may help
- And there may also be a place for alternative feed additives
- Payoff -↓mortality, ↑lifetime growth and ↓days to slaughter

Feed programs for weaned pigs

- Can be confusing due to conflicting information
- Many different ways to design and implement feeding programs
- What are the goals and objectives of nutritionist and farmer?
  - Maximise growth and optimize feed efficiency NOW
  - Maximise LIFETIME growth and optimize feed efficiency
  - Deal with post-weaning Diarrhoea etc.
- No 'one size fits all'
- Aim here is to understand the relationship between diet and growth
- Look at nutrient requirements & selection of feed additives

Feed additives/ingredients value

- 1 kg ↑ at weaning or at the end of Stage 1 = 3 kg at market slaughter
- But does ↑ finisher growth always follow ↑ post-weaning growth?

- YES if the pig is fundamentally changed?
  - Increasing weaning age (Main et al., 2004)
  - Increasing weaning weight (Collins et al., 2017; Schinckel et al., 2007; Wolter and Ellis, 2001).
  - Improved immune & digestive functions (Moeser et al., 2007; Smith et al., 2010).

Feed additives/ingredients value

- NO if the change resulting from the intervention is transitory?
  - Only during the period while the diet is fed
  - E.g. post-weaning diet complexity (Skinner et al., 2014; Whang et al., 2000; Wolter et al., 2003), addition of fat (Tokach et al., 1995), amino acids (Fabian et al., 2002; Main et al., 2008), antibiotics (Skinner et al., 2014), liquid milk replacers (Wolter and Ellis, 2001)

- Value of additive / ingredient: only consider the benefit gained during the period of feeding without projecting additional benefit,
- unless the additional benefit has been demonstrated and documented

Weaning Age

- Early weaning ↑ sow productivity
  but with more health/mortality problems and ↑ feed costs
- 1 day ↑ in weaning age = 500 g at 28 days
- Younger pigs have a less developed gut
- More undigested feed in the gut of younger pigs
- *E. coli* counts higher in 3 week compared to 4 week weaned pigs
- 5 week weaning? – 4 weeks is a compromise

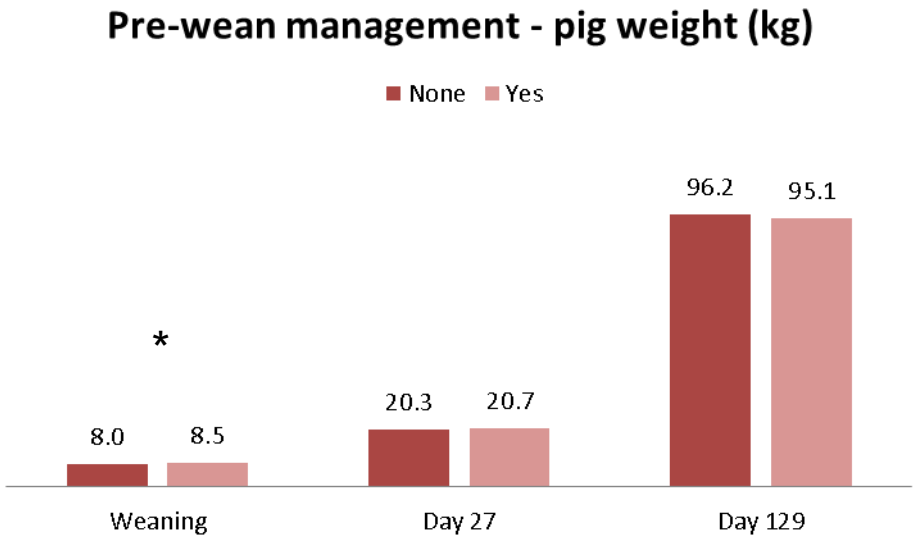
Effect of weaning age on growth performance to 10 wks of age

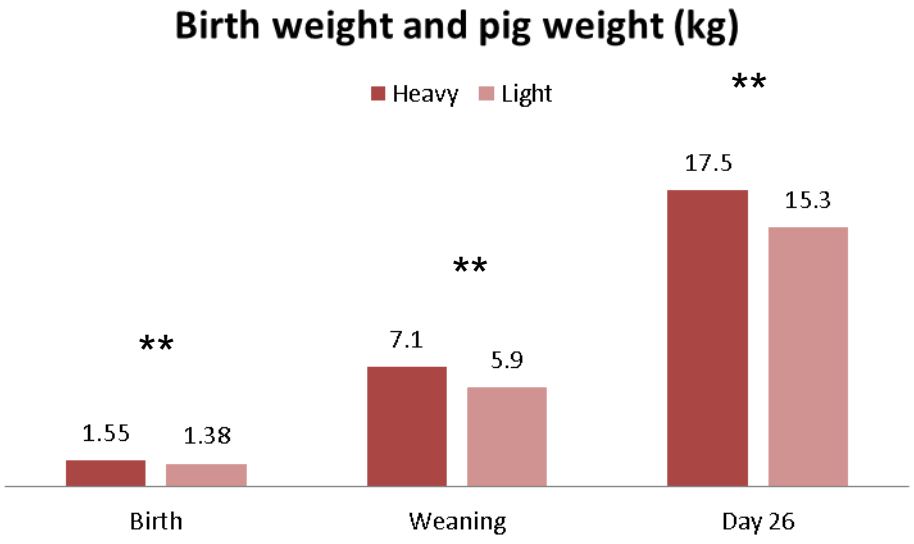
	Weaning age (wks)		
	3	**4**	**5**
Mortality (%)	14^{a}	1^{b}	4^{ab}
Average Daily Gain (g)	363^{a}	402^{b}	476^{c}
Average Daily Feed Intake (g)	560^{a}	621^{b}	680^{c}
Feed Conversion Ratio	1.57^{a}	1.55^{a}	1.43^{b}

Lawlor et al., 2003a; Leliveld et al., 2013

Weaning Weight

- High intake in first week after weaning = high lifetime growth
- KEY: wean heavier pigs
- **But does it matter how they are heavier?**





- Pre-weaning management cannot correct for low birth weight
- Importance of birth weight - muscle fibre number

Lawlor et al., 2002a

Post-weaning diet

Level of milk products

- Expensive but very important constituents of post-weaning diets
- 5 days reduction in days to slaughter
- Mortality, incidence of scour and veterinary interventions ↓
- Lactose most important (response up to 32-47% inclusion)
- Benefit from substituting casein for soy protein after 2 weeks is small

But

Effect is transitory

While feeding there is a weight advantage but this advantage is frequently lost by transfer to finisher stage (Lawlor et al., 2002)

Lawlor et al., 2003a; 2003b; 2005a

5. Post-weaning diet

Cooking cereals

- Responses to cooking maize and wheat are very variable
- Barley different – higher fibre content
- Where responses seen it may be due to a decontamination effect
- Use well screened grains with a low microbial load

Lawlor et al., 2003a; 2003b; 2005a

Quantity of starter and link to feed

- Must feed high density, **milk-rich** diets for fast and efficient lifetime growth
- But……expensive and overuse must be avoided
- Function: stimulate ↑energy intake after weaning and lifetime growth

Allocation of starter and link diets and growth

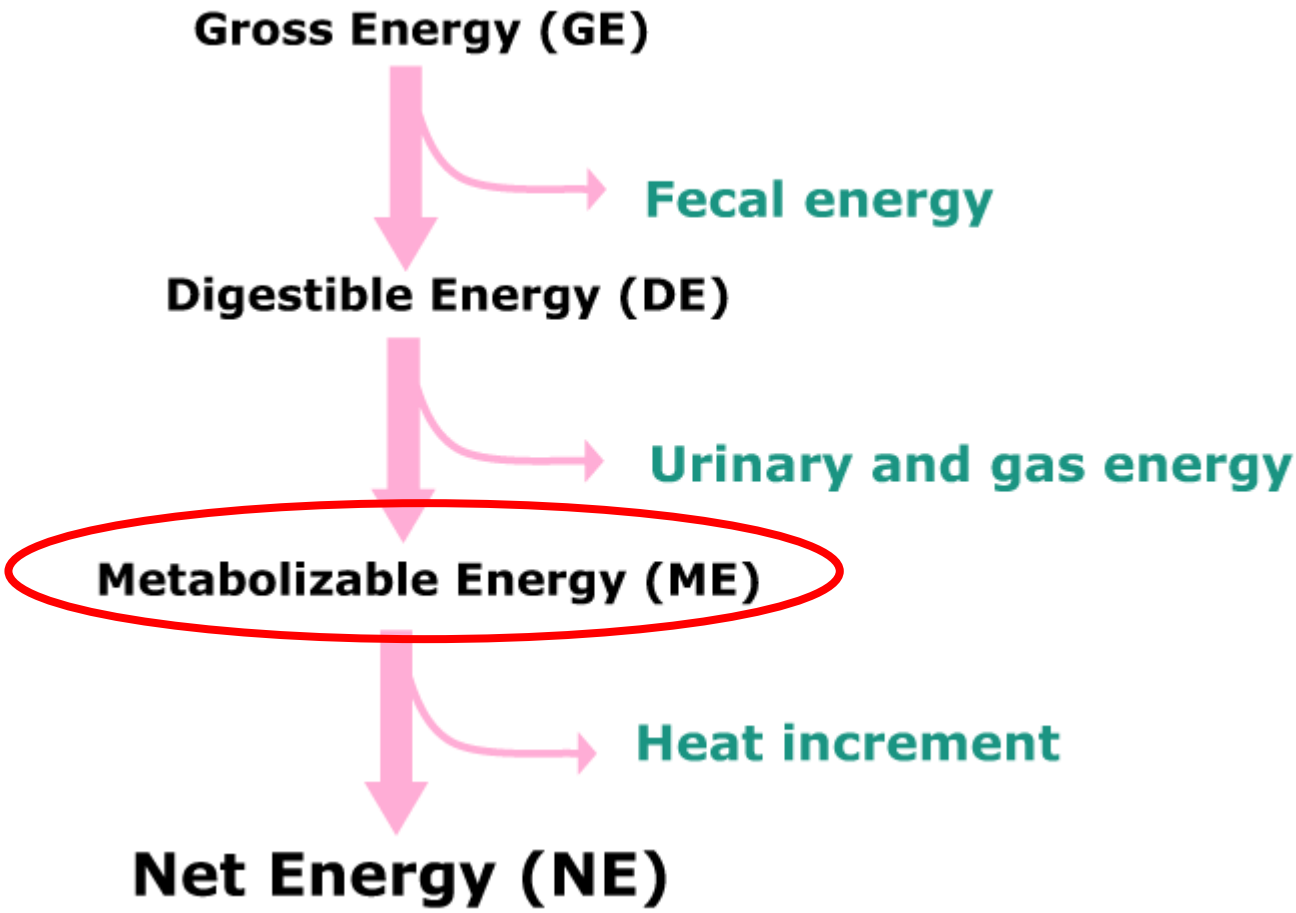
Starter diet (kg)	**1**	**2**	**3**	**4**	**s.e.**
Link diet (kg)	**3**	**6**	**9**	**12**	
Mortality (%)	10	10	4	2	
Weaning to 10 weeks of age					
Daily Gain (g)	416	411	432	395	14.8
Daily Feed Intake (g)	620	610	653	596	21.8
Feed Conversion Ratio	1.51	1.52	1.52	1.52	0.038

- Also look at health & mortality
- Starter and link as low as 1 and 3kg respectively to heavy healthy pigs
- Light pigs will likely benefit from higher allocation
- Health problems - pigs will also benefit from higher allocation of starter & link

Lawlor et al., 2002a; 2003b; 2005a; Leliveld et al., 2013

Nutritional Requirements

Energy


Gross Energy (GE)
Fecal energy
Digestible Energy (DE)
Urinary and gas energy
Metabolizable Energy (ME)
Heat increment
Net Energy (NE)

Energy

- Weaned pig's growth limited by feed intake capacity
- Energy dependant phase of growth
- ME intake (kcal/day) = -783.5 + 315.9 × body weight (BW) – 5.7685 × BW2
- Physical intake is low
- So, in reality this is never achieved
- But starter diets have a high energy density

to maximize energy intake

In Practice: Energy Intake = ADFI x Energy Density

Energy

Mean daily energy intakes based on post-weaning feed intake and growth compared with predicted energy intake (NRC 2012)

Week PW.	Energy density of diet MJ (ME/kg)	ADFI (g/day)	Energy intake (MJ ME/day)
1	16.0	220	3.5
2	15.0	450	6.8
3	15.0	700	10.5
4	14.2	1000	14.2

Energy

Mean daily energy intakes based on post-weaning feed intake and growth compared with predicted energy intake (NRC 2012)

Week PW.	Energy density of diet MJ (ME/kg)	ADFI (g/day)	Energy intake (MJ ME/day)	ADG (g/day)	Initial wt. (kg)	End wt. (kg)	Mean wt. (kg)	NRC energy intake (MJ ME/day)
1	16.0	220	3.5	200	8.0	9.4	8.7	6.4
2	15.0	450	6.8	375	9.4	12.0	10.7	8.1
3	15.0	700	10.5	560	12.0	15.9	14.0	10.5
4	14.2	1000	14.2	714	15.9	20.9	18.4	12.9

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Mean daily energy intakes based on post-weaning feed intake and growth compared with predicted energy intake (NRC 2012)

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1	16.0	220	3.5	200	8.0	9.4	8.7	6.4	55
2	15.0	450	6.8	375	9.4	12.0	10.7	8.1	84
3	15.0	700	10.5	560	12.0	15.9	14.0	10.5	100
4	14.2	1000	14.2	714	15.9	20.9	18.4	12.9	110

Energy

- 8kg weaned pig to achieve predicted intake in week 1 PW
- A 23 MJ ME/Kg diet would have to be fed
  - Simply not possible or economical

  or
- 360g/day intake on a 16.0 MJ ME/kg diet

  But
- Feed intakes of 200 to 250 g/day are generally considered good PW

  So
- Not surprising that there is a growth lag PW
- It is not until the third week following weaning that energy intake of the pig matches that predicted by NRC

Energy

Calculation of feed intake (g/day) required post-weaning to match the energy intake calculated from the National Research Council (NRC 2012)

Weaning weight	ME intake (MJ/day)	Energy density (MJ/kg)						
		15.0	15.5	16.0	16.5	17.0	17.5	18.0
5	2.7	182	176	171	165	160	156	152
5.5	3.3	218	210	204	198	192	186	181
6	3.8	252	244	237	229	223	216	210
6.5	4.3	286	277	268	260	253	245	239
7	4.8	320	309	300	291	282	274	266
7.5	5.3	352	341	330	320	311	302	293
8	5.8	384	371	360	349	338	329	320
8.5	6.2	414	401	388	377	366	355	345

Energy

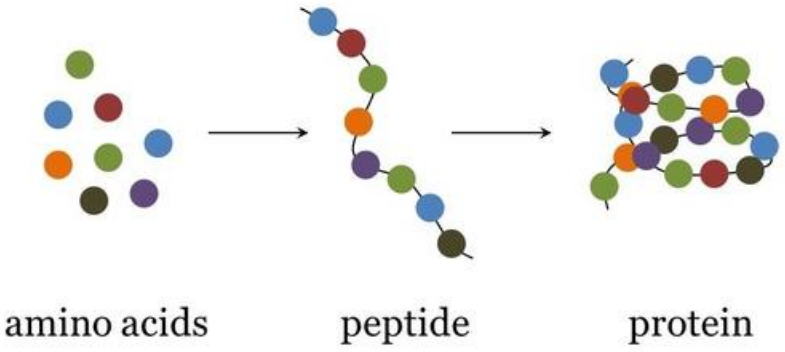
- Energy intake must increase as weaning weight of the pig increases
- ↑ dietary energy density will help

But

- there is a practical and economical limit to this

- In Practice: necessary to stimulate feed intake following weaning to maximise energy intake as diet alterations may not be either practical or economical
- Keep good records on intake and growth – custom design dietary energy density
- Then use correct nutrient to energy ratio to optimise FE

Amino Acids



- Standardized ileal digestible (SID) lysine requirement for weaned pigs between 5 and 20kg is 19g per kg weight gain
- To determine the correct lysine density in a PW diet - need to know
  - post-weaning growth rate
  - Post-weaning daily feed intake
- Otherwise quite imprecise LYS:energy ratios can result in
  - Reduced growth
  - Deterioration in FCE
- As this is a very energy dependant stage of growth it is critical that LYS:energy ratio is optimised

Amino Acids

Calculation of dietary SID lysine requirement and SID lysine to metabolizable energy (ME) ratio for weaned pigs using farm-specific data

Wk.	Energy density of diet (MJ ME /kg)	ADFI (g/day)	Energy intake (MJ ME /day)
1	16.0	220	3.5
2	15.0	450	6.8
3	15.0	700	10.5
4	14.2	1000	14.2

[1] Assumes 19 g SID lysine intake per kg BW gain (NRC, 2012)
[2] Assumes feeding starter in week 1, link in week 2 & 3 and weaner in week 4

Amino Acids

Calculation of dietary SID lysine requirement and SID lysine to metabolizable energy (ME) ratio for weaned pigs using farm-specific data

Wk.	Energy density of diet (MJ ME /kg)	ADFI (g/day)	Energy intake (MJ ME /day)	ADG (g/day)	Initial wt. (Kg)	End wt. (Kg)	Avg. wt. (Kg)	SID lys reqt on own ADG[1] (g/day)
1	16.0	220	3.5	200	8.0	9.4	8.7	3.80
2	15.0	450	6.8	375	9.4	12.0	10.7	7.13
3	15.0	700	10.5	560	12.0	15.9	14.0	10.64
4	14.2	1000	14.2	714	15.9	20.9	18.4	13.57

[1] Assumes 19 g SID lysine intake per kg BW gain (NRC, 2012)
[2] Assumes feeding starter in week 1, link in week 2 & 3 and weaner in week 4

Amino Acids

Calculation of dietary SID lysine requirement and SID lysine to metabolizable energy (ME) ratio for weaned pigs using farm-specific data

Wk.	Energy density of diet (MJ ME /kg)	ADFI (g/day)	Energy intake (MJ ME /day)	ADG (g/day)	Initial wt. (Kg)	End wt. (Kg)	Avg. wt. (Kg)	SID lys reqt on own ADG[1] (g/day)	SID lys: ME ratio (g/MJ)	Dietary SID lys (g/kg)
1	16.0	220	3.5	200	8.0	9.4	8.7	3.80	1.08	17.3
2	15.0	450	6.8	375	9.4	12.0	10.7	7.13	1.06	15.8
3	15.0	700	10.5	560	12.0	15.9	14.0	10.64	1.01	15.2
4	14.2	1000	14.2	714	15.9	20.9	18.4	13.57	0.96	13.6

[1] Assumes 19 g SID lysine intake per kg BW gain (NRC, 2012)
[2] Assumes feeding starter in week 1, link in week 2 & 3 and weaner in week 4

Amino Acids

- Practical diet Formulation
  - Determine energy intake = ADFI X Energy density
  - Calculate SID lysine requirement = 19g/kg gain
  - Determine & use a ratio of lysine to energy
  - Then include other amino acids as a percentage of lysine
- Ideal protein concept (i.e. lysine=100%)
- Different sources of recommendations
- There will be differences in recommendations due to differences in methodologies used, breed, health etc.

Amino Acids

Recommended minimum standardised ileal digestible amino acid ratios for piglets (5-25kg) according to various sources

	BSAS (2003)	NRC (2012)	Gloaguen *et al.* (2013)	Menegat *et al.* (2019)
Lysine	100	100	100	100
Threonine	65	59	65	62
Methionine	30	29	30	28
Methionine + Cysteine	59	55	60	58
Tryptophan	19	16	22	19
Valine	70	63	70	67
Isoleucine	58	51	52-60	52
Leucine	100	100	101	-
Histidine	34	34	31	30
Phenylalanine	57	59	54	
Phenylalanine + tyrosine	100	92	-	-
Tyrosine	-	-	40	-
Arginine	-	46	42	-

Reduced crude protein diets

- Prevents an excess of undigested protein reaching the large intestine
  - ↓ growth of pathogens, such as *E. coli* and
  - ↓ production of harmful compounds which negatively affect gut permeability
- Reduces the incidence of diarrhoea

But

- Requirements of weaned pigs for amino acids are high
  - for growth
  - also to counteract health challenges
- Therefore, low CP diets must be fortified with synthetic amino acids
- E.g. ↓ CP in post-weaning diets from 20.4 to 16.9% with correct synthetic amino acid supplementation ↓ diarrhoea, without affecting weight gain & protein deposition (Bellego and Noblet, 2002)

Compensatory Growth/Gain

- Extremely high SID Lys needed to meet estimated requirements especially with very low feed intake post-weaning
- Such high-lysine, high energy diets are very expensive and some are impractical
- Reduced SID lysine levels (starter, 1.40% and link, 1.35%) can be fed as long as lysine levels are adequate (1.30%) in the weaner phase (Nemecheck et al. 2018)
- Advantage:
  - Not so much specialty protein rich feed ingredients are required
  - Feed cost is reduced
  - Easier to pull back protein level in the diet when SID lysine level is reduced

Vitamins

- Vitamins are normally required as co-factors in metabolic reactions in the body.
- Inclusion in pig diets must be precise
- Over-inclusion can be expensive but also dangerous and under-inclusion can result in deficiencies and reduced growth
- Usual to ignore the presence of vitamins in the organic portion of the diet and to supplement the diet with vitamins as part of a vitamin and mineral mixture to supply each to a target inclusion in the finished pig feed
- Various sources for recommendations

Vitamins

Dietary vitamin requirements of pigs according to various sources (per kg of final air-dry feed)

Vitamin inclusion per kg	BSAS (2003)[1]	NRC (2012)[2]	IFIP (2005)[3]	Menegat *et al.* (2019)
Vitamin A (IU)	5,000 to 8,333	2,200	8,000 to 10,000	4,000
Vitamin D_3 (IU)	800 to 1000	220	1,500 to 2,000	1,650
Vitamin E (IU)	60 to 80	11 to 16	20 to 50	44
Vitamin K (as menadione; mg)	2	0.5	0.5 to 1	3.3
Biotin (mg)	0.15	0.5 to 0.8	0.1	none[4]
Choline (mg)	200	400 to 600	300 to 800	---
Folic acid (mg)	1.5	0.3	0.5	none[4]
Niacin / Nicotinic acid (B_3; mg)	20	30	15	50
Pantothenic acid (mg)	15	9 to 12	10	28
Riboflavin (B_2; mg)	4	3 to 4	4 to 8	8
Thiamin (B_1; mg)	2	1 to 1.5	0.5 to 1	none[4]
Pyridoxine (B_6; mg)	3	3 to 7	0 to 3.6	none[4]
Cyanocobalamin (B_{12}; µg)	40	15 to 20	30 to 35	33

Minerals

- Inclusion needs to be precise
- Mineral content of grains and oilseeds at low concentrations and availabilities
- Essential to balance the diets using supplemental mineral sources
- Ca and P essential for development and maintenance of skeleton, lean tissue deposition, muscle contraction etc.
- About 99% of the Ca and 80% of the P in the body are found in the skeleton
- Deficiencies in Ca and P result in reduced bone mineralization, bone strength, and growth
- Supply the individual requirements of Ca and P but must also provide at an adequate ratio
- A wide Ca to P ratio (>2.8) or excessive Ca and deficient P conc. reduce P absorption
- Other minerals, such as Na and Cl, also essential to optimize growth performance as is the case for the micro-minerals: iron, iodine, manganese, zinc and copper

Minerals

Dietary mineral requirements of pigs according to various sources (per kg of final air-dry feed)

Mineral inclusion per kg	BSAS (2003)[1]	NRC (2012)[2]	INRA (1984)	Bikker and Blok (2017)[3]
Macro minerals (g)				
Calcium	7.5 to 8.0	7.0 to 8.5	-	6.0 to 8.9 6.0 to 7.64[4]
ATTD phosphorus[5]	3.4 to 3.8	2.9 to 4.1	-	2.28 to 3.45
STDD phosphorus[6]	-	3.3 to 4.5	-	2.28 to 3.1[4]
Sodium (g)	1.7 to 2.0	2.8 to 4.0	1.5	
Chloride (g)	2.0	3.2 to 5.0	-	
Magnesium (g)	0.4	0.4	-	
Potassium (g)	2.5	2.6 to 3.0	-	

Minerals

Dietary mineral requirements of pigs according to various sources (per kg of final air-dry feed)

Mineral inclusion per kg	BSAS (2003)[1]	NRC (2012)[2]	INRA (1984)
Micro minerals (mg)			
Zinc	100	100	100
Manganese	30	3.0 to 4.0	40
Iron	120	100	100
Cobalt	0.2	-	0.1 to 0.5
Iodine	0.2	0.14	0.6
Selenium	0.2	0.25 to 0.3	0.3
Copper	6.0	6.0	10

Water 'The forgotten Nutrient'

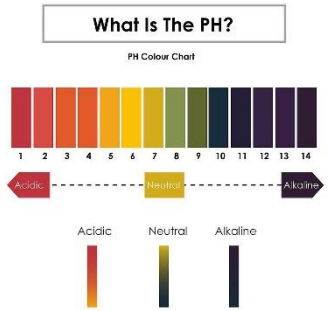
- More than a week after weaning to restore daily fluid intake
  - Suckling pig: ~680ml BUT….
  - 1st day post-weaning: ~290ml
  - 1st week post-weaning: ~442ml
  - 2nd week post-weaning: ~770ml/pig
- Restricted water flow: ↓feed intake and ADG by 15 %
- Supplementary drinkers
- Drinker position critical: height, angle & position
- Bowl drinkers waste 30% less water and easier for pigs to find water
- Use same type also in the farrowing house

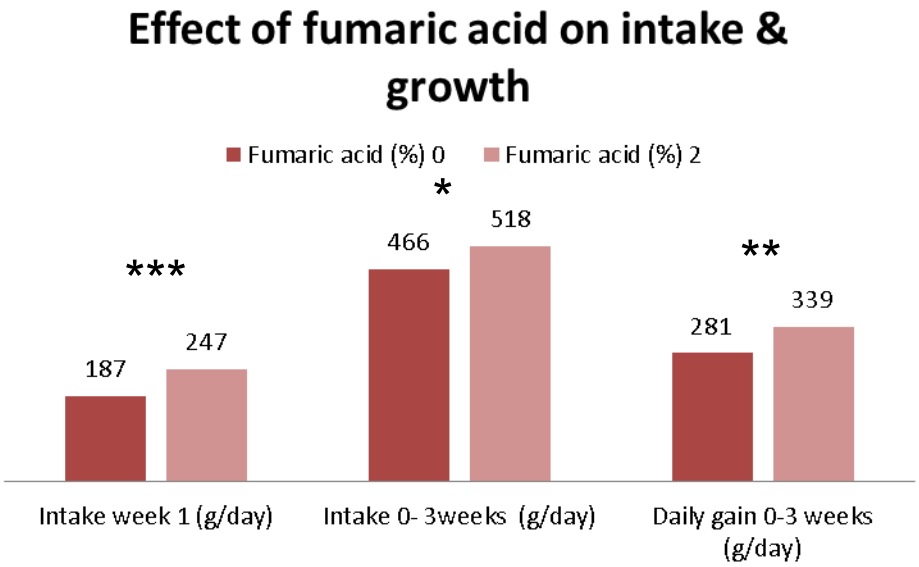
Feed Additives

Alternatives to zinc oxide and antibiotics

Diet Acidification

- Insufficient levels of gastric acid - high stomach pH at weaning
  - Protein digestion reduced
  - Growth of diarrhoea-causing micro-organisms
- Feed intake ↑~32% in week 1 and by 11% in 1st 3 weeks
- Response not always consistent – microbial challenge





Acid binding capacity

- Alternative approach
- Diet formulation
- Use ABC values for ingredients
- Ingredients differ in ABC
- Similar effect to acids

Lawlor et al., 2005a; 2005b; 2006

Probiotics/Prebiotics

Effect of feeding *Bacillus pumilus* for 22 days on post-weaning pig growth

	Non-medicated	**Medicated**	***B. pumilus***	**P value**
Day 0 BW (kg)	8.7	8.6	8.8	NS
Day 22 BW (kg)	**18.1**	**17.6**	**18.7**	**+**
ADFI (g/d)	471	458	475	NS
ADG (g/d)	427	405	455	+
FCE	1.11^{ab}	1.14^{a}	1.05^{b}	*

- Probiotics: 'Live microorganisms – adequate amounts - health benefit'
- Alternative to antibiotics? - Control pathogens & ↑ growth
- Immune modulation, competitive exclusion & antimicrobial production
- Now feeding to sow which seeds the piglet microbiome
- LIVE-5 - ↓ incidence & duration of scouring & ↑ growth in *Salmonella* challenge

- Prebiotics pass through upper gut & provide substrate for beneficial bacteria

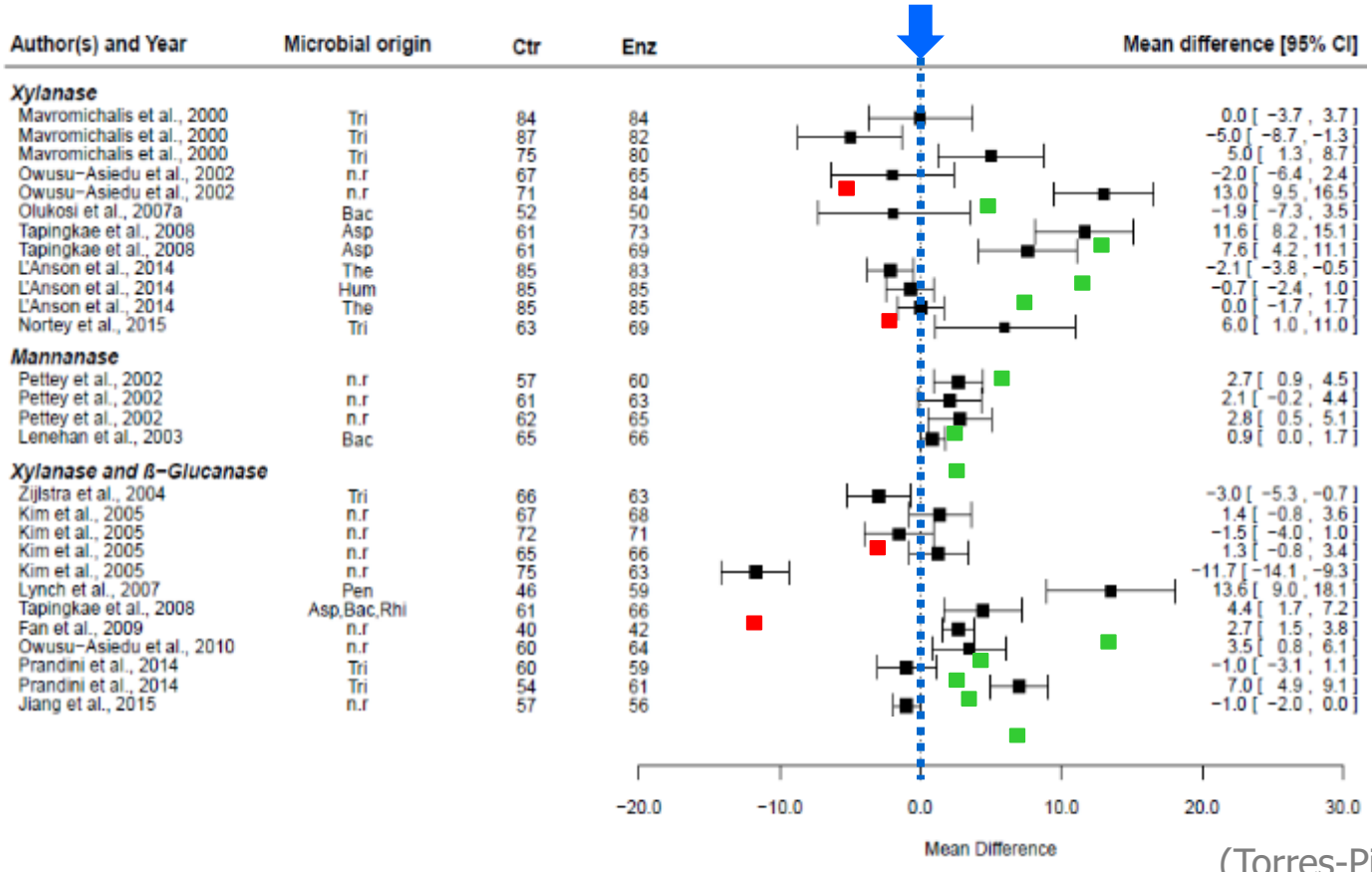
Casey et al. 2007; O'Sullivan et al., 2010; Prieto et al., 2013

Exogenous Enzymes

- It takes time for enzymatic activity in the pig to develop PW
- Exogenous enzyme use to bridge the gap
- Expands the range of feed ingredients that can be used
- Specific roles in pigs
  - carbohydrases (e.g. xylanase, β-glucanase, β-mannanase, and α-galactosidase) can increase the digestibility of substrates present in the dietary non-starch polysaccharide fraction (Masey O'Neill et al., 2014)
  - However, the efficacy of supplementary feed enzymes in weaned pigs is inconsistent (Torres-Pitach et al., 2017)

Results: carbohydrases

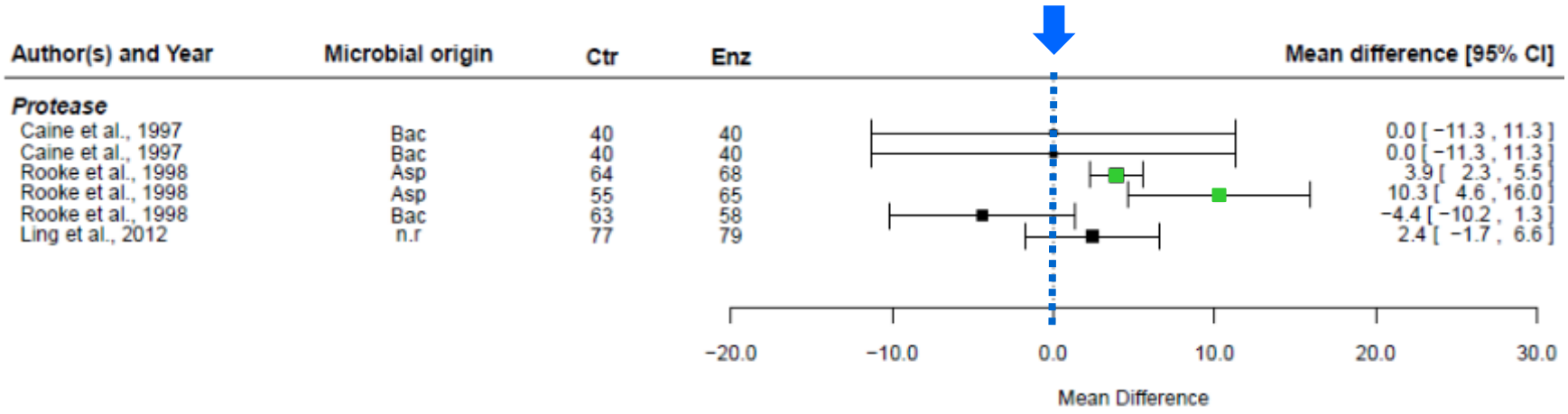
- ↑ ↓ Inconsistent results for feed efficiency and ATTD



(Torres-Pitach et al., 2017)

Results: protease

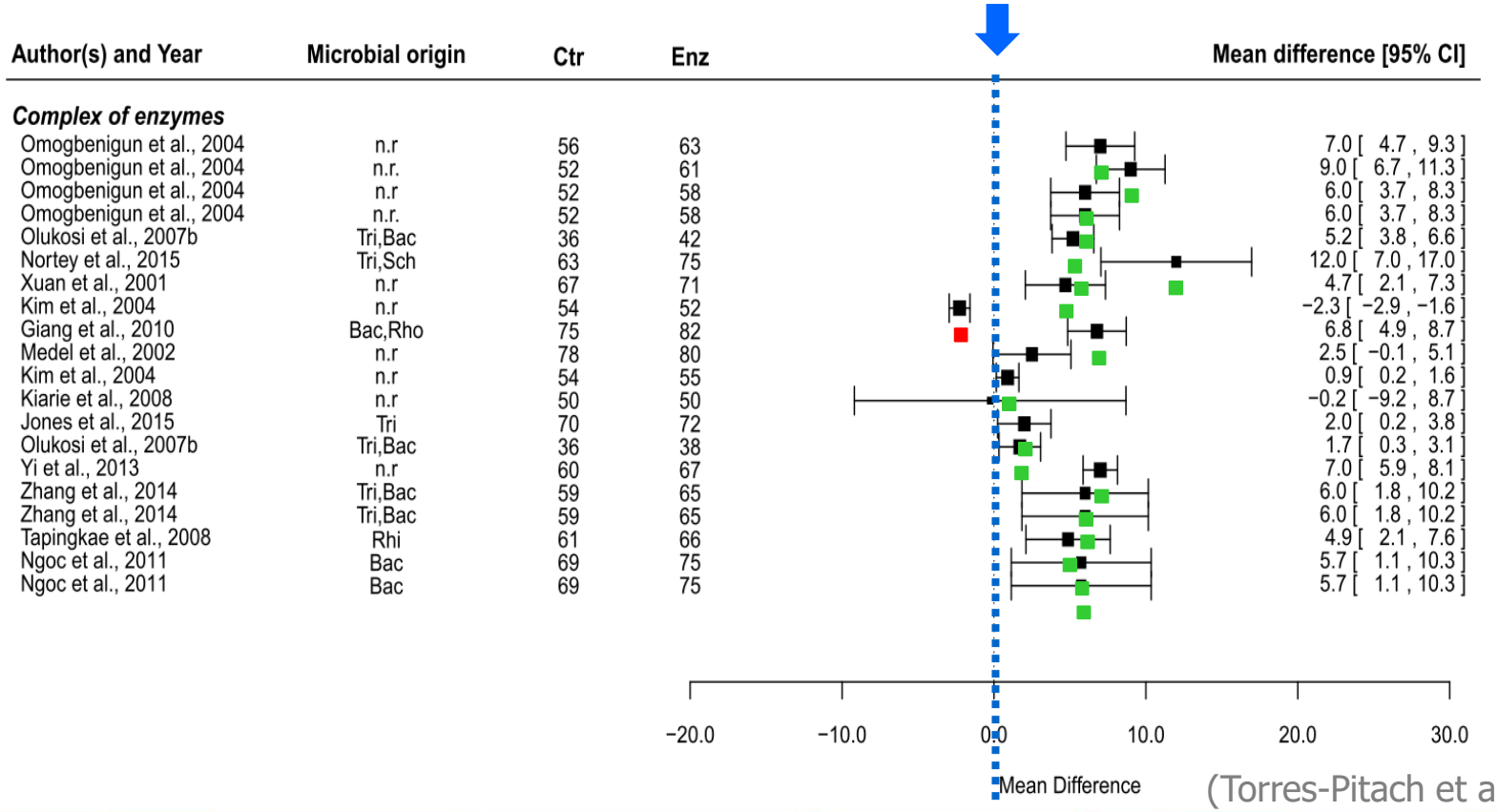
- ↑ ↓ *Inconsistent results for feed efficiency*
- *Low number of studies, improved feed intake.*



(Torres-Pitach et al., 2017)

Results: complex of enzymes

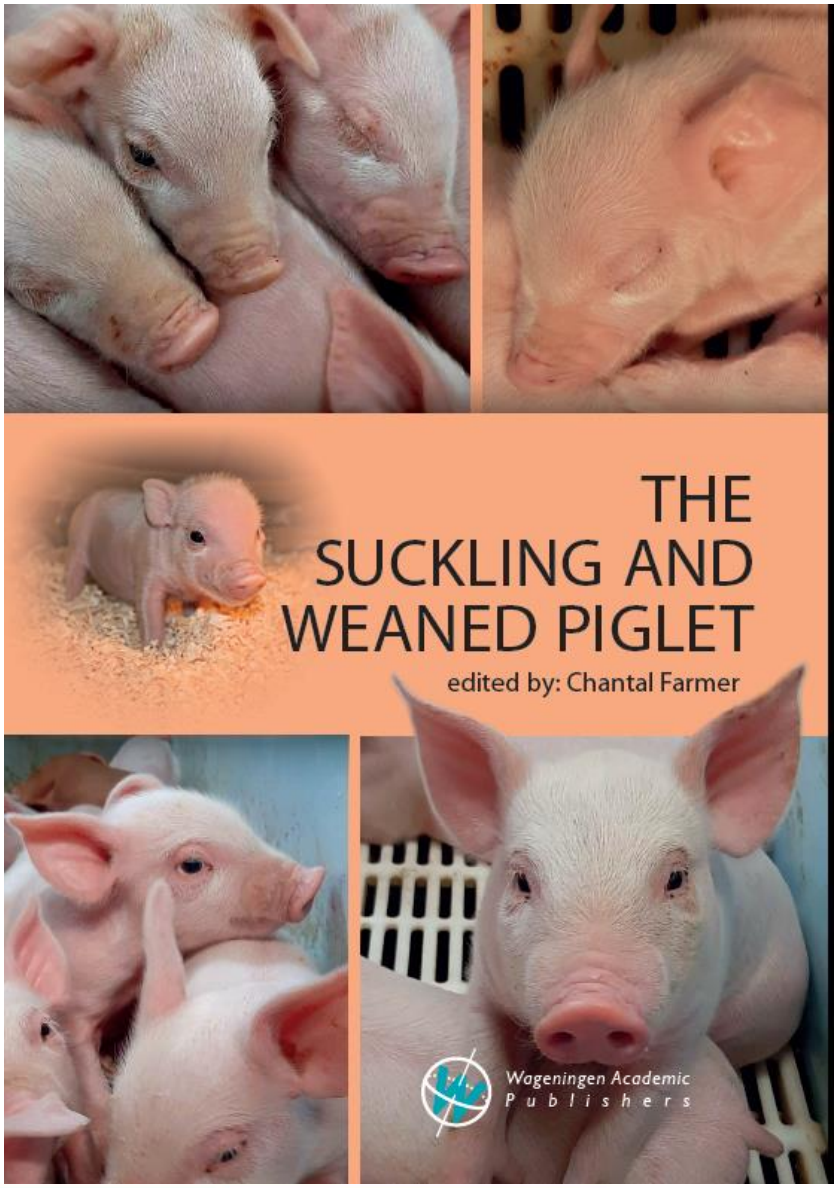
- ↑ *Feed efficiency*
- ↑ *Nutrient digestibility*



(Torres-Pitach et al., 2017)

9. Summary

- To overcome post-weaning "growth check", target increases in
  - feed and water intake
  - birth weight
- Good quality starter and link diets necessary for weaned pigs
- But….levels used should be geared towards pig weaning weight, health and optimization of lifetime growth
- Formulate diets based on Intake and growth of YOUR pigs
- Reducing Lys in starter and link diets to reduce protein content and avail of compensatory growth
- Additive: only consider the benefit gained during the period of feeding
- Intake in first few days after weaning is Key!



Chapter 10.
Feeding the weaned piglet

P.G. Lawlor, G.E. Gardiner and R.D. Goodband

AGRICULTURE AND FOOD DEVELOPMENT AUTHORITY

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