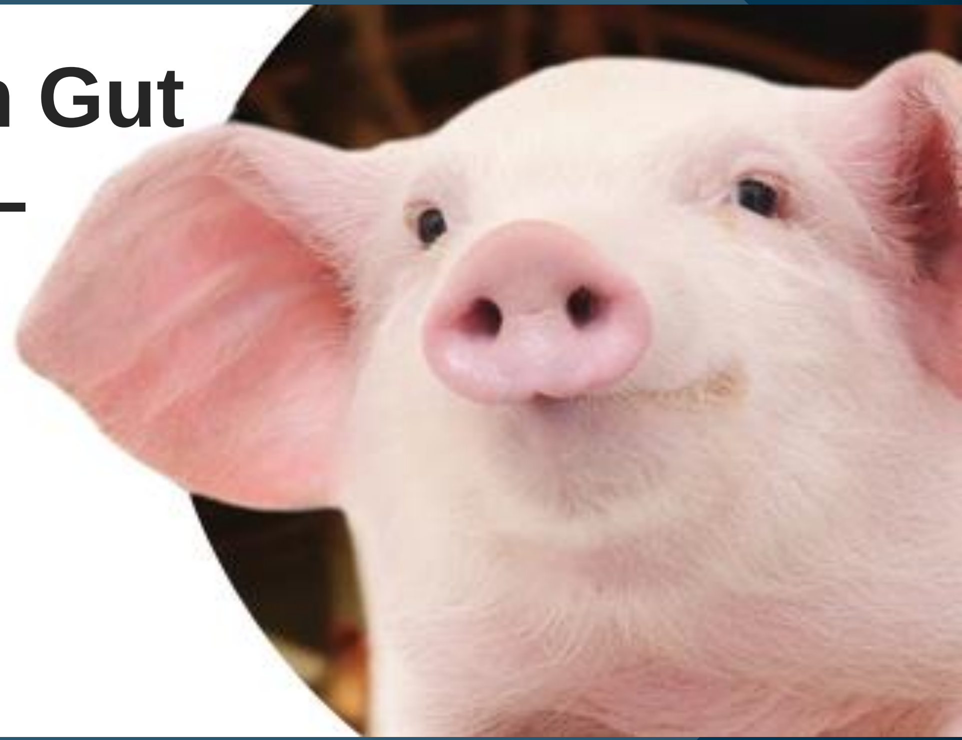
Establishing Optimum Gut Health In Young Pigs –

Key Challenges And Considerations



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About Danisco Animal Nutrition

Danisco Animal Nutrition(animalnutrition.dupont.com), a business division of DuPont Industrial Biosciences, helps animal producers around the world maximize the return on their feed investment, improve liveability and tackle commercial sustainability challenges.

The company achieves this by collaborating with them to deliver optimized enzyme, betaine and probiotic feed solutions. Its uniqueness centres on the way it combines these technologies - many of which are industry ”firsts”- to form solutions that deliver superior customer value. Its ability to shape a profitable and sustainable future for animal producers is underpinned by the quality and quantity of its worldwide trials, its unparalleled investment in innovative technologies and its collaboration with leading international industry, government and academic partners.

The company is also part of DuPont (www.dupont.com) , which has become one of the most innovative and admired biotechnology organizations in the world.

Today's Speakers

Dr. John Pluske

Australian-American Fulbright Commission Distinguished Chair in Agriculture and Life Sciences at Kansas State University and Professor at Murdoch University in Perth, Western Australia

Dr. Gary Partridge

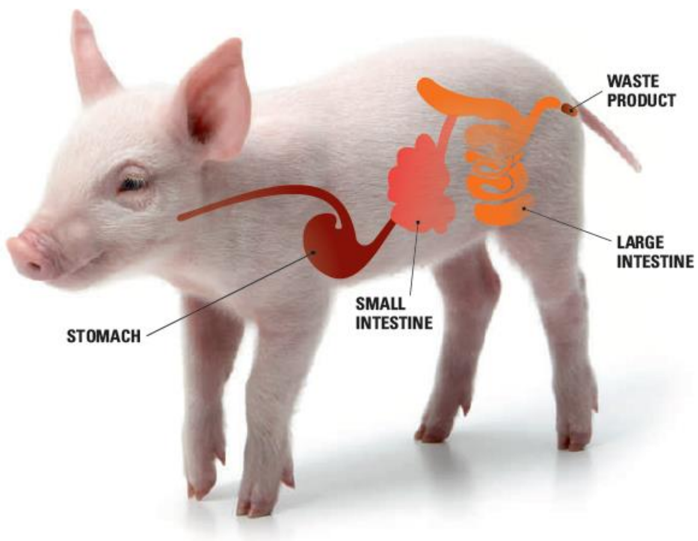
Global Development and Technical Director, Danisco Animal Nutrition

Dr. John Pluske is currently the Australian-American Fulbright Commission Distinguished Chair in Agriculture and Life Sciences at Kansas State University, and a Professor at Murdoch University in Perth, Western Australia. He gained his qualifications at the University of Western Australia, graduating first with a Bachelor of Science (Agriculture) degree and then a PhD. He has since carried out post-doctoral studies on pig nutrition and health at the Department of Animal Science at the University of Alberta, Edmonton, Canada and the School of Veterinary Studies at Murdoch University, Western Australia. John returned to Murdoch University in Perth in 1999 and has since worked in several senior roles in the School of Veterinary and Biomedical Sciences before assuming his current position. His current research is focussed on swine nutrition and the digestive physiology of pigs, particularly piglets and weanling pigs, and also swine immune function and controlling enteric diseases in pigs without antimicrobials.

Gut Health In Young Pigs – Perspectives And Considerations

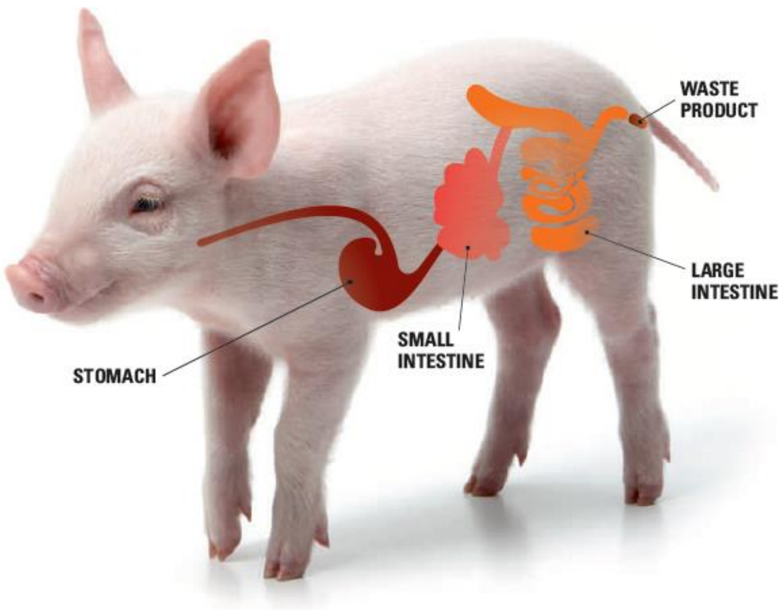
DR JOHN PLUSKE

FULBRIGHT DISTINGUISHED CHAIR, KANSAS STATE UNIVERSITY; MURDOCH UNIVERSITY, WESTERN AUSTRALIA



What I Will Cover Today

- What is gut health?
- Relevance of gut health to the weaned pig
- Two key considerations,
  - Gut barrier function
  - The gut microbiota

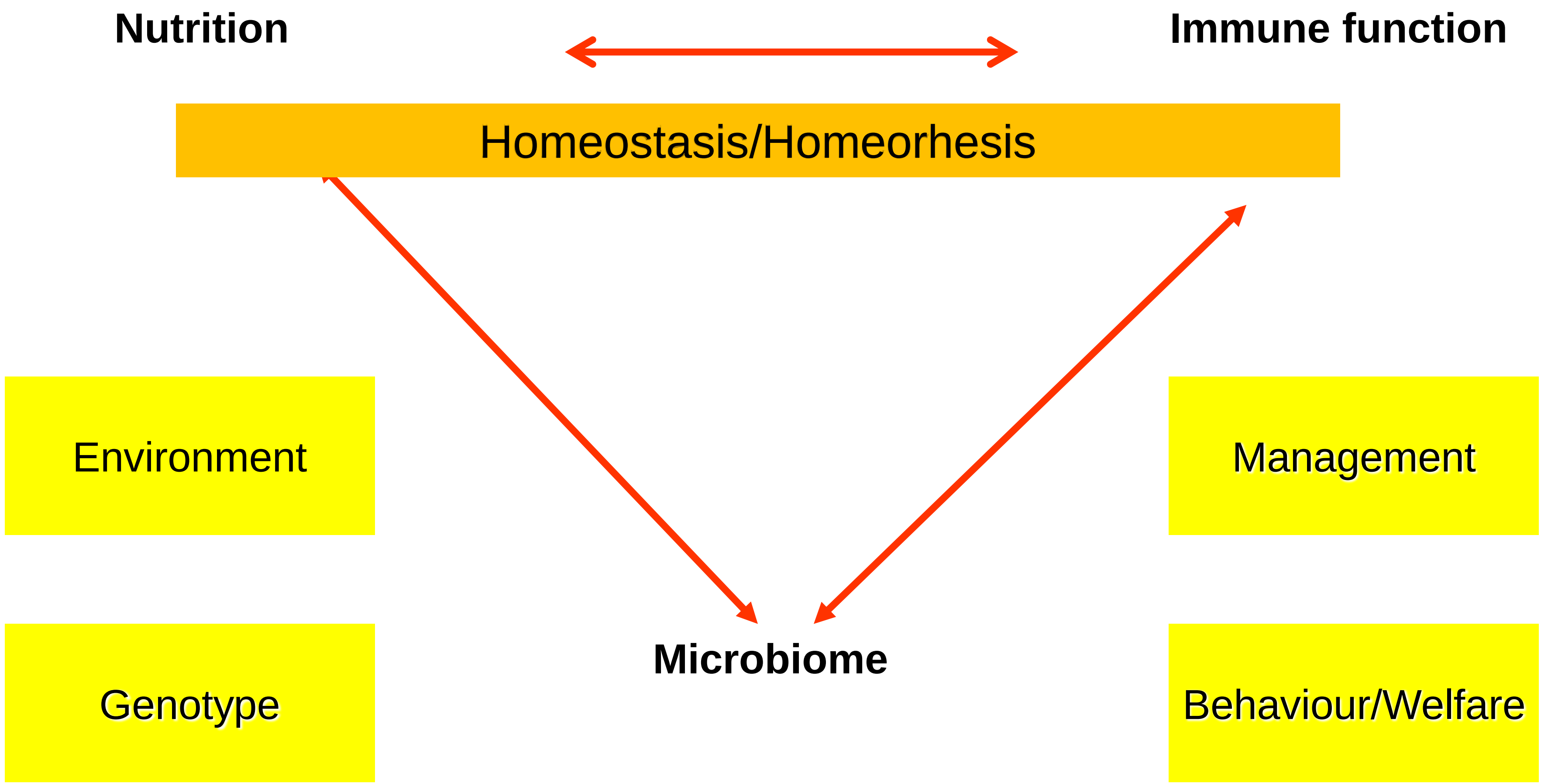


What Is Gut Health?

Gut health is a term that lacks a clear and concise definition, despite its repeated use in both animal and human health, medicine and nutrition. The best definition is by Bischoff, 2011 in *Gut health': a new objective in medicine?*(*BMC Medicine* **9:**24):

- Effective digestion and absorption of feed
- Absence of gastrointestinal tract illness
- Normal and stable microbiome of the gastrointestinal tract
- Effective immune status
- Status of animal ‘well-being’

What Influences Gut Health?



Relevance Of Gut Health?

- In pig production, it is *mostly* used in association with feed ingredients (nutrients)/additives and (or) feeding strategies, in relation to:
  - The post-weaning period, and concomitantly with,
  - ‘Antibiotic growth promoters’ (AGPs), ‘antibiotic resistance’, ‘antibiotic bans’ etc.
- For example: “*XXXXX is considered a good candidate for substitution of AGPs in diets, due to their potential positive influence on microbial activity and health of the host*”
- [Term should be used more generally to refer to any phase of the production cycle where an insult to the gastrointestinal tract occurs]

Antibiotic Uses In The Livestock Industries

- *Therapeutic* use
  - Treat clinically diseased animals
- *Prophylactic* use
  - Prevent and control common disease events
- *Sub-therapeutic* use
  - Weight gain
  - Feed efficiency
  - *Antibiotic growth promoters* (AGPs)

Changes in the use of antimicrobials and the effects on productivity of swine farms in Denmark

(Aarestrup *et al*., 2010; *Am. J.Vet. Res.* **71:**726–733)

Opinion

Cell PRESS

Treatment, promotion, commotion: antibiotic alternatives in food-producing animals

(Allen *et al*., 2013; *Trends Microbiol.* **21:**114-119)

Study In Denmark Shows No Negative Impact On Swine Productivity When Antimicrobial Use Is Reduced

"From 1992-1998, a >50% reduction in anti-microbial consumption per kg of pig produced was observed in Denmark…During the same period, overall swine productivity improved markedly, which suggests that the change in antimicrobial consumption has not had a negative impact on long terms swine productivity"

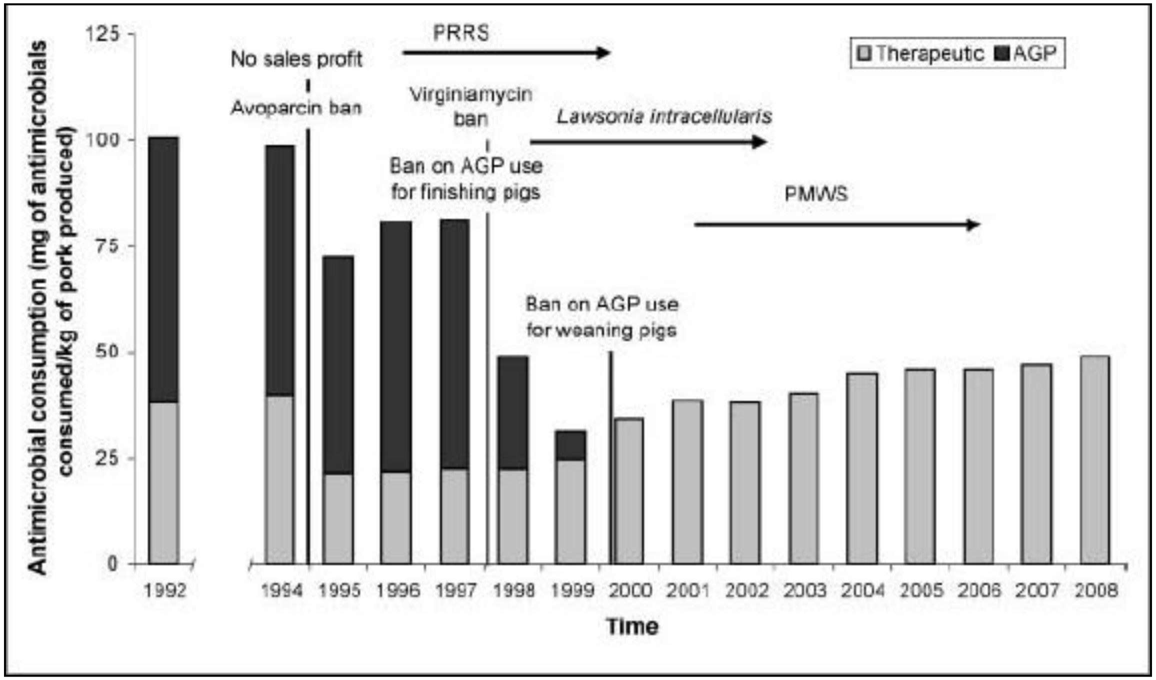
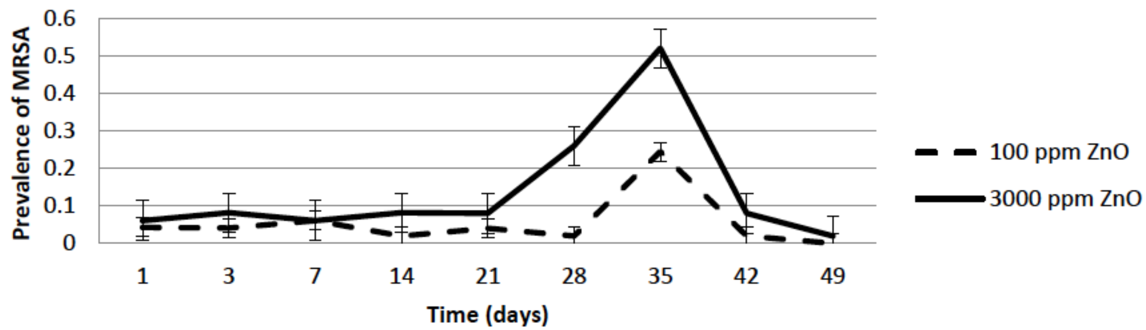


Table shows AGP consumption in black, therapeutic consumption in grey. AGP bans for finishers in 1998, weaners 2000

Weaners<35kg
Finishers >35kg

Taken from "Changes in the use of antimicrobials and the effects on productivity of swine farms in Denmark" Aarestrup *et al*., 2010; *Am. J. Vet. Res.* **71:**726–733)

Use Of High Levels Of Zn And Cu, Often Considered ‘Alternatives’ To AGPs, May Have Unintended Consequences



Prevalence of methicillin resistant *Staphylococcus aureus* (MRSA) from birth to 4-weeks post-weaning (exposure to starter ration containing ZnO began just after sampling on d 21)

(Slifierz *et al*., 2014; In *33rd Centralia Swine Research Update*, Kirkton, ON; 2014)

Environ Monit Assess (2014) 186:5297–5306
DOI 10.1007/s10661-014-3778-6

Effects of pig manure containing copper and zinc on microbial community assessed via phospholipids in soils

Weaning: A Critical Production Step That Impacts Gastro-intestinal Tract ‘Health

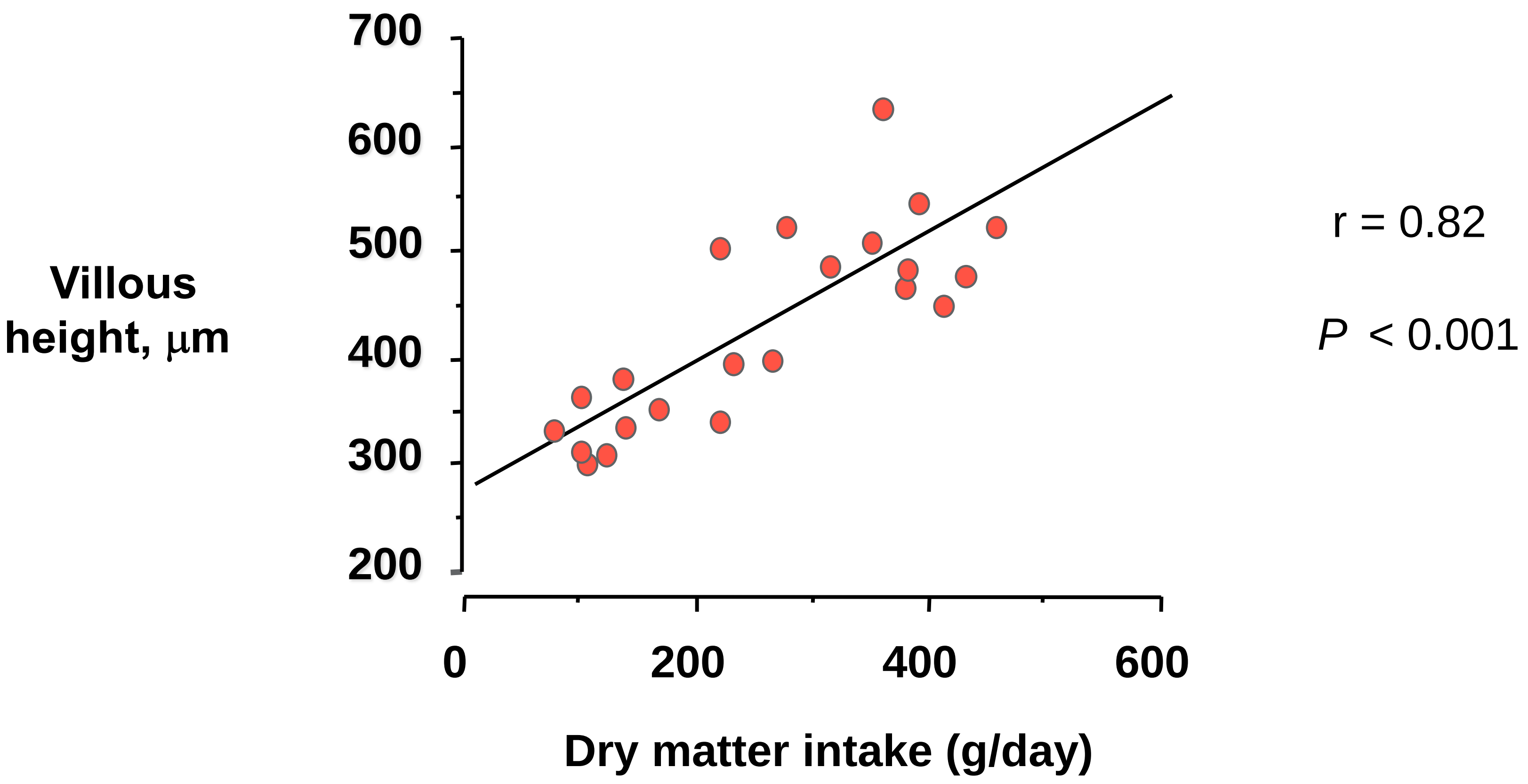
- Weaning imposes **multiple** and **simultaneous** stressors on young pigs,
  - Nutritional,
  - Psychological,
  - Environmental

- Post-weaning “growth check” . Aim after weaning is to **reduce** the **negative** impact weaning has on production, disease, morbidity and mortality

Sub-optimal Feed Intake After Weaning Compromises Gut Barrier Function

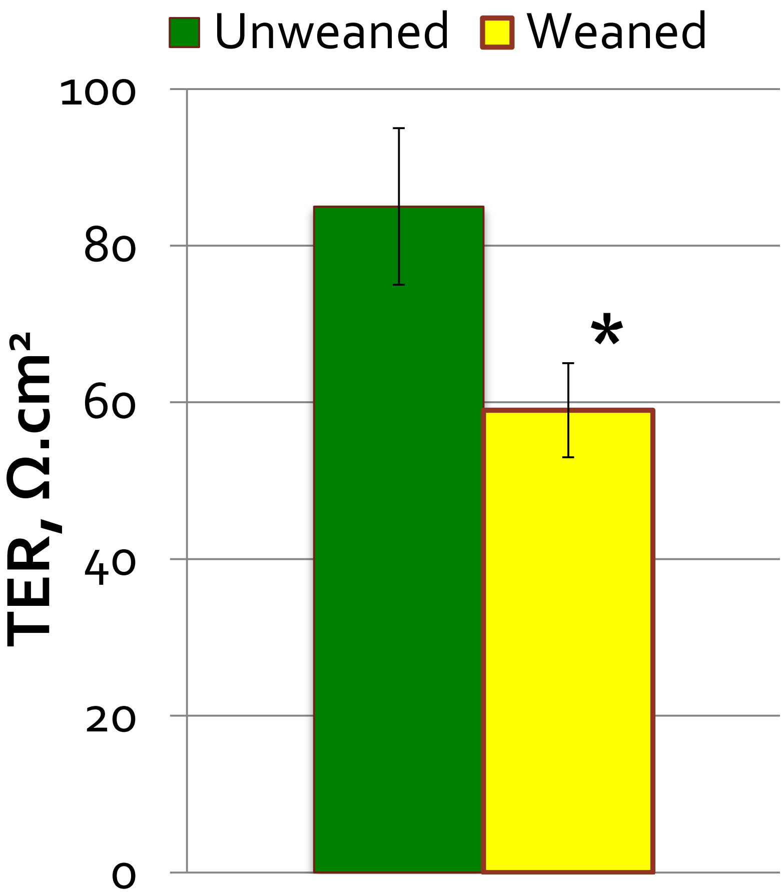
- Period of temporary **starvation** after weaning compromises gut barrier function
- Low feed intake:
  - Increases numbers of lymphocytes and infiltrated cells in epithelium
  - Causes a transient inflammatory response (up-regulation of e.g., IL-1β, IL-6, TNF-α)
  - Decreases epithelial tissue resistance (more “leaky” intestines)

Pigs Eating More Food After Weaning Have Higher Villi In The Small Intestine

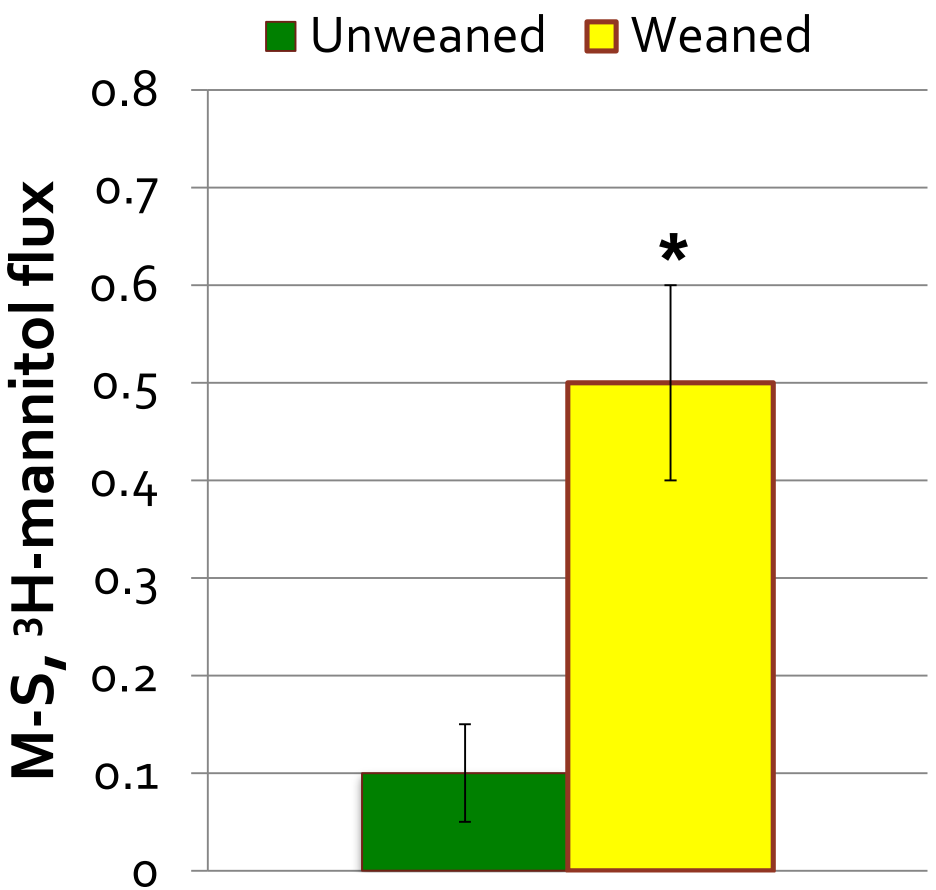


(Pluske *et al*., 1997, *Livest. Prod. Sci* **51:**215-236**)**

Barrier Function Is Compromised In Pigs Weaned At 19 Days Of Age



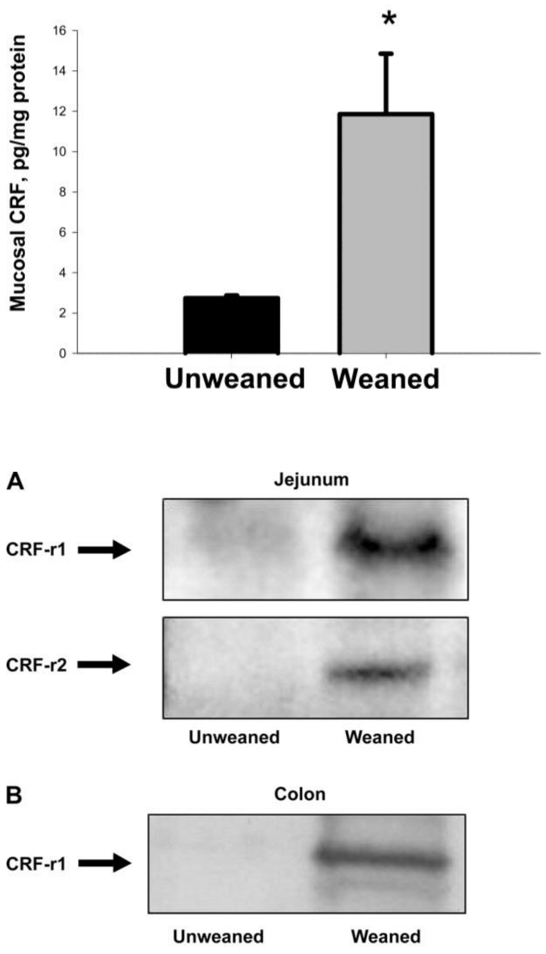
High TER; intact epithelial barrier
Low TER ; more permeable epithelial barrier

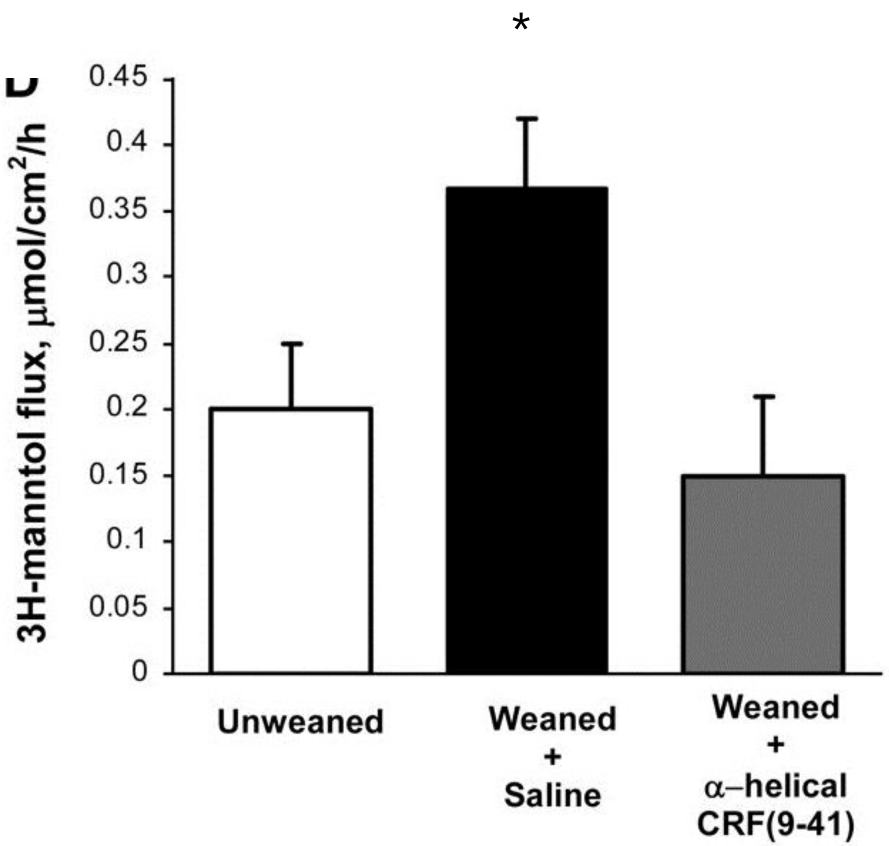


High Flux Rate; more permeable epithelial barrier
Low Flux Rate; intact epithelial barrier

(from Moeser *et al.*, 2007; *Am. J. Physiol*. **292:**G173-181)

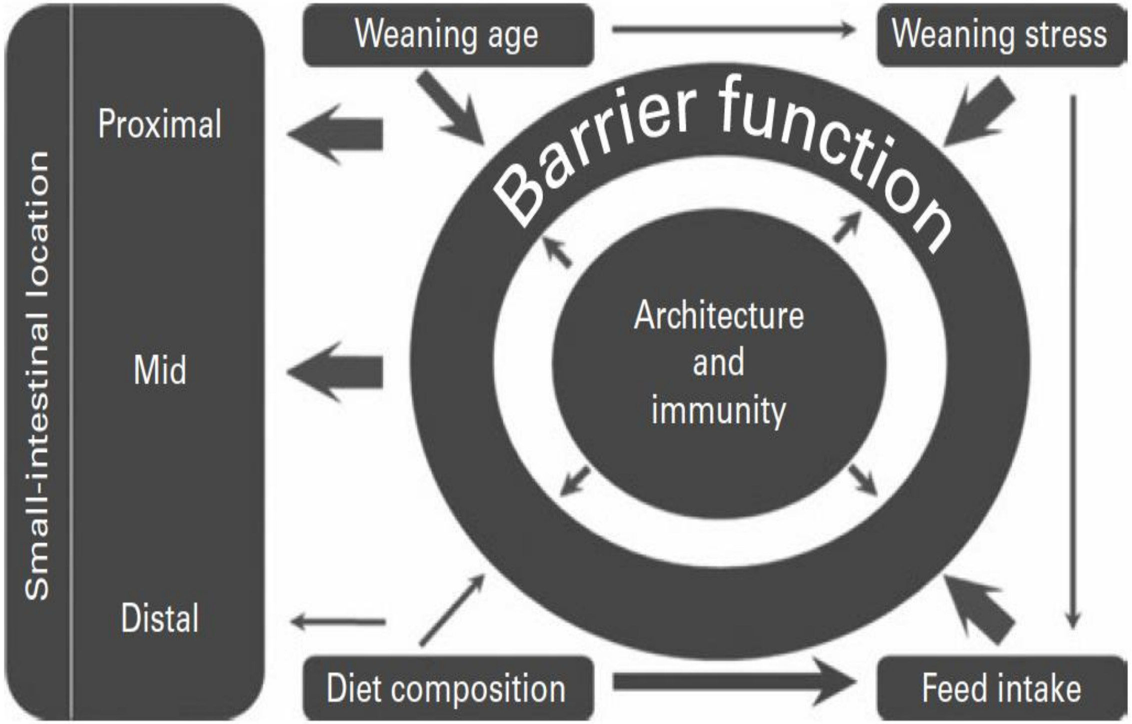
Weaning-induced Stress Causes Intestinal Epithelial Barrier Dysfunction





(*from* Moeser *et al*., 2007; *Am. J. Physiol.* 292**:**G173-181)

Major Factors Influencing Barrier Function After Weaning - a summary

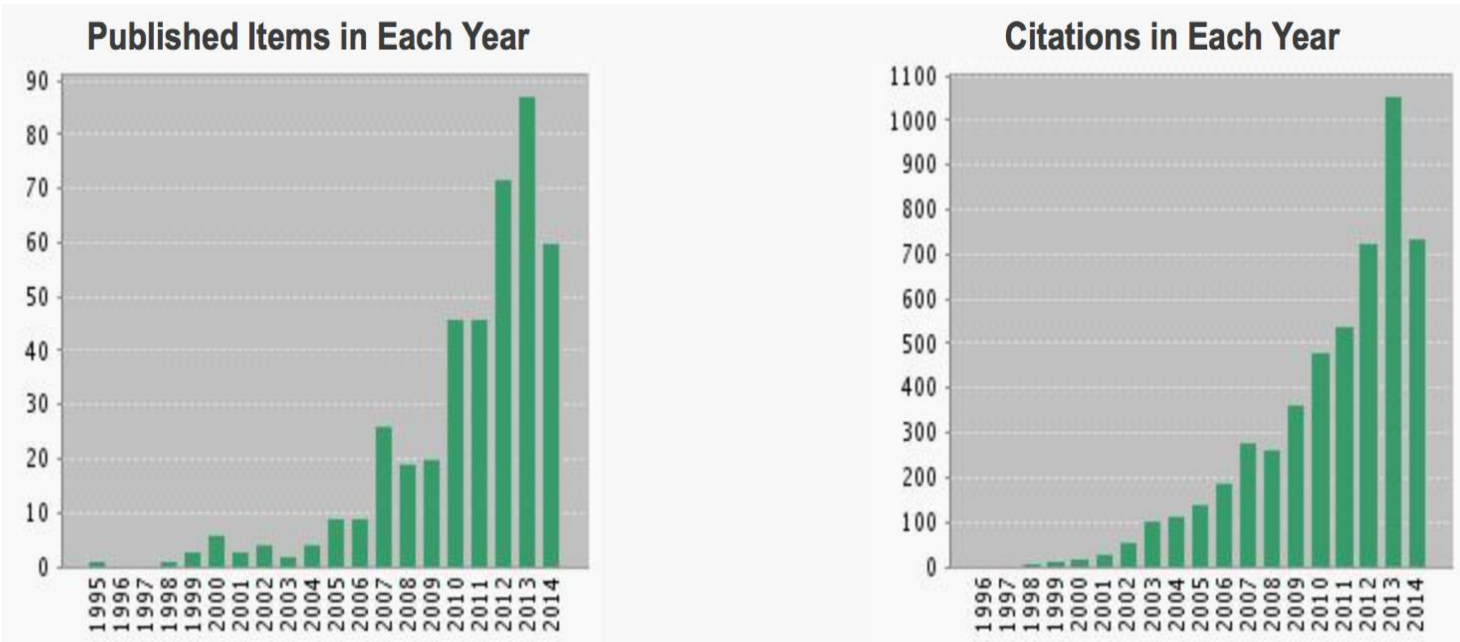


Thickness of arrows indicate biological significance of the relationship

(from Wijtten *et al*., 2011; *Br. J. Nutr.*, **105:**97–981)

The Pig Gut Microbiota – Many Searching For Answers!

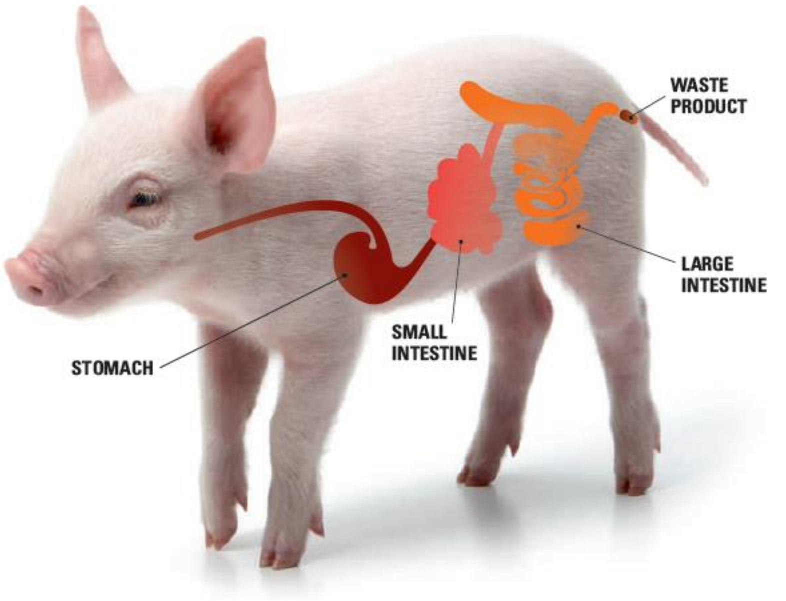
Number of publications and citations per paper (1995-2014) for the words “pig gut microbiota”



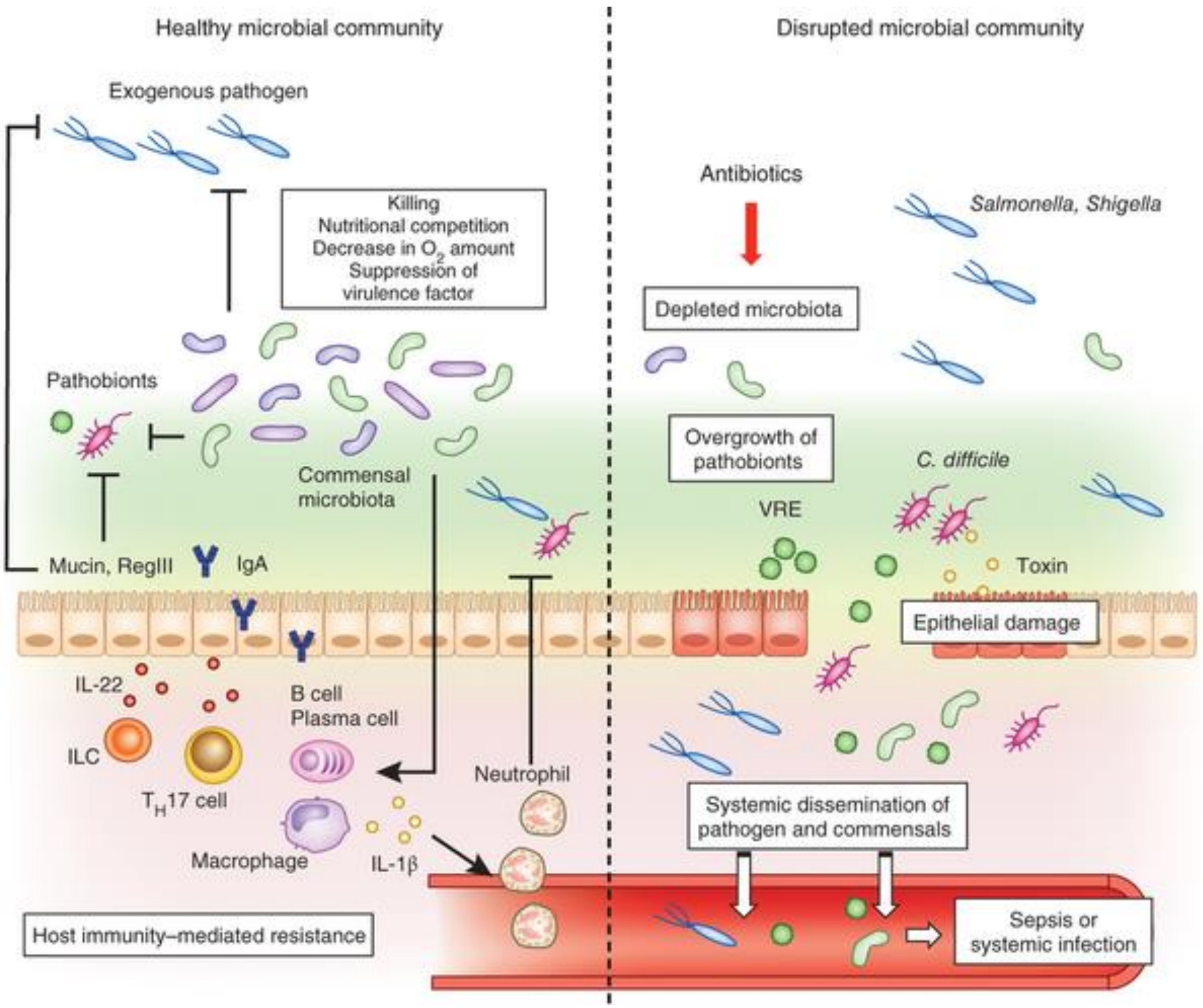
(Web of Science™; accessed 19th September, 2014)

Weaning: Influences On The Gut Microbiota

- The number, composition and diversity of the gut microbiota after weaning is influenced by *myriad* of interacting factors, e.g., nutrition (AGPs, different feed additives, ingredients etc.), digestibility, environment (indoor, outdoor), disease (clinical, sub-clinical), stress

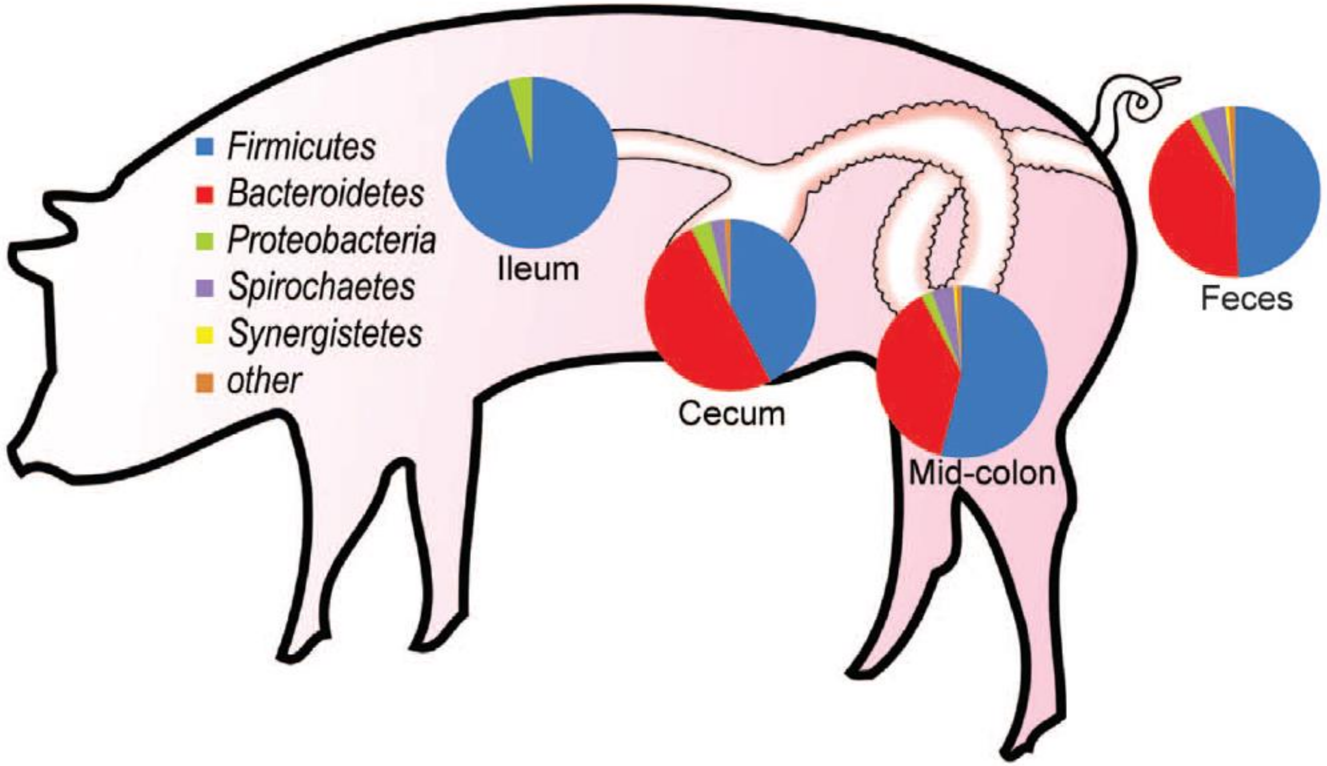


Commensal Microbiota Prevent Colonization By Exogenous Pathogens and Pathobionts



(from Kamada *et al*., 2013; *Nat. Immunol.* **14:**685-690)

Phylum-level Distribution Of The Microbiota Along The Gastrointestinal Tract Of The Growing Pig

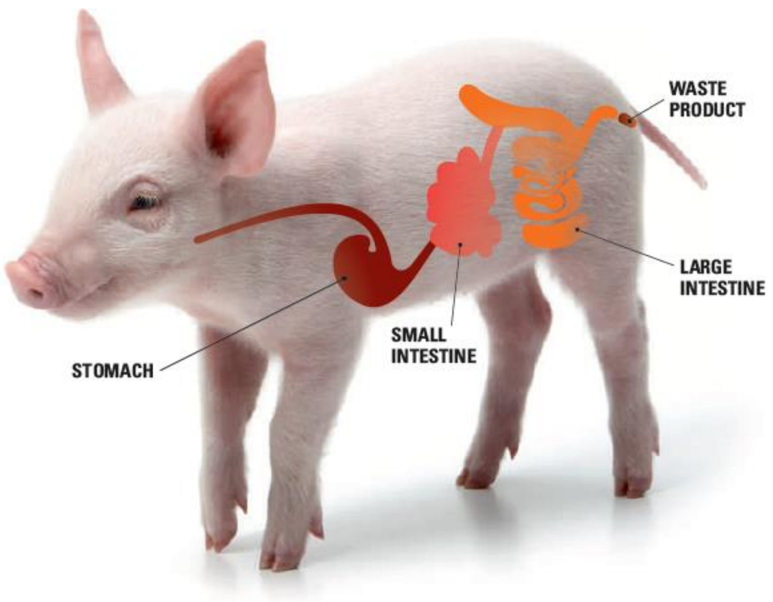


(Looft *et al*., 2014; *The ISME J*; doi:10.1038/ismej.2014.12)

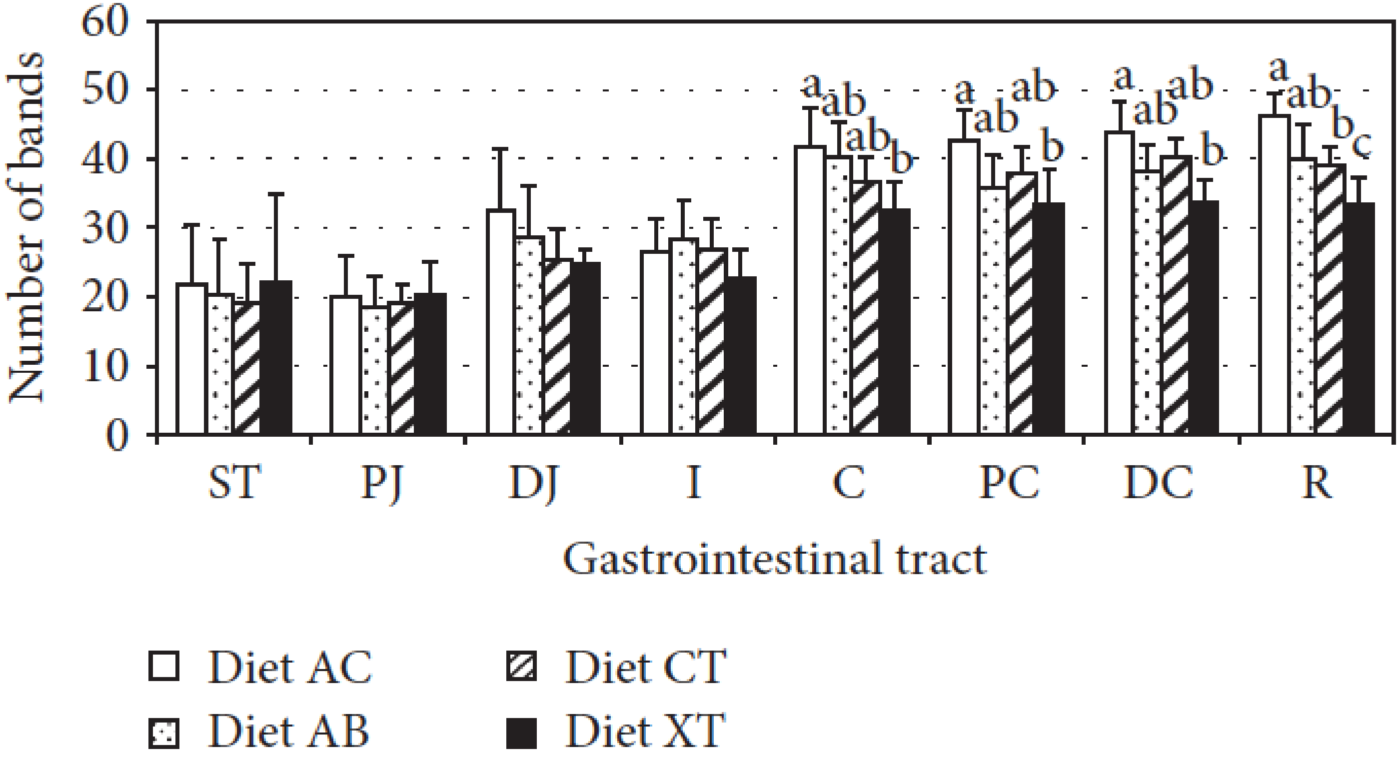
Weaning: Influences On The Gut Microbiota

- The number, composition and diversity of the gut microbiota after weaning is influenced by *myriad* of interacting factors, e.g., nutrition (AGPs, different feed additives, ingredients etc.), digestibility, environment (indoor, outdoor), disease (clinical, sub-clinical), stress

- Do changes in the microbiota (diversity, richness community structures) relate to changes in production indices and (or) disease-related measurements, e.g., scouring after weaning?



Changes in Bacterial Population of Gastrointestinal Tract of Weaned Pigs Fed with Different Additives



Results

3.1. Clinical and Production Parameters. No clinical signs andno diarrhoea episodes were observed in any animal duringthe whole experimental period. There were no significant differences in growth performance ($P > 0.05$).

Mercè Roca et al, BioMed Research International Volume 2014 (2014), Article ID 269402, 13 pages
http://dx.doi.org/10.1155/2014/269402

Dietary Plant Extracts Alleviate Diarrhea And Alter Immune Responses Of Weaned Pigs Experimentally Infected With A Pathogenic Escherichia Coli.

F-18 Escherichia coli

	E. coli				
Item	CON	CAP	GAR	TUR	SEM
Diarrhea score[5]					
d 0 to 2	1.93	1.67	1.35	1.36	0.36
d 3 to 5	3.43[a]	2.50[b]	2.13[b]	2.00[b]	0.31
d 6 to 8	2.86	2.58	2.83	2.90	0.52
d 9 to 11	3.51[a]	2.13[b]	1.21[c]	1.15[c]	0.26
Pig days[6]	53	64	64	53	
Frequency[7]	40	26	17	16	—

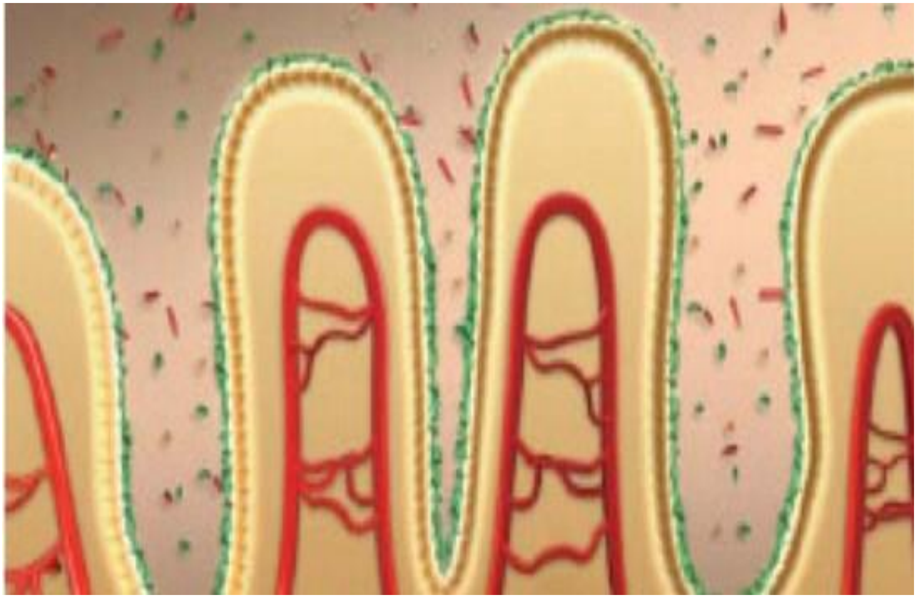
CON = control diet, CAP = control diet plus 10 g capsicum oleoresin/t, GAR = control diet plus 10 g garlic botanical/t, and TUR = control diet plus 10 g turmeric oleoresin/t.

(No effects of plant extracts on production measurements d 0-11 after weaning)

Lui et al, J Anim Sci. 2013 Nov;91(11):5294-306. doi: 10.2527/jas.2012-6194. Epub 2013 Sep 17.

How Much Do We Really Know About The Gastro-intestinal Tract Microbiota?

- The ultimate aim of (microbial) ecology is to understand the relationships of all organisms to their environment (Hungate (1960):



- Three principle questions:
  - What comprises the normal microbiota?
  - Where are they located?
  - What are they doing?

Further Research: The Gut Microbiota

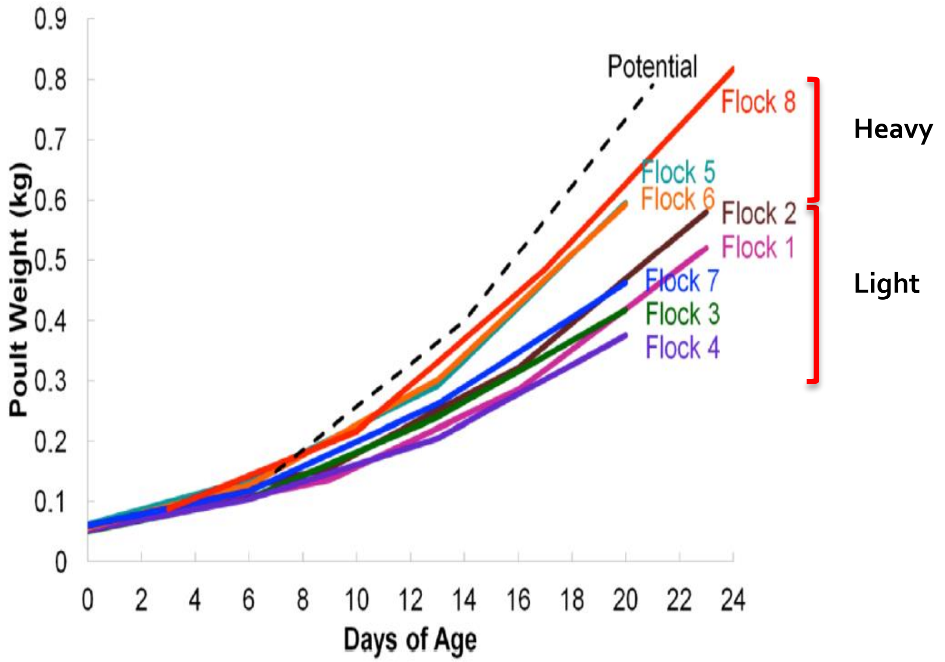
- Establishing associations, in a dynamic manner, between changes in the microbiome (e.g., due to diet, environment, stress etc.) and production,
  - Are changes in bacterial populations the cause, or the effect, of any production changes?
  - If the cause, then how can the change(s) be exploited commercially?

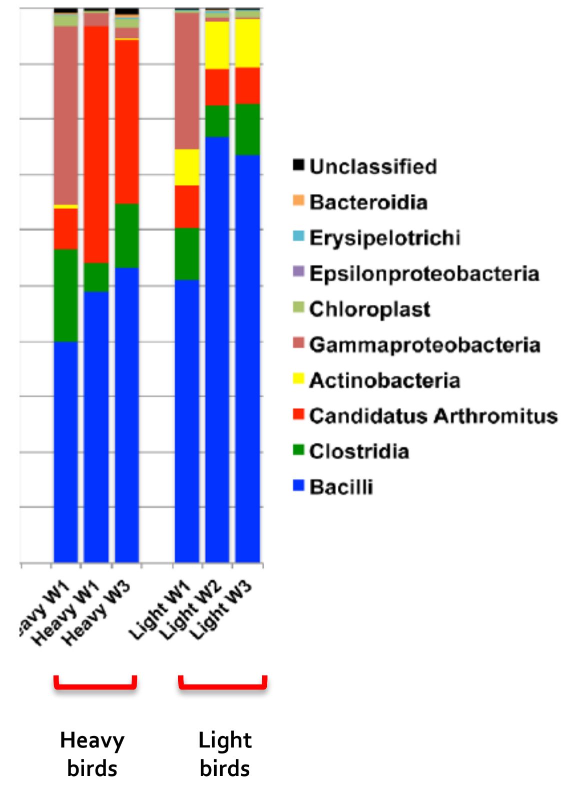
- Establishing associations, in a dynamic manner, between changes in the microbiome (e.g., due to diet, environment, stress etc.) and *outliers* in the production system,
  - Fall-back pigs

- Establishment of the 'appropriate' microbiota in the young (pre-weaned) pig,
  - Influence of the dam (and perhaps the boar?) in shaping the microbiome pattern in the host
  - Manipulation of the host

- Inconsistency of effects of feed/water additives purported to improve gut health,
  - Mechanisms of action
  - Conditions under which positive effects are observed?

Differences In Weights Of Turkeys (*Light Turkey Syndrome*) Are Associated With Changes In The Microbiome





(Succession of the turkey gastrointestinal bacterial microbiome related to weight gain, Danzeisen *et al*., 2013; *PeerJ* 1:e237; DOI 10.7717/peerj.237)

The *Ideal* Gastrointestinal Tract For The Weaned Pig (Any Pig?) Should:

- Maximize digestive and absorptive function
- Maintain appropriate balance of microbiota to minimize overgrowth and reduce risk of dysbiosis,
  - Limit increase in number of potentially pathogenic bacteria throughout the gut
  - Minimize diarrhea (microbial, secretory)
- Appropriate immune system (equilibrium; regulation *versus* inflammation)
- Minimize inflammatory insults/support antioxidant activity (e.g., under stress)
- Maintain/restore barrier function (if perturbed)
- Allow for optimum technical performance

Growth Rate Immediately After Weaning Impacts On Lifetime Performance

Weight (kg) on day after weaning:				
	Day 28	**Day 56**	**Day 156 (market)**	**Days to market**
g/day				
≤ 0	14.7	30.1	105.4	183.3
0-150	16.0	31.9	108.2	179.2
150-227	16.9	32.5	111.3	175.2
≥ 227	18.2	34.8	113.4	175.3

[Pigs weaned at average age of 21 d and 6.23 kg. Data for d 28 and d 56 from 1,350 pigs; data for d 156 from 566 pigs]

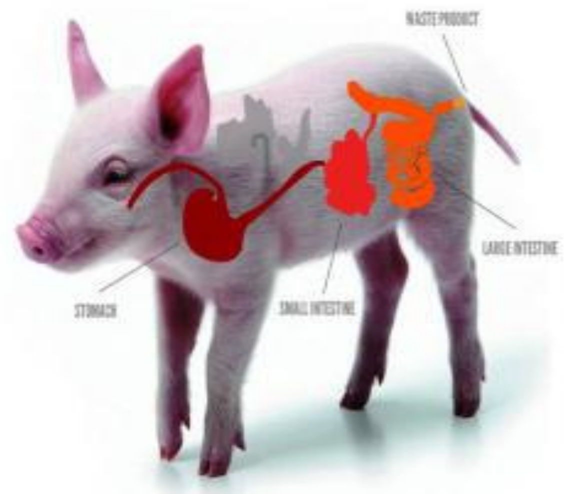
(*from* Tokach *et al.*, *Swine Day 1992*, Kansas State University; pp. 19-21)

Gary Partridge joined Danisco Animal Nutrition, which is today part of DuPont Industrial Biosciences, in 1994 and is now the company's Global Development and Technical Director, specializing in swine. Before joining Danisco Animal Nutrition, he worked as a senior researcher at the Rowett Institute in Aberdeen, Scotland and then as a technical swine specialist in a premix company in the UK that later became a part of Nutreco. Gary has penned numerous scientific peer-reviewed papers and abstracts over the years, as well as many trade press articles. A member of the British Society of Animal Science and the Nutrition Society, he is co-editor of the textbook "*Enzymes in Farm Animal Nutrition*".

Effects Of Anti-nutrients On Digestion In The Young Pig, And Feed Additives Relevant To Gut Integrity And Health

DR GARY PARTRIDGE

GLOBAL DEVELOPMENT AND TECHNICAL DIRECTOR
DANISCO ANIMAL NUTRITION



Some Targets To Support Optimal Growth In The Young Pig After Weaning

- **Maximize feed intake and diet digestibility**, without compromising gut health
- **Minimize costly endogenous losses** that increase maintenance energy and protein/amino acid requirements
- **Stimulate digestive function**
- **‘Feed the gut’** to maintain gut integrity and absorptive function
- **Stabilize the gut microbiota** to minimize risk of proliferation of non-beneficial bacteria
- **Support the developing immune system** of the young pig

The Long-term Benefits Of Improved Growth Rate In Young Pigs After Weaning Are Well Proven

Reference	Each kg of extra growth after weaning*, reduced days to slaughter by :
Tokach *et al* (1992)	**3.0 days**
Mahan *et al* (1998)	**8.3 days**
Pluske *et al* (1999)	**3.6 days**
Kim *et al* (2001)	**2.3 days**
Ilsley *et al* (2003)	**4.3 days**

On average, each extra kg of growth after weaning reduced days to slaughter by 4 – 5 days, worth ~€1.80 per pig at today's prices

** Nutritional treatments after weaning varied from 1 to 3 weeks duration*

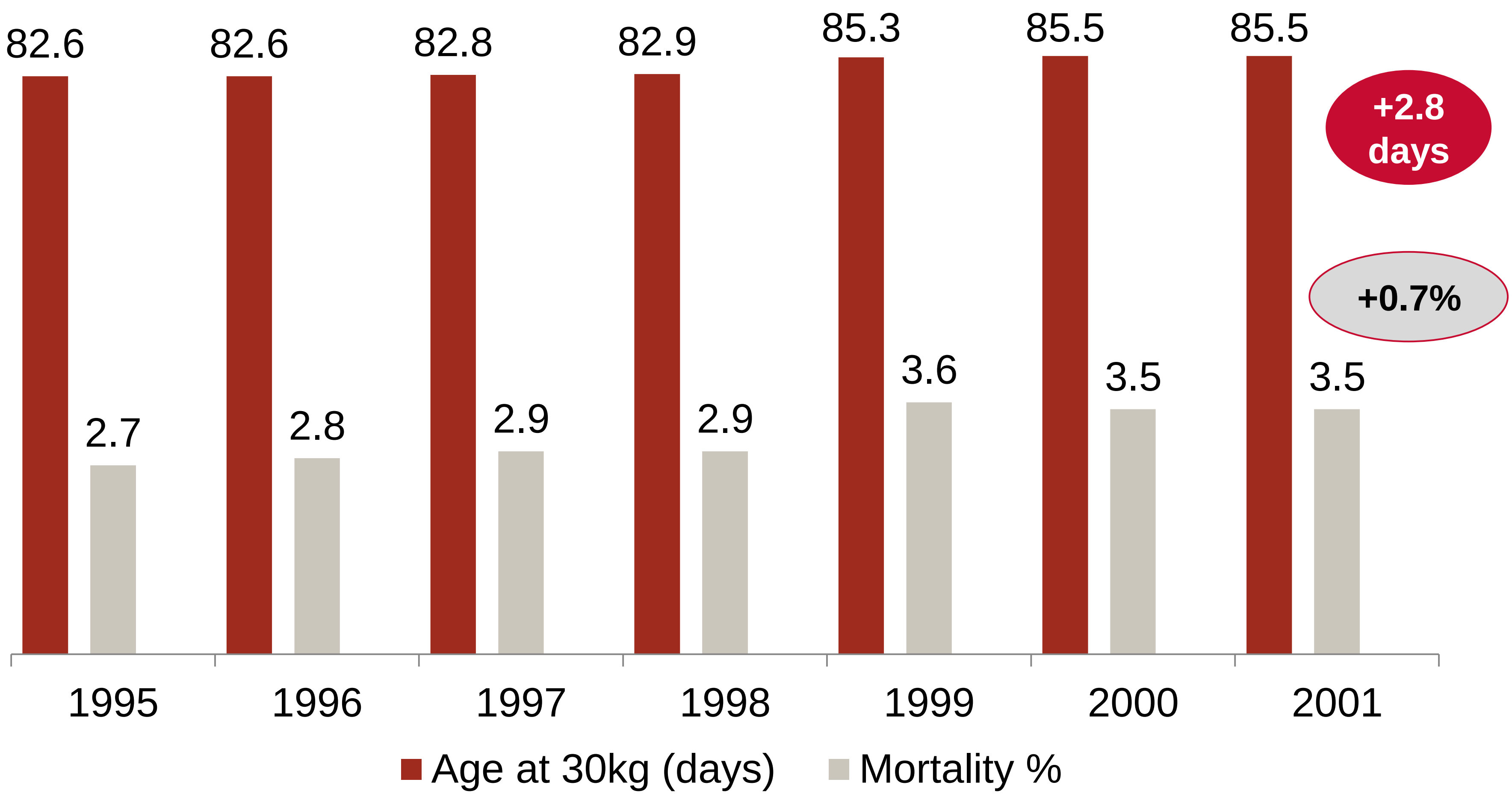
The Gut – A Major Metabolic Organ

Gut is 5-7% of body mass but accounts for:

- 20-35% of whole body energy expenditure
- 20-60% utilization of dietary amino acids
- 100% utilization of glutamate

Ball (2014)

Effect Of AGP Removal In Denmark On Weaner Pig Performance (WHO 2003)



------------------------With AGP---------------------- Reduced AGP---------No AGP--------

Feed additives that can be relevant to improving performance after weaning?

- **Probiotics = DFMs** e.g. live, spore-formers, 'ghost'
- **Nucleotides**
- **Symbiotics**
- **Additives** e.g. inulin, lactulose
- **Anti-microbial peptides**
- **Prebiotics**
- **Osmolytes** e.g. natural betaine
- **Bacteriophages**
- ***in situ* production** e.g. XOS
- **Herbs and spices**
- **Feed enzymes**
- **Essential oils**
- **Organic acids** e.g. sodium butyrate, lactic
- **Carbohydrases** e.g. xylanase
- **Raw materials** e.g. plasma proteins, bovine colostrum, whey, lactose
- **Amylases**
- **Antibiotics** e.g. zinc oxide
- **Yeast beta-glucans**
- **ASF**
- **Proteases**

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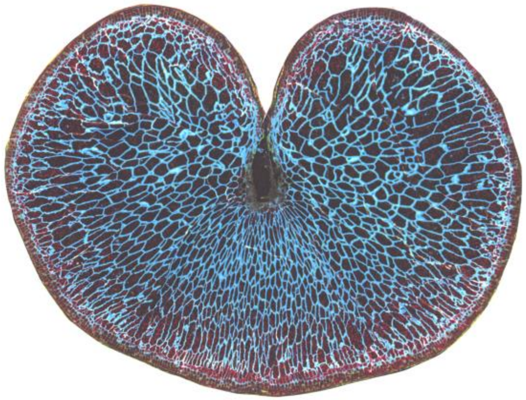
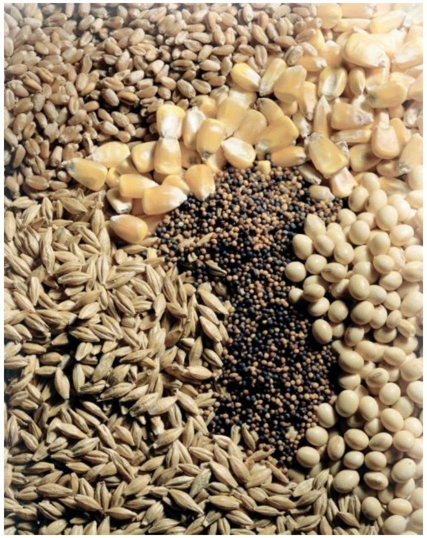
- Anti-microbial peptides
- Prebiotics
- Osmolytes e.g. natural betaine
- *in situ* production e.g. XOS
- Bacteriophages
- Herbs and spices
- Feed enzymes
- Essential oils
- Organic acids e.g. sodium butyrate, lactic
- Carbohydrases e.g. xylanase
- Raw materials e.g. plasma proteins, bovine colostrum, whey, lactose
- Amylases
- Antibiotics e.g. zinc oxide
- Yeast beta-glucans
- ASF
- Proteases

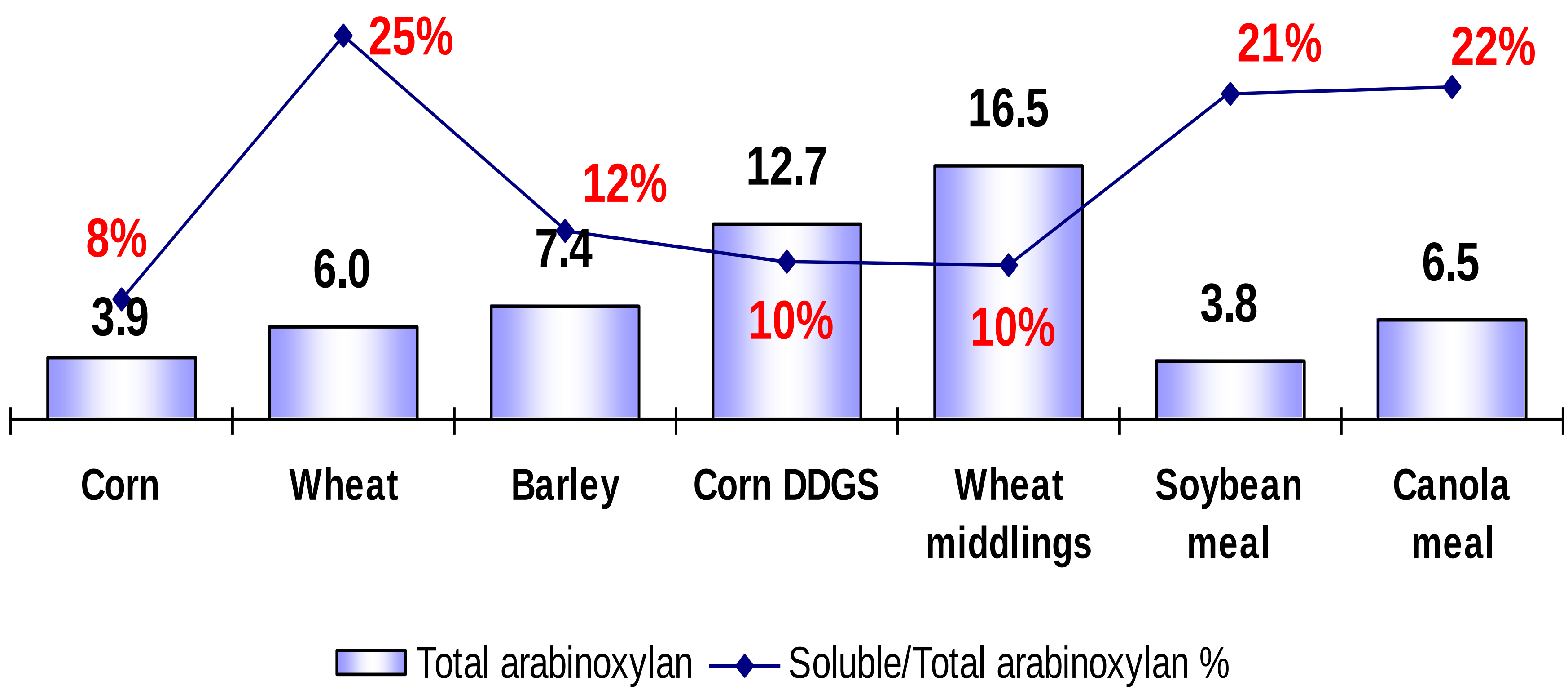
Negating the effects of dietary anti-nutrients in the young pig

FEED ENZYMES





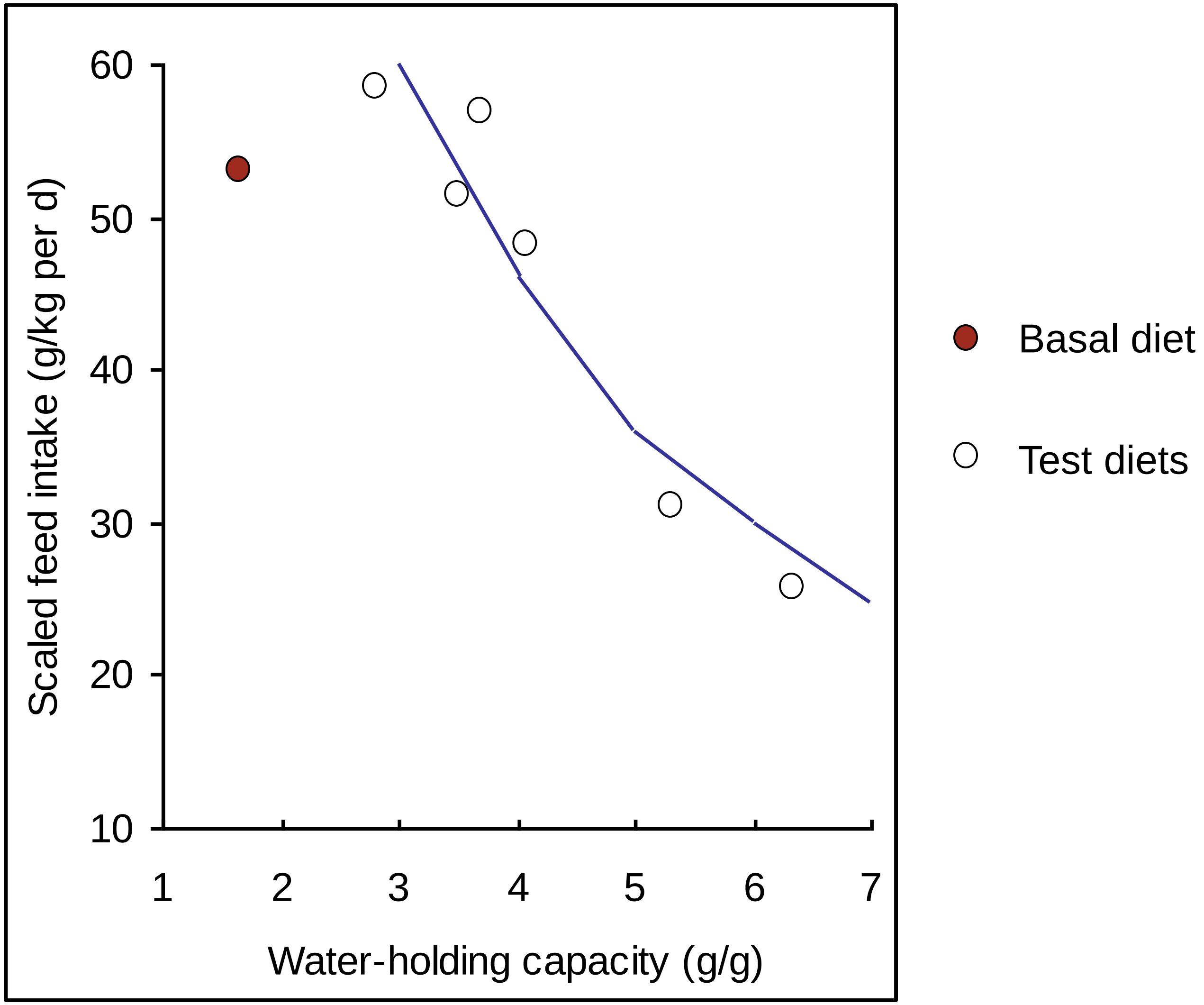
Arabinoxylan Content And Solubility* (%)



*As fed basis

Source: Danisco Animal Nutrition Non Starch Polysaccharide (NSP) database

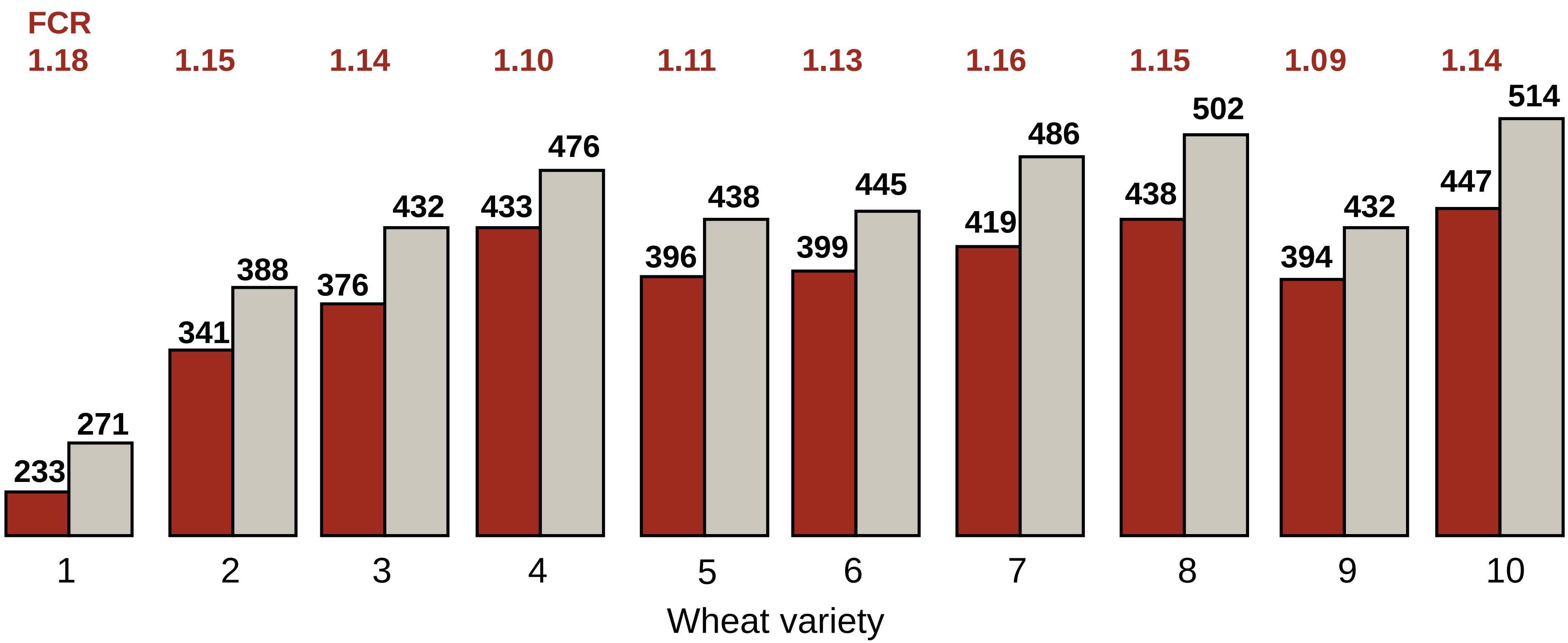
Water Holding Capacity Of The Feed And Its Effects On Feed Intake



Kyriazakis and Emmans (1995), 12-36kg pigs

Wheat Variety Can Influence Pig Growth And Feed Intake - Australia

31% variation in daily gain between the best and next-to-worst Australian wheat samples



Growth: P<0.001 Feed intake: P <0.001 Feed:gain: NS

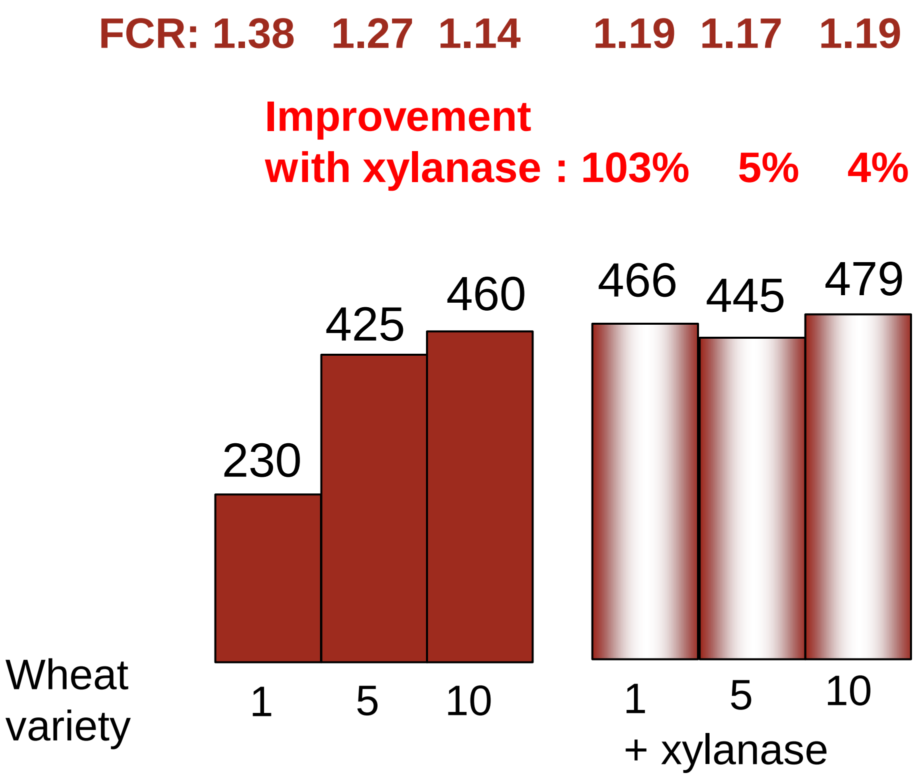
■ Daily gain (g)
□ Feed intake (g/day)

65% wheat in diets
Weight 7-16 kg

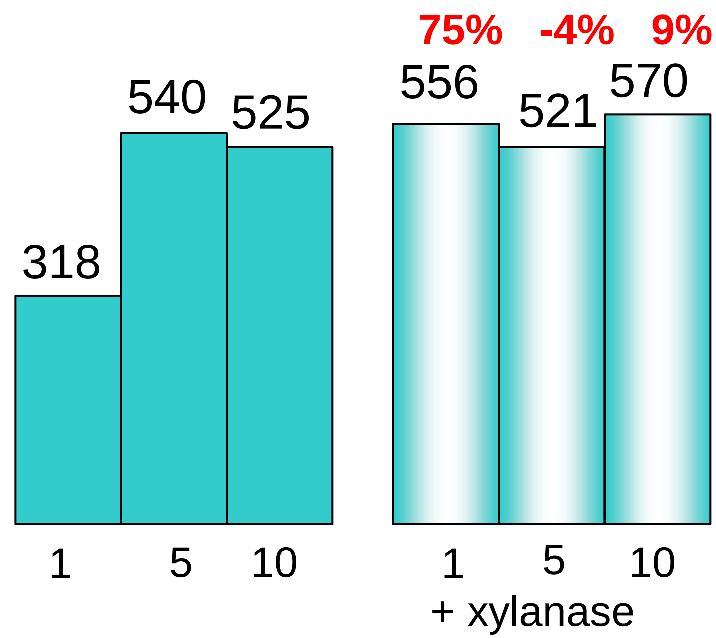
Source : Cadogan et al (1999)

Xylanase Reduces Variation In Performance Between Different Varieties Of Wheat

Daily gain (g)



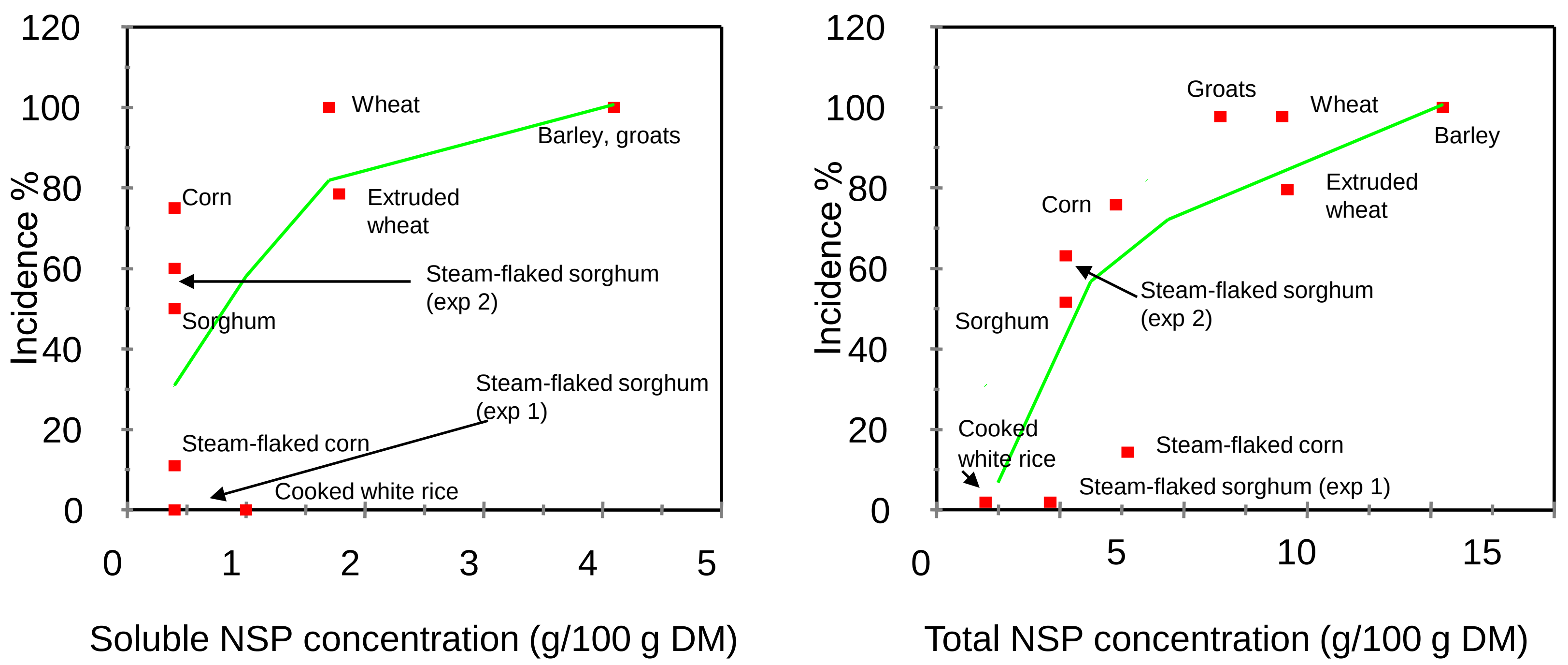
Feed intake (g/day)



Xylanase effects:
Daily gain P<0.001 Feed intake P<0.001 FCR NS
Wheat x Xylanase P <0.001

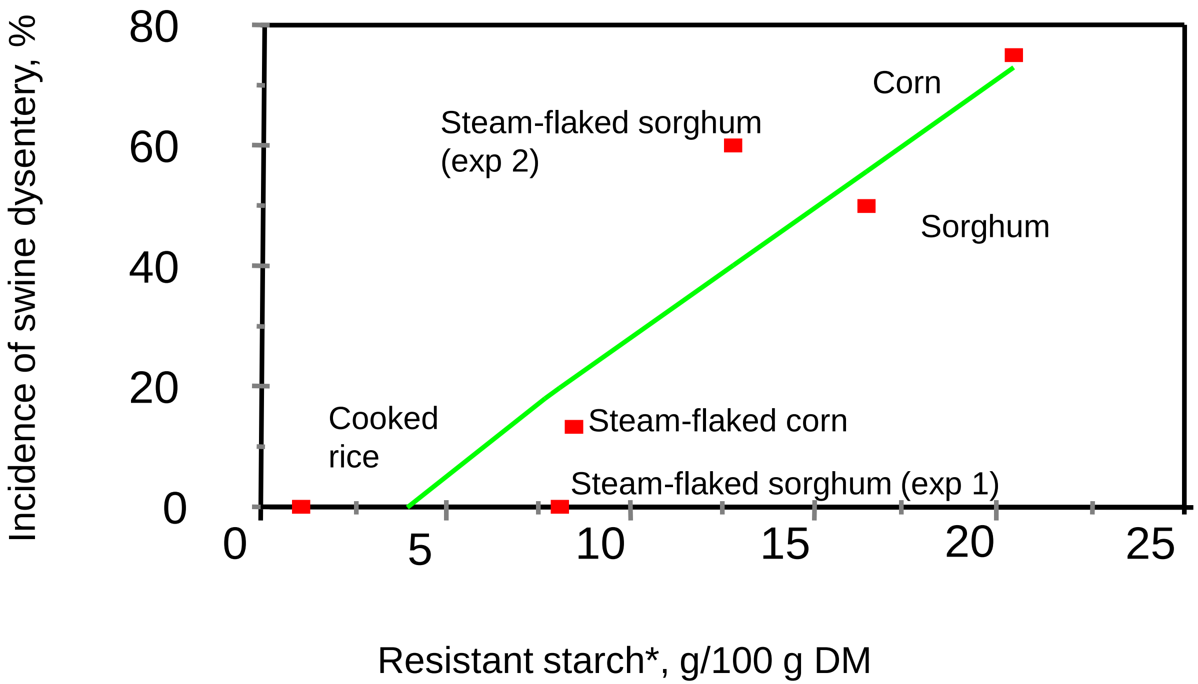
Source : Choct et al (1999)

Incidence Of Swine Dysentery & Non Starch Polysaccharide Concentration



Ref: Pluske et al (1996) J.Nutr.126,2920-2933

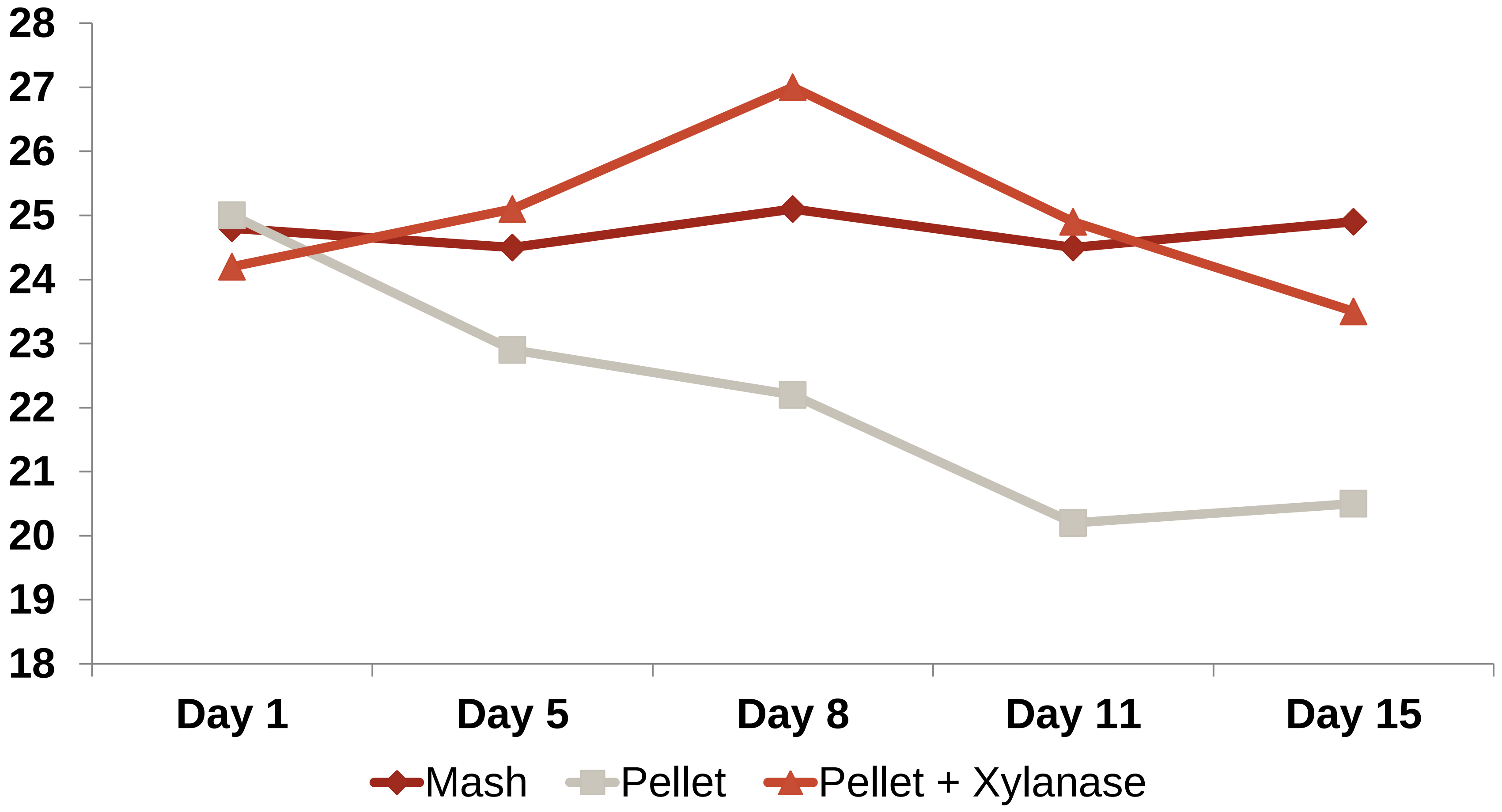
Incidence Of Swine Dysentery And Resistant Starch Concentration



**In vitro* estimation, after simulated digestion

Ref: Pluske et al (1996) J.Nutr.<u>126</u>,2920-2933

Faecal Dry Matter (%) On Wheat-based Diets On A Unit Suffering From Non-specific Colitis, UK – Effect Of Xylanase



Hazzledine and Partridge (1996)

Use Of Xylanase-supplemented Diets On A Pig Unit With A High Incidence Of *Salmonella*

Diets and feeding regime:

- *Ad libitum*
- Pelleted diets (81-85^{o}C) with fine ground wheat (2.5mm screen) -/+ xylanase*
- Mash diets with coarse ground wheat (4mm screen) -/+ xylanase*

Blood sampling:

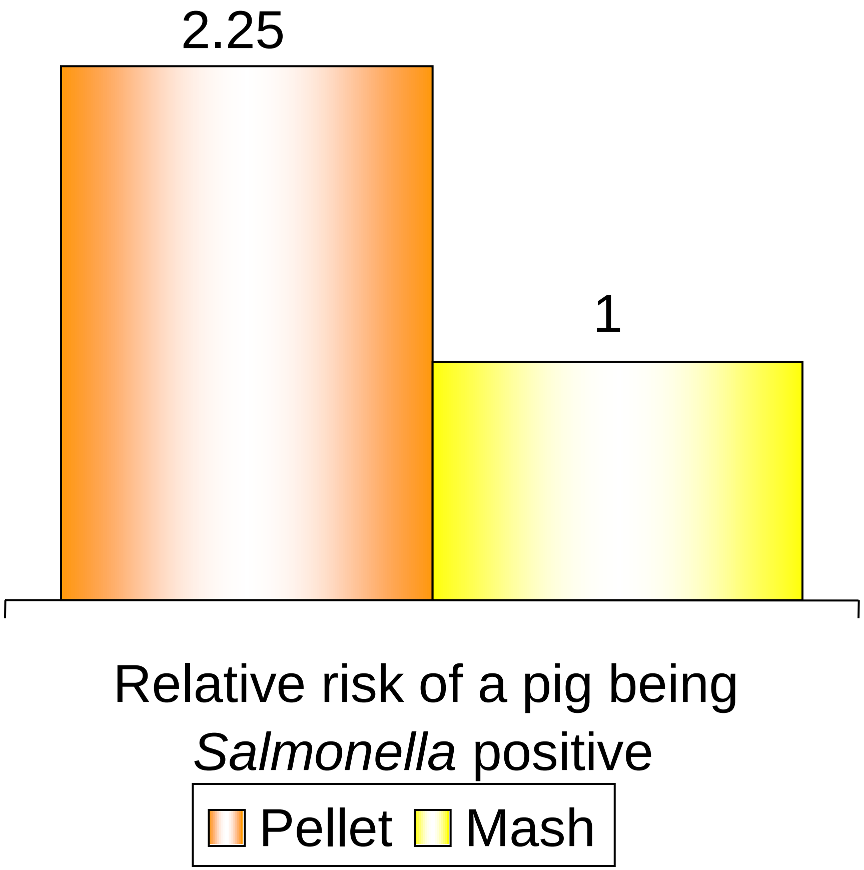
- Blood samples from 6 pigs per pen at random
- Blood samples analysed for *Salmonella* antibody titre by the 'Danish Mix ELISA test'
- *Salmonella* positive = optical density value >20

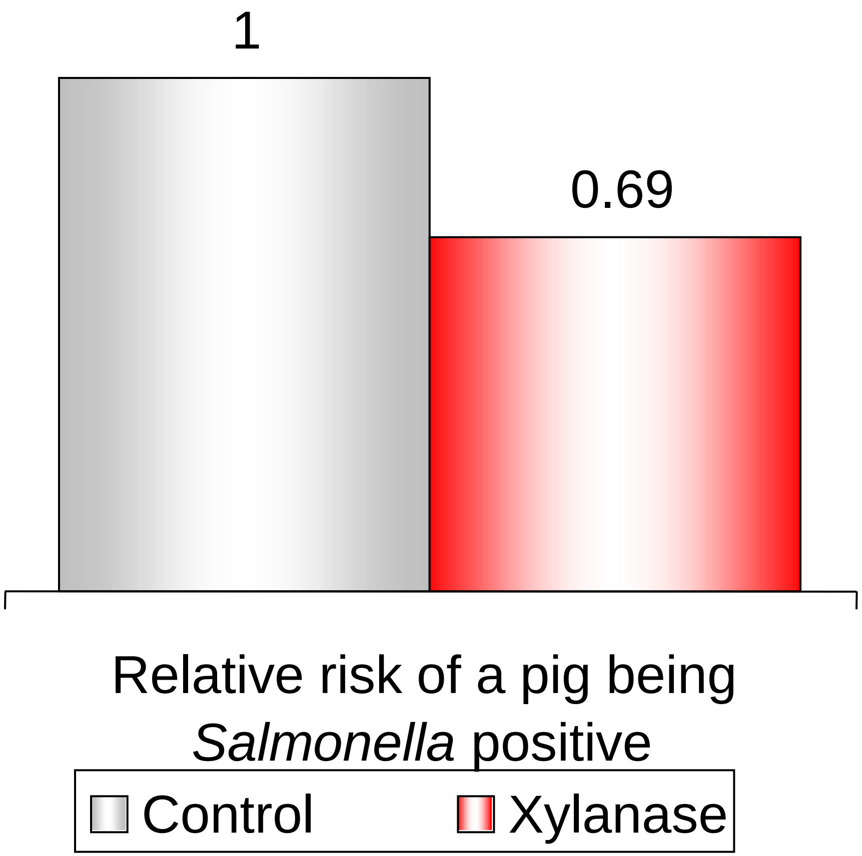
The National Committee for Pig Production (Danish Bacon and Meat Council)

Hansen et al (2003)

* 4000 U/kg feed

Both Xylanase Addition And Mash Feeding Reduced The Relative Risk Of A Pig Being *Salmonella* Positive





The National Committee for Pig Production (Danish Bacon and Meat Council)

Hansen et al (2003)

Variability In Xylanase Response In Grower-finisher Pigs[1]

Trial Report #	Pellets (P) or Mash (M)	Xylanase (X) product no.	Production Value Index[2]
403	P	X 1	107*
558.1	P	X 1	106*
558.2	M	X 1	109*
826	P	X 2	100
848	P	X 3	102
960	M	X 4	104

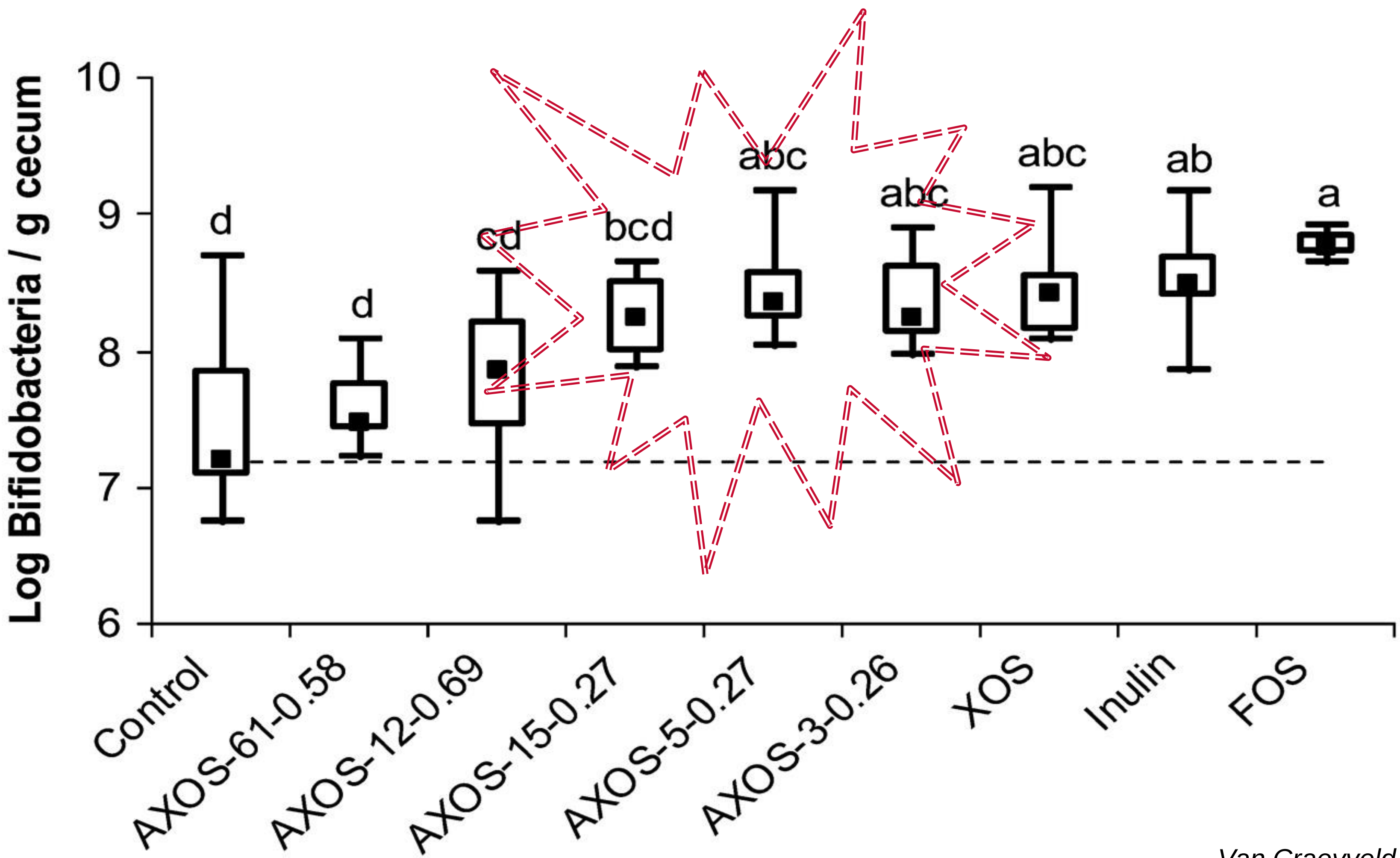
[1] www.danskeslagterier.dk

* Significant effects (P<0.05)

[2] Gross margin per pen place per year based on the same feed price and an average 5 year pig price (excluding xylanase costs). All data expressed versus control set at 100

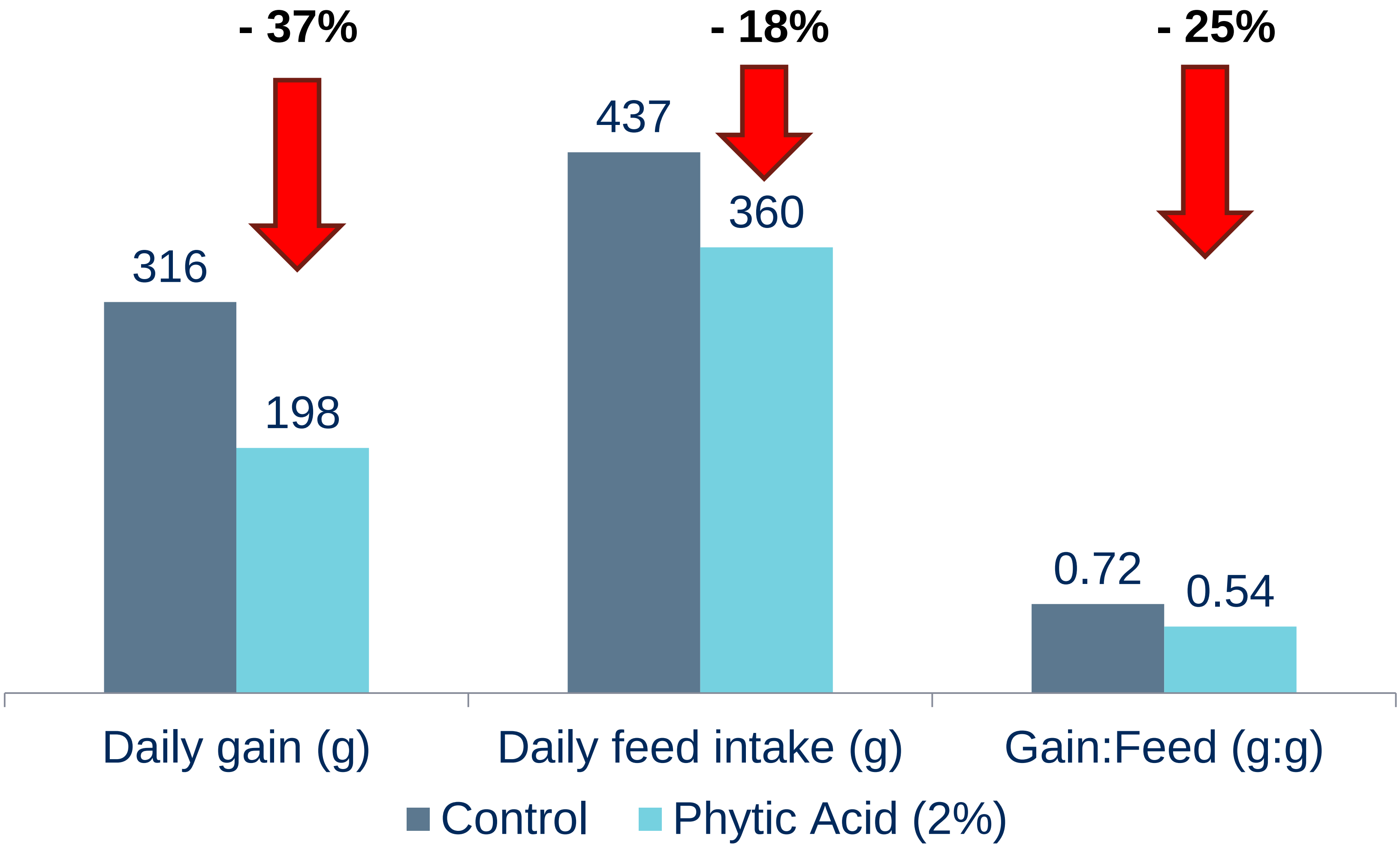
Short chain xyloligosaccharides (AXOS) derived "*in vitro*" from hydrolysis of wheat bran by xylanase are prebiotics

Effect of different oligosaccharides on the concentration of bifidobacteria in the cecum of rats fed diets containing structurally different wheat-derived AXOS for 14 days



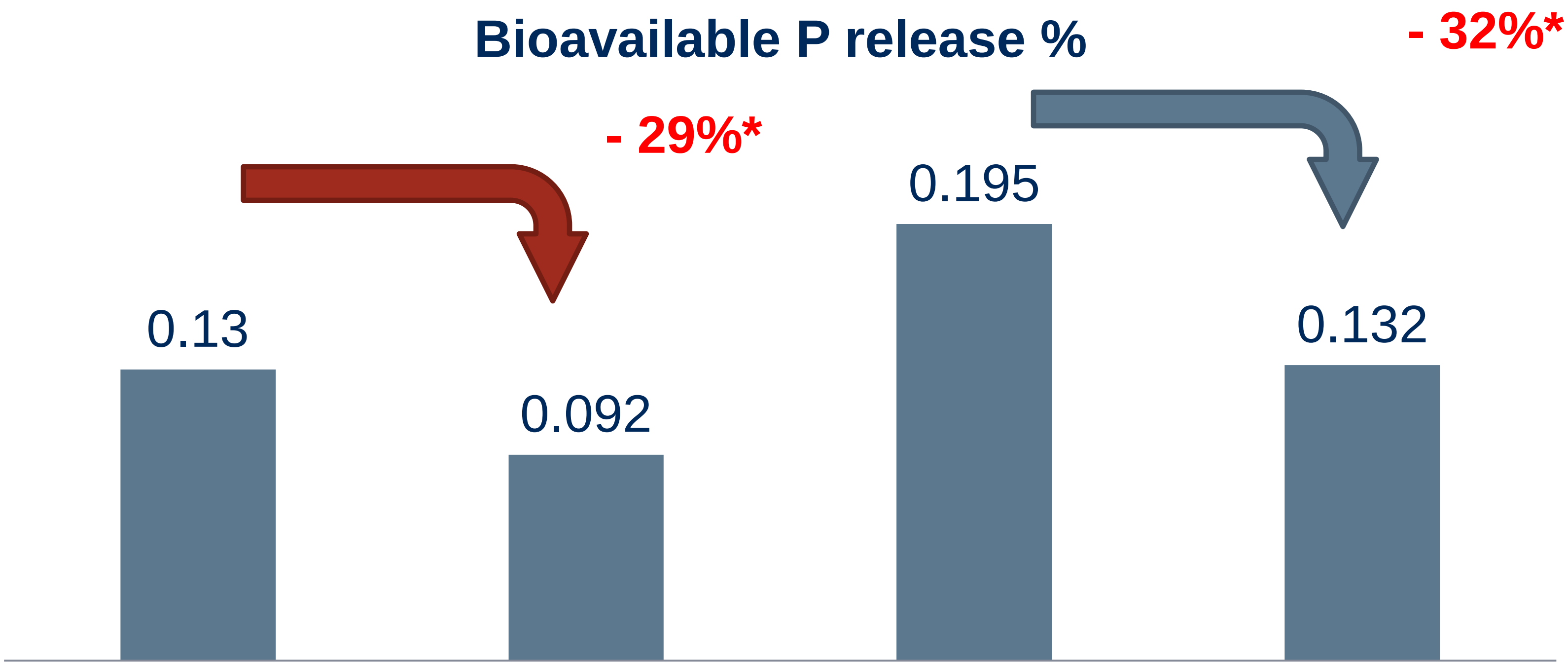
Van Craeyveld et al.2008

Phytate As An Anti-nutrient - Effects On Weaner Pig Performance



Woyengo et al 2012 Synthetic diets (casein-cornstarch) + 2% phytic acid (0.56% phytate P)
Weaning weight 7.4kg, 21 day trial

Zinc At High Levels Reduces Phytase Efficacy (Piglets 7-14 Kg)



Phytase	500 FTU/kg feed [1]		1000 FTU/kg feed [1]	
+ Zinc[2] 1500 mg/kg	-	✓	-	✓

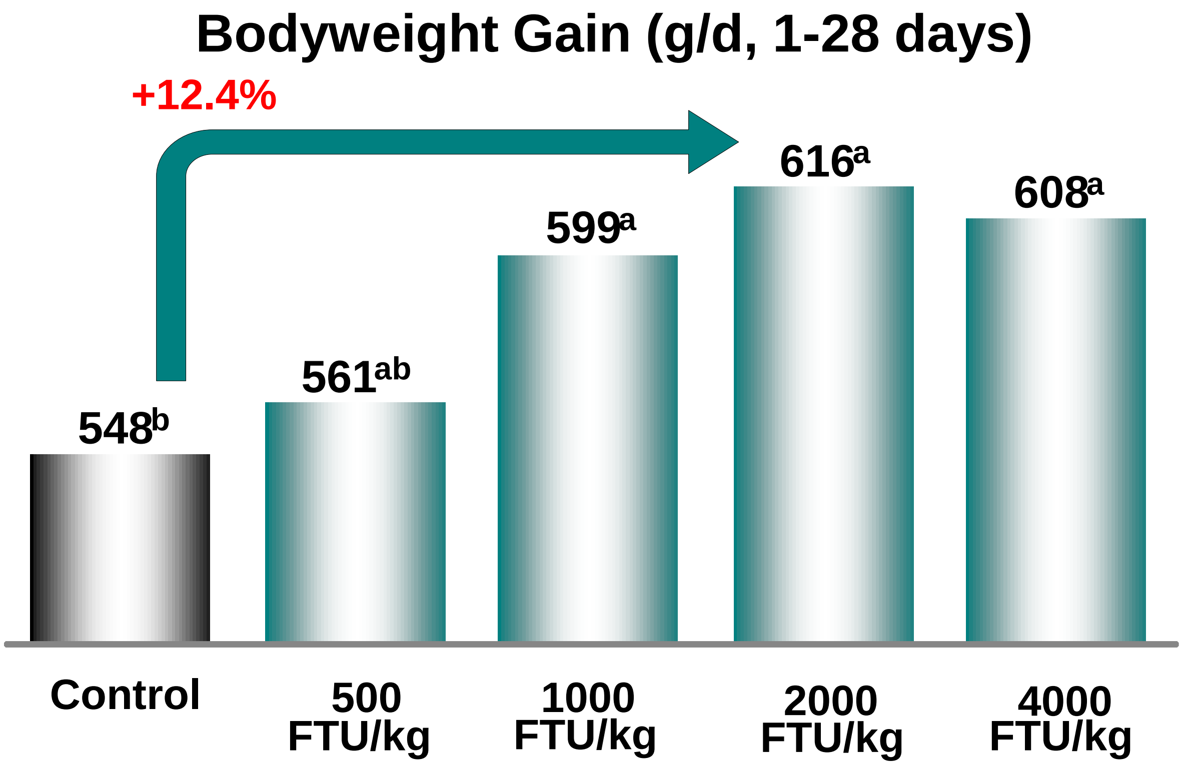
[1] *E.coli* phytase n.b. measured using an assay which usually underestimates FTU's versus other assays

P deficient basal diet 0.32% total P

[2] zinc oxide (ZnO) or basic zinc chloride ($Zn_5Cl_2(OH)_8$) *** P<0.01**

Augspurger et al (2004)

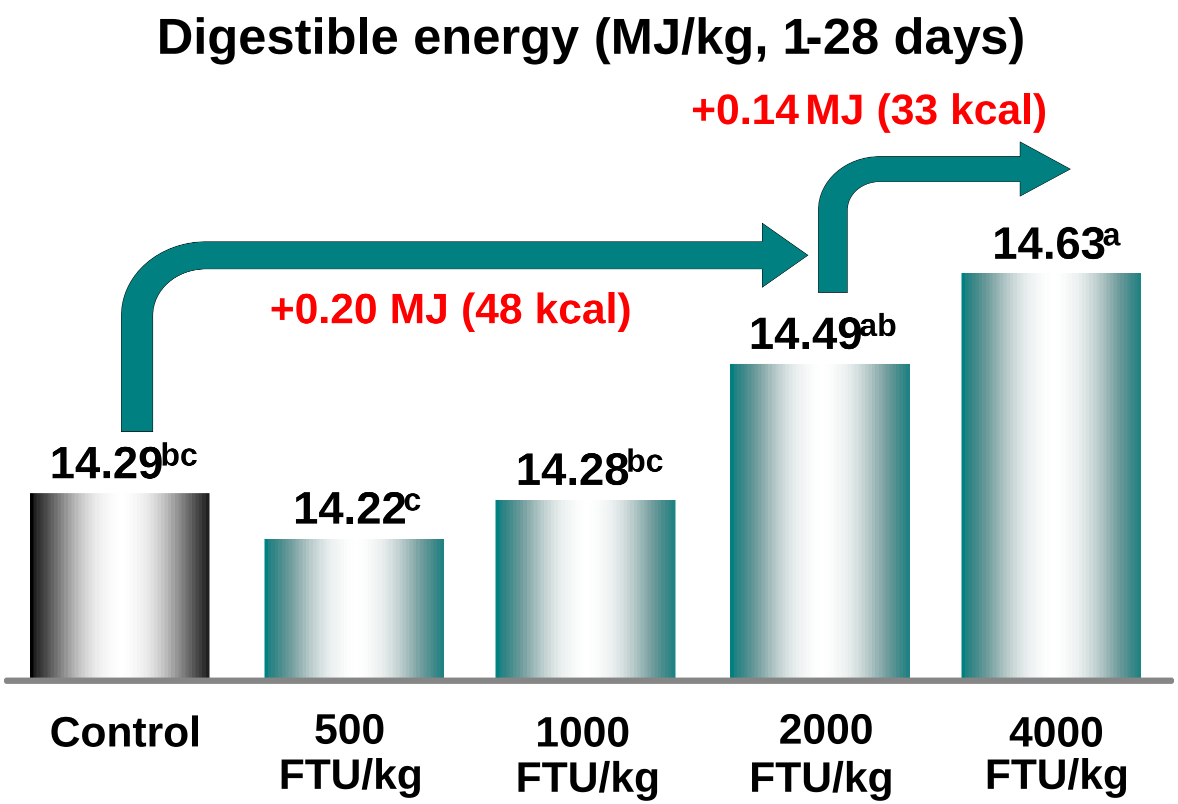
E.Coli Phytase From 500 To 2000 FTU/kg Feed Incrementally Improves Young Pig Performance In Presence Of High Zinc (2.5 kg/Tonne Zinc Oxide)



[a-b] **Means not sharing the same superscript differ significantly (P<0.05)**

R&I Centre, Rivalea, Australia

E.Coli Phytase From 500 To 2000 FTU/kg Feed Incrementally Improves Young Pig Performance In Presence Of High Zinc (2.5 kg/Tonne Zinc Oxide)

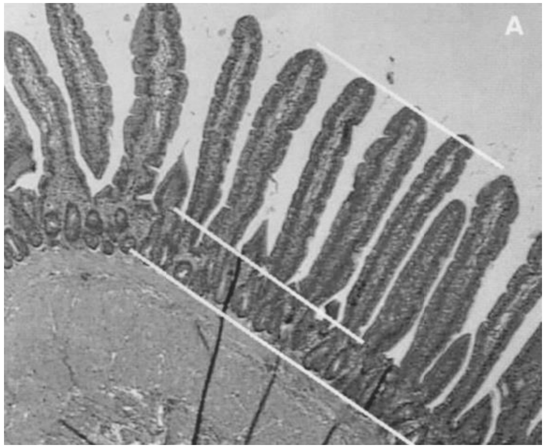


[a-c] Means not sharing the same superscript differ significantly (P<0.05)

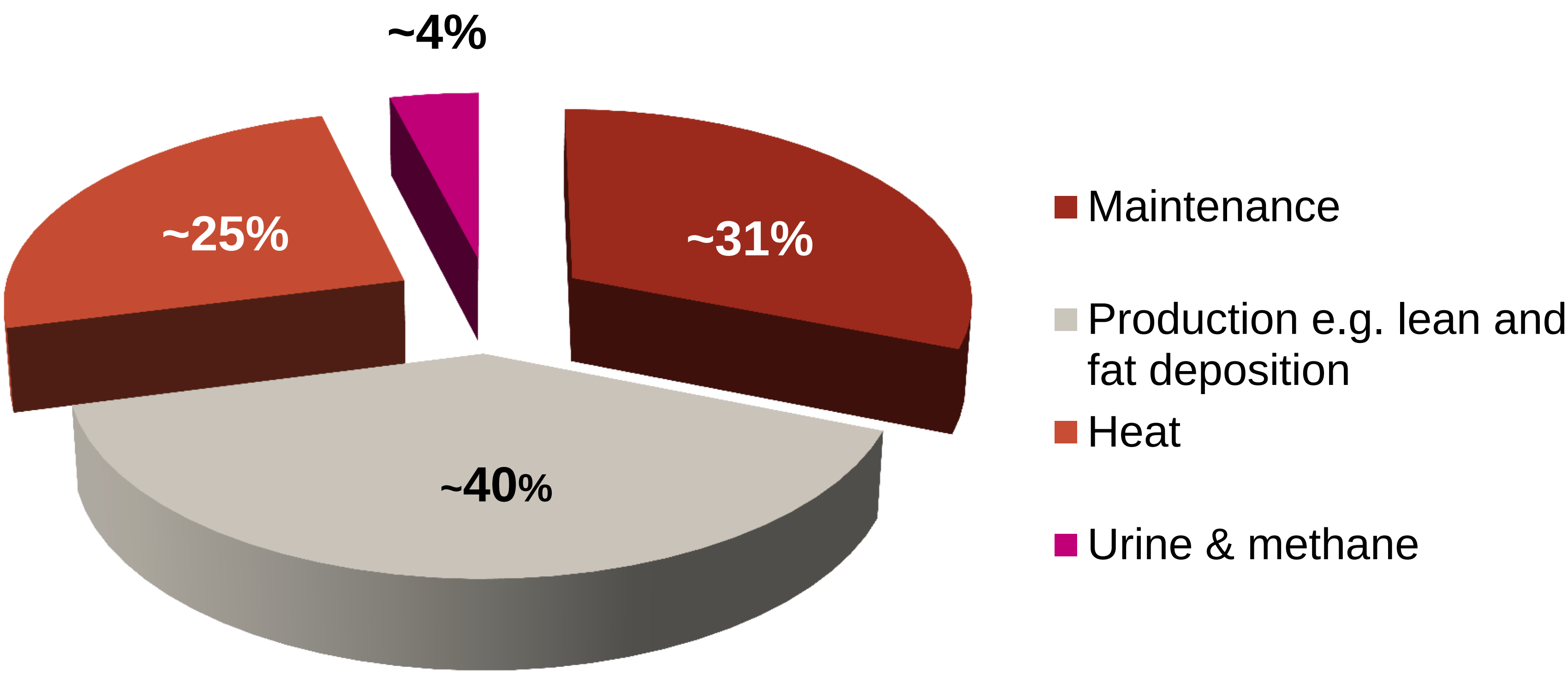
R&I Centre, Rivalea, Australia

Minimizing Maintenance Energy And Protein/Amino Acid Costs In The Young Pig

USE OF AN OSMOLYTE - NATURAL BETAINE




Energy Partitioning – The Importance Of ‘Maintenance’ Energy To Productive Performance In Pigs



Gut Maintenance Energy Requirements Are ~50% Of Total Maintenance Energy Requirements

Contributors include:

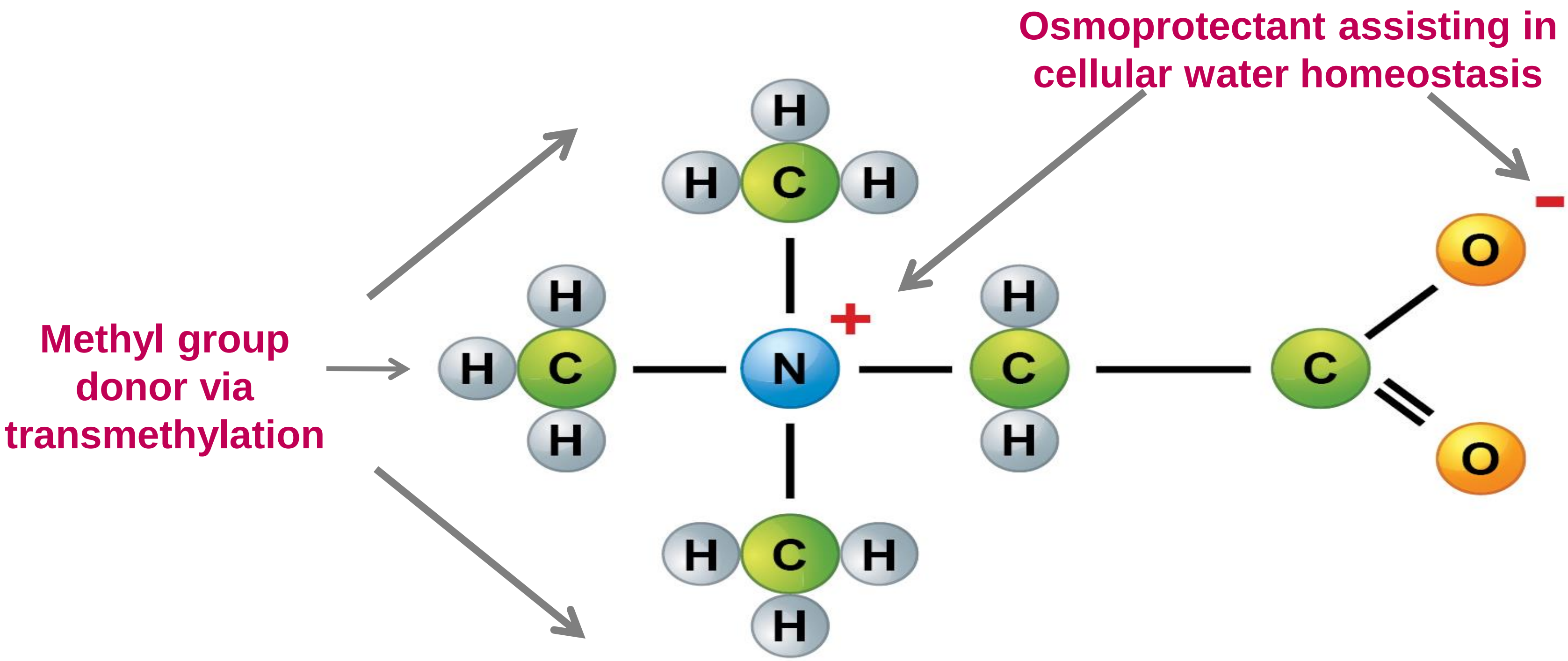
- **Endogenous losses**
  - Mucins
  - Sloughed gut cells
  - Endogenous enzymes
- **Immune secretions**
  - The gut – the largest immune organ in the body (Kraehenbuhl & Neutra 1992)
- **Electrolytes & maintaining osmotic balance**
  - Na^+/K^+ pump (~30-60% of the energy consumption of the gut epithelium and liver)
- **Gut size, gut mucosal structure and cell turnover**
  - n.b. a heavy gut ≠ a healthy gut!

Illustrates the importance of 'gut health' to productive performance

Natural Betaine – A Role In Optimal Nutrition After Weaning?

- Chemically, betaine is the trimethyl derivative of the amino acid glycine with a formula of $(CH_3)_3NCH_2COO$ and a molecular weight of 117.2

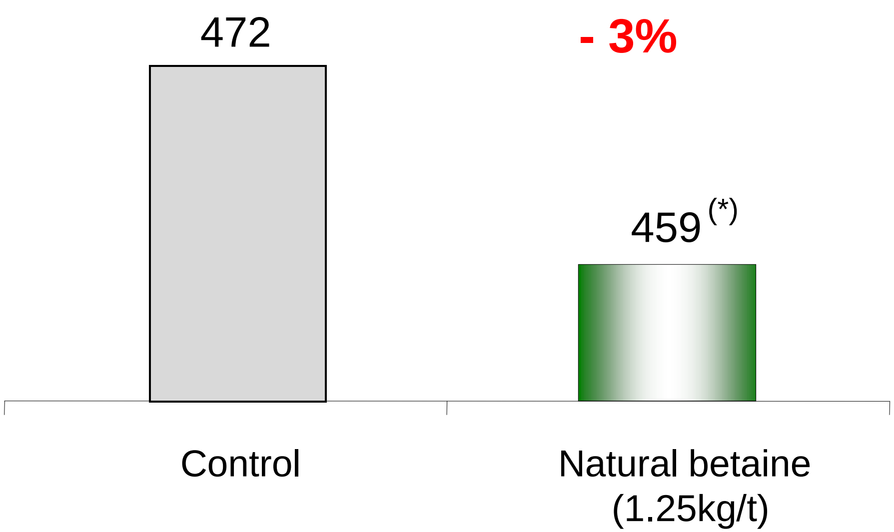
Natural betaine offers two functions from the same molecule



Natural Betaine Reduces Maintenance Energy Costs

Wageningen Institute, Netherlands

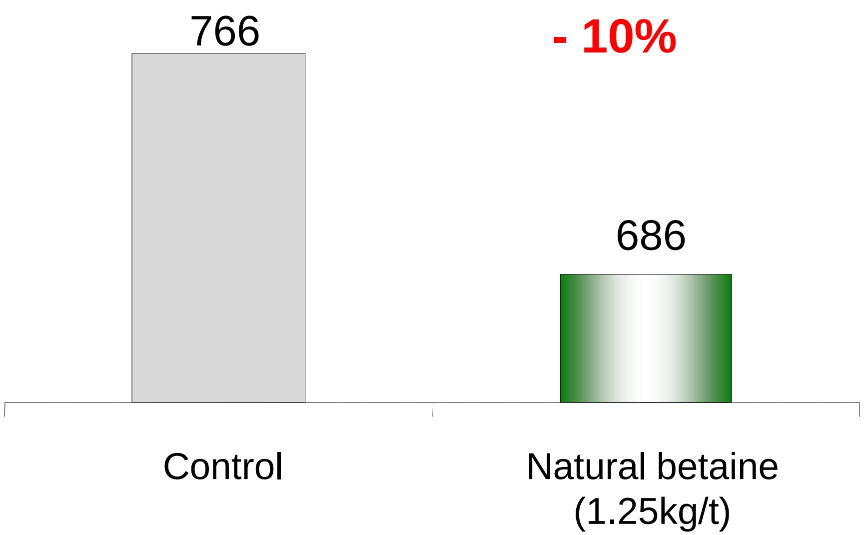
Castrates (46-60kg), small groups in calorimeters, gas exchange used to estimate maintenance energy requirements (kJ ME/kg $^{0.75}$/day)



(*) P<0.10 Schrama *et al* (2003)

Rivalea (formerly QAF), Australia

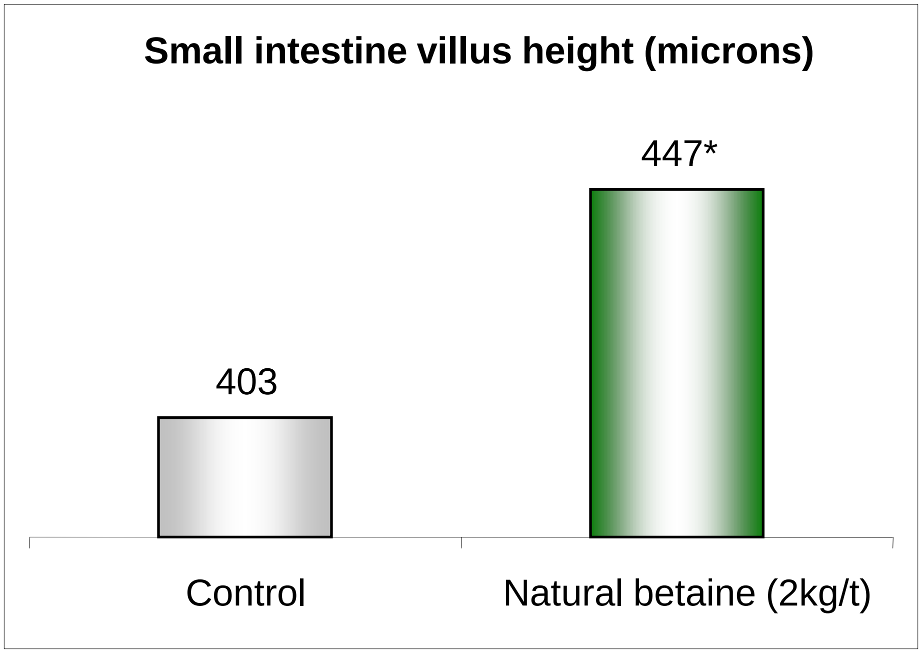
Boars (30-55kg), individually housed, serial slaughter used to estimate maintenance energy requirements (kJ DE/kg $^{0.75}$/day)

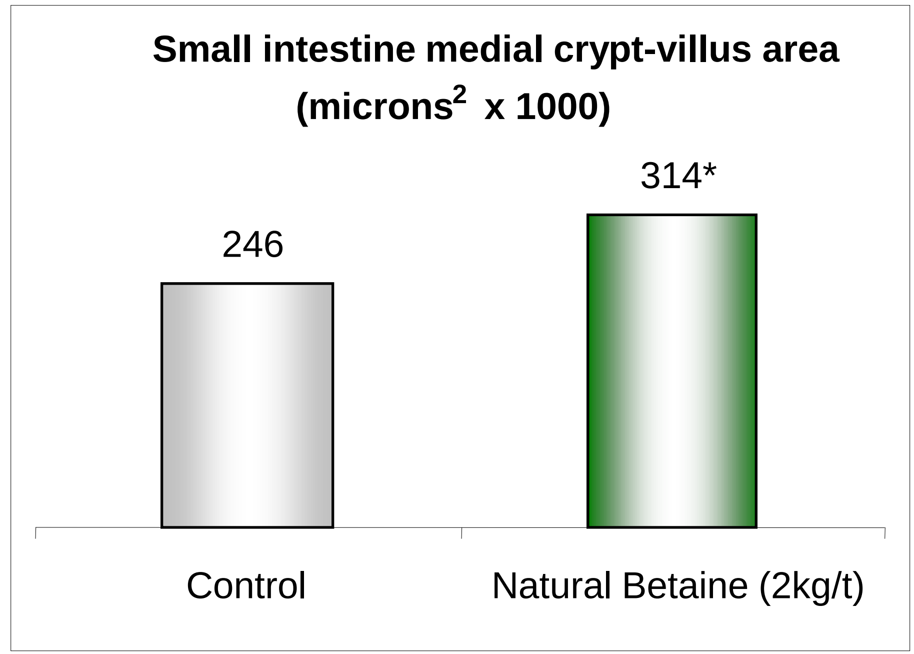


Campbell *et al* (1997)

Lower maintenance energy requirements for water balance - more energy available for growth and lean gain

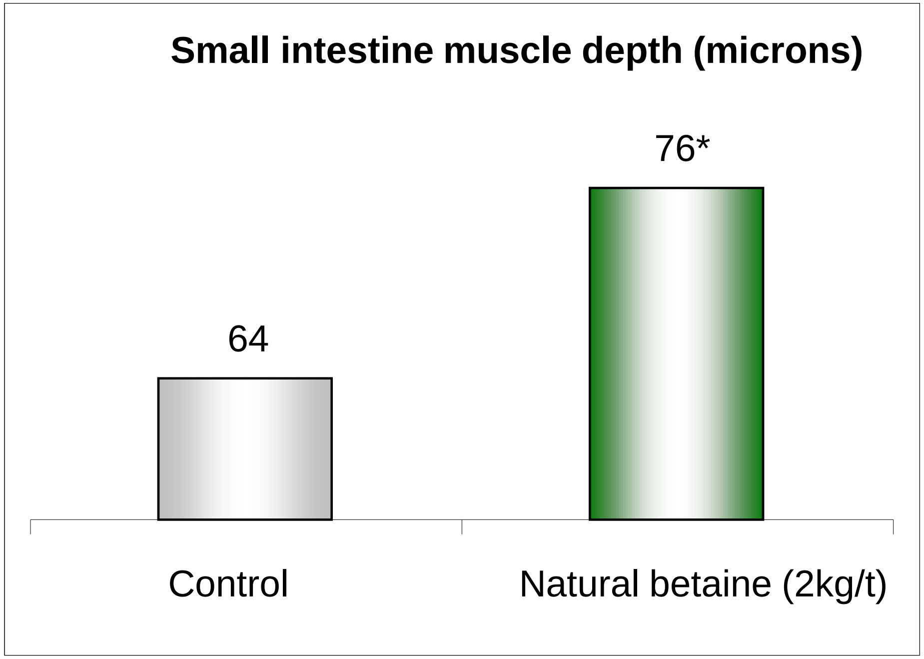
Natural Betaine Significantly Improved (*P<0.05) Villus Height And Crypt-villus Area At 20 Days After Weaning – Improved Absorptive Area For Nutrients After Weaning

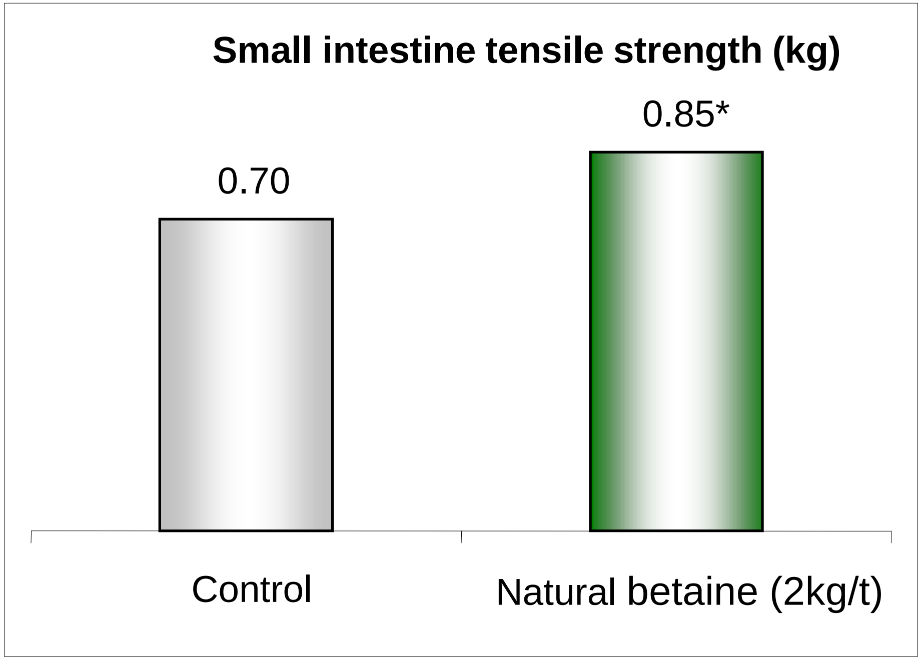




Slade *et al* (2004)

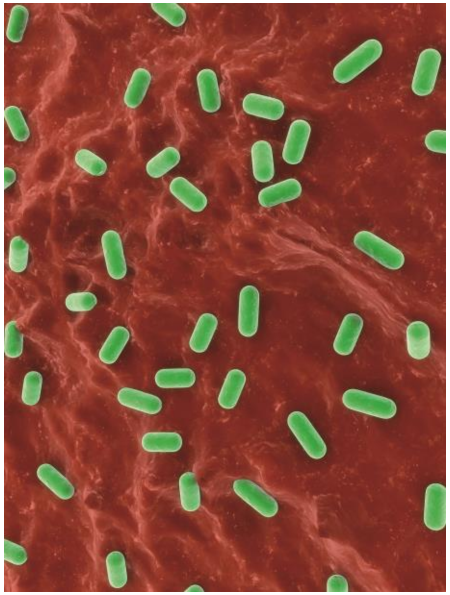
Natural Betaine Significantly Improved (*P<0.05) Muscle Depth And Tensile Strength In The Small Intestine At 20 Days After Weaning – A More Robust Gut Structure For Improved Digestion And Absorption





Slade *et al* (2004)

Stabilizing The Gut Microbiota In The Young Pig



Use Of A Direct Fed Microbial (DFM*) Product During Late Gestation And Lactation

- **Asymptomatic herd**
- **208 mixed parity sows (average parity 1.8)**
  - 104 sows fed control diets
  - 104 sows fed control diets + DFM* (0.05%)
  - Last 6 weeks of gestation & throughout lactation (range18-25 days)
- **Measurements**
  - Litter size (standardized at a mean of 10.97 piglets after birth by cross-fostering within dietary treatment)
  - Piglet and litter weight gain
  - Litter size at weaning and pre-weaning mortality (%)
  - Clostridial counts in the gut of piglets on day 3 of lactation

Rosener et al (2009)

* specially selected isolates of *Bacillus subtilis*

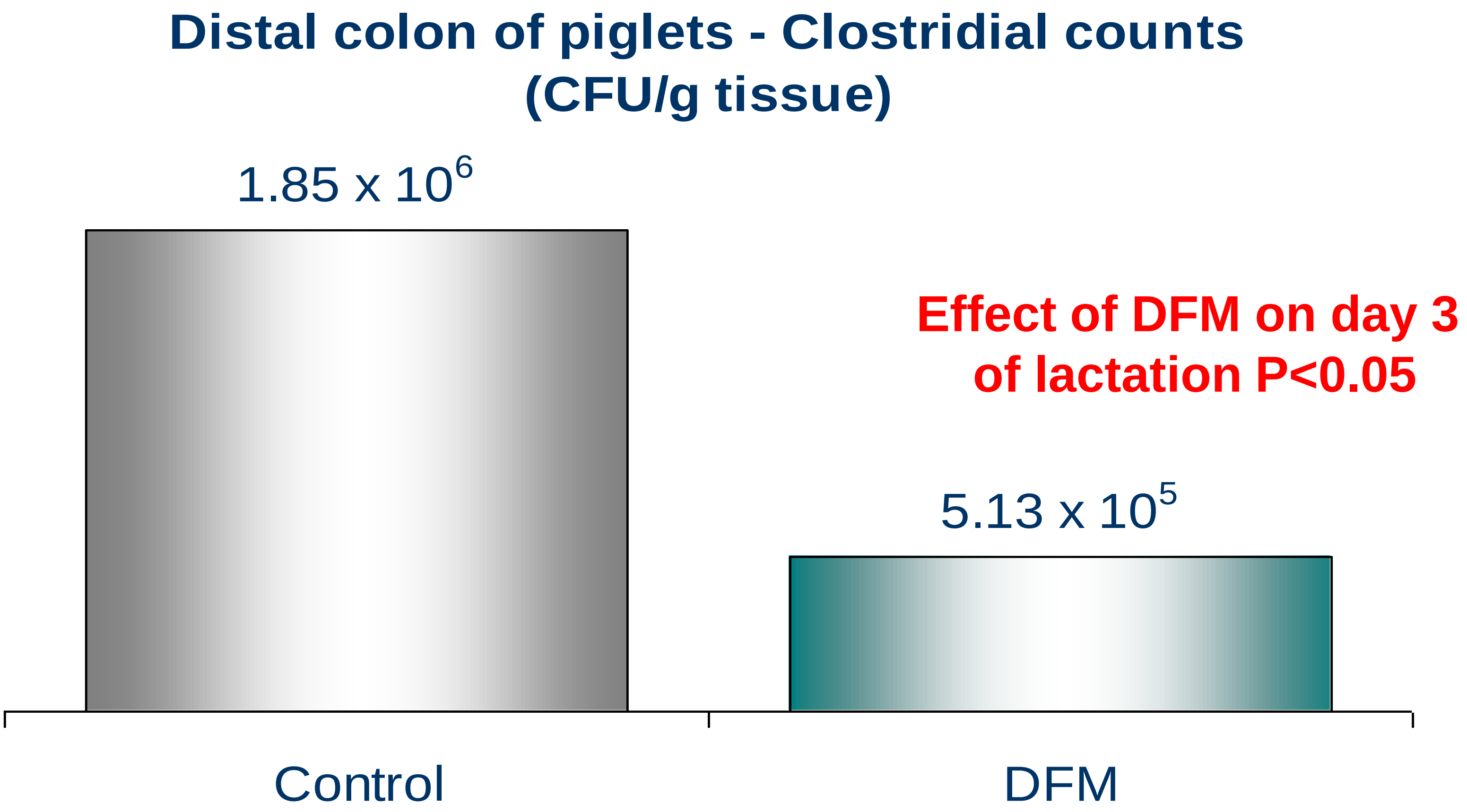
Use Of A Direct Fed Microbial (DFM) Product During Late Gestation And Lactation

	Litter size*	Initial litter weight* (kg)	Litter weaning weight (kg)	Litter average daily gain (kg)	Litter size at weaning	% pre-weaning mortality
Control	10.95	15.4	58.5	2.15	9.56	12.8
DFM	10.99	16.9 (+9.7%)	61.9 (+5.8%)	2.28 (+6.0%)	9.86 (+3.1%)	10.4
P value	*0.54*	*0.01*	*0.02*	*0.09*	*0.06*	*0.12*

* Standardised after birth by cross-fostering, within dietary treatment
n.b. **approx.1 more pig per litter born alive in DFM sows versus control**
12.2 versus 11.1 (P<0.01)

Rosener et al (2009)

Use Of A Direct Fed Microbial (DFM) Product During Late Gestation And Lactation



Rosener et al (2009)

Conclusions

Effective feed additives for the pig after weaning need to:

- **Minimize the pig's maintenance energy and protein/amino acid costs**
- **Stabilize the gut microbiota** and support the young pig's developing immune system
- **'Feed the gut'** to maintain gut integrity and absorptive function
- Have **complementary modes-of-action** – this will determine the best additive choices from a long list of 'potentials', **particularly when reducing antibiotics & removing antibiotic growth promoters**

Question and Answer

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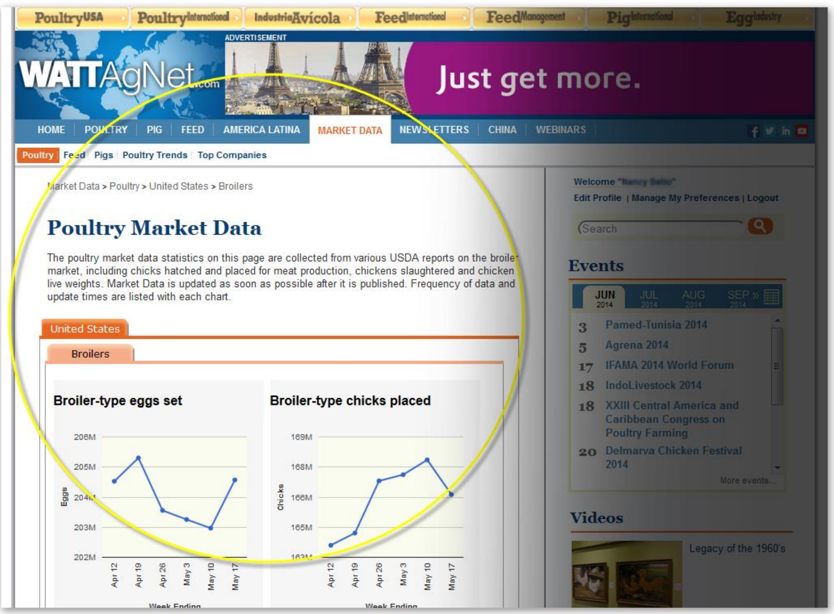

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