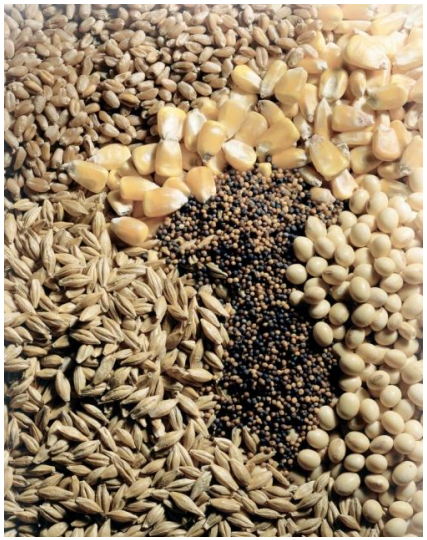
Advances in enzyme technology to improve the feeding value of grain by-products in swine nutrition

DR GARY PARTRIDGE
DEVELOPMENT & TECHNICAL DIRECTOR
DANISCO ANIMAL NUTRITION

Wednesday 2nd October 2013

AFMA Annual Symposium
Pretoria
South Africa



Topics

- Grain by-products in swine nutrition – both an opportunity and a challenge in feed formulation
- The importance of understanding substrates
- Experiences with enzyme addition to negate the physiological effects of dietary fibre
- Fibre, the microflora and a role for enzymes?
- Commercial applications and the value equation for the use of proven enzyme systems

Improving the feeding value of grain by-products for swine

- Improving the feeding value of grain by-products means dealing with the **anti-nutrient effects** of dietary fibre*

- The ‘challenging’ effects of dietary fibre include:
  - Satiety
  - Gut motility
  - Nutrient digestion and absorption
  - Gut microflora changes

* **N**on **S**tarch **P**olysaccharides + Lignin

Carbohydrates – defining the dietary fibre fraction

<table>
<tr><th colspan="7">CARBOHYDRATES</th></tr>
<tr><td>Ileal digestible carbohydrates</td><td colspan="6">Fermentable Carbohydrates</td></tr>
<tr><td></td><td></td><td colspan="5">Non Starch Polysaccharides (NSPs)</td></tr>
<tr><td>Mono- and di-saccharides, starch</td><td>Oligosacc-harides
e.g. FOS,MOS

Resistant starch</td><td>Storage NSPs
e.g. mannans
inulin</td><td>Pectins</td><td>Water soluble NSPs</td><td colspan="2">Insoluble cell wall NSPs</td></tr>
<tr><td colspan="4" rowspan="4">  </td><td rowspan="4">e.g. Soluble arabino-xylans increase viscosity in the gut</td><td colspan="2">Neutral Detergent Fibre (NDF)</td></tr>
<tr><td>Hemicellulose</td><td>Cellulose
Lignin</td></tr>
<tr><td rowspan="3">e.g. Insoluble arabinoxylans can ‘package’ useful nutrients making them unavailable to the animal</td><td>Acid Detergent Fibre (ADF)
Cellulose
Lignin</td></tr>
<tr><td>AD Lignin
Lignin</td></tr>
</table>

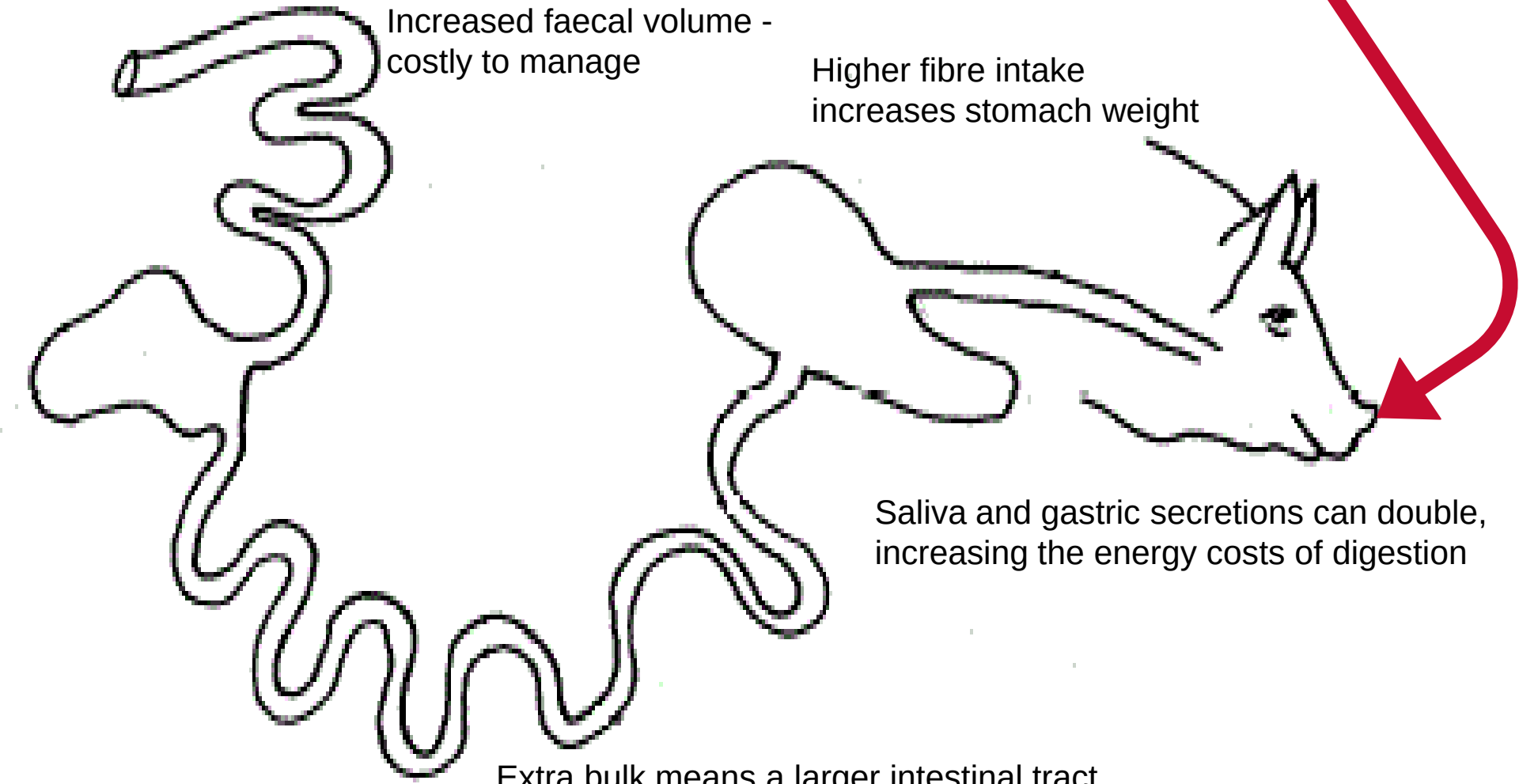
Please note that the size of the boxes in this figure is NOT in proportion to the levels of each component

The challenges posed by dietary fibre (1)

Extra chewing required

Increased faecal volume - costly to manage

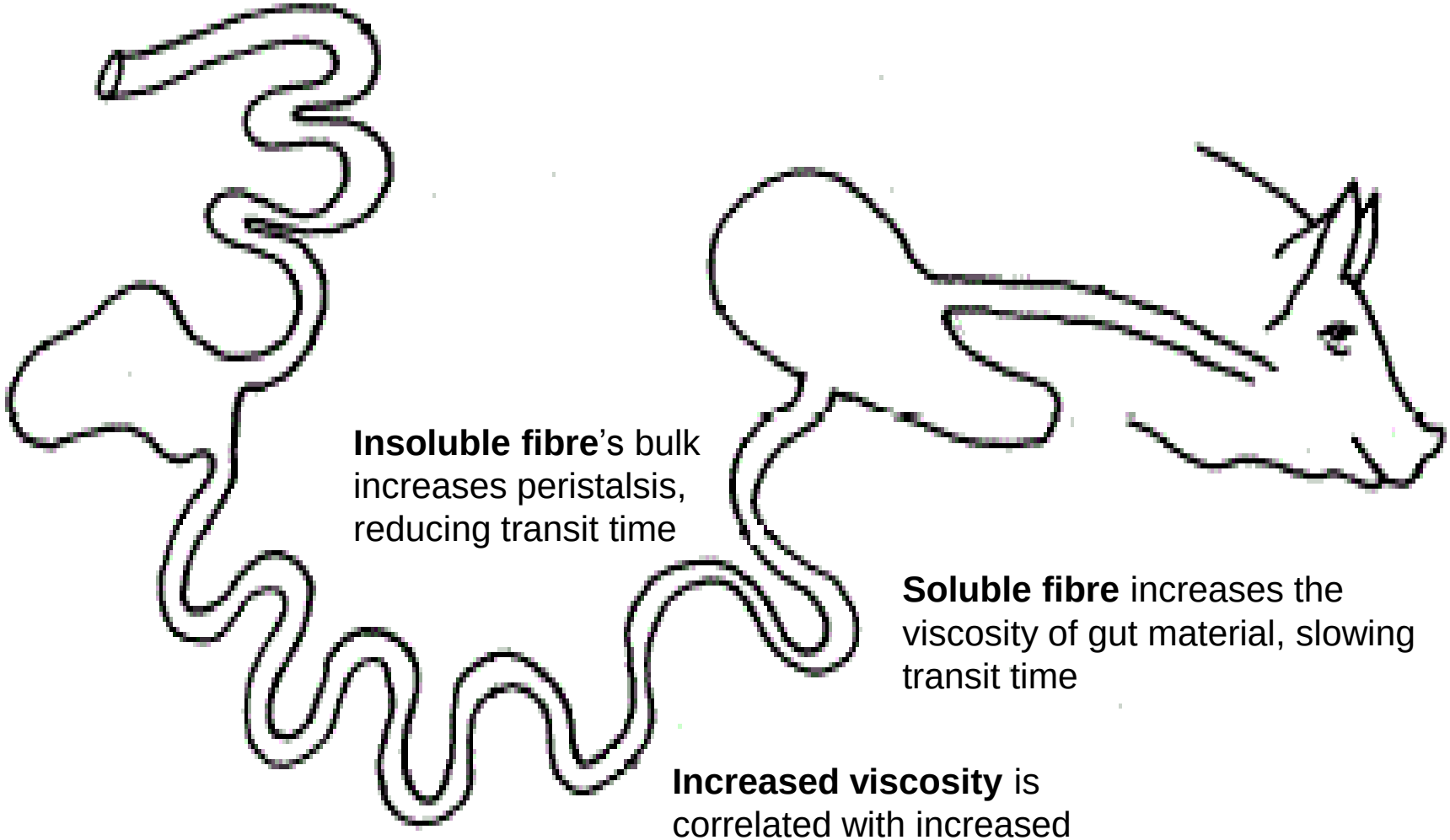
Higher fibre intake increases stomach weight



Saliva and gastric secretions can double, increasing the energy costs of digestion

Extra bulk means a larger intestinal tract, reducing final killing out percentage

The challenges posed by dietary fibre (2)



Insoluble fibre's bulk increases peristalsis, reducing transit time

Soluble fibre increases the viscosity of gut material, slowing transit time

Increased viscosity is correlated with increased endogenous nitrogen loss

Dietary fibre and the relative production of endogenous secretions in the gut of 50kg pigs[1]

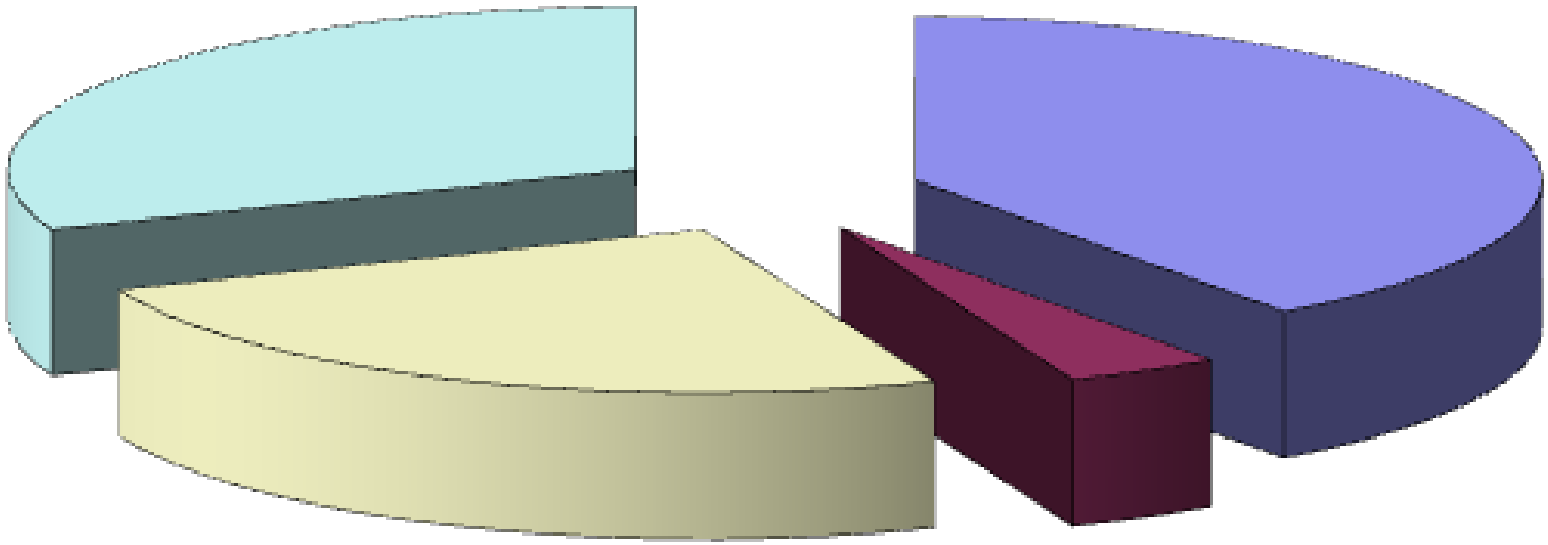
	Purified diet (casein, starch, cellulose)	Normal diet (barley, soybean meal, fishmeal)
Crude fibre	Identical	
Dietary fibre, g/kg	50	180
Saliva and gastric juice per day	1	2 x
Pancreatic juice per day	1	1.8 x
Bile per day	1	1.4 x

[1]Adapted from Zebrowska *et al.,* 1983

Energy partitioning – the importance of ‘maintenance’ energy to productive performance in pigs

Production e.g. lean and fat deposition ~40%

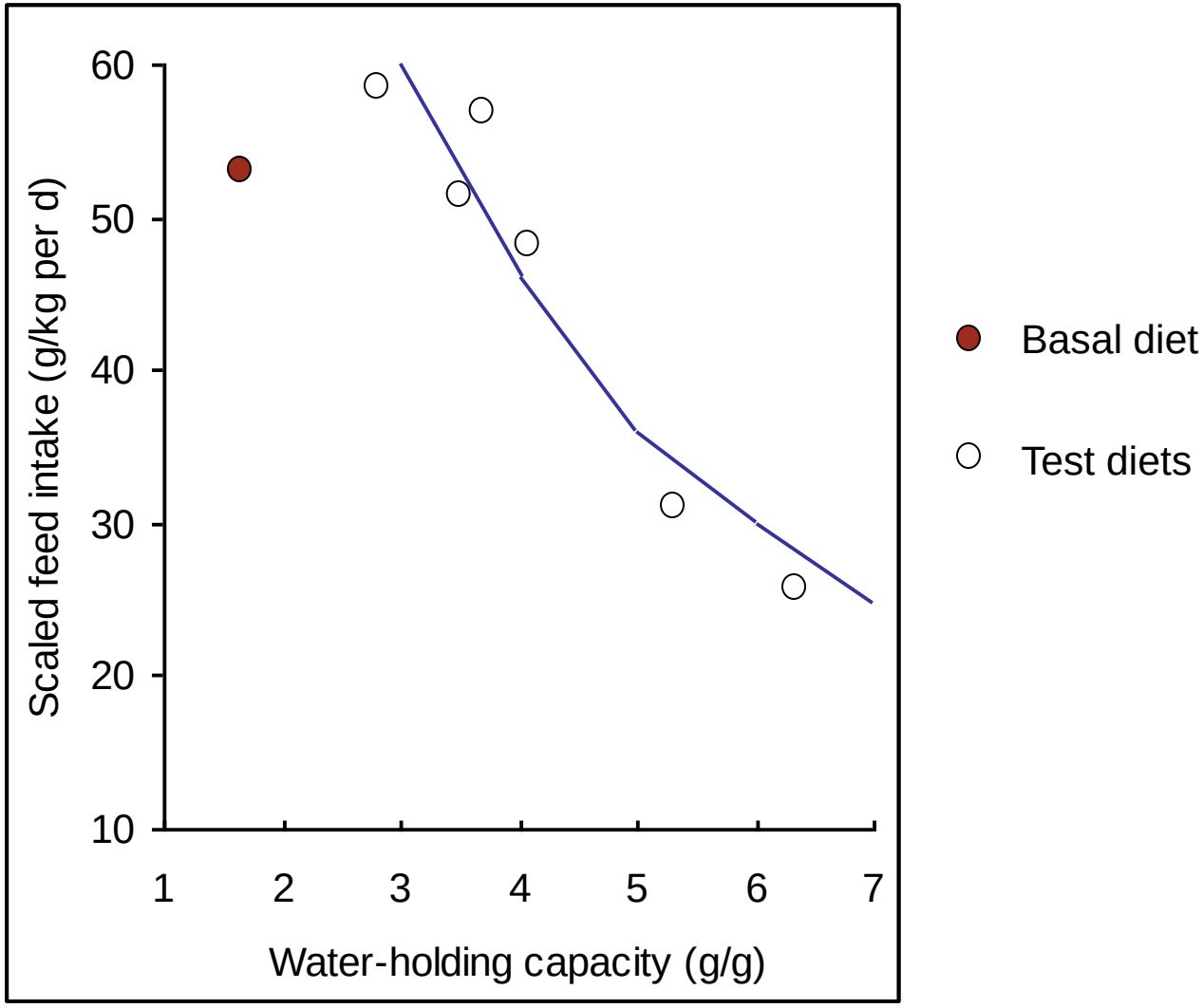
Maintenance ~31%



Heat ~25%

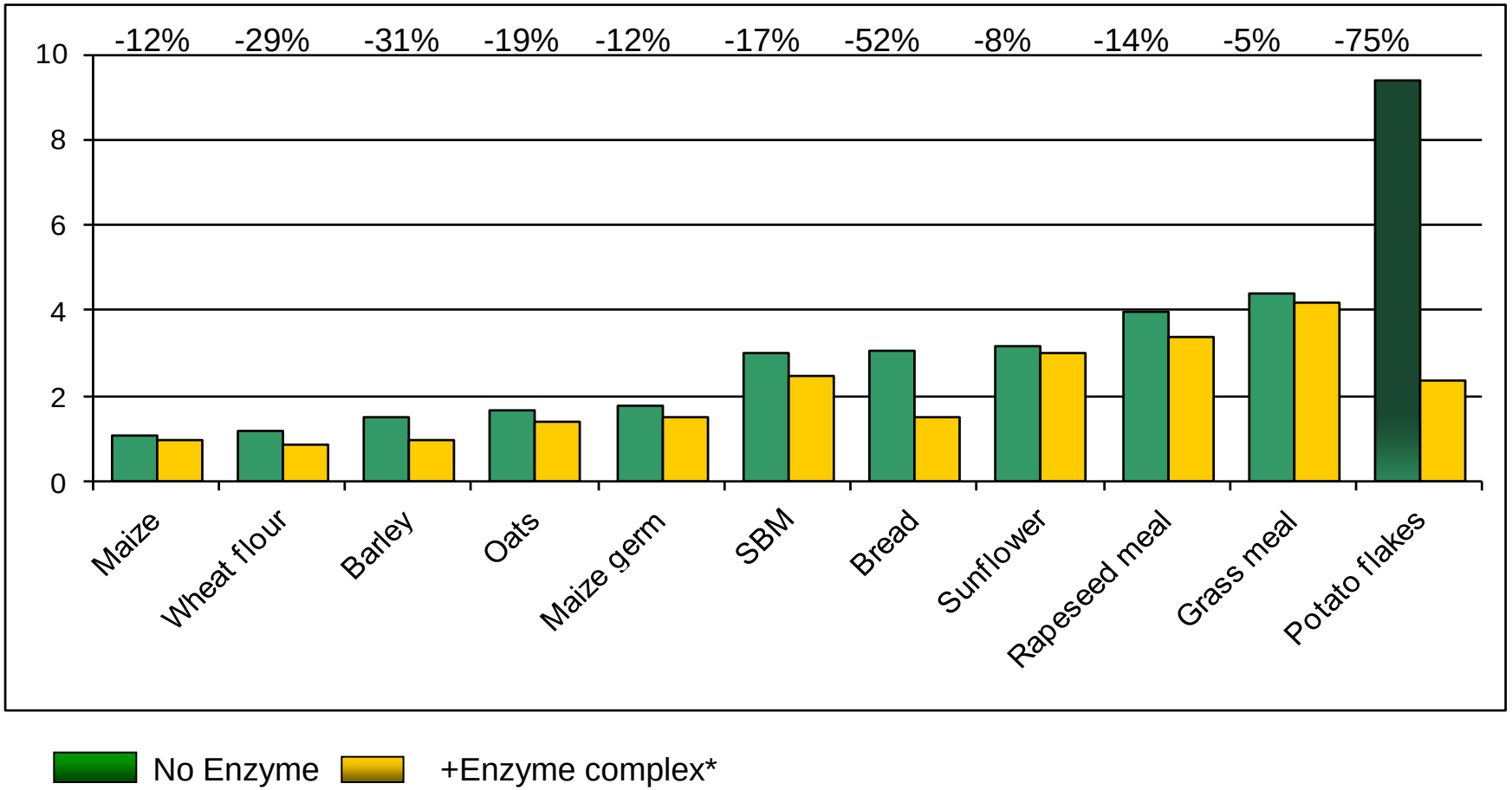
Urine & methane ~4%

Water holding capacity of the feed and its effects on feed intake



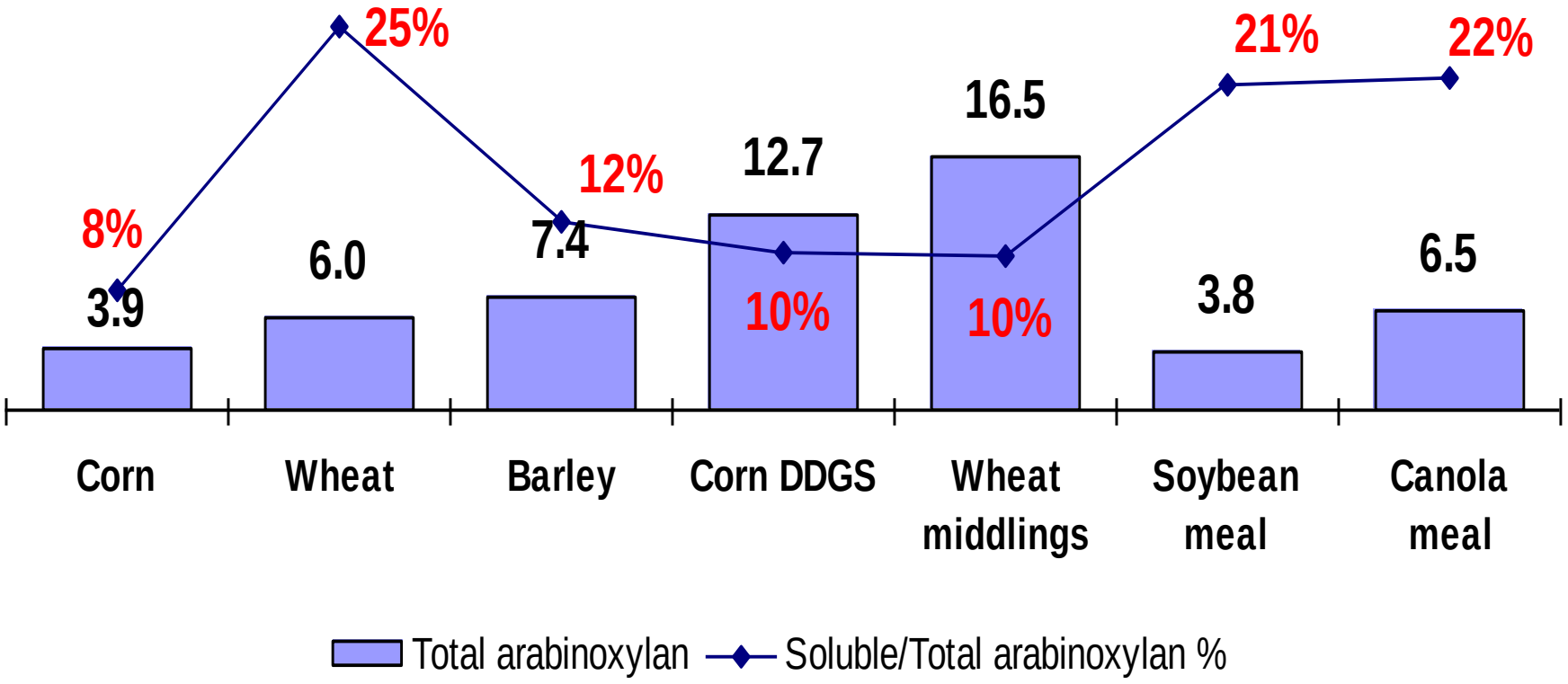
Kyriazakis and Emmans (1995), 12-36kg pigs

Effect of an enzyme complex on water holding capacity



* xylanase; beta-glucanase; protease

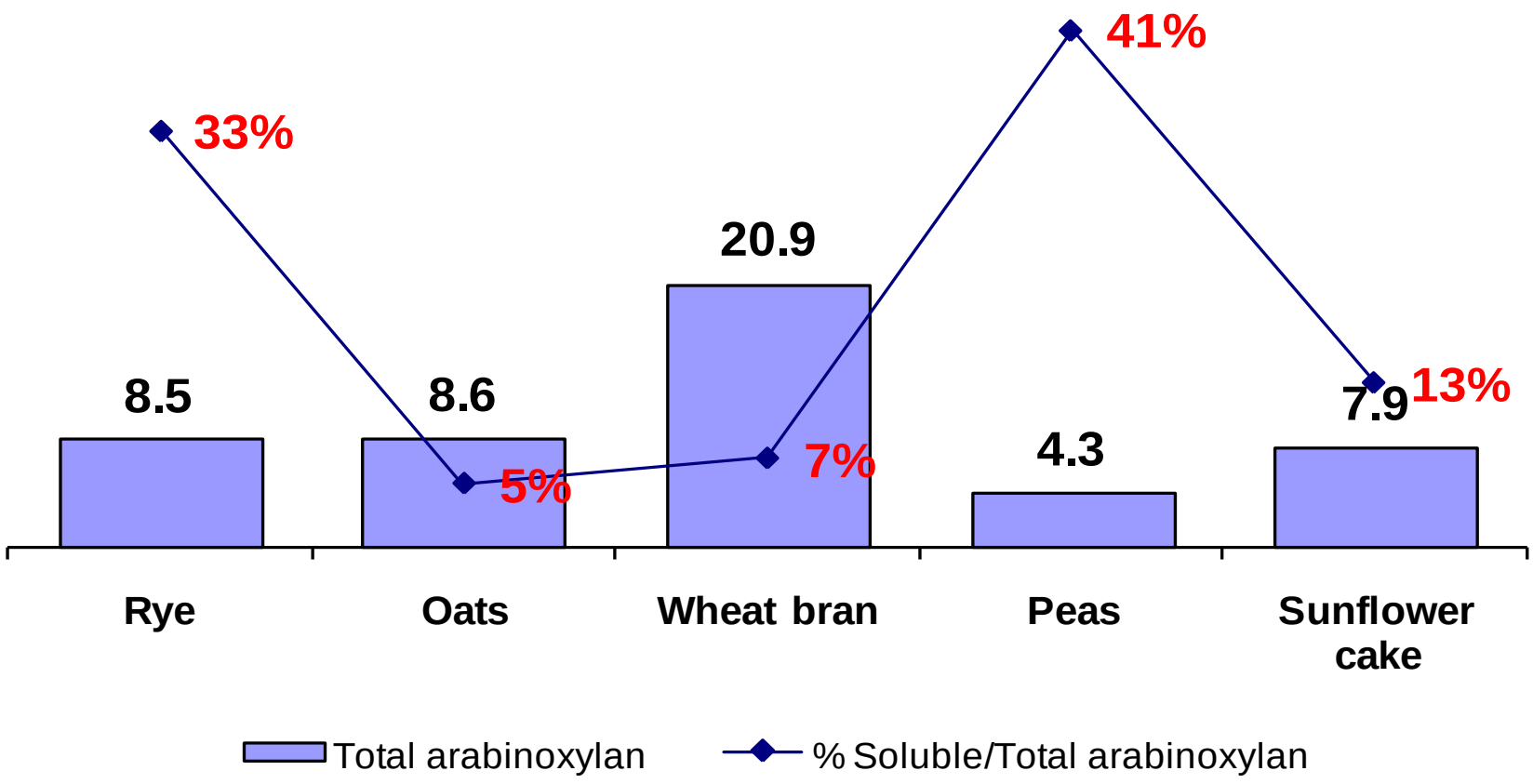
Arabinoxylan content and solubility* (%)



*As fed basis

Source: Danisco Non Starch Polysaccharide (NSP) database

Arabinoxylan content and solubility* (%)



*As fed basis (corrected to 88% Dry Matter)

Source: Bach Knudsen (1997)

Corn and wheat by-products (CVB, Netherlands 2011)

	Corn DDGS	Corn germ meal expeller	Corn gluten feed	Wheat Middlings
Dry Matter %	90.1	89.7	89.3	86.5
Crude Protein %	26.1	13.4	21.2	15.3
Ash %	5.1	4.4	6.0	5.0
Oil B %	9.2	5.6	3.9	4.1
Starch %	5.4	34.8	14.0	18.5
Neutral Detergent Fibre %	24.2	27.4	33.6	36.9
Total Phosphorus %	0.80	0.83	0.96	0.93
Phytate Phosphorus %	0.16 (20% of Total P)	0.62 (75% of Total P)	0.62 (65% of total P)	0.79 (85% of Total P)
Digestible P (pigs)	0.16	0.17	0.19	0.19
NE Pigs (kcal/kg)	2041 (79% of corn)	2244 (87% of corn)	1624 (63% of corn)	1550 (60% of corn)

Corn DDGS versus Wheat Middlings

	Corn DDGS	Wheat Middlings
Total **Soluble** Non Starch Polysaccharides	1.3%	1.3%
Total **Insoluble** Non Starch Polysaccharides	19.3%	24.7%

Danisco database information

Corn DDGS versus Wheat Middlings

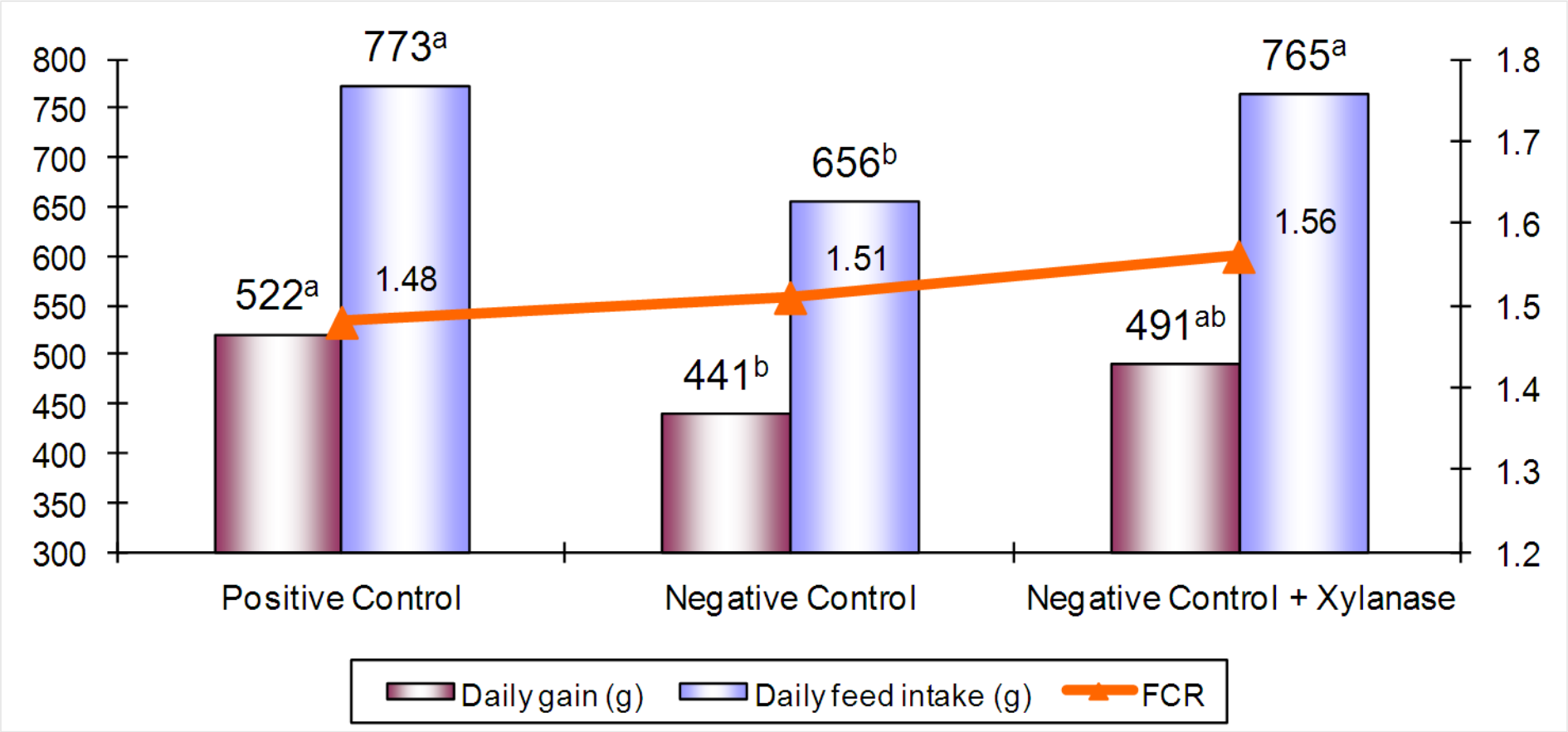
	Corn DDGS	Wheat Middlings
Total Insoluble NSPs/ Total NSPs	94%	95%
Total Insoluble Arabinoxylans/ Total insoluble NSPs	55%	61%

Danisco database information

Early experiences with xylanase addition in diets containing added grain by-products e.g. wheat middlings

Effects of xylanase addition on performance of young grower pigs (9-20kg) in 'high fibre' diets

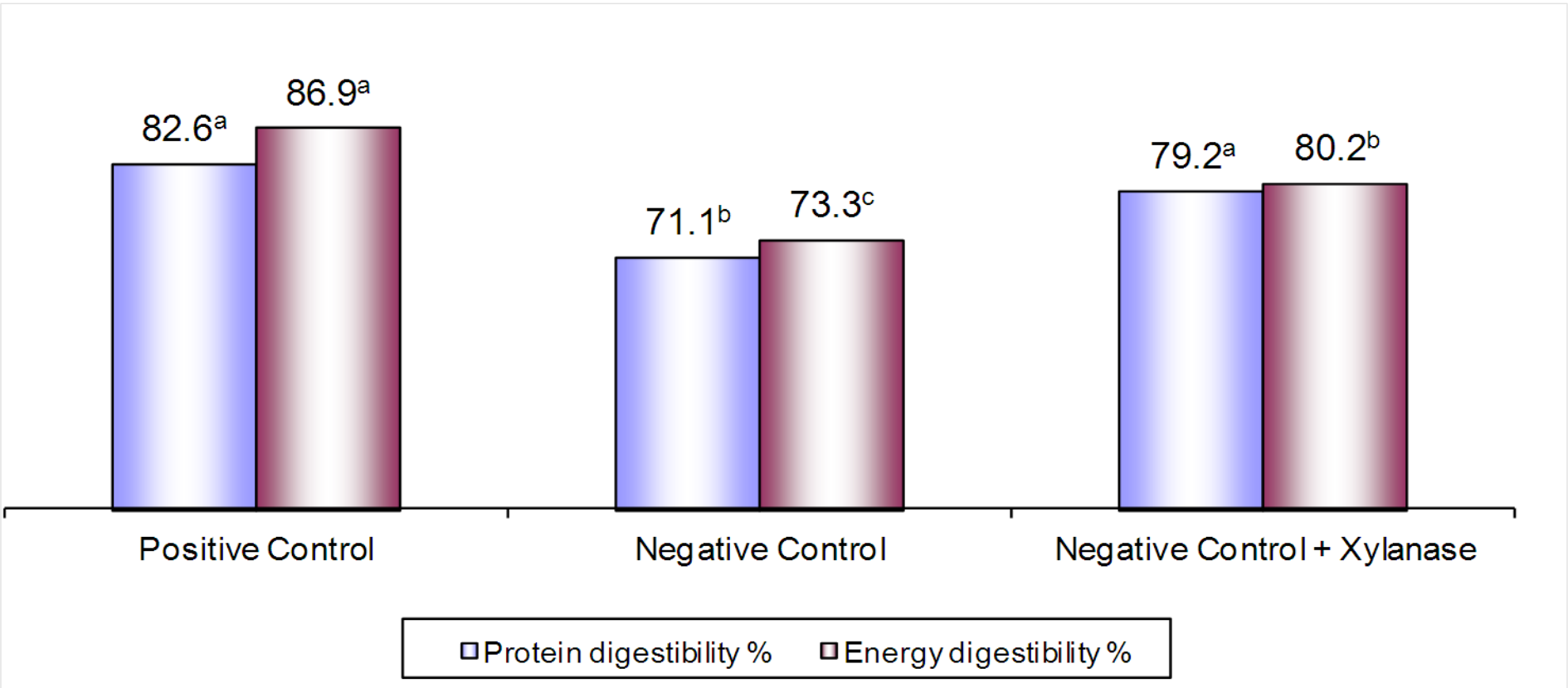
Positive Control: Corn 60%, Soybean meal 30%, Fishmeal 1.5%, Whey 3%, Fat 1%
Negative Control: Corn 33%, Soybean meal 28%, **Wheat middlings* 30%**, Fishmeal 1.5%, Whey 3%,Fat 1%
Protein 21-22%, Dig lys 1.1% DE Positive Control 3,395 kcal/kg Negative Control 3,155 kcal/kg



Contract research organisation, USA *Starch 36.4%; NSP 20.5% (95% insoluble)

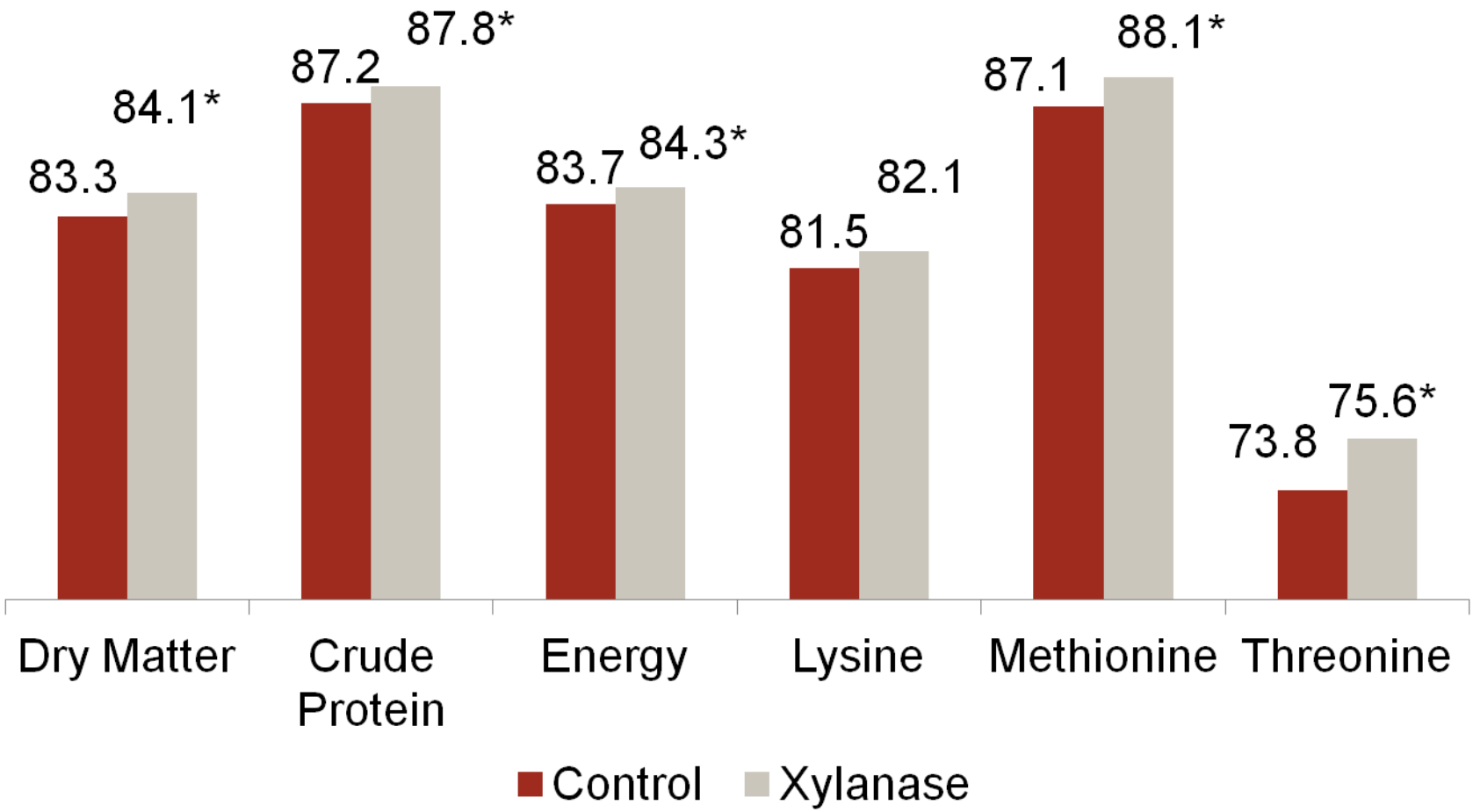
Effects of xylanase addition on protein & energy digestibility in 'high fibre' diets for grower pigs (35-40kg)

Positive Control: Corn 69%, Soybean meal 21%, Fat 4%
Negative Control: Corn 45%, Soybean meal 21%, **Wheat middlings 25%**, Fat 6.6%,
Protein 16%, Lysine 1.05% DE Positive & Negative Control 3,466 kcal/kg



Contract research organisation, USA

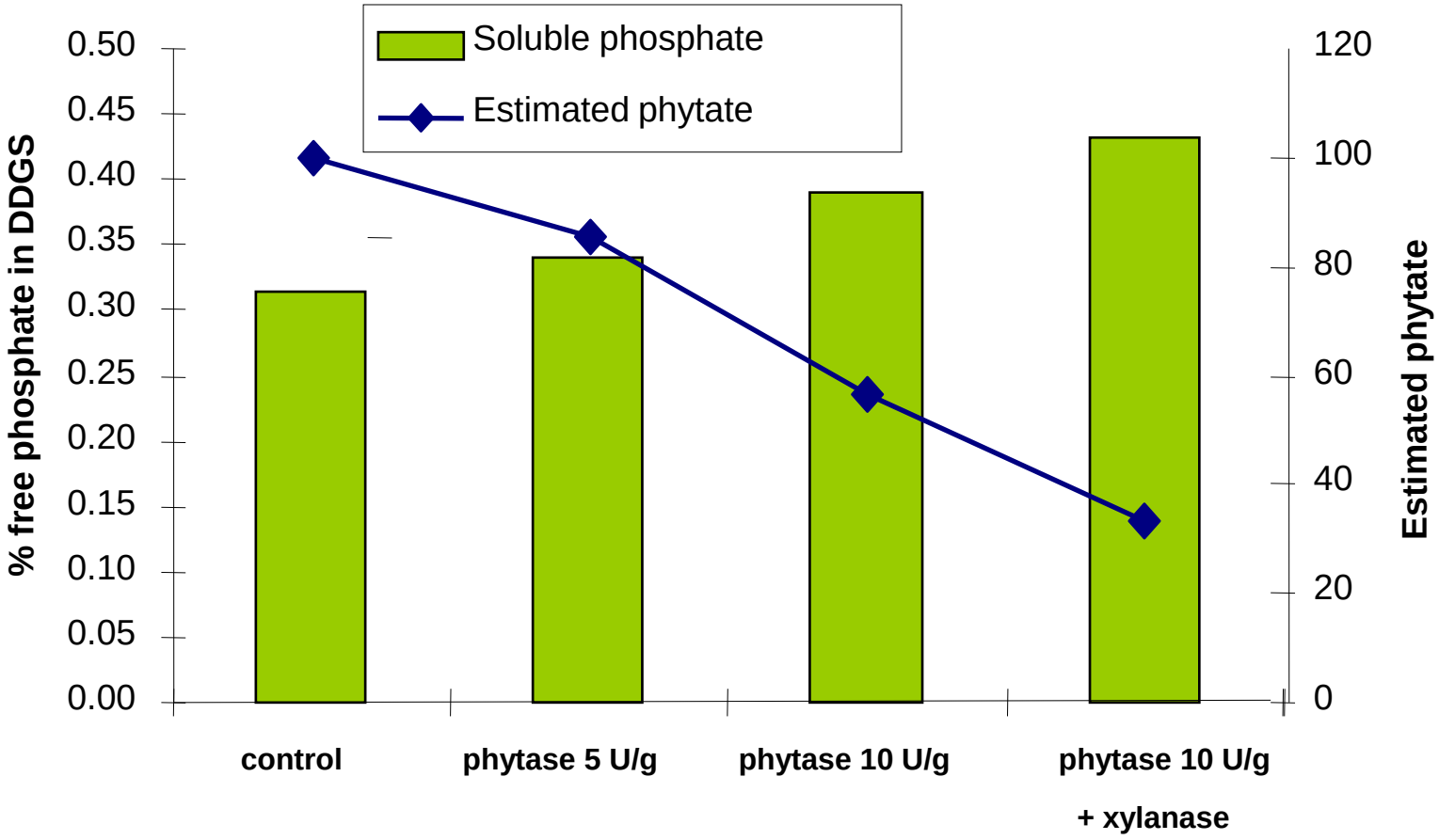
Digestibility responses (%) to xylanase in diets with varying additions of wheat by-products (middlings/bran)



* P< 0.05 DM, CP & Energy – faecal, amino acids - ileal

Ying *et al* (2000)

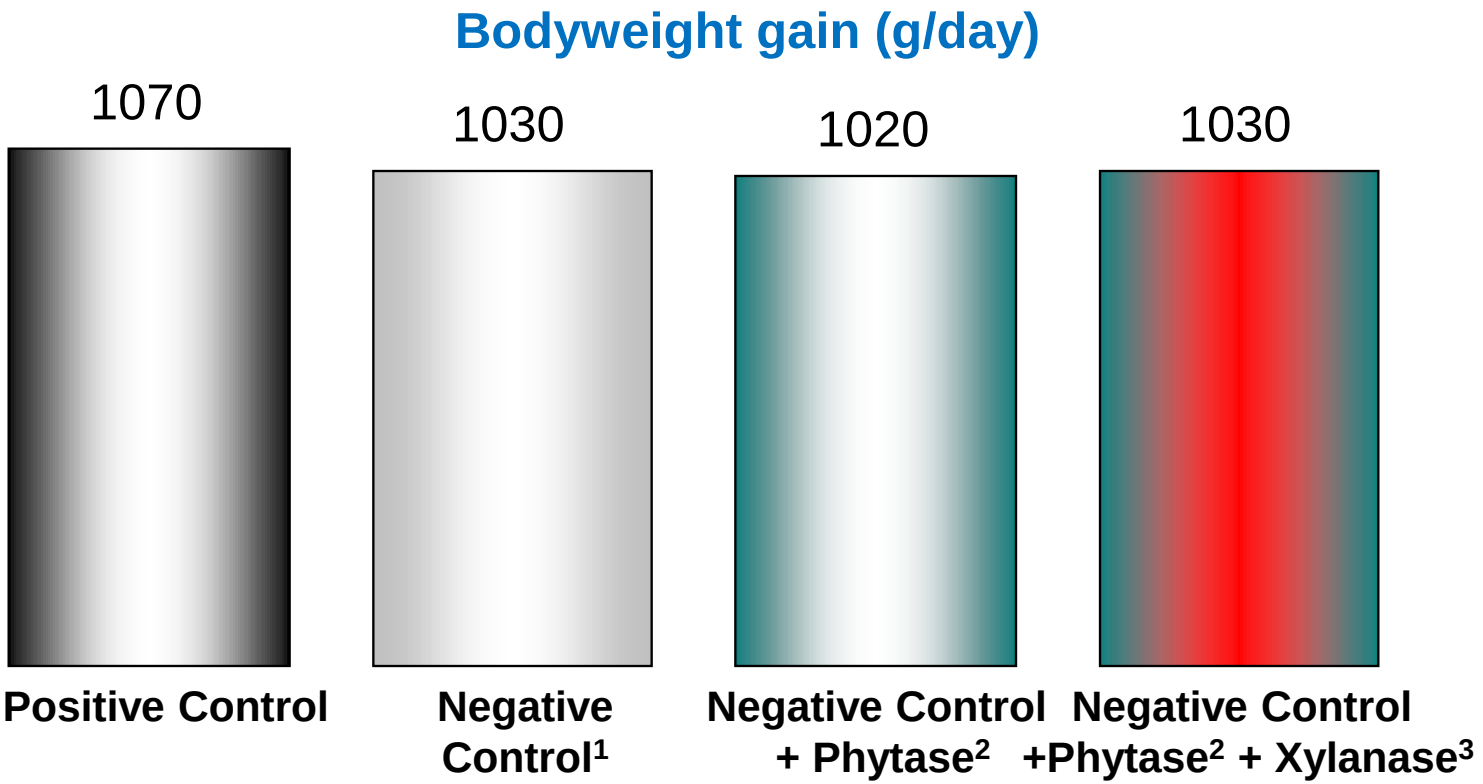
Xylanase and phytase in combination improves P release in DDGS



Recent experiences with xylanase addition in diets containing added grain by-products e.g. corn DDGS

Trial site (Bodyweight)	Diets	Performance	Digestibility
University of Kentucky, USA (61-123kg)	**+ve C**: Corn 53-62%; SBM 13-22%; DDGS 20%; Fat 3% **-ve C**: Corn 55-64%; SBM 13-22%; DDGS 20% Fat 1%	✓ Bodyweight gain & FCR	✓ Faecal
Purdue University, USA (25-60kg)	Corn 55%; SBM 23%; DDGS 20% CP 20.9%; DE 3227kcal; 0.20%AvP	-	✓ Ileal & Faecal
University of Illinois, USA (25-60kg)	Corn 55%; SBM 23%; DDGS 20% CP 20.9%; DE 3227kcal; 0.20%AvP	-	✓ Ileal & Faecal

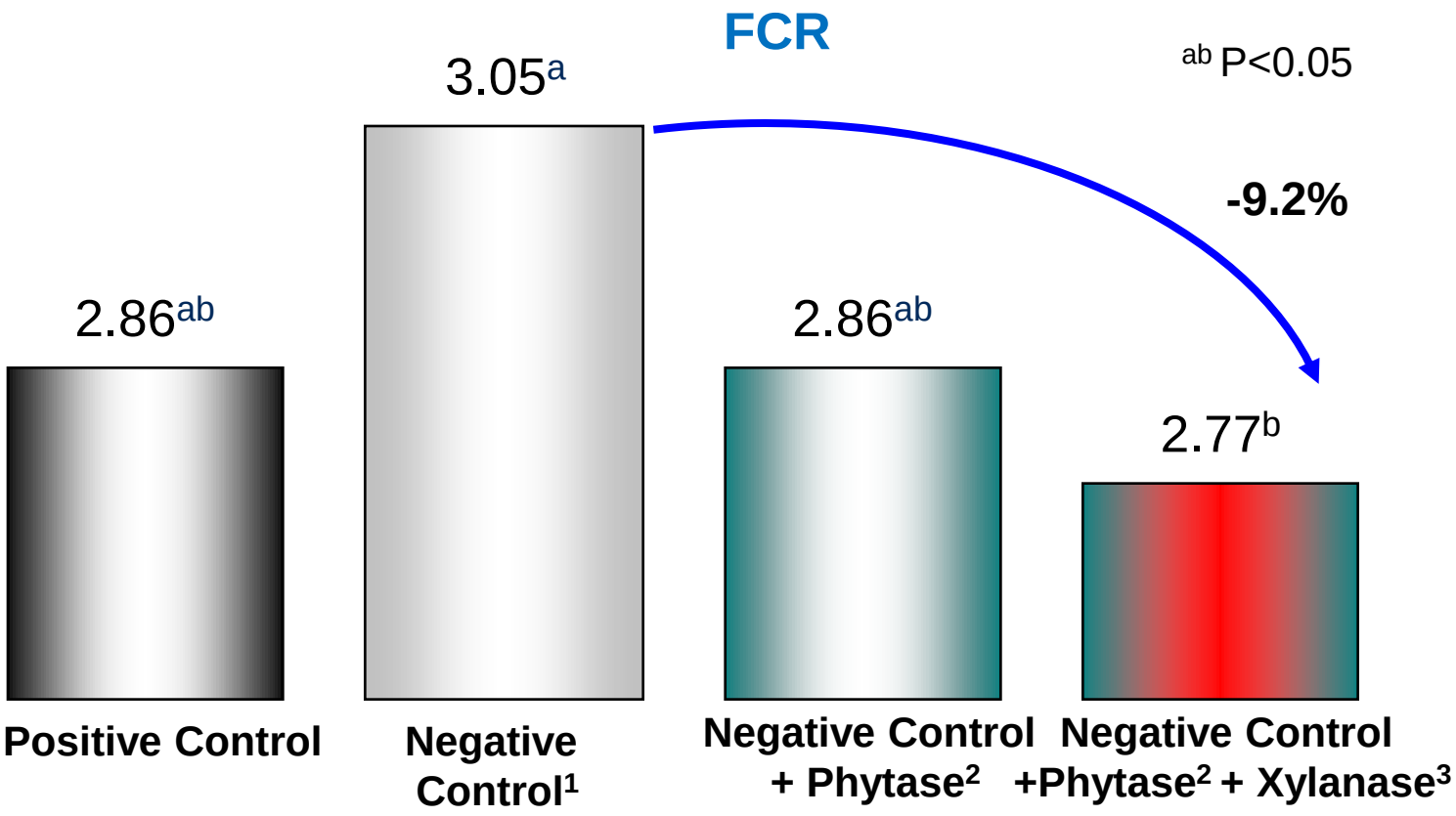
Effects of phytase -/+ xylanase in corn based diets containing 20% corn DDGS (61-123kg bodyweight)



[1] -95 kcal/kg DE versus Positive Control, 2% fat reduction
[2] 500 FTU/kg feed [3] 4000 U/kg feed

University of Kentucky, USA

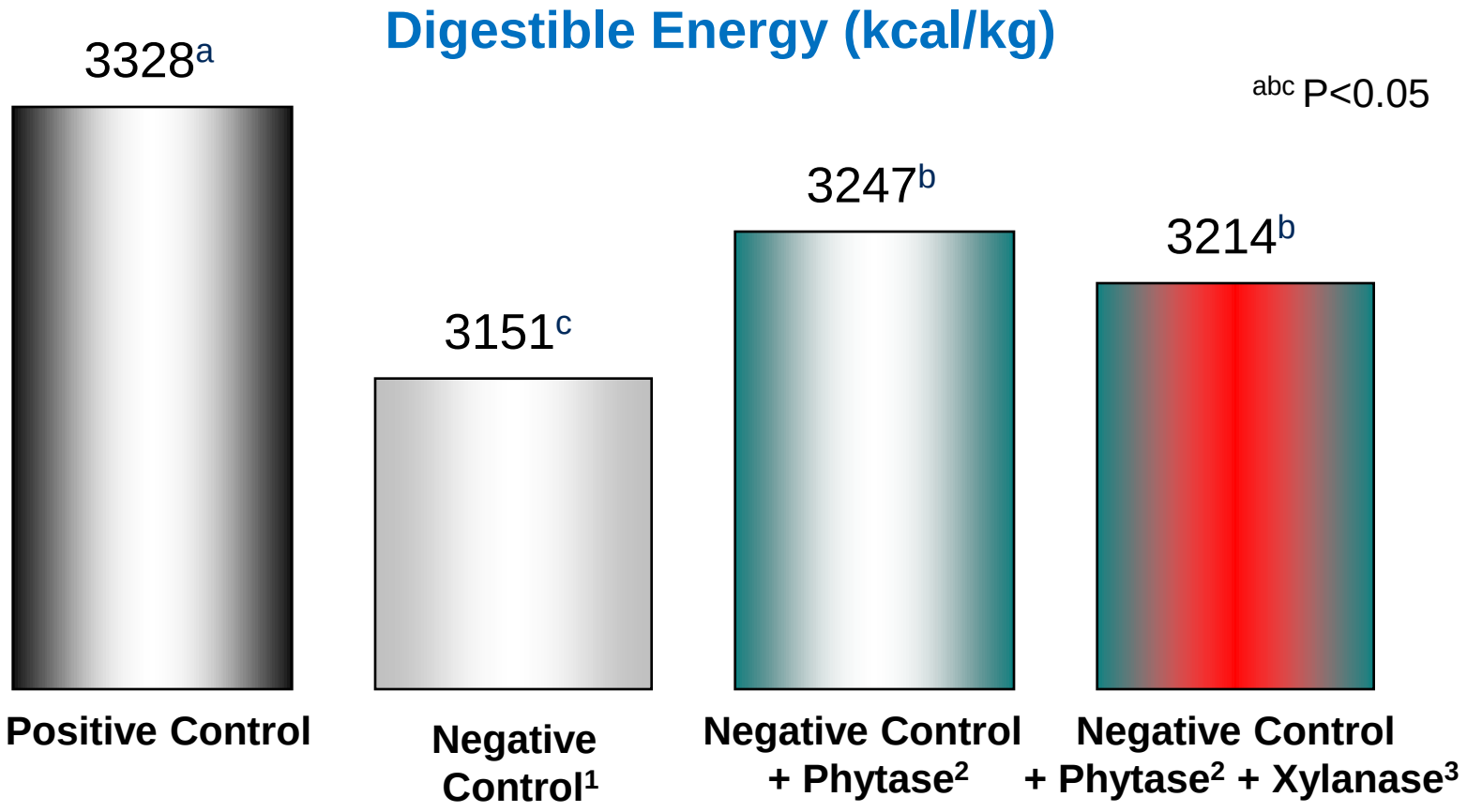
Effects of phytase -/+ xylanase in corn based diets containing 20% corn DDGS (61-123kg bodyweight)



1 -95 kcal/kg DE versus Positive Control, 2% fat reduction
2 500 FTU/kg feed 3 4000 U/kg feed

University of Kentucky, USA

Effects of phytase -/+ xylanase in corn based diets containing 20% corn DDGS (61-123kg bodyweight)



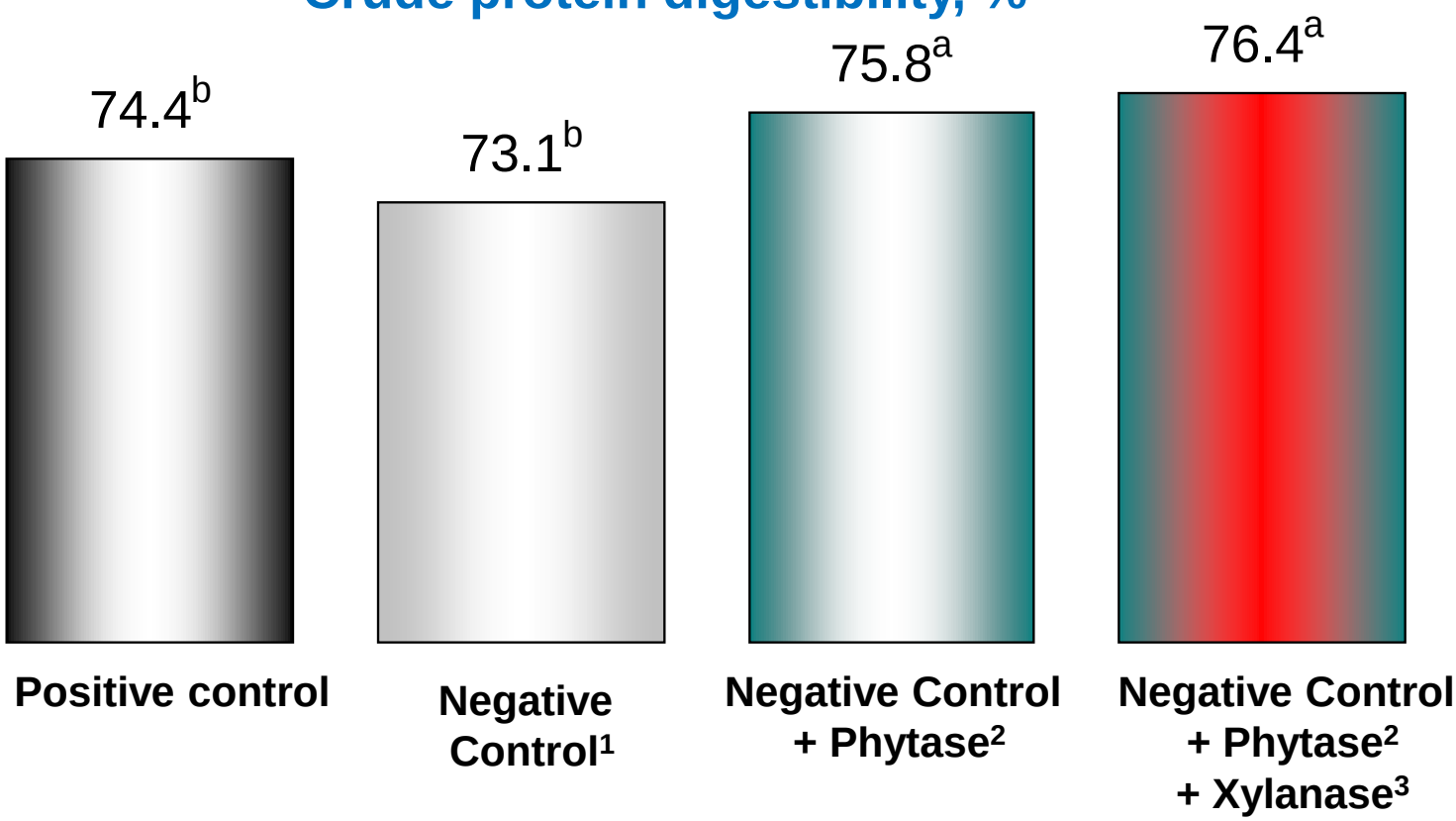
1 -95 kcal/kg DE versus Positive Control, 2% fat reduction
2 500 FTU/kg feed 3 4000 U/kg feed

University of Kentucky, USA

Effects of phytase -/+ xylanase in corn based diets containing 20% corn DDGS (61-123kg bodyweight)

Crude protein digestibility, %

^{ab} P<0.05

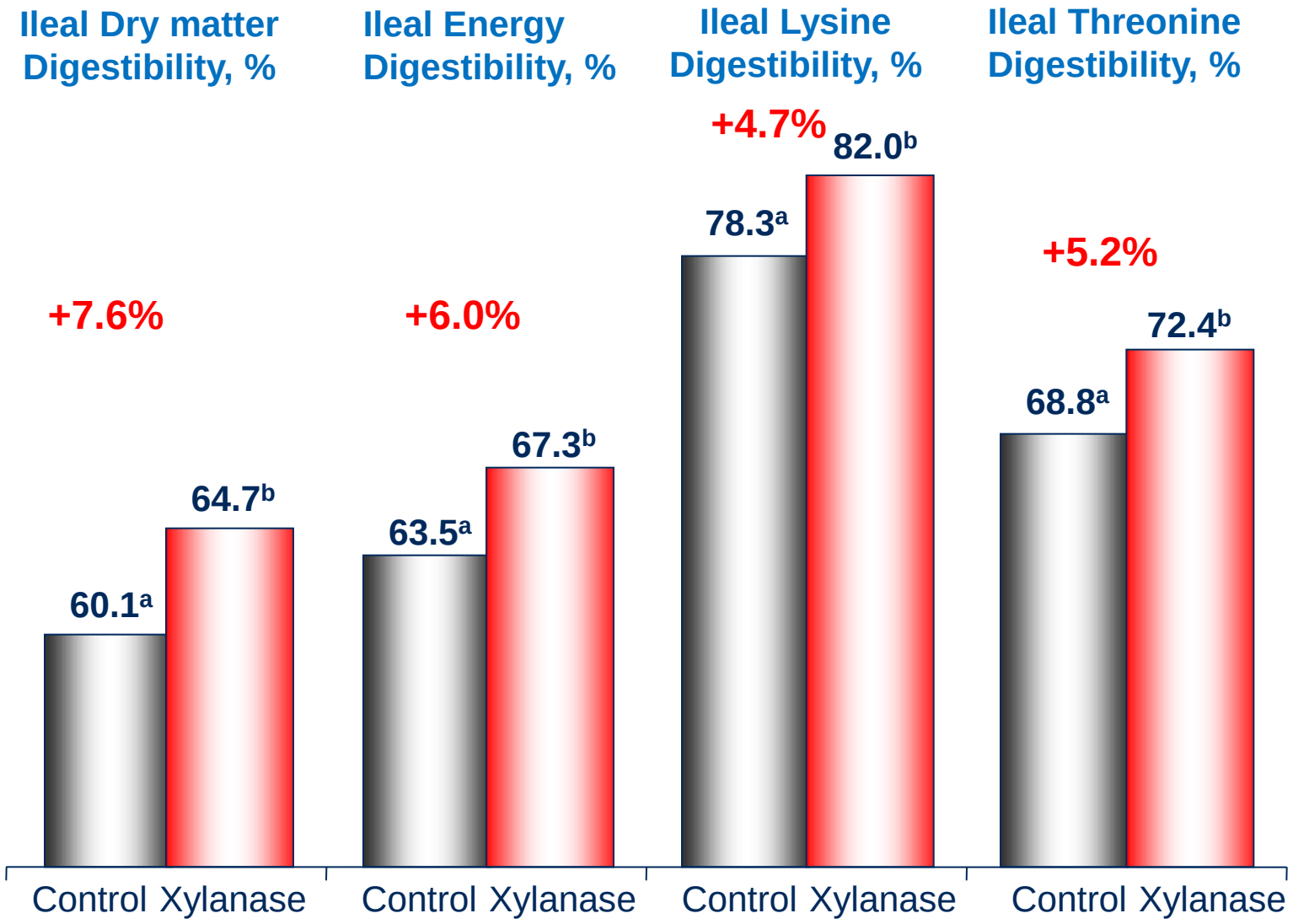


1 -95 kcal/kg DE versus Positive Control, 2% fat reduction

2 500 FTU/kg feed 3 4000 U/kg feed

University of Kentucky, USA

Effects of xylanase[1] in corn based diets containing 20% corn DDGS (25-60kg bodyweight)

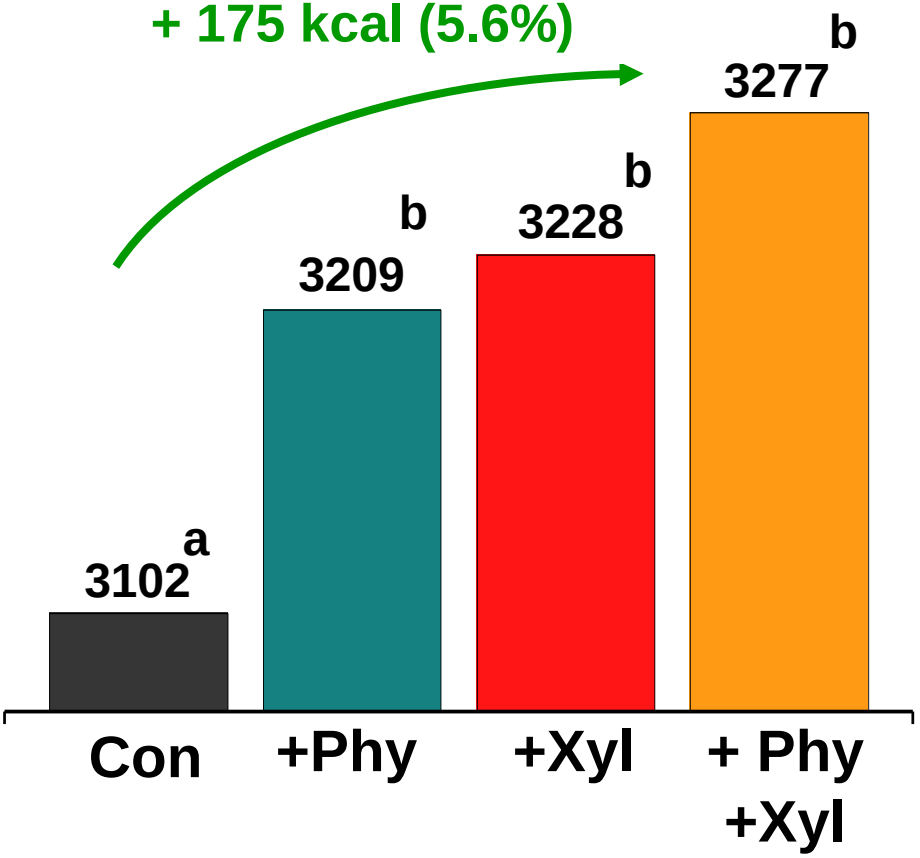


[1] 2000 U/kg feed

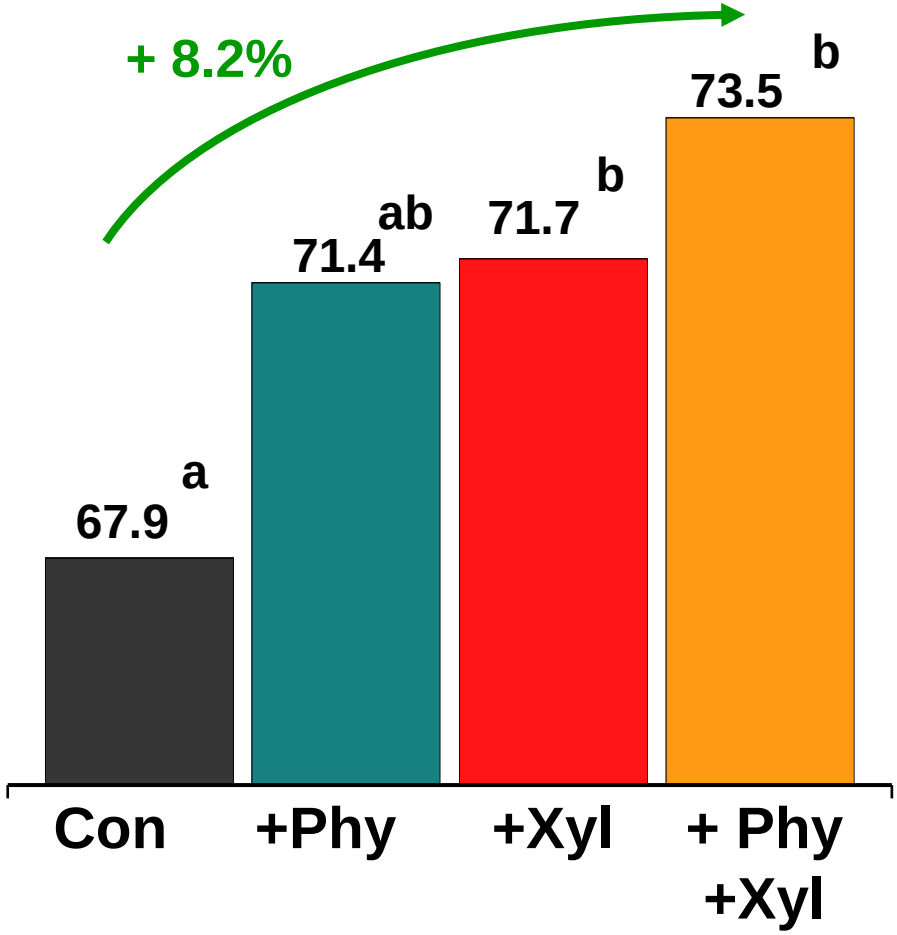
Purdue University, USA

Effects of xylanase +/- phytase in corn based diets containing 20% corn DDGS (25-60kg bodyweight)

DE (kcal/kg)



Ileal Protein digestibility (%)



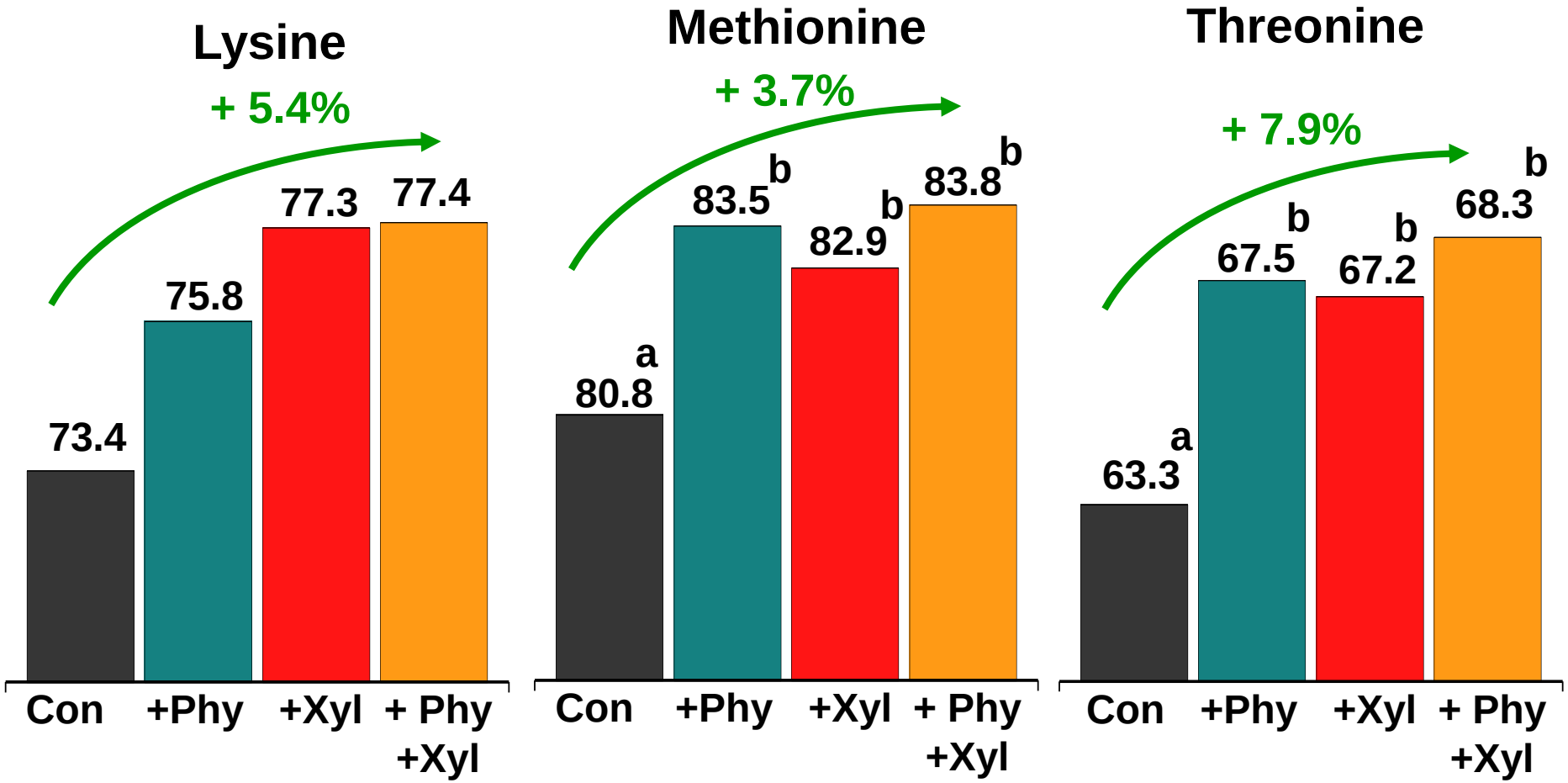
a-b P<0.05

Phytase 500 FTU/kg feed, Xylanase 2000 U/kg feed

University of Illinois, USA

Effects of xylanase +/- phytase in corn based diets containing 20% corn DDGS (25-60kg bodyweight)

Ileal amino acid digestibility (%)



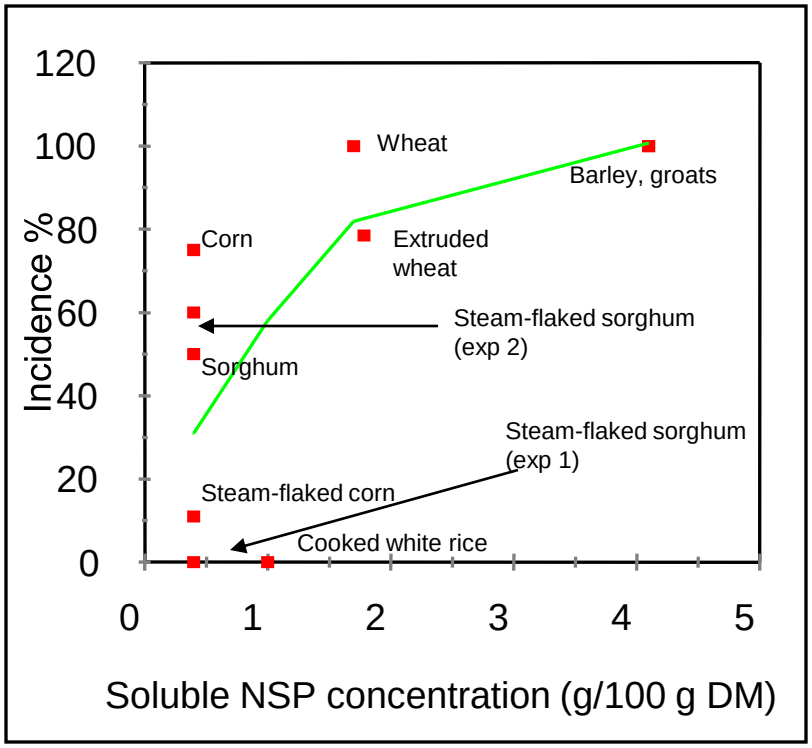
a-b P<0.05

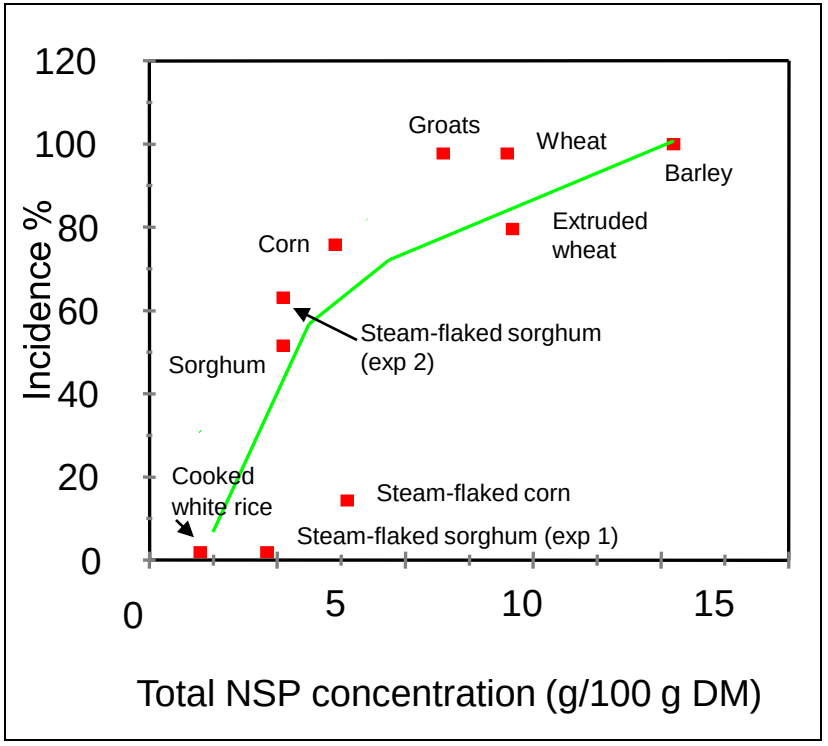
Phytase 500 FTU/kg feed, Xylanase 2000 U/kg feed

University of Illinois, USA

Dietary fibre and gut health, zoonoses -/+ enzymes

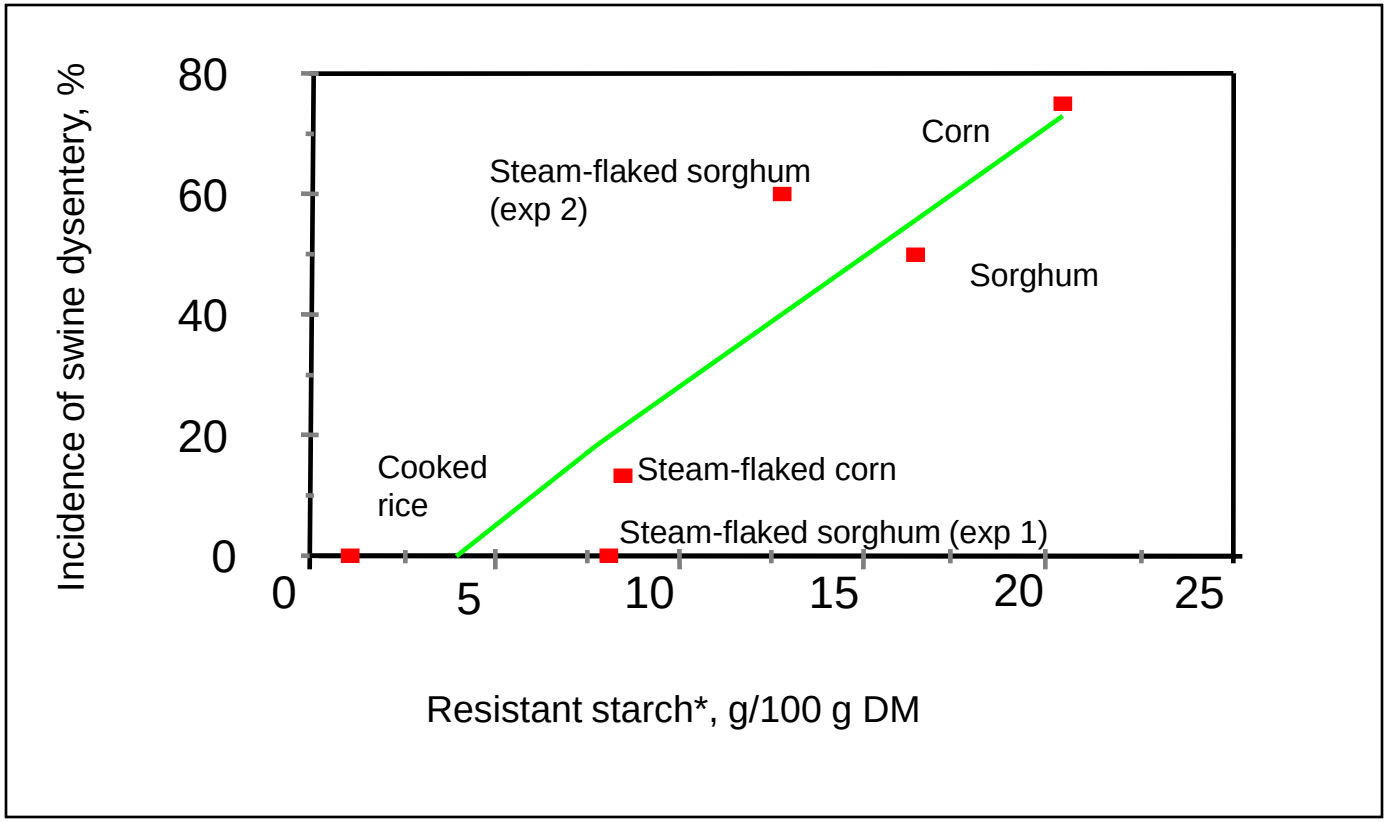
Incidence of swine dysentery & non starch polysaccharide concentration





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.126,2920-2933

Salmonella issues in pigs

~2,000 known serotypes but only ~10% of these are associated with food-borne infections in humans in any one year (MAFF, UK)

In pigs some types of *Salmonella* (e.g. *S. typhimurium*) are more likely to cause disease and produce clinical signs in humans

Salmonella sometimes causes disease and death in pigs – mainly after weaning, but many infected animals can become symptomless 'carriers'

Animals that appear clinically normal may be excreting or carrying *Salmonella* at slaughter and can therefore potentially be responsible for contamination of pig meat

EFSA Journal (2009)

- Overall EU prevalence of *Salmonella*-positive breeding pig & production holdings was on average ~30% (one year study January – December 2008)
- Prevalence of *Salmonella*-positive holdings for *S.typhimurium* and *S.derby* was 7-9%

Prendergast *et al* (2009) – Irish retail pork (500 samples from butchers & supermarkets)

- *Salmonella* species detected in 2.6% of pork cuts. Direct association between *Salmonella* contamination of pork & *Enterobacteriaceae* illustrating the importance of hygiene practices at retail

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*

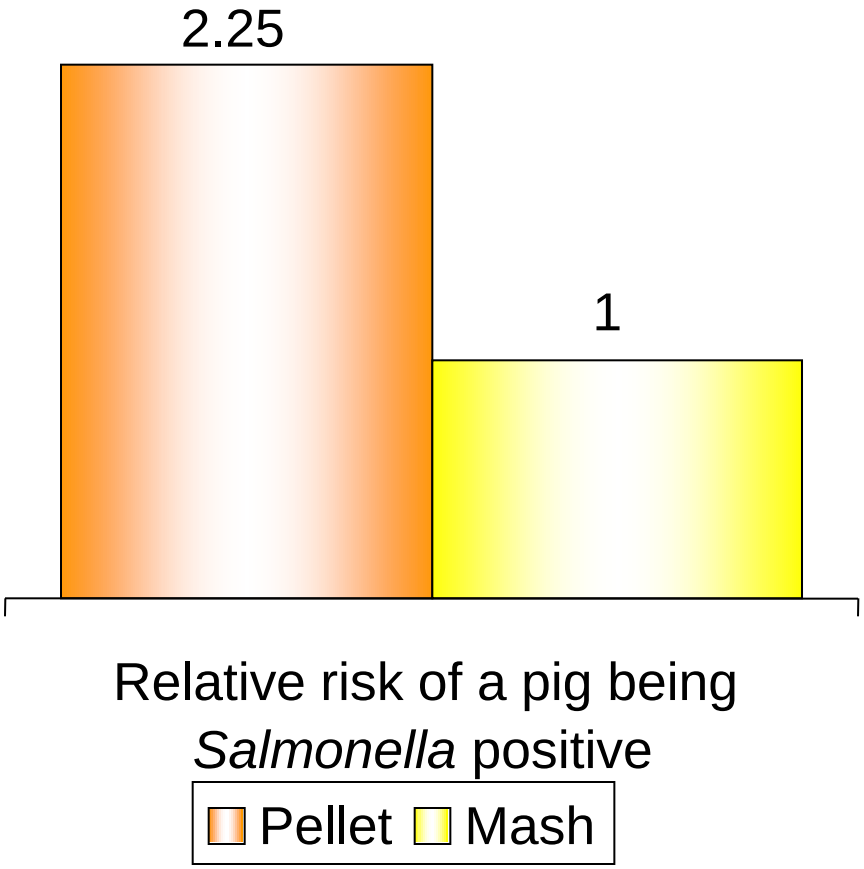
Blood sampling:

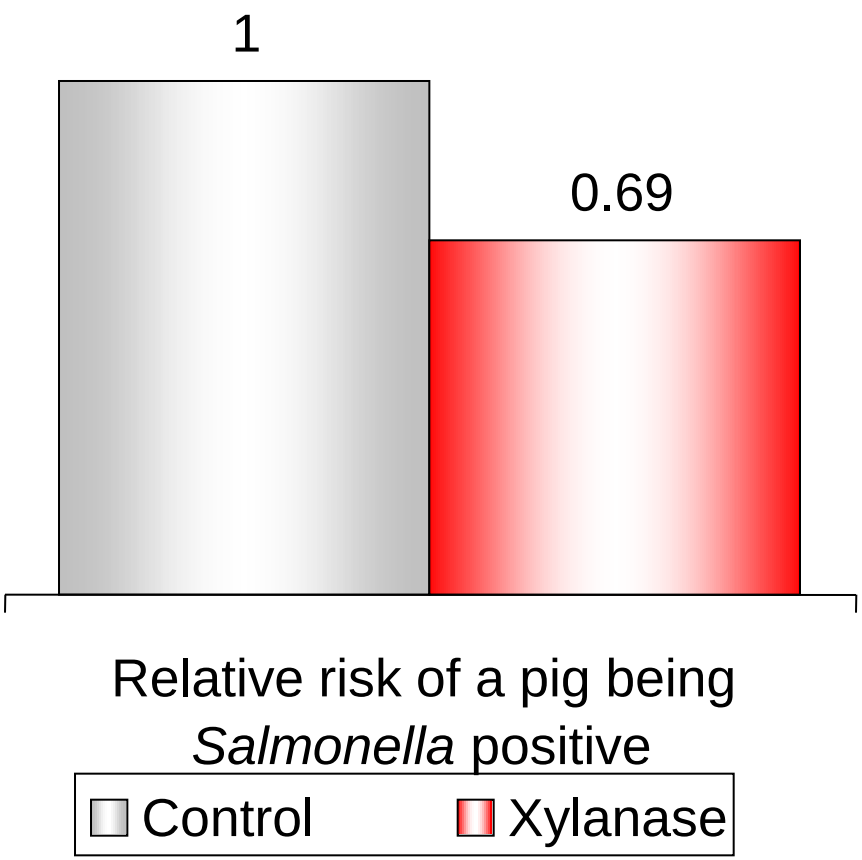
- Blood samples from 6 pigs per pen at random
- Blood samples analysed for *Salmonella* antibody titre by the 'Danish Mix ELISA test'
- *Salmonella* positive = optical density value >20

* 4000 U/kg feed

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

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)

Does the xylanase source matter?

Danish Pig Production[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

[1] www.danskeslagterier.dk

[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

Summary

- **Grain by-products** offer interesting opportunities to save costs in swine rations
- However, their relatively **high fibre content** offers physiological challenges to the pig that can potentially negate these cost-saving opportunities
- **Enzyme technology**, based (e.g.) on a well-proven, highly effective in-feed xylanase, offers clear opportunities for feed cost savings and in trials (Danske Slagterier) has been shown to help reduce the relative risk of pigs being *Salmonella* positive
- All xylanases have their own unique characteristics (e.g. pH, temperature optimum, K_m etc) so are **not equal in their bio-efficacy in the animal** - so care must be taken to find clear supporting evidence of 'value'/'ROI' from independent sources
- With **Net Energy costs** of ~9 Euro cents/kcal in Europe currently it's important to exploit all possible opportunities to save feed costs!

The miracles of science™