美国农业部猪饲料效率项目
USDA SWINE FEED EFFICIENCY PROJECT

最终报告及改进建议
Final report and recommendations for improvement

Drs. John Patience
Jack Dekkers, Nick Gabler, Mariana Rossoni Serao and Chris Tuggle
Iowa State University,
Ames, IA

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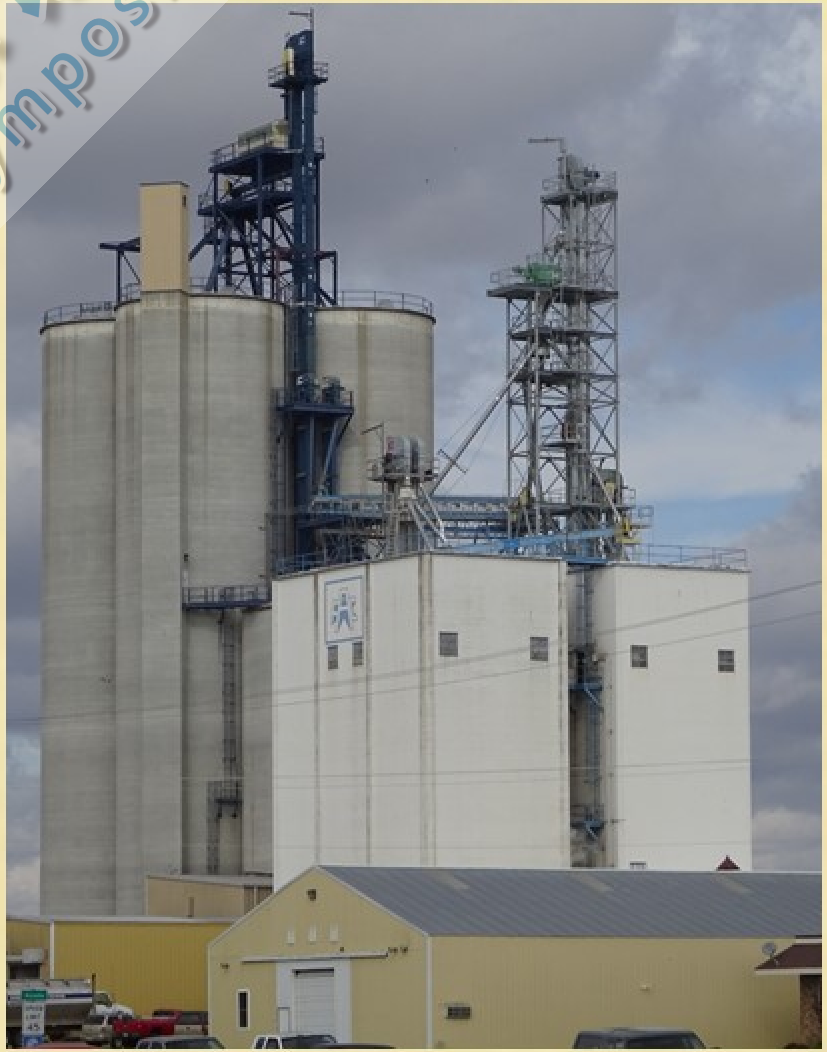
演讲大纲 Presentation outline

- AFRI项目概况
  AFRI project overview
- 项目成果
  Project outcomes
- 饲料效率为目标
  Using feed efficiency as a farm benchmark
- 提高饲料利用率和净利润的实用的建议
  Practical recommendations to improve feed efficiency and net income
- 关键信息
  Take home messages



项目总体目标 Project overall goal

通过研究和推广关键措施和综合措施，提高猪肉生产中的**养分利用率**和**饲料效率**，增强猪肉产业的竞争力，降低对谷物和蛋白原料的需求。

To increase **nutrient utilization** and **feed efficiency** in pork production, thereby strengthening the competitiveness of the pork industry and reducing its demand on grains and proteins, through focused and integrated initiatives in research and extension.

多学科的方法 Multidisciplinary approach

- 营养学 Nutrition
- 生理学 Physiology
- 肉类科学 Meat science
- 微生物学 Microbiology
- 免疫学 Immunology
- 行为学 Behaviour

- 基因组学 Genomics
- 数量遗传学 Quantitative genetics
- 转录学 Transcriptomics
- 蛋白质学 Proteomics
- 生物信息学 Bioinformatics
- 统计学 Statistics

多方面的技术转移 Multifaceted technology transfer

- 网站 Website
- 会议 Conferences
- 演讲 Presentations
- 小型研讨会 Mini-symposia
- 说明书 Fact sheets
- 农场示范项目 On-farm demonstration projects
- 决策工具 Decision-making tools

已报告过的研究结果 Previously reported findings

经过饲料效率选育后的品种

Pigs genetically selected for improved feed efficiency:

- 不会更容易感染疾病
  Are not more susceptible to disease
- 不会更容易受应激影响
  Are not more easily stressed
- 猪肉质量不会更差
  Do not produce inferior quality pork
- 胴体瘦肉率更高，肌内脂肪更少，但在质量上略有不同（猪肉颜色略有差异）
  Have leaner carcasses, less intramuscular fat, but few differences in quality (small difference in redness)
- 当喂食低能量高纤维饮食时，选育的品种失去优势
  Lose their superiority when fed a low energy high fiber diet

近期研究结果 Recent findings

- 饲料效率的遗传比较复杂
  Feed efficiency is complex genetically
  - 许多不同的基因都有影响，影响都比较小
    many different genes have small effects

- 饲料效率高或低的猪之间，血清中的三种蛋白质总是存在差异
  Three proteins in blood serum are consistently different between more efficient and less efficient pigs
  - 在5-6周龄时就可以检测到
    Identifiable at 5-6 weeks of age

提高饲料效率和净收入的实用建议
Practical recommendations to improve feed efficiency and net income

饲料效率受多种因素的影响
Feed efficiency is influenced by many factors

- **饲料成分** **Feed composition**
  - 能量、氨基酸等的含量 Levels of energy, amino acids, etc
  - 营养缺乏 Deficiencies in nutrients
  - 饲料加工：粉碎、制粒 Feed processing: grinding, pelleting
  - 饲料添加剂 Feed additives

- **环境因素** **Environmental factors**
  - 温度 Temperature
  - 健康（庞大的） Health (huge),
  - 饲料的供给 Access to feed

- **猪** **Pig**
  - 增长率、蛋白:脂肪、初始重和末重、死亡率
    Growth rate, protein:lipid ratio, starting and final weight, mortality

由于许多因素影响饲料效率，它是一个高风险的基准指标
Because so many factors influence feed efficiency, it is a risky benchmark KPI

哪一群猪饲料效率更高？是饲料转化率为2.41的这群还是饲料转化率为2.53的这群？

Which group of pigs is more feed efficient? A group with a feed conversion of 2.41 or the group with a feed conversion of 2.53?

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哪一组猪饲料效率更高？
A组：25到125kg；饲料转化=2.67。
B组：28到128kg；饲料转化=2.67。

Which group of pigs is more feed efficient?
Group A: 25 to 125 kg; FC = 2.67.
Group B: 28 to 128 kg; FC = 2.72.

料肉比是饲料效率的最佳指标吗？还有其它效果更好的指标吗？
Is feed:gain the best measure of feed efficiency? What are some useful alternatives?

- 能量效率 Energetic efficiency
  - Mcal/公斤增重 Mcal/kg gain
- 饲料成本/出栏猪 Feed cost/pig sold
  - $/猪 $/pig
- 每头猪的饲料成本投资回报 Return over feed cost per pig
  - $/猪 $/pig
- 每头猪空间的饲料成本投资回报 Return over feed cost per pig place
  - $/猪位 $/pig place

整群饲料效率：母猪+出栏生猪
Whole herd feed efficiency: sow herd + market hogs

例如：断奶到出栏的饲料转化率=2.7：
Example: wean-to-finish feed conversion = 2.7:1

- 整群饲料转化率（出栏20头猪/母猪/年）=2.91
  Whole herd feed conversion (20 pigs sold/sow/yr) = 2.91
- 整群饲料转化率（出栏25头猪/母猪/年）=2.87
  Whole herd feed conversion (25 pigs sold/sow/yr) = 2.87
- 整群饲料转化率（出栏30头猪/母猪/年=2.84
  Whole herd feed conversion (30 pigs sold/sow/yr = 2.84

猪肉生产的成功将越来越多的取决于：
Increasingly, success in pork production will depend, in part, on:

- **谁可以以最低价格购买到日粮中的能量**
  who can buy dietary calories at the lowest cost
- **谁的能量利用效率最高**
  who can use those calories most efficiently

配方师面临的最困难的挑战是确定最佳的日粮能量浓度

One of the most difficult challenges facing the nutritionist is selecting the optimal dietary energy concentration

日粮消化能	DIET DE, Mcal/kg	3.05	3.19	3.33	3.47	3.61
初始重	Initial wt., kg	31.2	31.1	31.5	31.2	31.1
末重	Final wt., kg	115.1	115.5	115.3	115	115.6
日增重	Daily gain, kg	1.00	1.02	1.04	1.02	1.03
采食量	Daily feed, kg[1]	2.66	2.62	2.62	2.52	2.44
肉料比	Feed conversion[1]	0.39	0.40	0.41	0.42	0.44
消化能摄入量	DE intake, Mcal/d	8.22	8.49	8.76	8.61	8.71

[1]日粮代谢能含量影响显著

Effect of diet ME content significant, $P < 0.05$.

低消化能日粮含有16.4%中性洗涤纤维；高消化能日粮含有9.6%中性洗涤纤维

Low DE diet contained 16.4% NDF; high DE diet contained 9.6% NDF

Source: Beaulieu et al., 2009

低能日粮效益评估 Economics of lower energy diets

		玉米-豆粕 Corn/SBM	净能 NE -50 kcal /kg	净能 NE -100 Kcal /kg	净能 NE -150 kcal /kg
参数/猪	**Parameter/pig**	**0%**	**3.75%**	**7.50%**	**15%**
饲料成本	Feed cost in trial	$63.89	$62.64	$63.80	$61.16
额外胴体增重，公斤	Carcass gain needed, kg	-	1.8	1.4	4.0
额外天数	Days needed	-	2.8	2.1	6.3
空间成本	Cost of space	-	$0.39	$.30	$.88
额外饲料成本	Cost of additional feed	-	$2.40	$1.91	$5.28
总成本	**Total cost**	**$63.89**	**$65.43**	**$66.00**	**$67.32**
与对照组差异	Difference from control	-	$1.54	$2.11	$3.43

Source: Frederick and Cline, 2015

添加脂肪将提高饲料效率，但不一定提高收益率 Adding fat to the diet will always improve feed efficiency but not necessarily rate of gain[1]

项目	Item	处理Treatment 玉米油 Corn oil 2%	4%	6%	精炼动物油 Choice white grease 2%	4%	6%	SEM	*P*值 P-value[2] FS	FL
日增重	ADG, kg	0.90	0.92	0.92	0.90	0.90	0.93	0.01	0.928	0.445
采食量	ADFI, kg	2.60	2.57	2.47	2.58	2.49	2.46	0.03	0.428	0.094
肉料比	Gain to feed	0.35	0.36	0.37	0.35	0.36	0.38	0.003	0.120	<0.001
消化能摄入量	ME intake, Mcal/d	8.71	8.91	8.77	8.65	8.63	8.74	0.14	0.426	0.890
平均出栏重	market BW, kg	140	141	141	140	140	140	1	0.757	0.537
猪出栏天数	Pig days to market	119	119	119	120	119	116	2	0.512	0.578

[1]1每个处理组10个圈，200头猪，初始重32kg 10 pens and 200 pigs per treatment; Starting BW 32.0 ± 0.4 kg.
[2]脂肪来源和脂肪水平之间的无互作 No significant interaction between fat source and fat level was evident (*P* >0.30).

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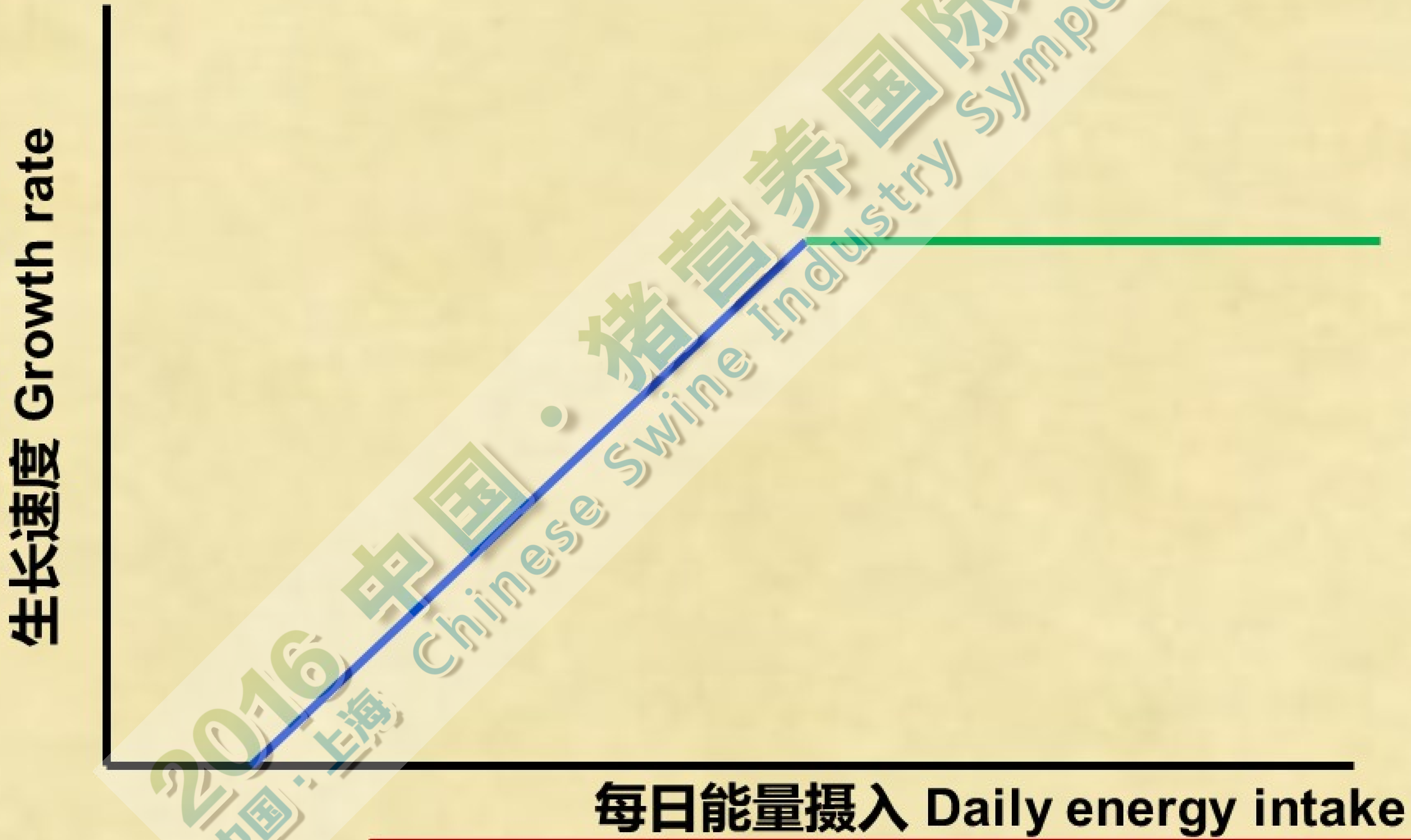
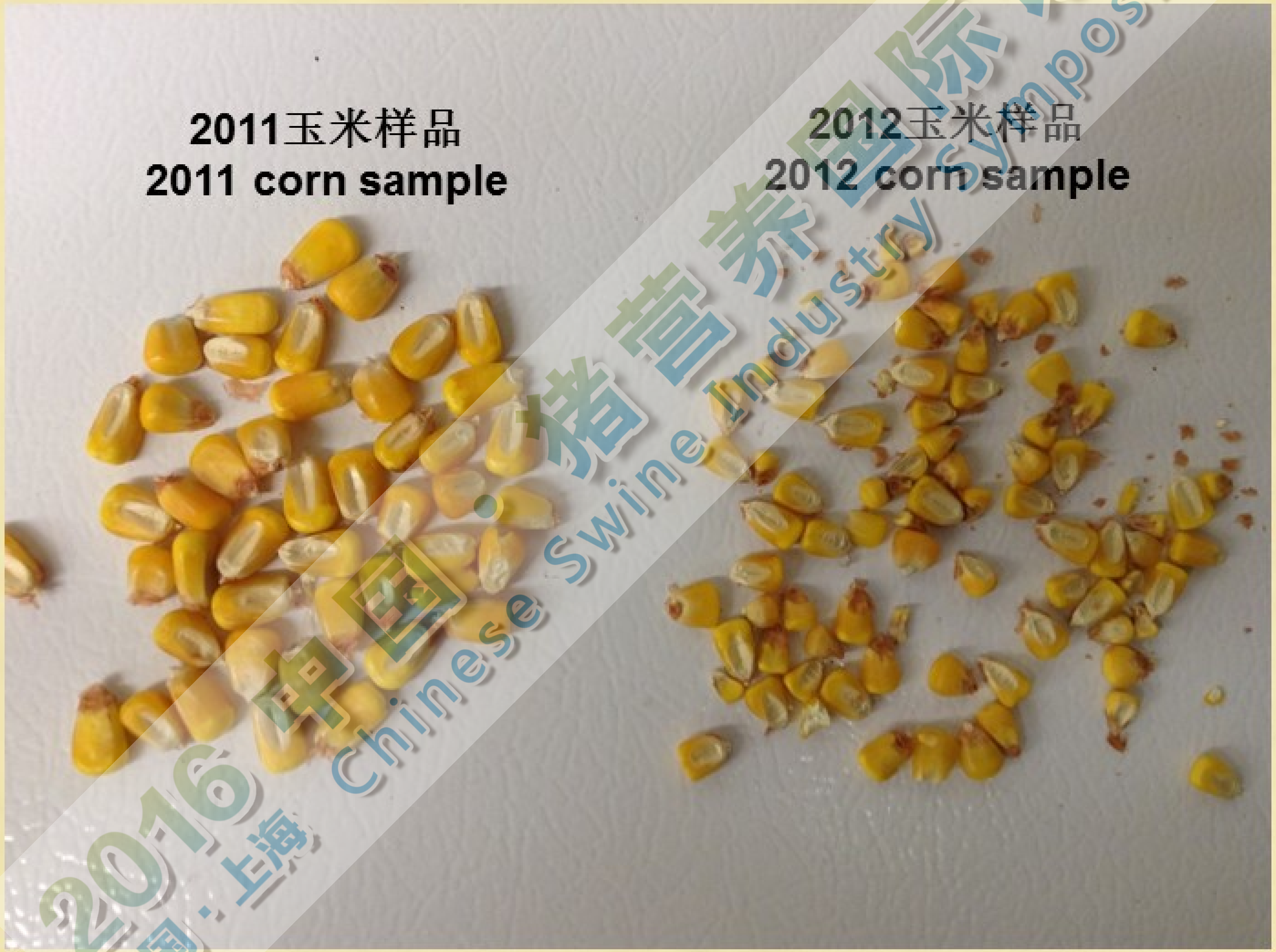
Kellner et al., 2016

当日粮代谢能改变时，猪群采食量也不同（能量摄入也不同），从而生产性能也会不同
Herds differ widely in daily feed – and thus energy – intake, leading to differing outcomes when diet ME changes



成功的饲料配方最基本的要求是营养/能量含量的准确性
Successful diet formulation requires, as a foundation, accurate data on nutrient/energy content



正常或干旱（DS）条件下玉米的化学成分
Chemical composition of corn grown under normal or drought (DS) conditions

项目 Item		正常 CNTRL[2]	干旱 DS[3]	干旱组范围 DS range	SEM	*P*值 *P*-value
样本数	n	2	28	--	--	--
粗蛋白	Crude protein, %	8.56	9.18	7.98 – 11.07	0.379	0.108
总脂肪	Total fat, %	4.07	3.96	2.91 – 4.83	0.183	0.579
酸性洗涤纤维	ADF, %	1.89	2.23	1.82 – 3.14	0.073	<0.001
中性洗涤纤维	NDF, %	6.92	8.19	7.02 – 10.14	0.489	0.015
淀粉	Starch, %	70.5	69.5	67.4 – 71.6	1.21	0.419

[1]干物质基础 All values presented on dry-matter basis

[2]CNTRL =对照组作物样品2011年从爱荷华州立大学收集来的 CNTRL =control samples from 2011 crop; collected from Ames, IA

[3]DS =2012年美国中西部的作物在干旱条件下生长的样品 DS=samples grown in drought-stressed conditions from 2012 crop across US Midwest

正常或干旱条件下（DS）玉米的消化率和能量含量
Digestibility and energy content of corn grown under normal or drought (DS) conditions

项目 Item		正常 CNTRL[2]	干旱 DS[3]	干旱组范围 DS range	SEM	*P*值 *P*-value
样品数	n	2	28	--	--	--
干物质量	DM, %	89.41	89.79	86.3 – 92.3	0.352	0.280
总能	GE, %	4.42	4.43	4.40 – 4.49	0.007	0.116
干物质消化率	ATTD of DM, %	84.4	83.4	81.4 – 85.0	0.20	<0.001
总能消化率	ATTD of GE, %	84.3	83.1	80.6 – 85.6	0.81	0.150
消化能	DE, Mcal/kg	3.72	3.68	3.54 – 3.82	0.042	0.359
代谢能	ME, Mcal/kg[4]	3.66	3.62	3.48 – 3.75	0.041	0.299
净能	NE, Mcal/kg[5]	2.92	2.87	2.76 – 2.97	0.031	0.160

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[4]使用诺布偶和佩雷斯计算（1993） Calculated using Nobletand Perez (1993)
[5]使用诺布偶等计算（1994）Calculated using Noblet *et. al* (1994)

玉米质量对回肠表观和表观总消化率，后肠道发酵的影响
Effect of corn quality on apparent ileal and apparent total tract digestibility, and hindgut fermentation by difference

项目 Item	高能玉米样品 Higher energy corn samples		低能玉米样品 Lower energy corn samples		标准差 SEM	*P*值 P-value
回肠表观消化率 AID, %						
总能 GE	79.12	80.18	80.20	79.67	1.04	0.744
干物质 DM	77.46	78.22	78.86	78.52	1.11	0.686
发酵 Fermentation, %						
总能 GE	5.59	5.48	2.76	3.79	1.49	0.092
干物质 DM	6.30	6.50	3.67	4.52	1.69	0.113
总能表观总肠道消化率 ATTD, %						
总能 GE	84.39	85.68	83.15	83.60	1.05	0.008
干物质 DM	83.47	84.82	82.82	83.25	1.11	0.007

Source: Newman and Patience, 2014

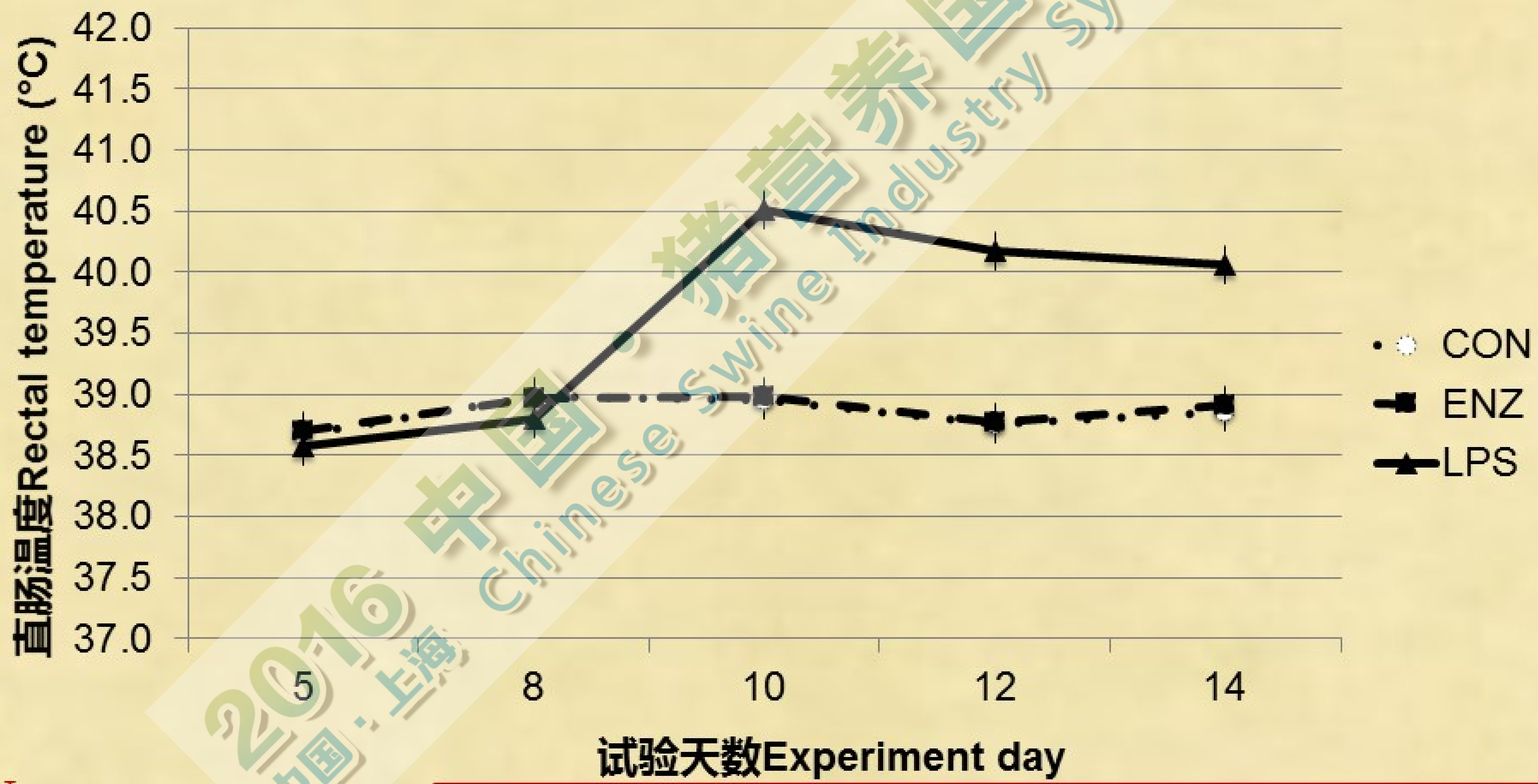
应激、肠道功能和饲料效率
Stress, gut function and feed efficiency

- 常见的应激对肠屏障功能有明显的破坏作用
  Common stressors have marked, deleterious influence on gut barrier function
  - 肠道通透性增加 Increased intestinal permeability
  - 免疫细胞活化 Immune cell activation
  - 分泌过多 Hypersecretion
- 应激和胃肠功能受损会对饲料效率产生负面影响
  Stress and impaired gut function can negatively influence feed efficiency
  - 消化吸收受损
    Impaired digestive and absorptive processes
  - 免疫系统长时间处于激活状态
    Persistent gut immune system activation
  - 菌群的变化
    Changes in microbiota

Source: Moeser, 2015

处理对直肠温度的影响
Effect of treatment on rectal temperature

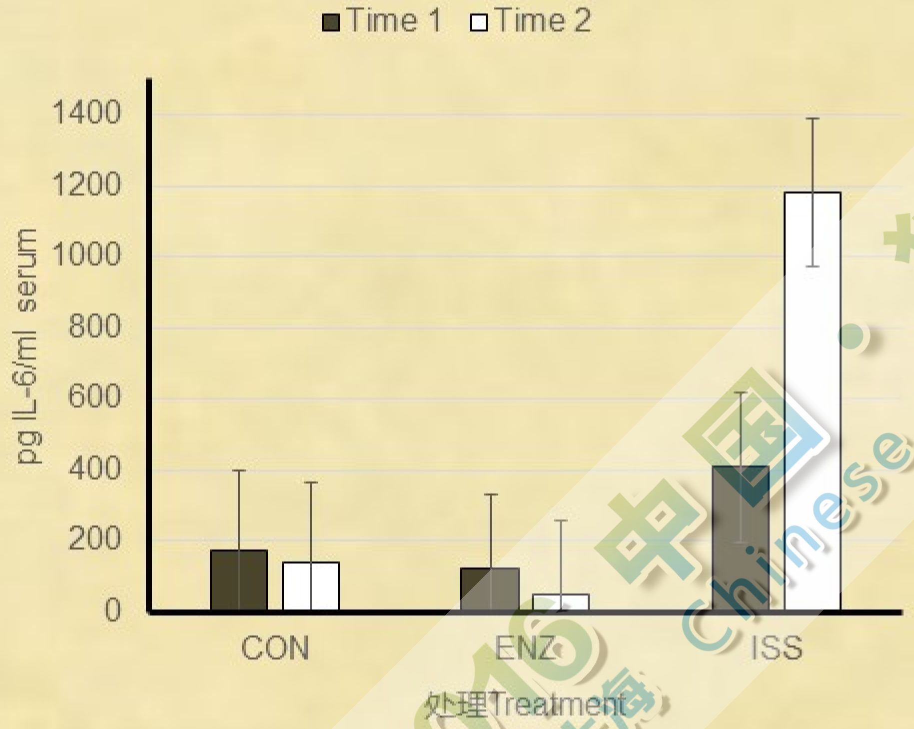
P-value:
TRT < 0.001; Day < 0.001; TRT × Day < 0.001; Block = 0.002



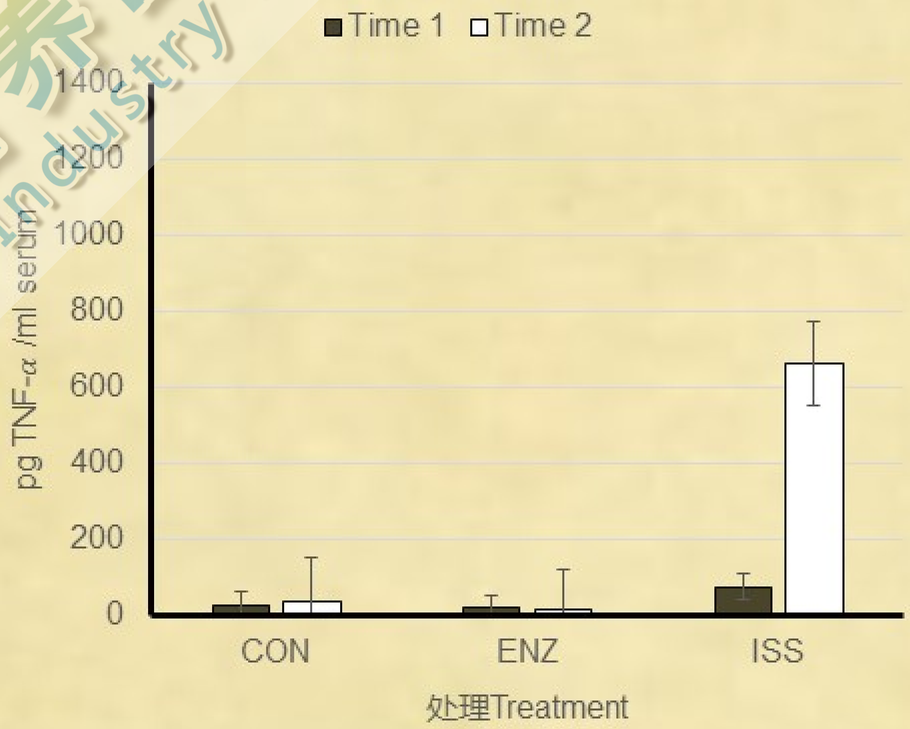
Source: Huntley and Patience, 2016

处理对系统性免疫指标的影响
Effect of treatment on systemic immune parameters

白细胞介素-6
Interleukin-6 (IL-6)



肿瘤坏死因子-α
Tumor Necrosis Factor-α (TNF-α)



Source: Huntley and Patience, 2016

处理对产热的影响
Effect of treatment on heat production

项目	Item	CON	ENZ	ISS	SEM	P值 Trt *P*-value
能量平衡	Energy balance, kcal/d/$BW^{0.60}$/kg DMI					
产热	Heat production (HP)					
总产热	HP_{total}	278.8[b]	274.9[b]	333.0[a]	14.9	0.040
绝食产热	FHP	207.8	206.6	243.3	12.9	0.13
沉积的能量	Retained energy					
总供给蛋白	As protein	197.5	173.6	191.0	18.3	0.627
总供给脂肪	As lipid	291.4[a]	302.9[a]	227.7[b]	19.2	0.046
k_{mg}		87.07	86.44	83.01	1.34	0.130
代谢能	ME_m	239.0[b]	239.5[b]	295.5[a]	15.3	0.045
营养物质沉积	Nutrient deposition, g/d					
蛋白	As protein	87.74	78.55	69.80	5.86	0.150
脂肪	As lipid	76.22[a]	79.43[a]	55.45[b]	6.21	0.047

[a,b]不同处理间差异指标 Means among treatments with different superscripts differ, $P < 0.05$n = 7 pigs / treatment
Total HP (HP_{total})=超过22 h进食状态的平均总产热量 avg HP over 22 h fed state,后注射post-injection; Fasting HP (FHP) =12 h禁食状态下平均10个最低总产热值avg. of 10 lowest HP values over the 12 h fasted state; 代谢能的维持和增长效率ME efficiency for maintenance and growth (k_{mg}) = (1 – HI) × 100; 维持中使用的代谢能ME used for maintenance (ME_m) = FHP × 100/k_{mg}

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Source: Huntley and Patience, 2016

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Source: Huntley and Patience, 2016

健康状况对生长性能的影响
Impact of health status on grow-finish performance

	项目 Item	良好的健康状态 Good Health Status	适度的健康状况 Moderate Health Status	健康状况不佳 Poor Health Status	标准差 SEM	P值 P-value
饲喂天数	Days on feed, d	148	162	169		
开始重	Start Wt, kg	13.3[a]	13.7[a]	12.4[b]	0.34	<.0001
出栏重	Market Wt, kg	129.3	131.3	129.9	10.1	0.19
日增重	ADG, kg/d	0.84[a]	0.76[b]	0.66[c]	0.03	<.0001
采食量	ADFI, kg	2.05[a]	2.01[a]	1.81[b]	0.05	<.0001
饲料转化率	F:G	2.45[a]	2.64[b]	2.76[c]	0.05	<.0001

Source: Cornelison and Patience, 2016

维持需要大量的能量，疾病需要更多的维持能量
Maintenance requires a lot of energy; disease increases it even more

功能	Functions	增重 Gain	摄入的代谢能 ME intake, Mcal/d
维持需要	Maintenance	-	2.52 (34%)
蛋白质（瘦肉）沉积	Protein (lean) gain	138 g/d (16%)	1.46 (20%)
脂肪沉积	Fat gain	267 g/d (31%)	3.36 (46%)
总计	Total	862 g/d	7.3 (100%)

假设饮食含有3.31Mcal代谢能/kg和0.85%SID赖氨酸。猪重约70公斤，体重增加900克/天（长大后总的日增重=840克/天）和吃饲料2.20千克/天，得到2.58的饲料转化率（总的喂养的饲料与最终的纤维性碳水化合物的比值为2.85:1）。

Assume the diet contains 3.31 Mcal ME/kg and 0.85% SID lysine. The pig weighs about 70 kg, is gaining about 900 g/d (total growout ADG = 840 g/d) and is eating 2.20 kg of feed/day, giving a feed conversion of 2.58 (total feeder to finish growout FC is 2.85:1).

添加30%与60%的玉米干酒糟对生猪的性能比较
Comparison of 30% versus 60% DDGS inclusion on live pig performance

		日粮 Diet		标准差 SEM	P值 *P* - value
		D30	D60		
体重	BW, kg				
d 57	d 57	30.3[a]	29.3[b]	0.25	0.005
出栏重	Market	122.4	121.9	0.45	0.41
日增重	ADG, kg	0.91	0.92	0.008	0.59
胴体日增重	ADG carcass, kg	0.71	0.69	0.005	
日均采食量	ADFI, kg	2.07	2.03	0.021	0.21
肉料比	G:F, live	0.44	0.45	0.005	0.11
胴体重:采食量	G:F, carcass	0.34	0.34	0.004	0.91

Source: Weber et al, 2013

玉米干酒糟添加量对胴体指标的影响
Impact of DDGS inclusion level on carcass measurements

		日粮 Diet		SEM	*P* - value
		D30	D60		
胴体重	HCW, kg	93.9	92.7	0.25	0.004
屠宰率	Yield, %	76.1	75.2	0.20	0.005
背膘厚度	Backfat depth, mm	12.6	12.9	0.46	0.60
腰肌深度	Loin depth, mm	64.9	62.9	0.63	0.047

Source: Weber et al, 2013

关键信息
Take home messages

1. 经过饲料效率选育的品种，不会降低肉的品质、抗病力和抗应激能力。Selecting pigs intensively for feed efficiency does not appear to harm meat quality, resistance to disease or susceptibility to stress.

关键信息
Take home messages

1. Selecting pigs intensively for feed efficiency does not appear to harm meat quality, resistance to disease, susceptibility to stress.
2. 在不久的将来，我们在猪5-6周龄时通过一个简单的血液测试，就可以选育高饲料效率的猪。
   It may be possible in the near future to select more efficient pigs at 5 – 6 weeks of age based on a simple blood test.

关键信息
Take home messages

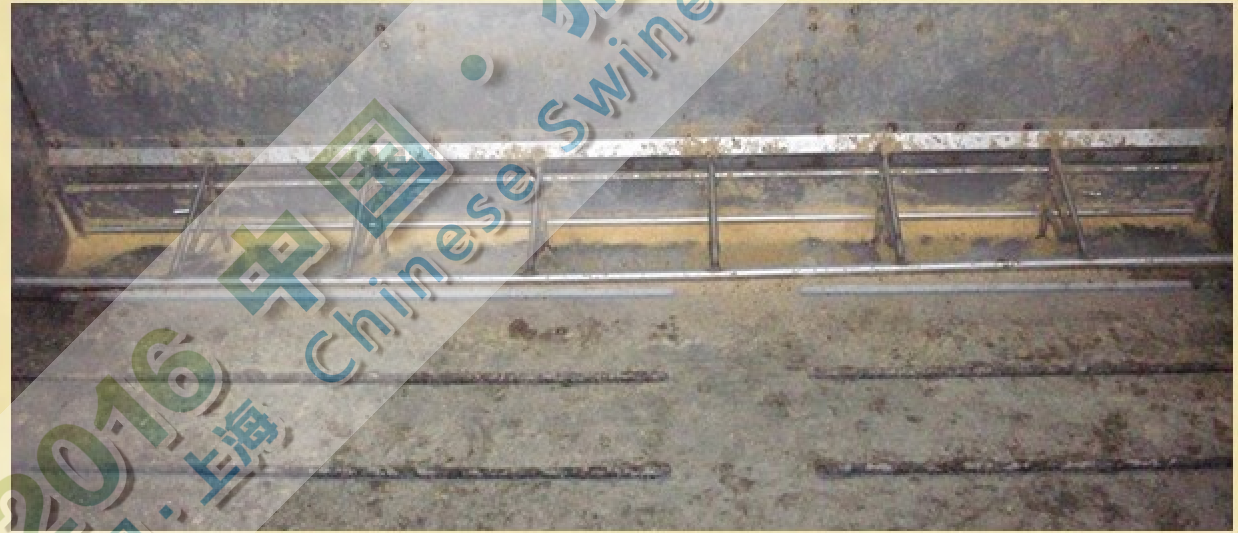
1. Selecting pigs intensively for feed efficiency does not appear to harm meat quality, resistance to disease, susceptibility to stress.
2. It may be possible in the near future to select more efficient pigs at 5 – 6 weeks of age based on a simple blood test.
3. 猪肉生产的成功一定程度上取决于日粮的能量采购成本和能量的利用率。
   Success in pork production is due, in part, to buying feed calories as cheaply as possible and using these calories most efficiently.

关键信息
Take home messages

4. 饲料转化率是一个高风险的基准指标。
   Feed conversion is a risky benchmark KPI.

关键信息
Take home messages

4. Feed conversion is a risky benchmark KPI.
5. 料肉比是不是饲料效率的唯一指标，也未必是最好的指标。最佳指标应该要考虑到经济效益。
   Feed:gain is not the only, and may not be the best, measure of feed efficiency. Best measures include financial indicators.



关键信息
Take home messages

4. Feed conversion is a risky benchmark KPI.
5. Feed:gain is not the only, and may not be the best, measure of feed efficiency. Best measures include financial indicators.
6. 原料成分变异大，所以精确评估原料，并以此为基础配制日粮十分关键。
   Ingredients are variable, so assaying ingredients and formulating based on these assays is essential for best results.

关键信息
Take home messages

7. 免疫系统的激活增加了维持能量的需要，从而降低了饲料效率。
   Stimulation of the immune system increases maintenance energy requirements, which reduces feed efficiency.

关键信息
Take home messages

7. Stimulation of the immune system increases maintenance energy requirements, which reduces feed efficiency.
8. 饲喂高纤维日粮将降低胴体屠宰率，这反过来又会降低胴体饲料效率。
   Feeding higher fiber diets will reduce carcass dressing percentage, which in turn will reduce carcass-based feed efficiency.

关键信息
Take home messages

7. Stimulation of the immune system increases maintenance energy requirements, which reduces feed efficiency.
8. Feeding higher fiber diets will reduce carcass dressing percentage, which in turn will reduce carcass based feed efficiency.
9. 母猪也会采食饲料，因此会影响整群的饲料转化率。
The sow herd uses feed as well, and therefore affects whole herd feed conversion.


饲料转化率可能并不是一个很好的关键生产指标（KPI）但它是一个重要的盈利指标
Feed conversion may be a poor Key Productivity Indicator (KPI) but it is an important contributor to financial success

谢谢 Thank you

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