The effects of amino acids and their ratios to lysine, and net energy concentration on growth performance, carcass composition and feed cost of finishing pigs fed low protein diets

低蛋白日粮中氨基酸含量、氨基酸与赖氨酸比，及日粮净能含量对育肥猪生长性能和胴体组成的影响

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Introduction: current challenges of commercial pig production

前言：商品猪的生产当前遇到的挑战

Goal : profitable but in a sustainable way

目标：以可持续的方式生产，并获得利润

Climate change

- Environmental pollution

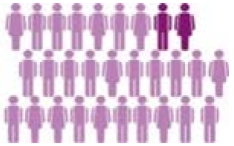
气候变化：环境污染

The pollution regulations affecting China's pork producers

20 December 2017

全球变暖

影响中国养猪业的环境污染相关的法律法规
（2017年12月20日）



Food demand

- Population growth

粮食需求：人口的增长

High feed cost

- Over supply of meat, export restriction

高饲料成本：肉类供应过剩，出口限制

Animal health / welfare

- Sub-optimal immune status (AGPs-ban)

动物健康/福利：亚健康状态（禁用抗生素生长促进剂）

Consequences: increased regulation toward minimizing N/P pollution
结论：加强管制使氮磷污染降至最低

GHG emission target (2020 vs. 1990)

- o **EU: 20%** reduction
- o **Germany: 40%** (1,252 mil. ton CO_2e)

New fertilizer ordinance (2017)

- o **France: 12% reduction** from agri. GHG emissions (2028 vs. 1990)

温室气体排放目标（2020vs.1990）

- o **欧盟:减排20%**
- o **德国:40%(12亿5200万吨二氧化碳)**

新肥料条例(2017)

- o **法国:农业减排12%。** 温室气体排放(2028vs.1990)

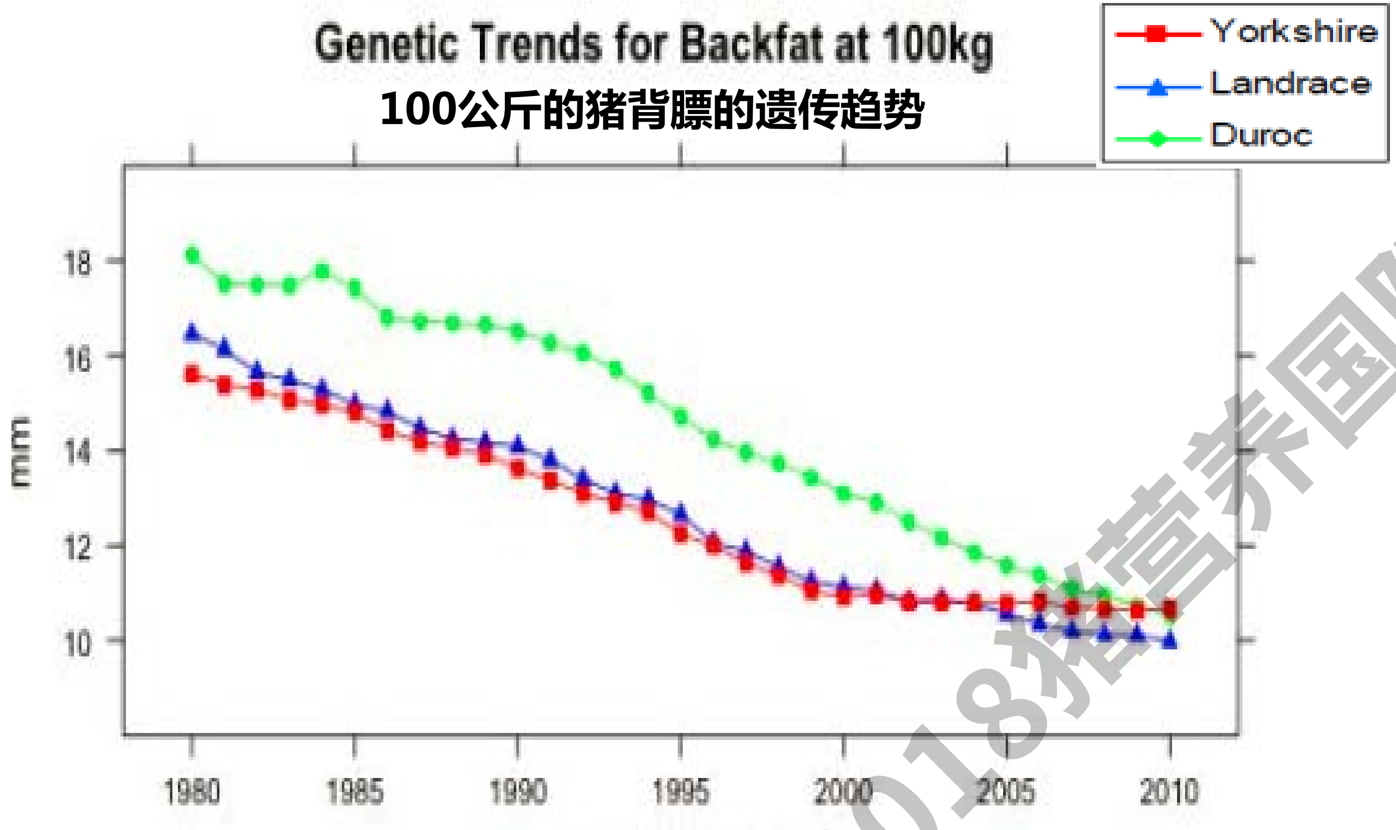
Solutions to mitigate pollution

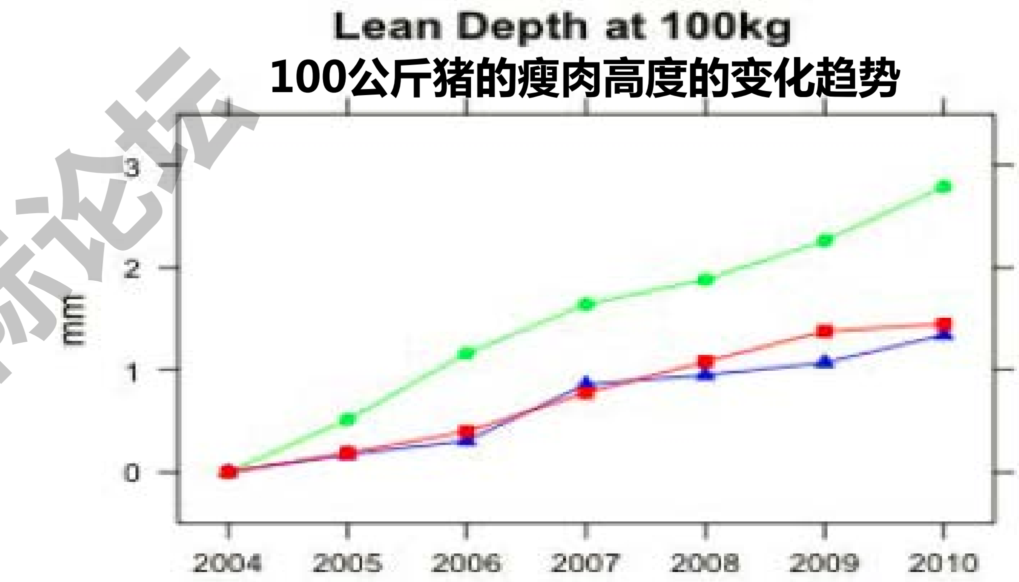
- o **Low CP-AA diets (minimize N output; improve efficiency)**
- o Increased use of alternative / local feedstuffs (insect meal, DDGS,…)
- o Genetic potentials (breeding)
- o Enzymes, probiotics, prebiotics, or acids

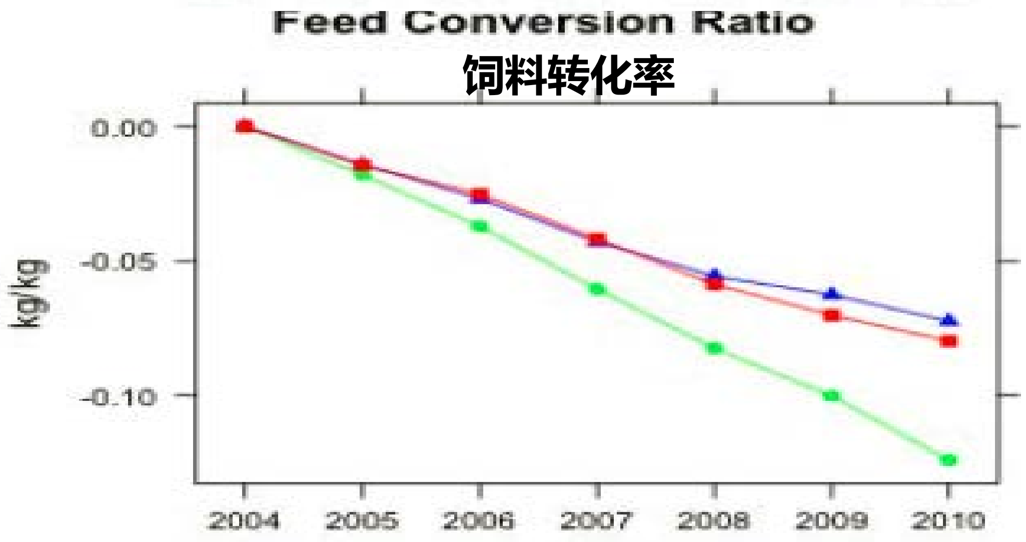
减轻污染的解决方案

- o **添加氨基酸的低蛋白日粮（氮排放降到最低；提高效率）**
- o **增加替代的或者当地的饲料原料（昆虫粉，DDGS…）**
- o **遗传潜力（育种）**
- o **酶，益生菌，益生元或者酸类**

Genetic trends for backfat, loin and FCR at 100 kg (1980-2010)#
100公斤的猪背膘厚度、眼肌和饲料转化率的遗传进展（1980-2010）#







~85 herds across Canada participated in the program.
加拿大85个畜群参与了这个项目

Canadian Centre for Swine Improvement (2010-11)
加拿大猪改良中心（2010-11）

Meeting the animal's nutrient requirements
满足动物的营养需要

For optimum growth, pig's diet must contain adequate quantities of all nutrients, including AA.
为了获得最佳的生长性能，猪的饲粮中必需含有足够量的全部的营养素，包括氨基酸。

Animal's requirement
动物的需求

Supply via feed
饲粮的供应

Key nutrients关键营养

- **Water 水**
- **Amino acids 氨基酸**
- **Energy: 能量**
  carbohydrates and lipids
  碳水化合物和脂类
- **Minerals: 矿物质**
  macro and micro **常量元素和微量元素**
- **Vitamins: 维生素**
  fat soluble and water soluble
  脂溶性和水溶性

Lys
赖氨酸

- **body protein synthesis**
  机体蛋白质合成
- Maintenance (<3%)
  维持（<3%）
- first limiting AA
  第一限制性氨基酸
- most studied AA in pigs
  猪的领域研究最多的氨基酸

Importance of adequate dietary energy on performance and feed cost
充足的日粮能量对生长性能和饲料成本的重要性

- Energy is the most expensive portion of the feed, and it can affect feed intake, nutrient utilization, and performance.
  能量是饲料中最贵的部分，并且它会影响采食量、养分利用率和生长性能。
- Finishing pigs (70 kg to slaughter BW), consume 50% of the feed in weaned-to-slaughter pork production, affecting the profitability.
  育肥猪在70kg到出栏的阶段，饲料的消耗几乎占断奶到出栏全阶段的50%，对利润有很大的影响。
- Among the energy systems, NE considers heat lost associated with metabolism.
  在能量系统中，净能系统考虑了在新陈代谢过程中损失的热量。
- Published data on the optimal NE levels or SID Lys:NE ratios in pig diets are scarce.
  关于猪饲粮的最佳净能水平或回肠标准可消化赖氨酸与净能的比值的研究数据发表甚少。
- Optimal dietary levels of AA and energy should be individually evaluated (Cline et al., 2016).
  应该单独评估饲粮中最佳的氨基酸水平和能量水平 (Cline等人, 2016)。

Review of SID lysine requirements for 80-125 kg finishing pigs (n=5)
80-125公斤育肥猪回肠标准可消化赖氨酸的需要量的研究总结(n=5)

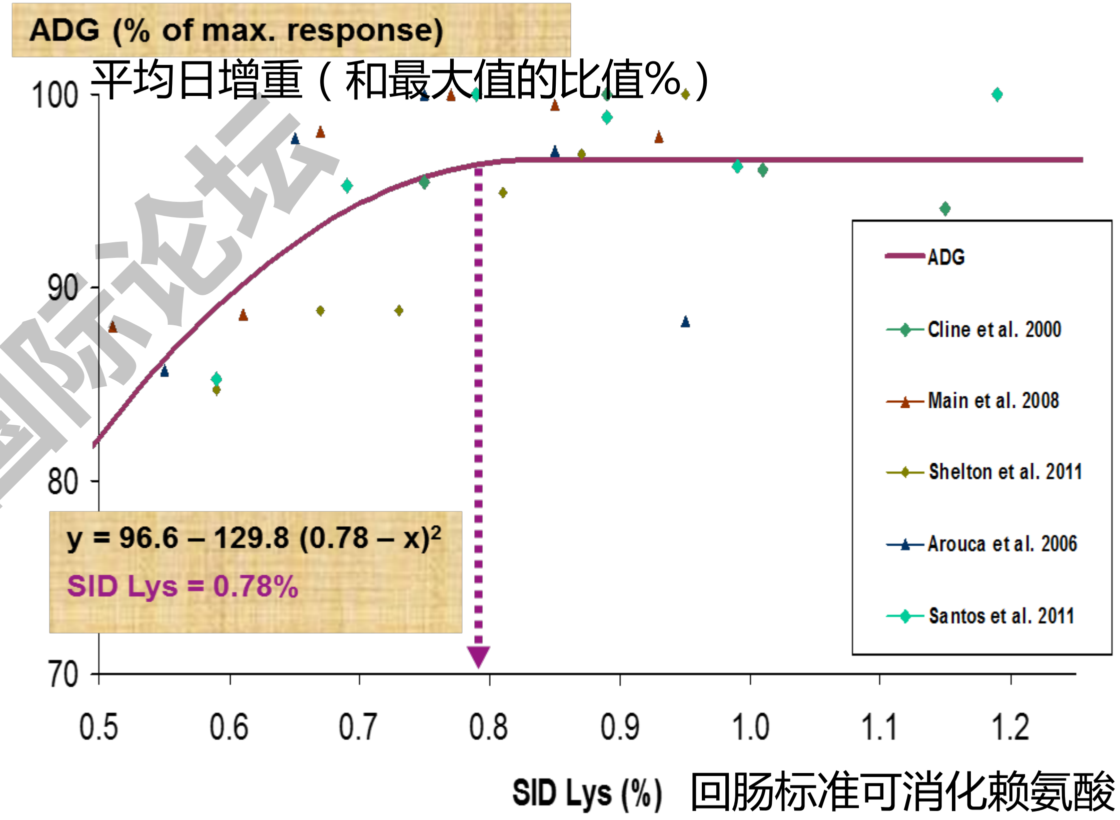
BW,体重	Sex[a]	Optimal performance, g 最佳的性能			Optimal SID Lys 最佳的SID赖氨酸		Reference 文献
kg	性别	ADG 日增重	ADFI 日采食量	G:F 增重耗料比	% diet 日粮	mg/g ADG 日增重	
55-116	G	850	2730	0.31	0.73[b]	23.5	Cline et al. 2000
78-103	G	916	2545	0.36	0.72	20.0	Main et al. 2008
84-110	G	980	2540	0.39	0.89	23.0	Shelton et al. 2011
95-122	B	1095	3508	0.31	0.63[b]	20.3	Arouca et al. 2007
95-125	B	1081	2940	0.37	0.74	20.6	Santos et al. 2011a
80-125					**0.74**	**21.5**	**Average 平均值**
80-125					**0.67**		**NRC, 2012**

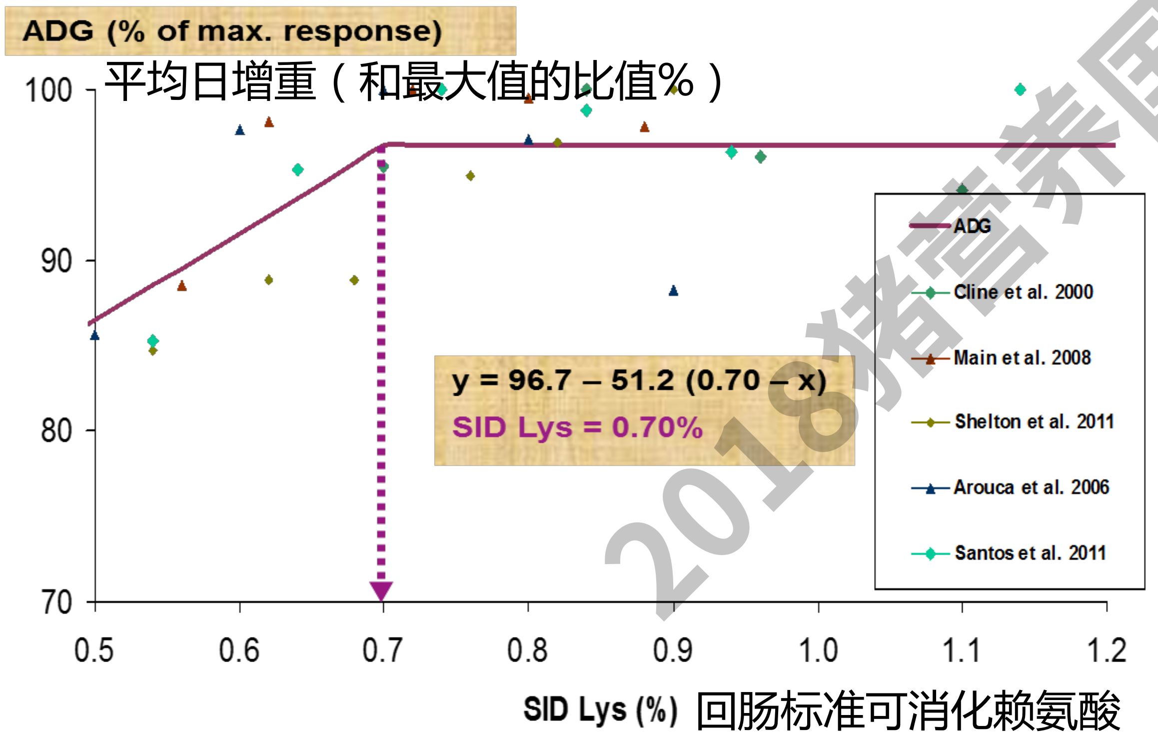
[a] B = barrows, G = gilts.
[a] B = 阉公猪, G =小母猪.
[b]SID Lys was calculated from total Lys content assuming 88% digestibility.
[b]回肠标准可消化赖氨酸是由总赖氨酸计算得出，其中假设消化率为88%。

Review of SID lysine requirements for 80-125 kg finishing pigs by regressions

通过回归分析对80-125公斤肥育猪回肠标准可消化赖氨酸需求量的研究总结

BW	Sex	Breed[2]	Optimal performance			Optimal SID Lys		Model	Response	Reference
kg			ADG	ADFI	G:F	% diet	mg/g ADG		criteria	
55-116	G	n/a	850	2730	0.31	0.73[1]	23.5	QBL	ADG	Cline et al. 2000
78-103	G	PIC	916	2545	0.36	0.72	20.0	ANOVA	ADG, G:F	Main et al. 2008
84-110	G	PIC	980	2540	0.39	0.89	23.0	BL	ADG	Shelton et al. 2011
95-122	B	PIC	1095	3508	0.31	0.63[1]	20.3	Q	ADG, G:F	Arouca et al. 2007
95-125	B	PIC	1081	2940	0.37	0.74	20.6	QBL	ADG	Santos et al. 2011a
80-115						0.74	21.5	0.74%		Average





Lit. average (table)	0.74 %
Regression (BL, QBL)	0.74 %
NRC, 2012	0.67%

Ideal (optimal) AA ratio concept
理想的（最佳的）氨基酸比例概念

“A perfect pattern of AA in the diet without any excesses or deficiencies”.
“日粮中完美的氨基酸模式就是一点也不多一点也不少，恰到好处。”

- **Lys:** set at 100% (other AA as % of Lys)　赖氨酸：设置成100%（其他氨基酸以赖氨酸作为相对值%来表示）
- should be based on digestible (SID) AA　应以回肠标准可消化氨基酸为基础
- applied by swine industry　可被养猪业实际应用的

✓ Introduced by ARC (1981)　农业研究委员会（1981）引入

The optimum dietary amino acid pattern for growing pigs

1. Experiments by amino acid deletion

BY T. C. WANG AND M. F. FULLER
Rowett Research Institute, Bucksburn, Aberdeen AB2 9SB

(Received 16 August 1988 – Accepted 20 January 1989)

生长猪最佳的日粮氨基酸模式

Ideal Amino Acid Pattern for 10-Kilogram Pigs[1]

T. K. Chung[2] and D. H. Baker[3]
Department of Animal Sciences, University of Illinois, Urbana 61801

J. Anim. Sci. 1992. 70:3102–3111

10公斤猪的理想氨基酸模式

First and next limiting amino acids in pigs
猪的第一个和下一个限制性氨基酸

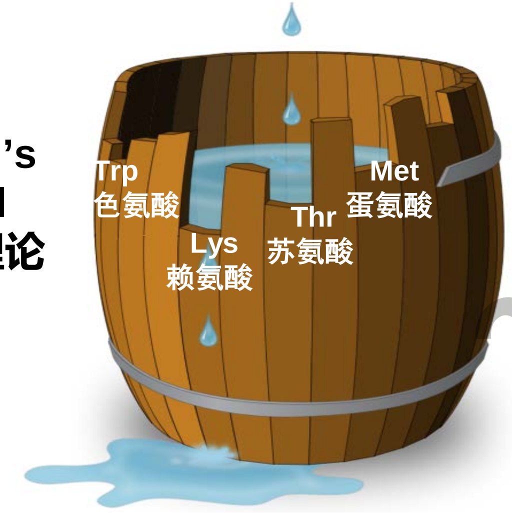
The synergy:
协同作用

Progress of nutritional concepts:
营养观念的进展：

1st phase 第一阶段	2nd phase 第二阶段	3rd phase 第三阶段	4th phase 第四阶段	5th phase 第五阶段
Lysine 赖氨酸	Lysine 赖氨酸 Threonine 苏氨酸	Lysine 赖氨酸 Threonine 苏氨酸 Methionine 蛋氨酸	Lysine 赖氨酸 Threonine 苏氨酸 Methionine 蛋氨酸	Methionine蛋氨酸 Lysine 赖氨酸 Threonine苏氨酸 Tryptophan色氨酸 Valine缬氨酸

principle of the "next limiting amino acid"
"下一个限制性氨基酸"的原理

Liebig's barrel
木桶理论

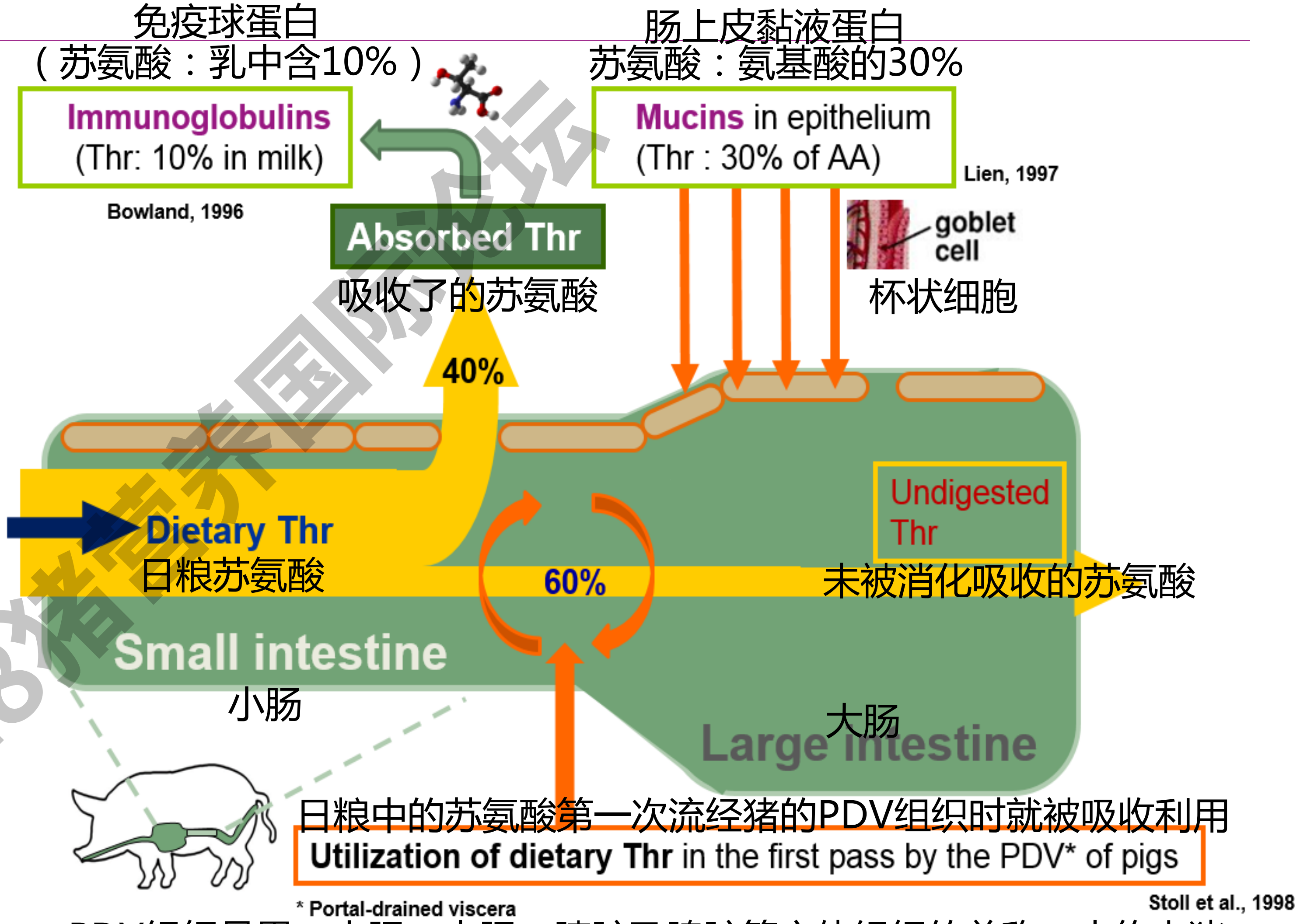


- Protein synthesis is "**all or nothing**".
  蛋白质的合成"1或者0"
- **First limiting AA** = AA with lowest amount relative requirement, and limits PD.
  第一限制性氨基酸即为氨基酸中最为缺乏的一种，并且会影响限制机体对蛋白质的利用率
- Lys is the first limiting AA in typical pig diets (before Thr, Met and Trp, Val and Ile)
  在传统的猪日粮中赖氨酸是第一限制性氨基酸（在苏氨酸，蛋氨酸，色氨酸，缬氨酸和异亮氨酸之前）

Roles of threonine
苏氨酸的作用

Thr
苏氨酸

- second- or third-limiting AA
  第二/三限制性氨基酸
- mucosal proteins and mucins
  肠黏膜蛋白和肠上皮黏液蛋白
- immune system
  免疫系统



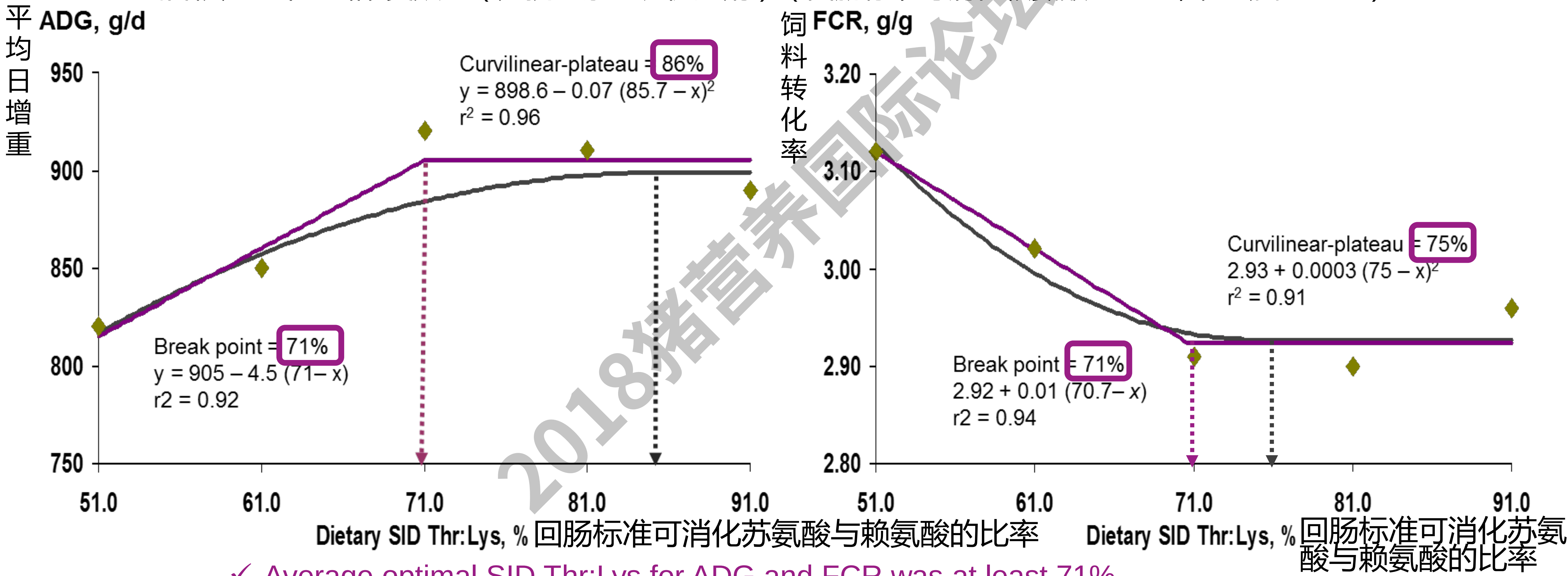
PDV组织是胃、小肠、大肠、胰脏及脾脏等实体组织的总称，大约占猪体重的5%，然其蛋白质周转和能量消耗占整体20%-35%。

Effect of dietary SID Thr:Lys ratio on performance of 73- to 96-kg pigs fed AGP-free diets under commercial facility (Xie et al., 2013)

无抗生素生长促进剂日粮中SID苏:赖对73-96公斤的商品猪生长性能的影响

#Corn-soybean meal, wheat bran (AGP-free) based diets (SID Lys = 0.61%; CP = 10.5%); 5 rep (6 barrows) / trt.

基础日粮为玉米-豆粕-麦麸型（无抗生素生长促进剂）（回肠标准可消化赖氨酸0.61%；粗蛋白10.5%）



✓ Average optimal SID Thr:Lys for ADG and FCR was at least 71%.

要获得最佳的平均日增重和饲料转化率，回肠标准可消化苏氨酸和赖氨酸的比率均值至少为71%

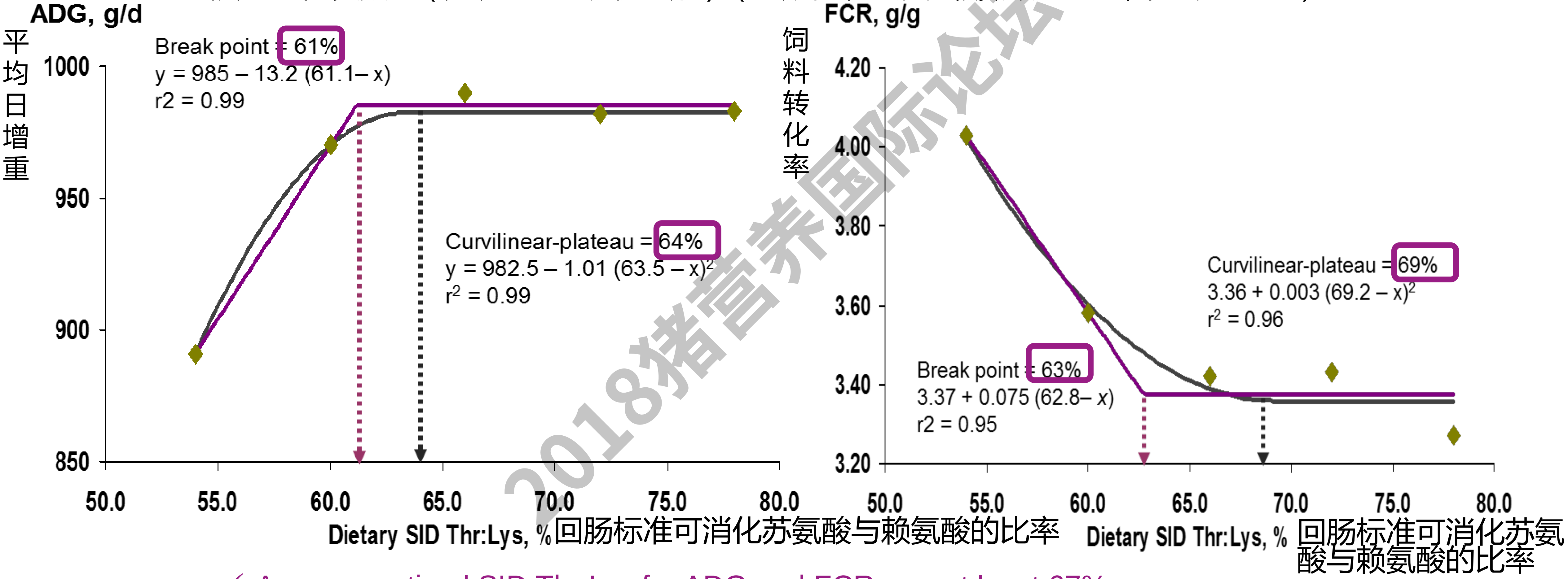
Optimal Thr:Lys ratio estimates of finishing pigs

Effect of dietary SID Thr:Lys ratio on performance of 90- to 118-kg gilts fed AGP-free diets[#] (Ma et al., 2015a)

无抗生素生长促进剂日粮中SID苏:赖对90-118公斤的小母猪生长性能的影响

[#]Corn-wheat bran (AGP-free) based diets (SID Lys = 0.51%; CP = 9.5%); 6 rep (3 gilts) / trt.

基础日粮为玉米-麦麸型（无抗生素生长促进剂）（回肠标准可消化赖氨酸0.51%；粗蛋白9.5%）



✓ Average optimal SID Thr:Lys for ADG and FCR was at least 67%.

要获得最佳的平均日增重和饲料转化率，回肠标准可消化苏氨酸和赖氨酸的比率均值至少为67%

Review of optimal SID Thr:Lys ratios for 80-115 kg growing pigs (n=4)
80-115公斤生长猪最佳SID苏:赖的研究总结

BW, 体重 kg	Sex[a] 性别	Lys 赖氨酸 (SID, %) 回肠标准可消化率	Thr:Lys 苏：赖	AB[b] 抗生素	Optimal SID Thr:Lys 最佳的回肠标准可消化苏氨酸和赖氨酸的比率 (%)	Reference 引用
65-100	M	0.61	54 to 72	(-)	69	Ettle et al, 2004
72-104	B	0.61	56 to 77	(-)	71	Xie et al., 2014
90-118	G	0.51	54 to 78	(-)	67	Ma et al, 2015a
95-125	B	0.81	58 to 73	(+)	65	Santos et al., 2010
80-115					68	Average 平均值
75-125					64	NRC, 2012

[a] B = barrows, G = gilts, M = mixed-sex. [a] B = 阉公猪, G = 小母猪, M = 混群

[b]AB = Antibiotics: (-) refers to without AB and (+) means AB was added in the diet.

[b]AB=抗生素；（-）意味着未加抗生素（+）意味日粮中加入抗生素

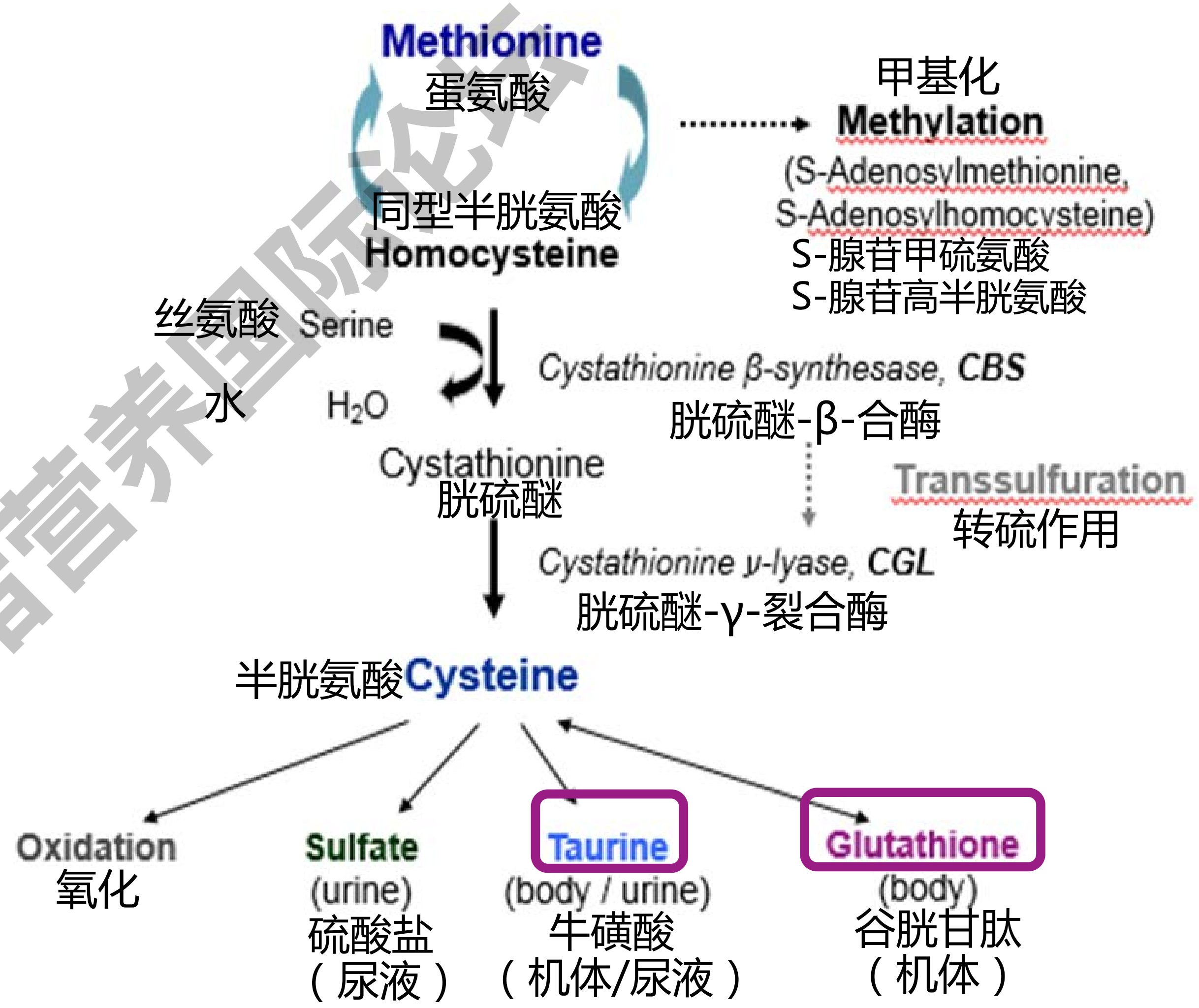
Roles of sulfur amino acids (Met and Cys)
含硫氨基酸（蛋氨酸+半胱氨酸）的作用

Met
蛋氨酸

- second- or third-limiting AA
  第二或第三限制性氨基酸
- can supply Cys 可以转化成半胱氨酸

Cys
半胱氨酸

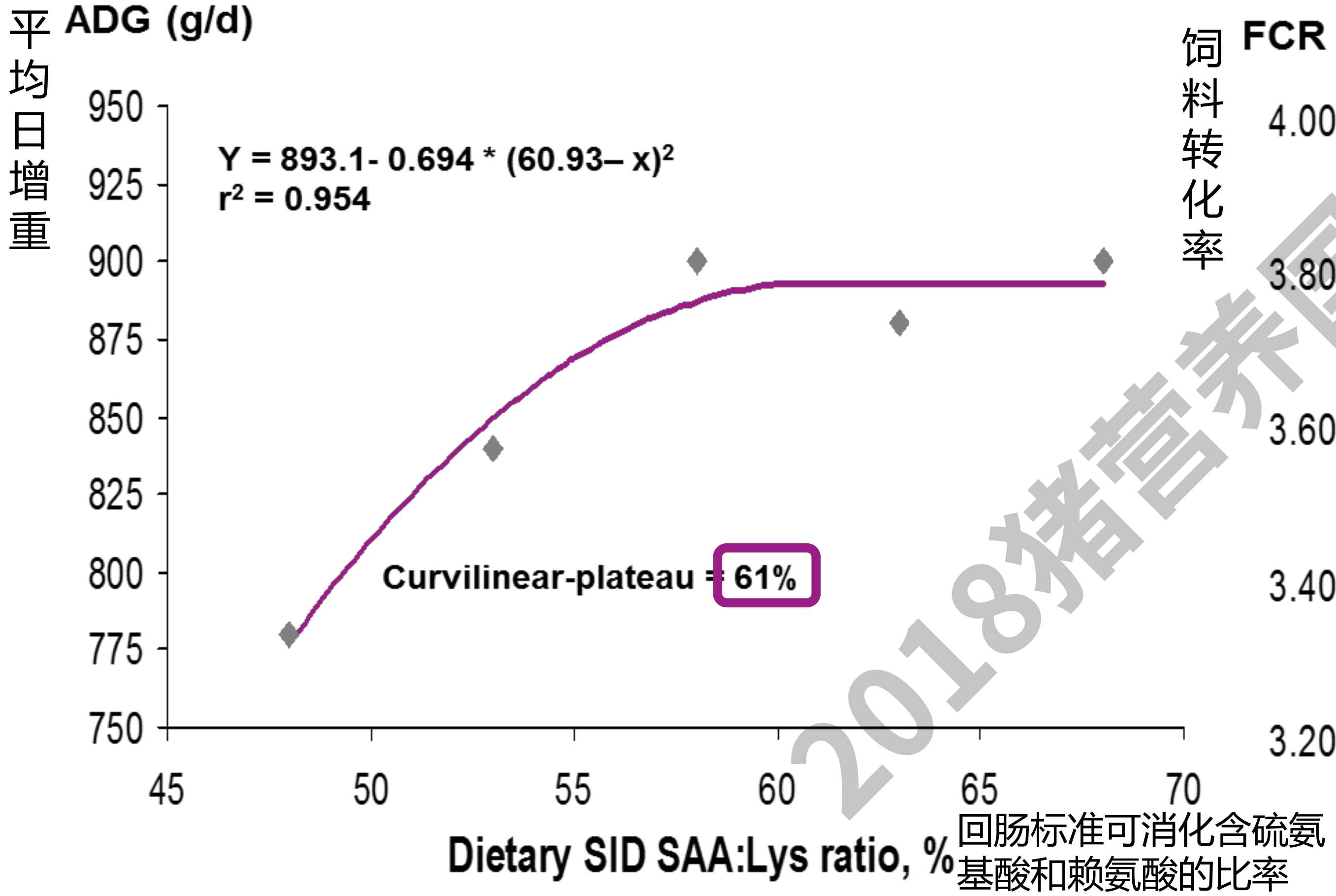
- synthesis of compounds important for immune response, i.e. glutathione, taurine and acute phase proteins (Litvak et al., 2012).
  参与合成与免疫应答相关的物质的重要组分，如谷胱甘肽，牛磺酸和急性期蛋白(Litvak et al., 2012)。

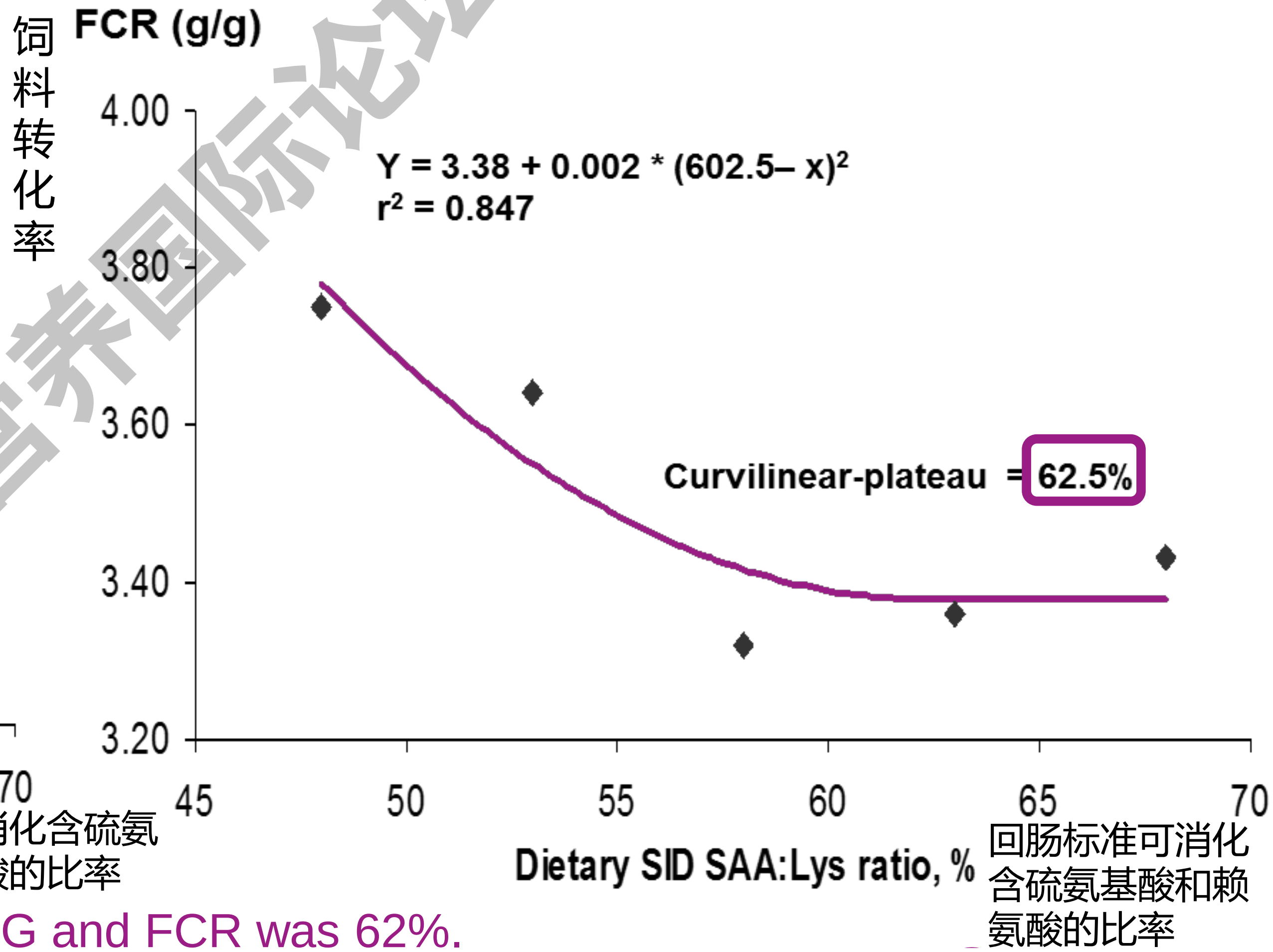


Effect of dietary SID Met+Cys:Lys ratio on performance of 96- to 120-kg pigs fed AGP-free diets under commercial facility (Ma et al., 2016)

无抗生素生长促进剂日粮中SID含硫氨基酸:赖氨酸对96-120公斤的商品猪生长性能的影响

#Corn-wheat bran (AGP-free) based diets (SID Lys = 0.51%; CP = 8.8%); 6 rep (3 gilts) / trt.
基础日粮为玉米-麦麸型（无抗生素生长促进剂）（回肠标准可消化赖氨酸0.51%；粗蛋白8.8%）





✓ Average optimal SID Met+Cys:Lys for ADG and FCR was 62%.
要获得最佳的平均日增重和饲料转化率，回肠标准可消化含硫氨基酸和赖氨酸的比率平均值为62%

Optimal SAA:Lys ratio estimates of finishing pigs

Review of optimal SID SAA:Lys ratios for 80-115 kg growing pigs (n=4)

80-115公斤生长猪最佳SID含硫氨基酸:赖氨酸的研究总结

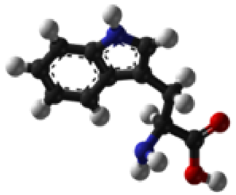
BW, 体重 kg	Sex[a] 性别	Lys 赖氨酸 (SID, %)	SAA:Lys 含硫氨基酸：赖氨酸 (SID, %)	AB[b] 抗生素	Optimal SID SAA:Lys 最佳的回肠标准可消化含硫氨基酸与赖氨酸的比率 (%)	Reference 引用
53-105	M	0.48	44 to 69	(-)	61	Roth et al., 2000
84-110	B	0.94	54 to 66	(+)	60	Pena et al., 2008
95-125	B	0.75	57 to 73	(+)	57	Santos et al. 2011b
96-120	G	0.51	48 to 68	(-)	62	Ma et al., 2016
80-115					$\boxed{60}$	Average 平均值
75-125					58	NRC, 2012

[a] B = barrows, G = gilts, M = mixed-sex. [a] B = 阉公猪, G = 小母猪, M = 混群
[b]AB = Antibiotics: (-) refers to without AB and (+) means AB was added in the diet.
[b]AB=抗生素；（-）意味着未加抗生素（+）意味日粮中加入抗生素

Roles of tryptophan
色氨酸的作用

Trp
色氨酸

- fourth-limiting AA
  第四限制性氨基酸
- immune response
  免疫应答
- serotonin
  血清素



色氨酸（可消化的）
Tryptophan (digested)

可消化的66%
66% of digested[1]

[1]Heger et al. (2002)

Body protein deposition (PD) 机体蛋白的沉积

5%　95%

血清素 **Serotonin**

褪黑素 **Melatonin**

Indoleamine 2,3-dioxygenase (IDO; immune cells)
吲哚胺-2,3-双加氧酶
IDO;免疫细胞

色氨酸-2,3-双加氧酶 TDO;肝脏
Trp 2, 3-dioxygenase (TDO; liver)

犬尿氨酸
Kynurenine

犬尿酸
Kynurenic acid

Anthranilic acid
邻氨基苯甲酸

犬尿氨酸-3-单加氧酶
Kynurenine 3-hydroxylase

3-羟基犬尿氨酸
3-Hydroxy kynurenine

Xanthurenic acid
黄尿酸

犬尿氨酸酶
Kynureninse

喹啉酸
Quinolinic acid

CO_2
二氧化碳

烟酸（VB_3）
Niacin (Vit. B_3)

IDO（免疫细胞）是在免疫刺激时在干扰素γ诱导下将色氨酸降解为犬尿氨酸

IDO (immune cells) is induced by cytokine interferon-γ during immune stimulation

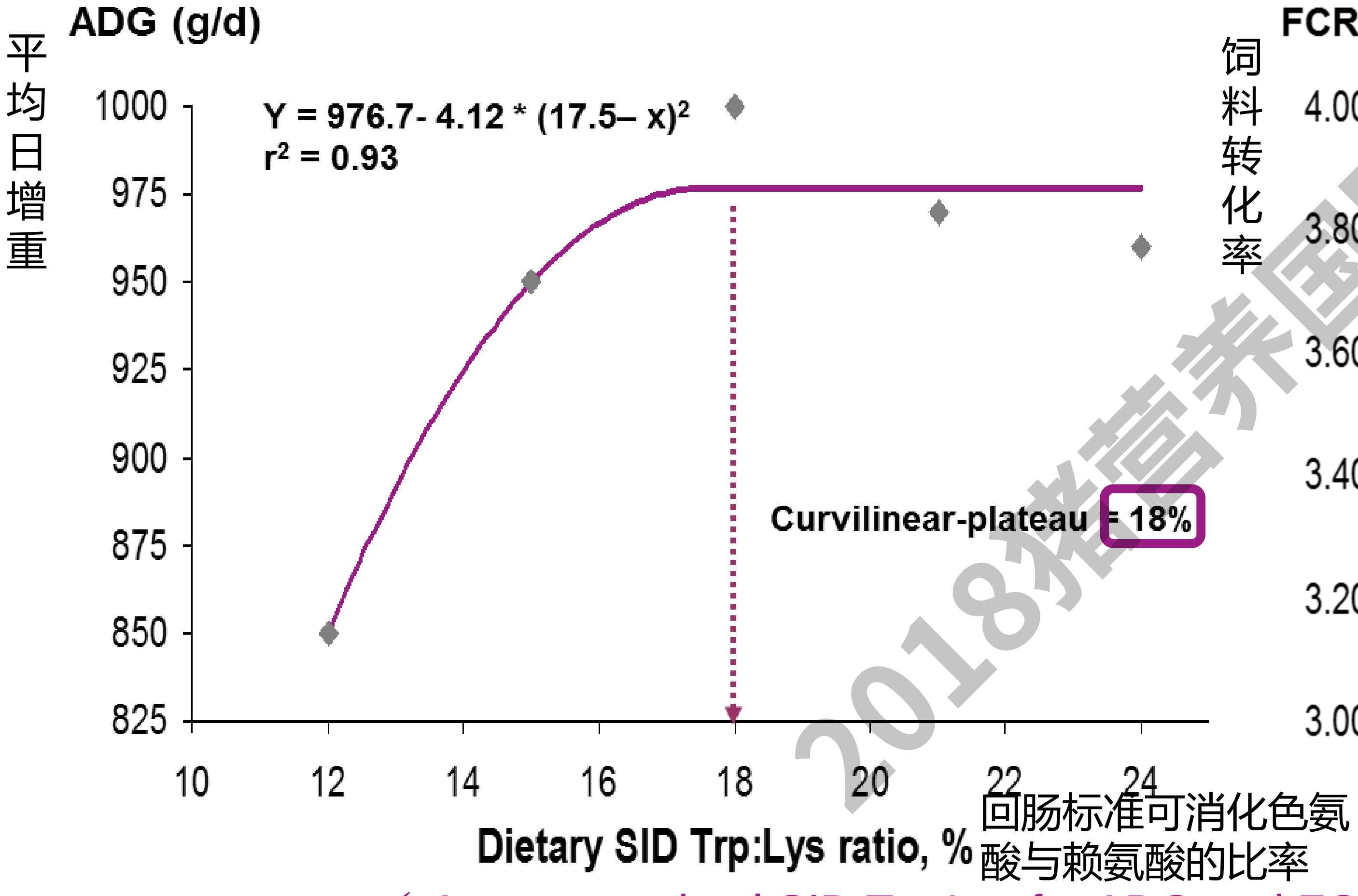
Immune proteins, e.g. haptoglobin, are high in Trp

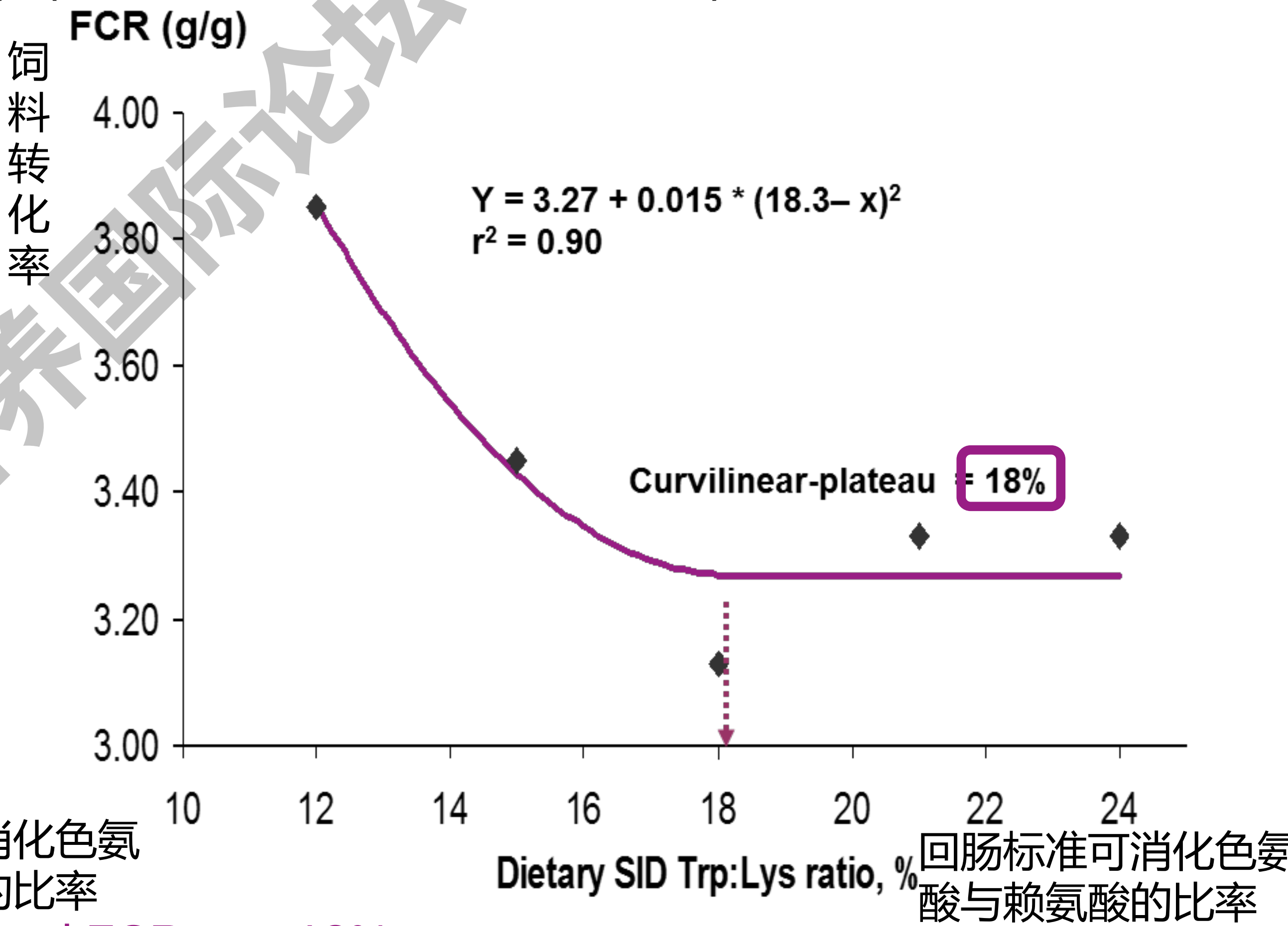
免疫蛋白，如触珠蛋白，其中色氨酸的含量很高

Effect of dietary SID Trp:Lys ratio on performance of 89- to 121-kg pigs fed AGP-free diets under research facility (Ma et al., 2015) **无抗生素生长促进剂日粮中SID色:赖对89-121公斤的商品猪生长性能的影响**

#Corn-wheat bran (AGP-free) based diets (SID Lys = 0.51%; CP = 9.6%); 6 rep (3 gilts) / trt.

基础日粮为玉米-麦麸型（无抗生素生长促进剂）（SID赖氨酸0.51%；粗蛋白9.6%）





✓ Average optimal SID Trp:Lys for ADG and FCR was 18%.
要获得最佳的平均日增重和饲料转化率，回肠标准可消化色氨酸和赖氨酸的比率平均值为18%

Review of optimal SID Trp:Lys ratios for 80-125 kg growing pigs (n=10)

80-125公斤生长猪最佳SID色:赖的研究总结

BW,体重 kg	Sex[a] 性别	Lys 赖氨酸 (SID, %) 回肠标准可消化率	Trp:Lys 色：赖 (SID, %) 回肠标准可消化率	AB[b] 抗生素	Optimal SID Trp:Lys 最佳的SID色:赖 (%)	Reference 文献
55-110	G	0.55	15 to 24	(-)	19	Van der Aar et al. 2012
66-124	M	0.78	15 to 19.5	(-)	19.5	Salyer et al. 2013
67-96	B	0.61	13.1 to 26.2	(-)	22	Xie et al. 2014
80-105	B	0.52	11.5 to 23.1	(-)	19	Guzik et al. 2005
80-115	G	0.56	12.3 to 22.9	(-)	20	Eder et al. 2003
89-114	B	0.55	10.9 to 21.8	(-)	15	Kendall et al. 2007
91-123	B	0.55	13.0 to 23.5	(+)	20	Kendall et al. 2007
99-123	B	0.55	13.0 to 21.0	(-)	17	Kendall et al. 2007
89-121	G	0.51	12 to 24	(-)	18	Ma et al. 2015b
107-125	G	0.75	14.5 to 24.5	(-)	19.8	Goncalves et al. 2015
80-125					19	Average 平均值
75-125					18	NRC, 2012

[a] B = barrows, G = gilts, M = mixed-sex. [a] B = 阉公猪, G = 小母猪, M = 混群

[b]AB = Antibiotics: (-) refers to without AB and (+) means AB was added in the diet.

[b]AB=抗生素；（-）意味着未加抗生素（+）意味日粮中加入抗生素

Roles of branched-chain amino acids (Val, Ile and Leu)
支链氨基酸的作用（缬氨酸，异亮氨酸和亮氨酸）

Val
缬氨酸

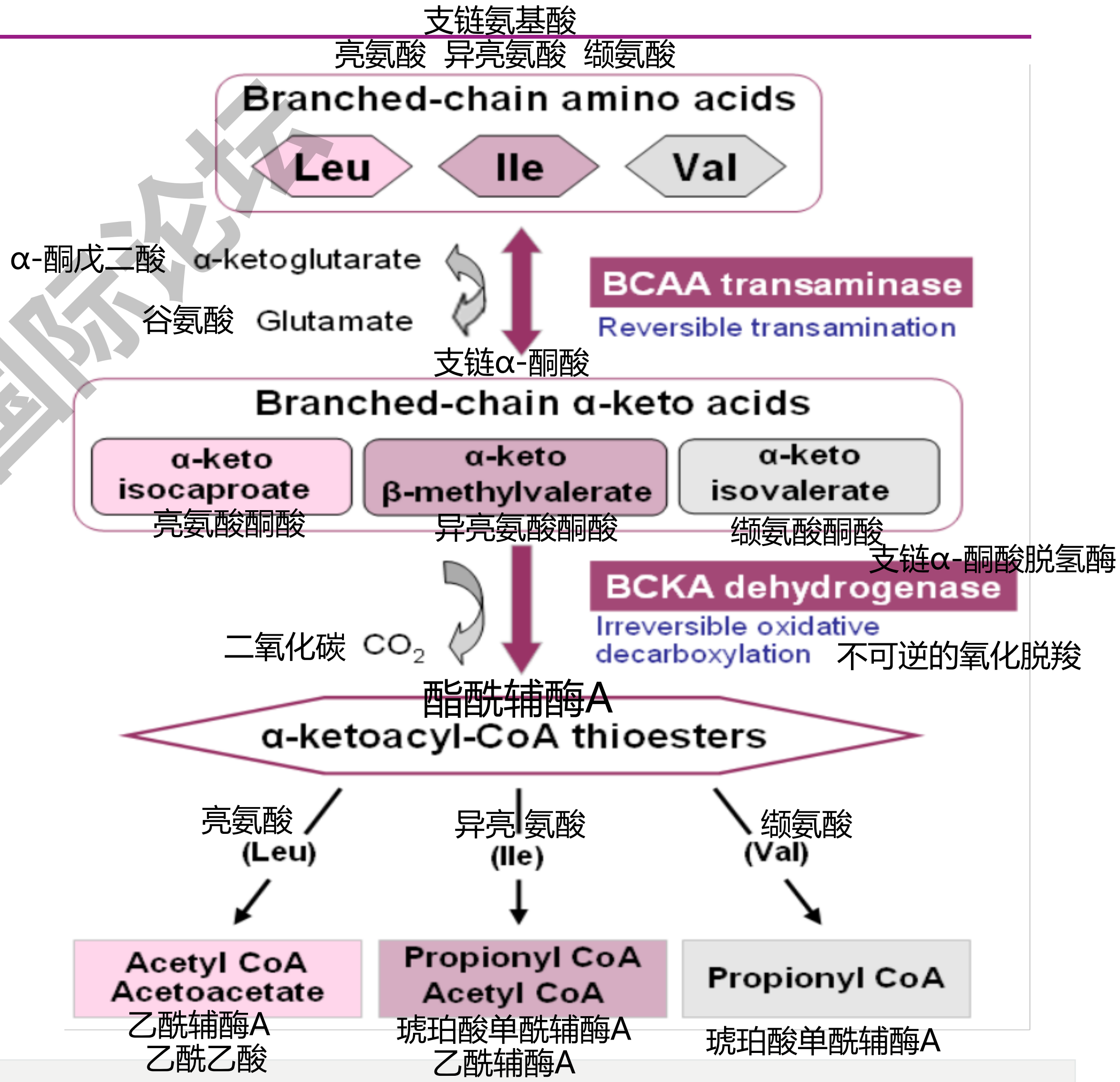
Ile
异亮氨酸

- are 5th and 6th limiting AA 第五第六限制性氨基酸

Leu
亮氨酸

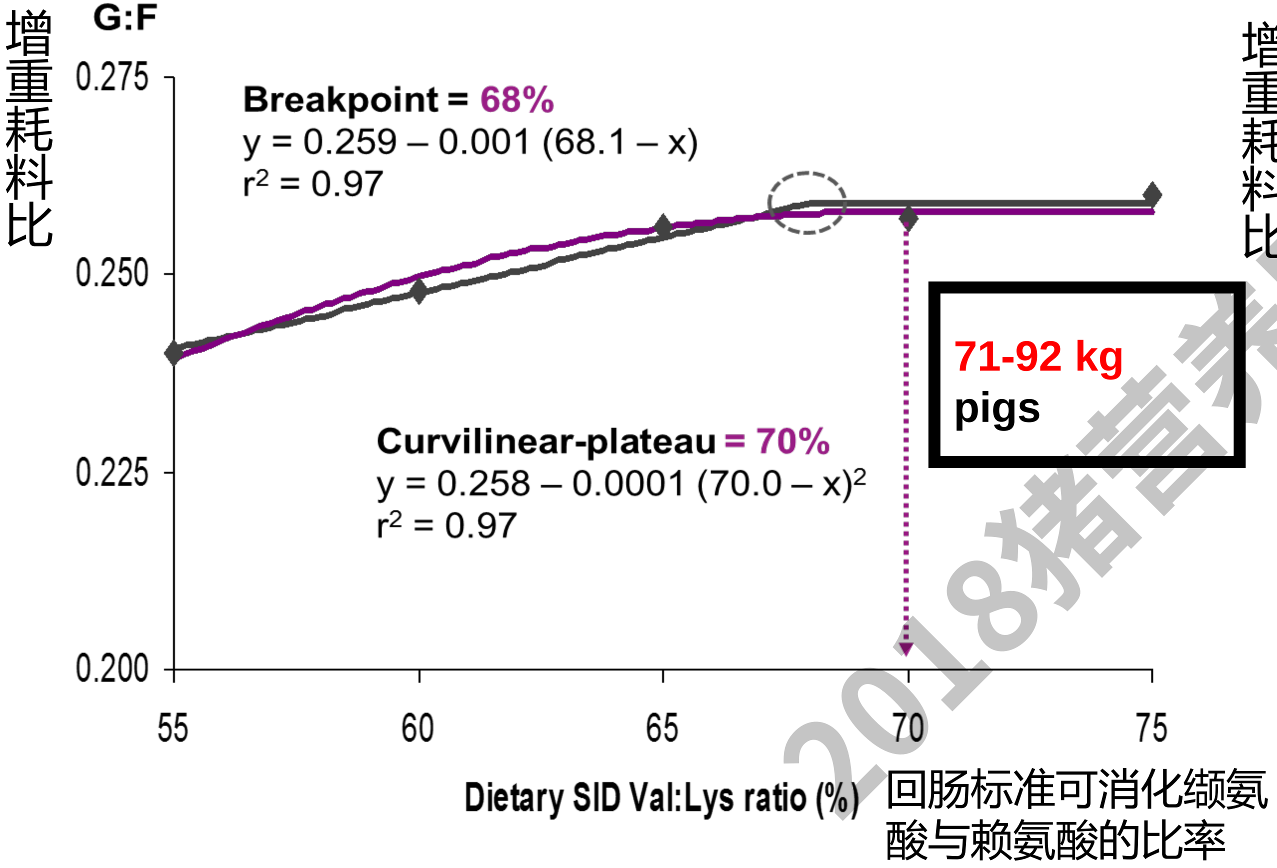
- regulation of muscles protein synthesis
  调控肌肉蛋白的合成

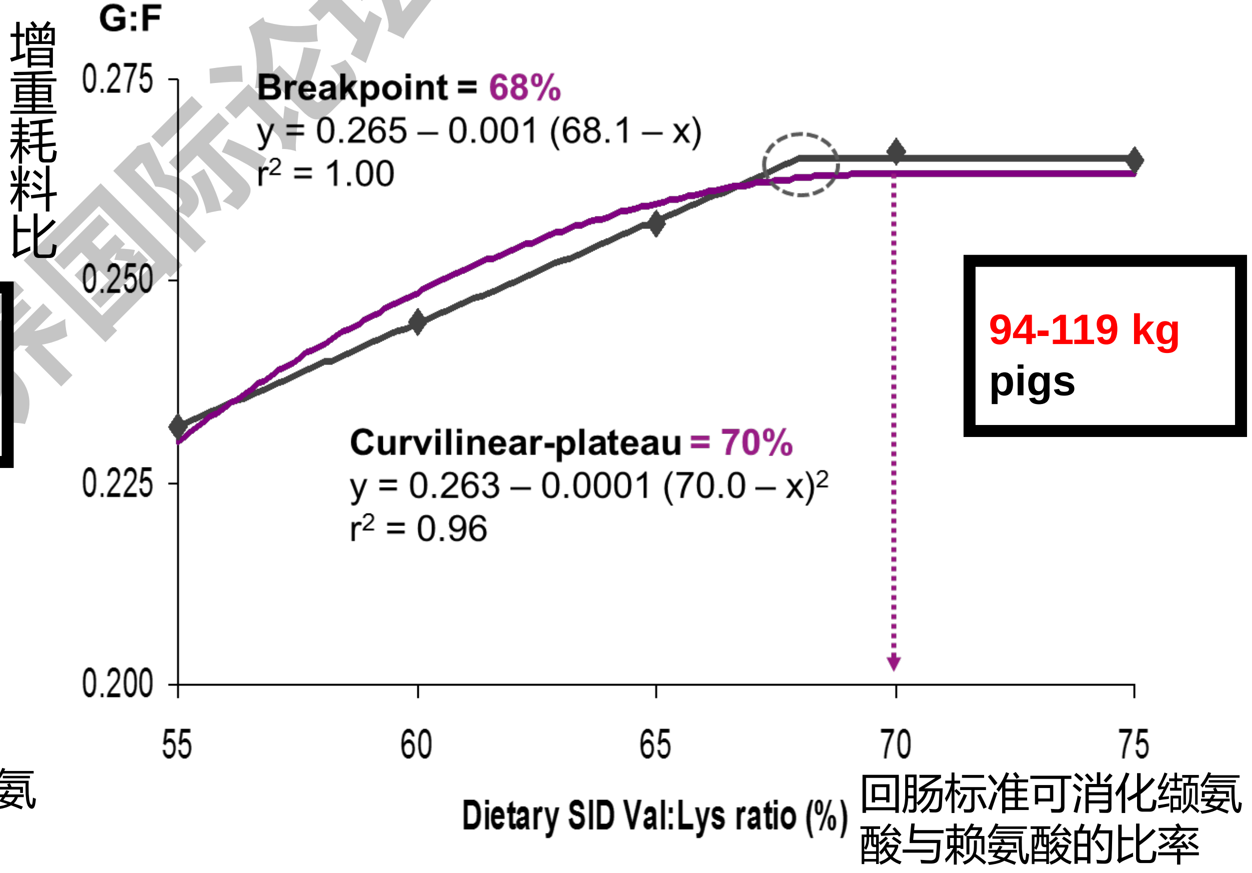
- signaling through activation of mTOR
  通过激活mTOR信号通路而活化肌源卫星细胞
  哺乳动物雷帕霉素靶蛋白(mammalian target of rapamycin,mTOR)



Effect of dietary SID Val:Lys ratio on performance of 71 to 92 kg and 94 to 119 kg pigs fed AGP-free diets under research facility (Liu et al., 2015) **无抗生素生长促进剂日粮中SID缬:赖对71-92公斤和94-119公斤的商品猪生长性能的影响**

#Corn-wheat bran (AGP-free) based diets (SID Lys = 0.71; 0.57%; CP = 9.2; 8.3%); 6 rep (5; 3 pigs) / trt.
基础日粮为玉米-麦麸型（无抗生素生长促进剂）（回肠标准可消化赖氨酸0.71%；0.57%；粗蛋白9.2%；8.3%）





✓ Average optimal SID Val:Lys for G:F of finishing pigs was 69%.
为使育肥猪获得最佳的增重耗料比回肠标准可消化缬氨酸与赖氨酸的比率平均值为69%

Review of optimal SID Val:Lys and Ile:Lys ratios for 80-125 kg pigs

80-125公斤生长猪最佳SID缬:赖及SID异亮:赖的研究总结

BW 体重 kg	Sex[a] 性别	SDBC[b] 喷雾干燥血球	Lys 赖氨酸 (SID, %) 回肠标准可消化率	Leu:Lys 亮：赖 (SID, %) 回肠标准可消化率	Optimal ratio 最佳比率 %	Reference 引用
					SID Val:Lys, % SID缬:赖	
71-92	M	0	0.61	128	70	Liu et al., 2015
94-119	M	0	0.51	141	70	Liu et al., 2015
75-125					65	NRC, 2012
					SID Ile:Lys, % SID异亮:赖	
97-122	M	0	0.52	148	53	Fu et al., 2005
90-120	B	3.9	0.52	238	60	Fu et al., 2005
75-125					53	NRC, 2012

[a] B = barrows, M = mixed-sex; [b]SDBC = spray-dried blood cells.
[a]B=阉公猪，M=混群；[b]SDBC=喷雾干燥血球

Summary on SID Lys and optimal AA:Lys ratios for 80-115 kg pigs
80-115公斤的猪最佳的SID赖氨酸及SID氨基酸:赖氨酸总结

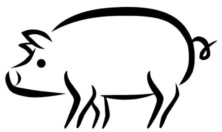
BW 体重	SID Lys SID赖氨酸	SID Lys SID赖氨酸	Thr:Lys 苏：赖	SAA:Lys 含硫氨：赖	Trp:Lys 色：赖	Val:Lys 缬：赖	Ile:Lys 异亮：赖	Leu:Lys 亮：赖
kg	% diet %日粮中	mg/g ADG mg/g日增重	SID, %	SID, %	SID, %	SID, %	SID, %	SID, %
Literature 文献	0.73	21.5	68	61	19	70	53-60	107
Evonik	0.72		70	65	19	68	55-60	100

- Lysine requirement has increased over the years for today’s high lean pigs.
  随着现在高瘦肉生产能力的高瘦肉型育肥猪的猪增加，猪对赖氨酸的需求也越来越高。
- These values could be used for applying the “Ideal Protein” concept for AGP-free feed formulation.
  这些数据可以结合“理想蛋白质”理念应用在无抗生素生长促进剂的饲料配方中。

Effects of NE and SID Lys concentrations on performance and carcass traits of 60-100 kg finishing pigs (Htoo and Morales, 2017)

净能值和回肠标准可消化赖氨酸对60-100公斤的育肥猪生长性能和胴体品质的影响

- o 288 pigs (PIC GP1050; initial BW 59.2 ± 0.44 kg)
  288头猪（PIC GP1050;初始体重59.2 ± 0.44 kg）
- o Duration: 45 days 试验时间：45天
- o 6 replicates (3 barrows and 3 gilts/pen)/ treatment
  每个处理6个重复（三组阉公猪三组小母猪）
- o 6 diets based on corn, SBM, wheat bran 基础日粮均为玉米-豆粕-麦麸型
  - *2 x 3 factorial design 2x3 多因素设计*



SID Lys, % 回肠标准可消化赖氨酸	NE, MJ/kg 净能 MJ/kg	NE, Mcal/kg 净能 Mcal/kg
0.70%	9.40	2.25
	9.75	2.33
	10.10	2.41
0.80%	9.40	2.25
	9.75	2.33
	10.10	2.41

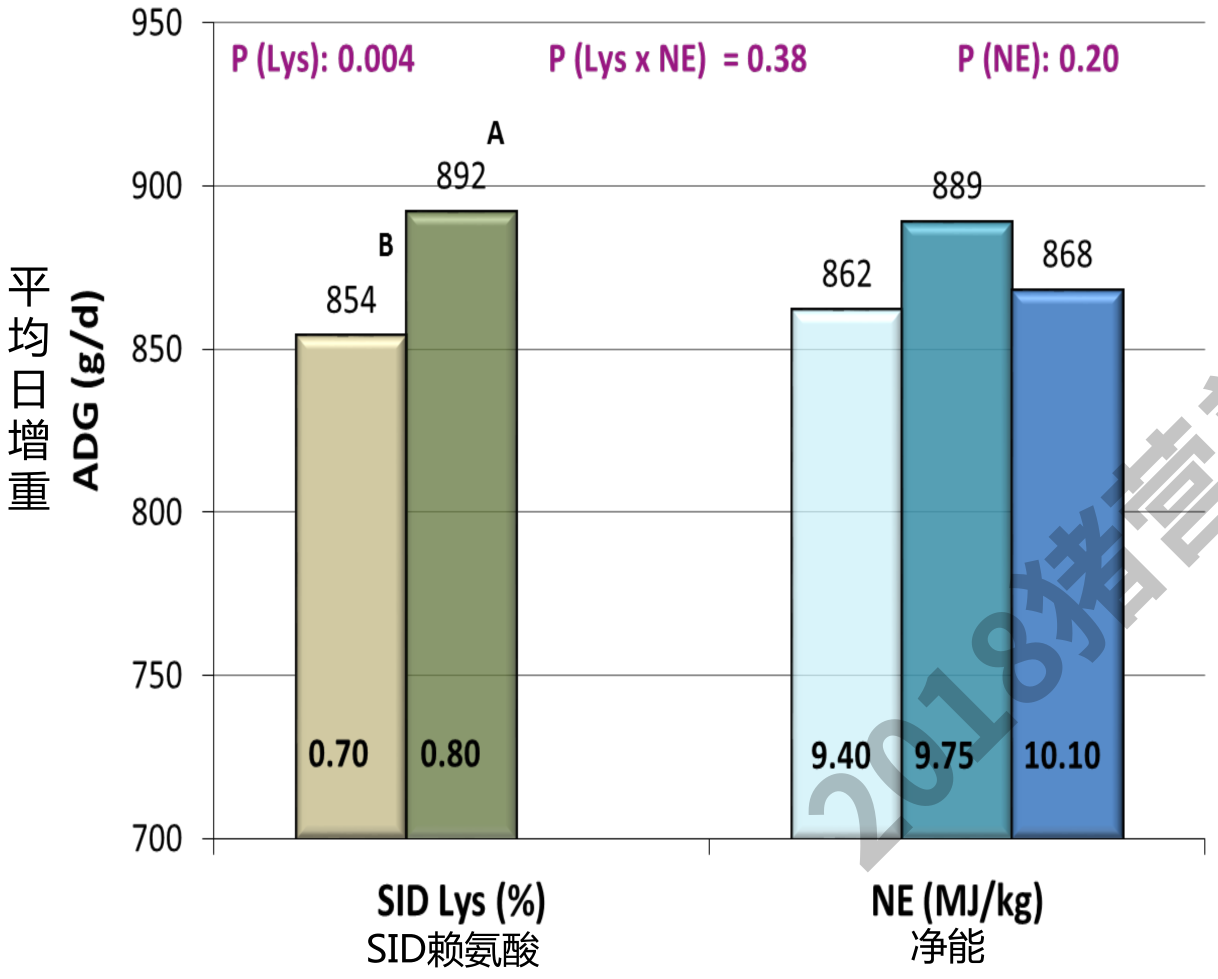
- Corn was increased to increase NE replacing wheat bran 用玉米替代麦麸来提高净能值

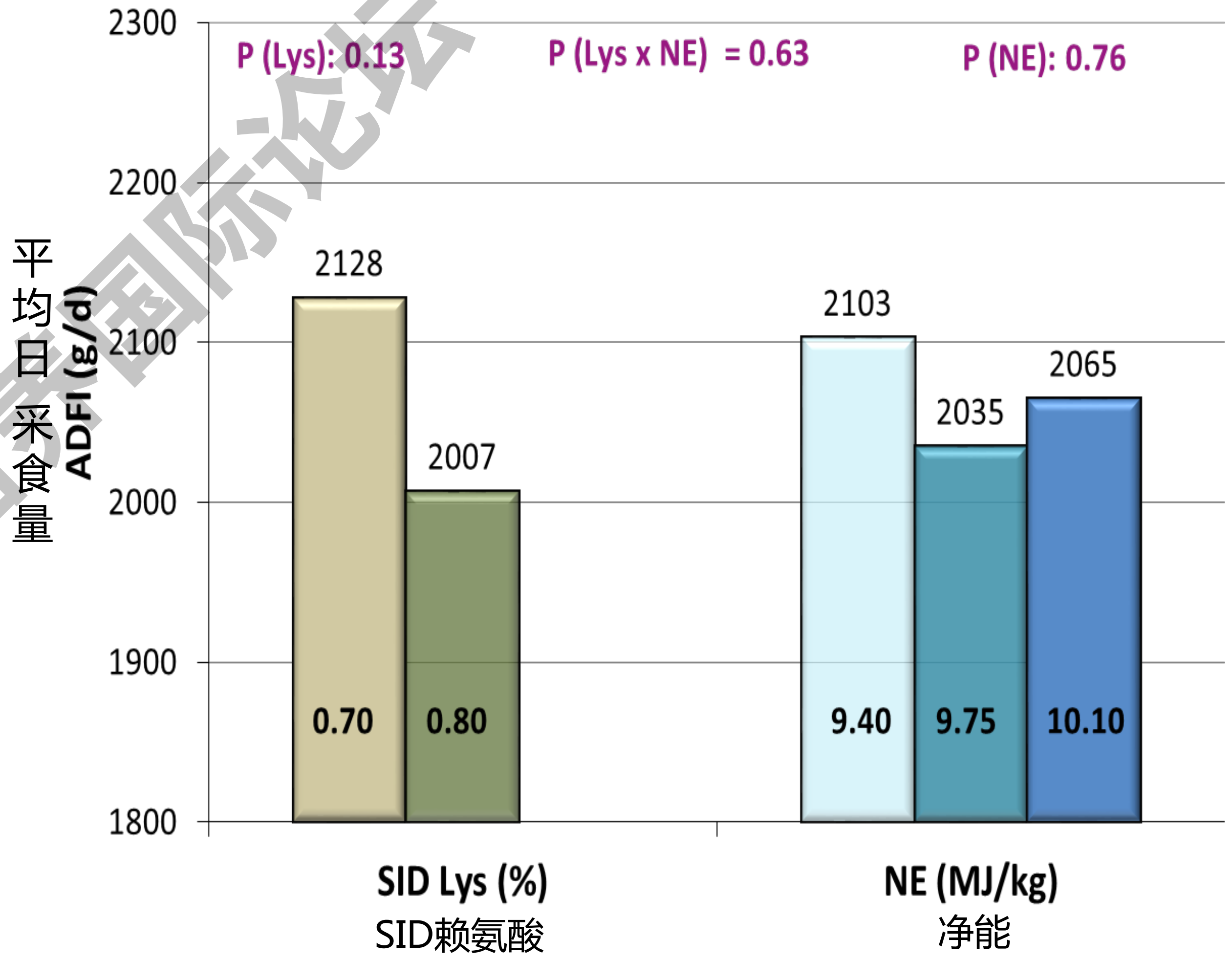
		育肥猪
原料	Ingredients	Finisher
玉米	Corn	66.55
豆粕	Soybean meal	11.06
麦麸	Wheat bran	20.00
磷酸二氢钙，石粉，盐 预混料	DCP, $CaCO_3$, salt, premix	1.93
L-赖氨酸盐酸盐	L-Lys.HCl	0.263
DL-蛋氨酸	DL-Met	0.071
L-苏氨酸	L-Thr	0.110
L-色氨酸	L-Trp	0.011
净能	NE (MJ/kg)	9.40
粗蛋白	CP, %	14.12
SID赖氨酸	SID Lys, %	0.70
SID蛋氨酸	SID Met, %	0.26
SID蛋氨酸+半胱氨酸	SID Met + Cys, %	0.47
SID苏氨酸	SID Thr, %	0.50
SID色氨酸	SID Trp, %	0.14
SID异亮氨酸	SID Ile, %	0.43
SID缬氨酸	SID Val, %	0.52
总赖氨酸	*Total Lys, %*	0.84 (0.85*)
总能	*GE, MJ/kg*	16.39*

*Analyzed values.

*分析值

Effects of NE and SID Lys concentrations on ADG and ADFI of 60-100 kg finishing pigs (Htoo and Morales, 2017) 净能和SID赖氨酸对60-100公斤的育肥猪平均日增重和平均日采食量的影响

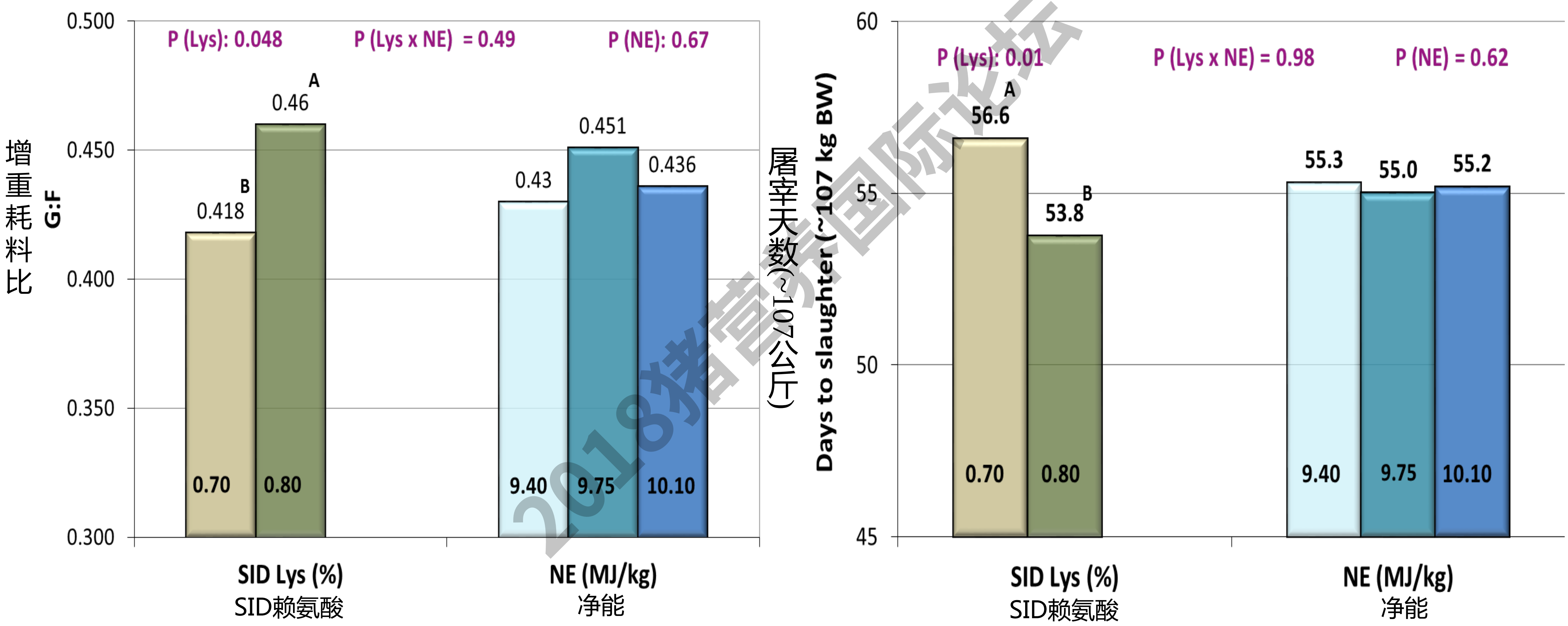




Effects of net energy concentrations on performance and carcass traits of finishing pigs

Effects of NE and SID Lys concentrations on G:F and grow-out days to slaughter of 60-100 kg finishing pigs (Htoo and Morales, 2017)

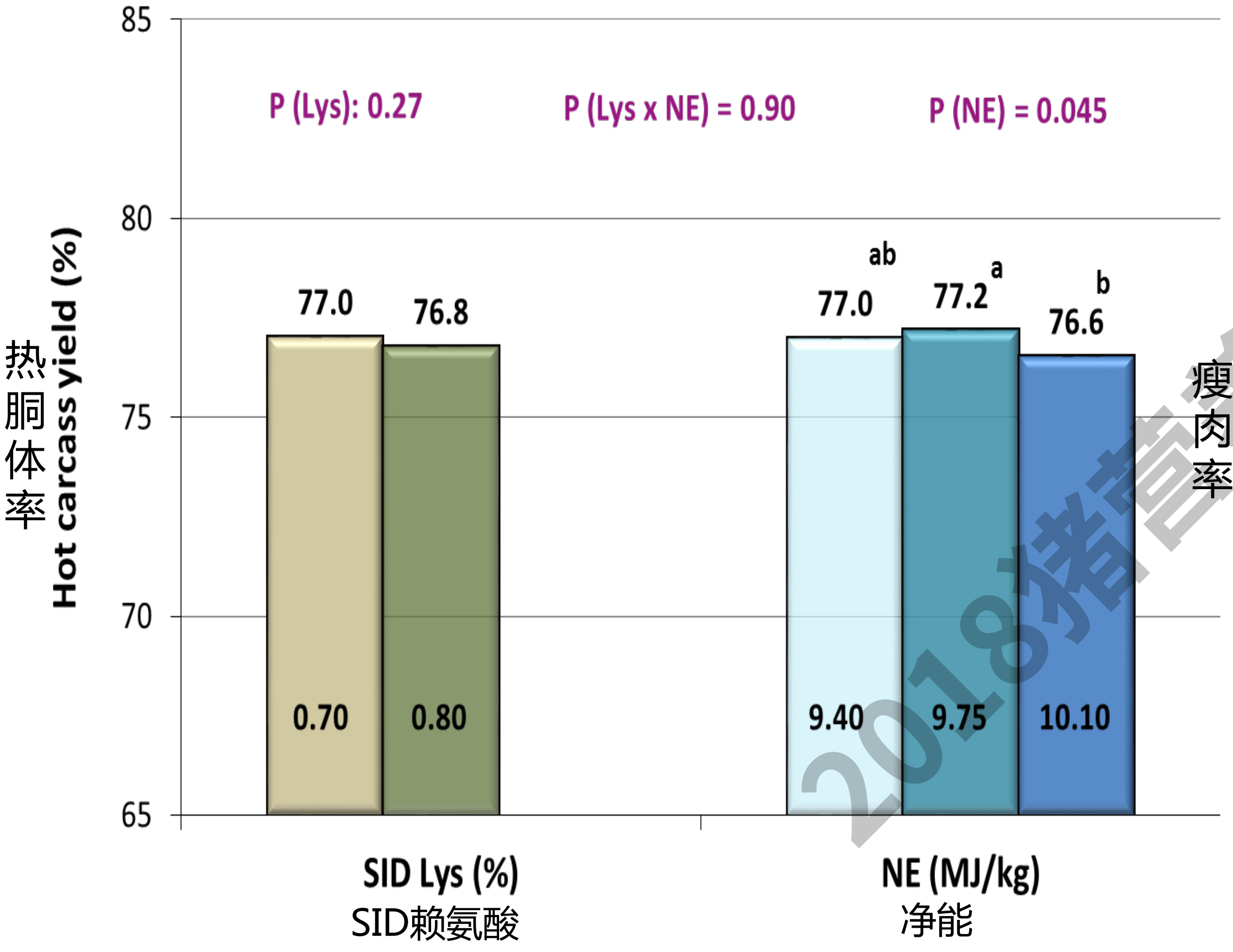
净能和SID赖氨酸对60-100公斤的育肥猪增重耗料比和屠宰天数的影响

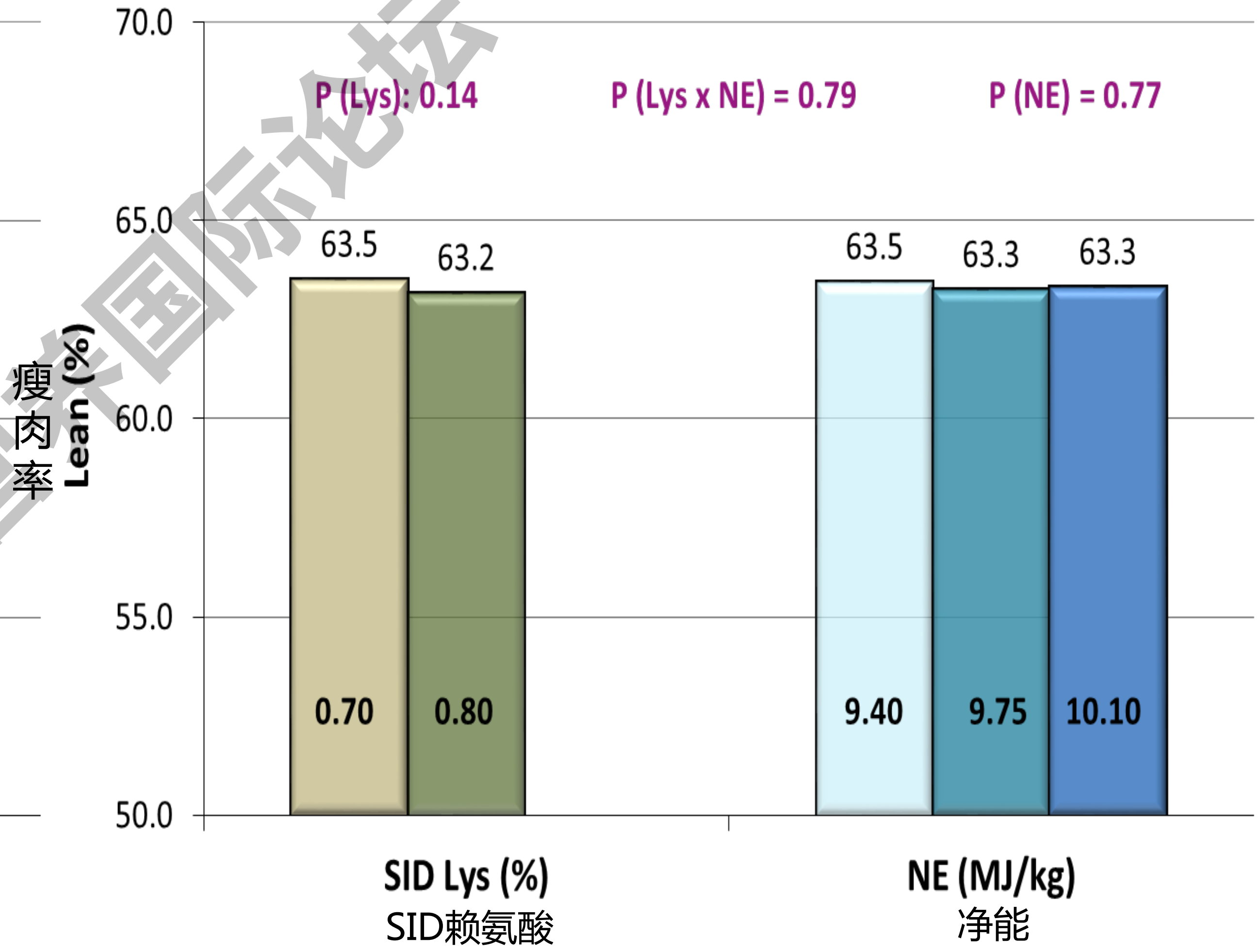


Effects of net energy concentrations on performance and carcass traits of finishing pigs

Effects of NE and SID Lys concentrations on hot carcass yield and lean % of 60-100 kg finishing pigs (Htoo and Morales, 2017)

净能和SID赖氨酸对60-100公斤的育肥猪热胴体率和瘦肉率的影响

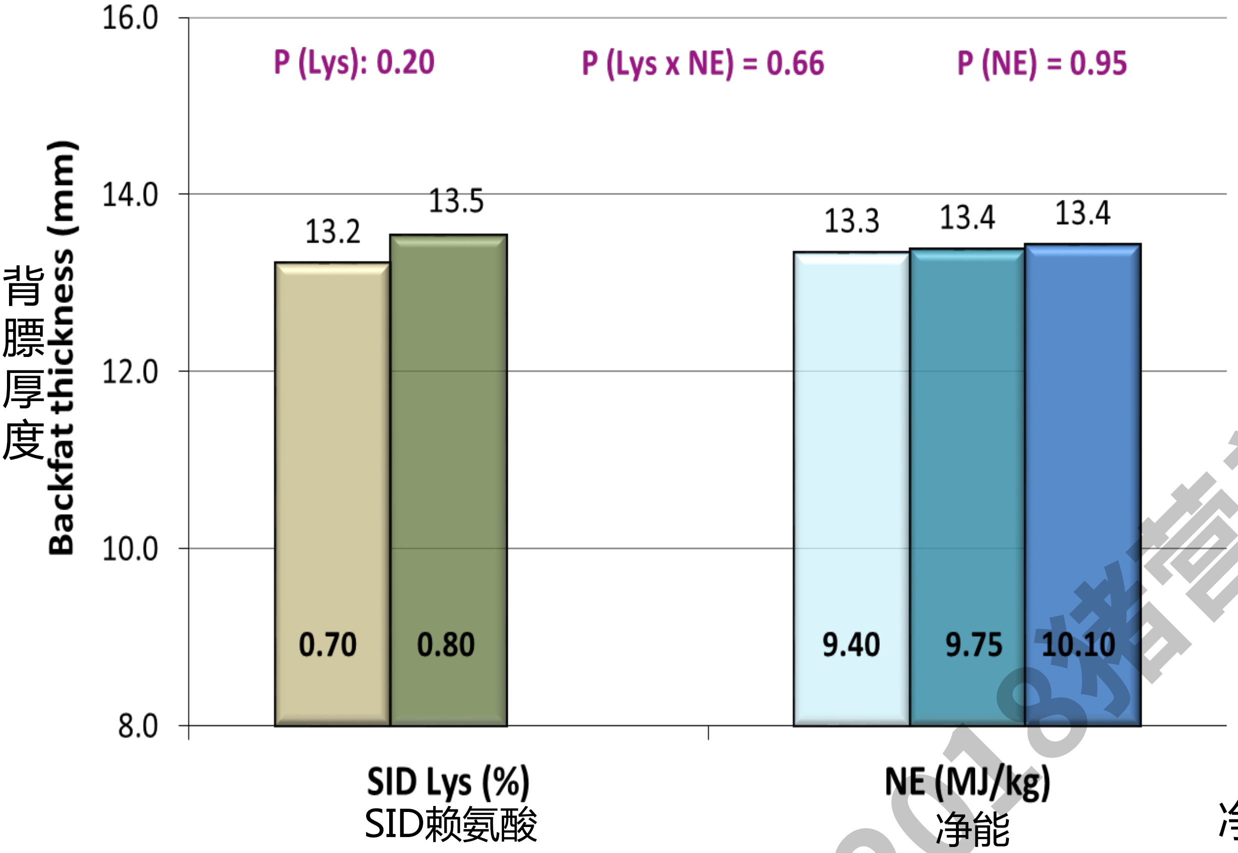




Effects of net energy concentrations on performance and carcass traits of finishing pigs

Effects of NE and SID Lys concentrations on backfat thickness and energy utilization efficiency of 60-100 kg finishing pigs (Htoo and Morales, 2017)

净能和SID赖氨酸对60-100公斤的育肥猪背膘厚度和能量利用率的影响



A greater Lys supply improves energy utilization efficiency

随着赖氨酸含量的增加能量利用率会提高

	SID赖氨酸 SID Lys (%)		净能 NE (MJ/kg)			P-值 *P-values*		
	0.70	0.80	9.40	9.75	10.10	*Lys*	*NE*	*Lys x NE*
NE, MJ/kg gain 净能/增重	24.3	22.1	23.0	22.4	24.1	0.06	0.452	0.53

✓ Performance and carcass yield of 60-100 kg pigs maximized at 0.80 % SID Lys and 9.75 MJ/kg NE.

为使60-100公斤的育肥猪有最佳的生长性能和胴体率，饲粮中SID赖氨酸应为 0.80 % ，净能值为9.75 MJ/kg

Review of optimal dietary net energy concentration of finishing pigs
育肥猪日粮最佳的净能值的研究综述

BW 体重 kg	SID Lys SID赖氨酸 %	NE 净能 MJ/kg	ADFI 日采食量 g/d	ADG 日增重 g/d	G:F 增重耗料比 g/g	Carcass 胴体重 kg	Back fat 背膘 mm	Lean 瘦肉率 %	Opt. NE 最佳净能值 MJ/kg	Opt. NE 最佳净能值 kcal/kg	Reference 引用
69-95	0.66	9.87	2400[1]	760[1]	0.32	65.7	19.0	57.3[3]	**9.87**	**2359**	Chen et al., 2011
	0.66	10.13	2370	760	0.32[t]	65.6	19.5	55.6			
	0.67	10.46	2330	710	0.3	66.3	21.9	55.4			
	0.67	10.79	2280	720	0.32	65.9	20.5	53.7			
	0.67	11.05	2240	680	0.31	65.3	20	53.0			
62 - 101	0.69	9.41	2420	810	0.33	72.4	20.2	48.1	**9.83**	**2349**	
	0.67	9.62	2360	810	0.34	72.2	20.3	47.9			
	0.66	9.83	2360	870[2]	0.37[2]	78.1	17.7	49			
	0.68	10.04	2330	860	0.37	76.3	17.4[2]	49.4[2]			
	0.69	10.25	2370	820	0.35	74.7	19.8	48.1			

[t] Tendency (0.05<P<0.10); [α] Average value; [1] Linear effect (P<0.05); [2] Quadratic effect (P<0.05); [3] Linear and quadratic effects (P<0.05).
[t] 趋势(0.05 < P < 0.10);α)平均值;[1]线性效应(P < 0.05);[2]二次效应(P < 0.05);[3] 线性和二次效应(P<0.05)。

Effects of net energy concentrations on performance and carcass traits of finishing pigs

Review of optimal dietary net energy concentration of finishing pigs (Contin.)
育肥猪日粮最佳的净能值的研究总结

BW 体重	SID Lys SID赖氨酸	NE 净能	ADFI 日采食量	ADG 日增重	G:F 肉料比	Carcass 胴体重	Back fat 背膘	Lean 瘦肉率	Opt. NE 最佳净能值		Reference
kg	%	MJ/kg	g/d	g/d	g/g	kg	mm	%	MJ/kg	kcal/kg	引用
63 - 99	0.75^{α}	9.83	2471	853^{b}	0.35^{a}						Zhang et al., 2011
	0.77^{α}	10.04	2433	903^{a}	0.37^{b}				**10.04**	**2400**	
	0.79^{α}	9.83	2512	918^{a}	0.37^{b}						
60 - 100	0.70	9.40	2167	846^{ab}	0.41	83.3	13.3	63.6			Htoo and Morales, 2017
	0.70	9.75	2048	879^{ab}	0.45	83.3	13.3	63.3			
	0.70	10.10	2169	837^{b}	0.4	83.0	13.1	63.6			
	0.80	9.40	2039	878^{ab}	0.45	81.8	13.4	63.3			
	0.80	9.75	2022	899^{a}	0.46	82.7	13.5	63.2	**9.75**	**2330**	
	0.80	10.10	1961	899^{a}	0.47	81.8	13.7	63.1			
60-100								**平均值 Average**	**9.9**	**2366**	
								NRC, 2012	**10.38**	**2480**	

✓ Energy need for body fat deposition is 1.7 times greater than for protein deposition (Ewan, 2001).
同样单位的体脂沉积需要的能量是蛋白沉积所需的1.7倍。

Lowering dietary CP level improves energy utilization efficiency
低蛋白日粮可以提高能量利用率

Noblet et al. (1994)

总能
Gross Energy (100 %)

DE:GE 82% → 粪能 Fecal Energy (18%)

消化能
Digestible Energy (82%)

ME:DE 96% → Urine (3%) 尿 → Methane (0.3%) 甲烷

代谢能
Metabolizable Energy (78.7%)

NE:ME 74% → 热增耗 Heat prod. (20.5%)

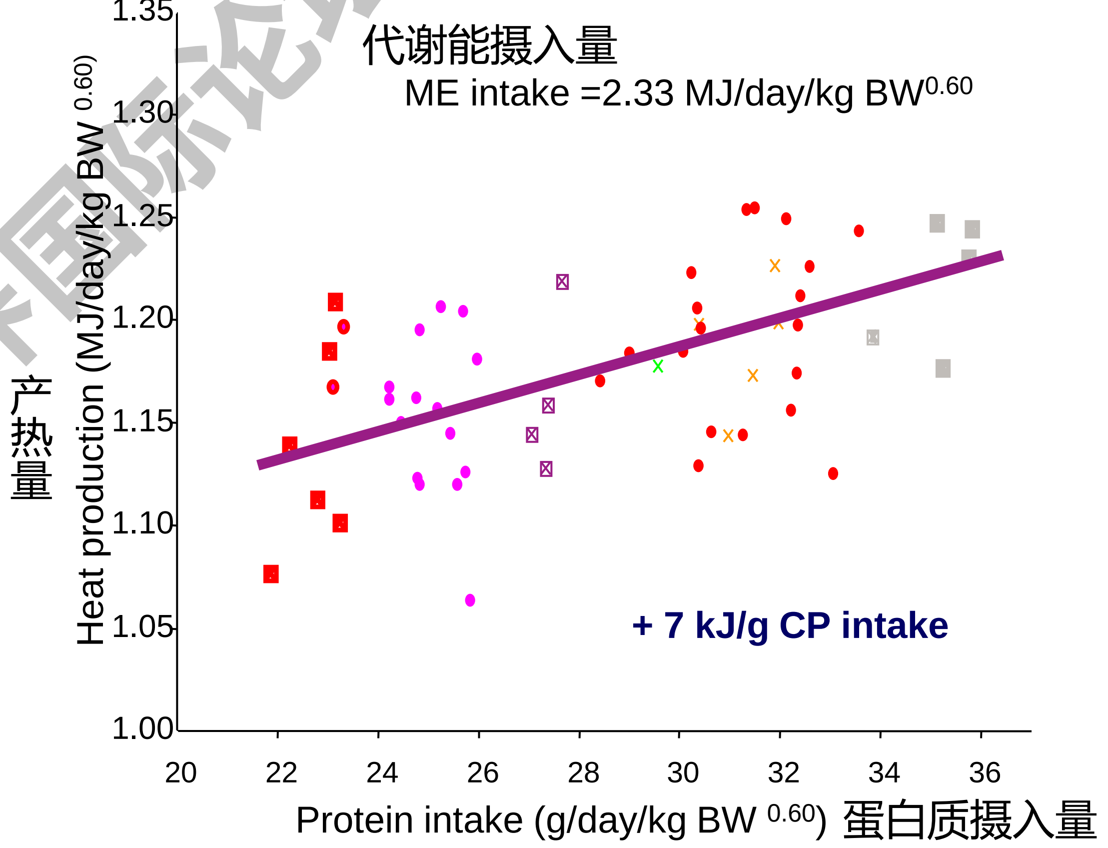
净能
Net Energy (58.2%)

代谢不同营养物质时净能与代谢能的比值

Efficiency of metabolic utilization of ME for NE

	Protein, Fiber 蛋白质，纤维	Starch 淀粉	Fat 脂肪
NE:ME, %	60	82	90

Le Bellego et al. (2001)



Increased fat deposition can be prevented by balancing the same SID Lys:NE.
通过平衡回肠标准可消化赖氨酸和净能的比值可以阻止脂肪的沉积。

Effect of reducing CP on performance and carcass of 69-97 kg pigs (Chen et al., 2011)

降低蛋白对69-97公斤的猪生长性能和胴体品质的影响

CP, % 粗蛋白	Ingredient 原料	NE, MJ/kg 净能	SID Lys, % 回肠标准可消化赖氨酸	SID EAA	EAA added 添加的必需氨基酸	SID Lys:CP**, % SID赖氨酸：粗蛋白
16.0	Corn, SBM 玉米，豆粕	**10.46**	0.70	Adeq.	-	4.4 (5.3)
12.0	Corn, SBM 玉米，豆粕	**10.46**	0.67	Adeq.	4	5.6 (6.5)
11.2	Corn, SBM, WB*玉米豆粕麦麸	**10.13** (97%)	0.66	Adeq.	4	5.9 (6.8)
11.9	Corn, SBM, WB*玉米豆粕麦麸	**9.83** (94%)	0.66	Adeq.	4	5.5 (6.5)

*Wheat bran (12.5%); ** total Lys:Lys ratio in parenthesis. *麦麸（12.5%）**括号里数值为总赖氨酸与赖氨酸的比率。

NE, MJ/kg 净能	**10.46**	**10.46**	**10.13**	**9.83**
CP, % 粗蛋白	**16.03**	**12.00**	**11.22**	**11.91**
Feed intake, kg/d 采食量	2.34	2.33	2.37	2.40
ADG, kg/d 平均日增重	0.75	0.71	0.76	0.76
G:F, g/g 肉料比	0.32	0.30	0.32	0.32
Gain:NE intake, kg/Mcal 增重：摄入净能	0.13[a]	0.12[ab]	0.14[a]	0.13[a]
Dressing, % 屠宰率	69.4	70.5	69.3	69.5
Carcass lean, % 胴体瘦肉率	56.0	55.4	55.6	57.3
Total fat, % 总脂肪含量	25.4	26.2	25.4	24.8

[a,b] Within a row, values with different letters are different (*P* < 0.05). 同一行数值上角标字母不同表示差异显著（P < 0.05）

Review: effects of feeding low CP, AA-supplemented diets on the performance and carcass traits of finishing pigs 总结：添加氨基酸的低蛋白日粮对育肥猪生长性能和胴体品质的影响

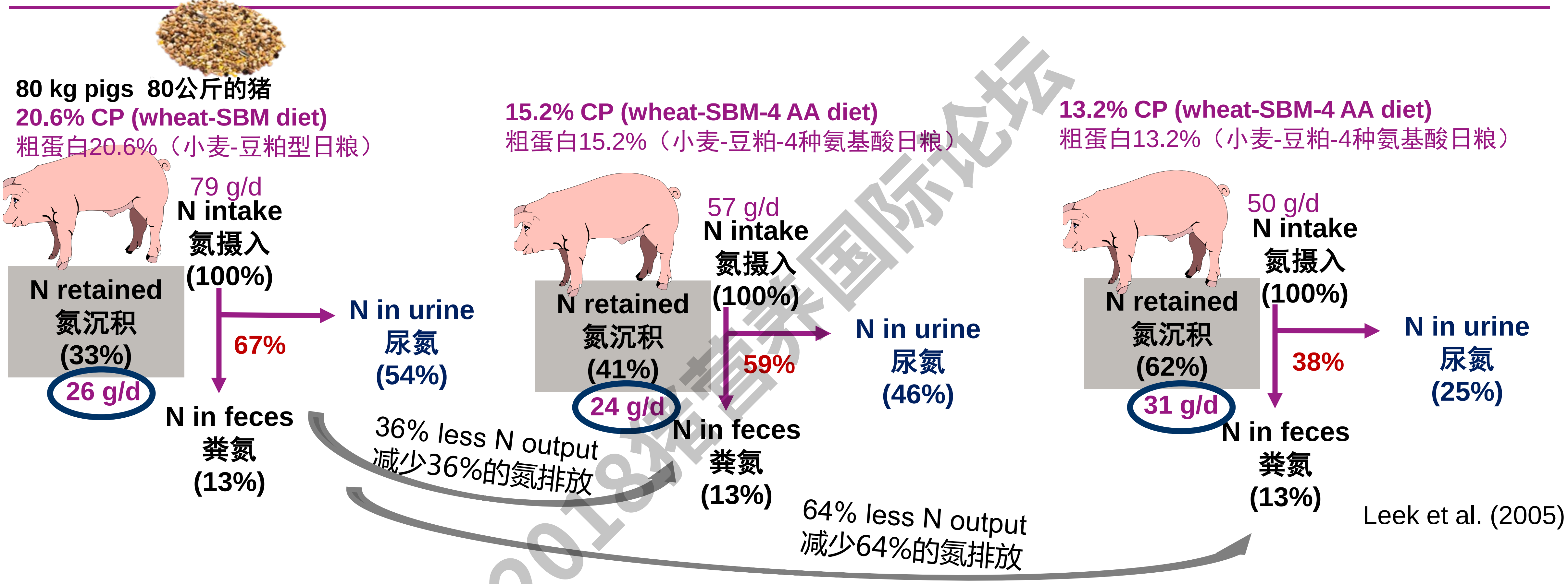
BW 体重	Dietary CP % 日粮粗蛋白%		Energy 能量	Lys 赖氨酸	LP performance(relative to HP)[†] 相较于饲喂高蛋白，饲喂低蛋白日粮的生长性能				Reference 引用
kg	HP 高蛋白	LP 低蛋白	MJ/kg	SID, % 回肠标准可消化率	ADG, g 日增重	FCR 饲料转化率	Dres.% 屠宰率	BF，cm 背膘	
69-95	16.0	12.0	10.5 NE	0.67	-40	+0.16	+1.10	+0.80	Chen et al., 2011
		11.2	10.1 NE	0.66	+10	+0.00	-0.10	0.00	
		11.9	9.9 NE	0.66	+10	+0.04	+0.10	-0.60	
68-95	16.2	13.7	13.6 ME	0.75	+11	+0.07	+0.00	+0.48[§]	Rodrigues et al., 2012
70-100	18.0	13.5	13.5 ME	0.81	-36	-0.01	+0.93	-0.46	Vidal et al., 2010
83-173	12.0	9.8	13.2 ME	0.65[a]	+21	+0.03	+0.60	+0.30	Galassi et al., 2010
75-120	12.6	9.1	11.3 NE	0.64[a]	0	-0.15	-1.30		Knowles et al., 1998
77-108	15.2	12.1	11.1 NE	0.75[a]	-50	+0.12	+0.20		
85-119	13.4	9.7	13.9 ME	0.54	-50	+0.20	+1.70		Dean et al., 2007
	13.3	9.5	13.8 ME	0.54	+60	-0.03	+1.20		

✓ Increase in backfat thickness of pigs may be due to more efficient energy utilization with low CP diet.
或许低蛋白日粮具有更高的能量利用率，使得一部分剩余能量以体脂的形式沉积下来,背膘厚度增加。

Effects of low CP, AA-supplemented diets on feed cost and N excretion of finishing pigs

Excess dietary of CP is the main cause for N pollution (Leek et al., 2005)

日粮中过量的添加蛋白，是引起氮污染的主要原因



- Partial replacing of protein sources with AA improves N utilization.用氨基酸部分替代蛋白原料可以提高氮的利用率。
- 1%-point CP reduction results about 9% reduction in N output. 降低1%的粗蛋白大约降低9%的氮排放。

Effect of reducing dietary CP level on the cost of finisher pig diets (Vidal et al., 2010)

降低日粮中蛋白水平对育肥猪饲料成本的影响(Vidal 等人, 2010)

		Dietary CP, %			
原料	Ingredients, %	17.95	16.45	14.95	13.45
玉米	Corn	70.844	70.844	70.844	70.844
豆粕	Soybean meal	26.696	22.897	18.915	14.905
大豆油	Soy oil	0.263	0.263	0.263	0.263
玉米淀粉	Corn starch	0.000	2.847	5.779	7.963
豆皮	Soy hulls	0.000	0.623	1.276	1.933
L-赖氨酸盐酸盐	L-Lys.HCl	0.00	0.120	0.246	0.372
L-苏氨酸	L-Thr	0.00	0.002	0.068	0.134
DL-蛋氨酸	DL-Met	0.00	0.009	0.054	0.099
L-色氨酸	L-Trp	0.00	0.00	0.007	0.030
L-缬氨酸	L-Val	0.00	0.00	0.00	0.018
其他	Others[a]	2.197	2.395	2.550	3.355
代谢能	ME (kcal/kg)	3230	3230	3230	3230
粗蛋白	CP, %	17.95	16.45	14.95	13.45
SID赖氨酸	SID Lys, %	0.81	0.81	0.81	0.81
SID蛋氨酸+半胱氨酸	SID Met + Cys	0.54	0.54	0.54	0.54
SID苏氨酸	SID Thr, %	0.60	0.60	0.60	0.60
SID色氨酸	SID Trp, %	0.19	0.19	0.19	0.19
SID缬氨酸	SID Val, %	0.76	0.76	0.76	0.76
成本	Cost ($/MT)[b]	239.09	231.28	225.6	221.59
节约	Saving ($/MT)		7.81	13.49	17.50

} 13.5 MJ/kg

[a] Includes di-Ca-phosphate, limestone, salt and min-vit premix, inert and antibiotics.

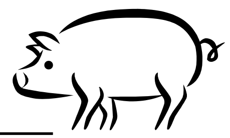
a包括磷酸二氢钙，石粉，盐，维生素预混料，惰性载体和抗生素。

[b] Based in ingredients prices (FeedInfo; July 2018) and L-Val price of 5.9 US$/kg.

b根据2018年7月原料价格的反馈信息，缬氨酸的价格为5.9 US$/kg。

Effects of low CP, AA-supplemented diets on feed cost and N excretion of finishing pigs

Effect of reducing dietary CP level on income over feed cost and N excretion (70-100 kg pigs; Vidal et al. 2010) 降低日粮蛋白对利润和氮排放的影响(70-100 kg的猪; Vidal等，2010)



	Dietary CP, % 日粮粗蛋白，%			
	17.95	16.45	14.95	13.45
Performance 生长性能				
Final BW, kg 末重	102.1	102.0	104.7	101.4
ADG, kg/d[NS] 平均日增重	1.05	1.04	1.12	1.02
ADFI, kg/d[NS] 平均日采食量	3.13	2.82	3.09	3.01
FCR[NS] 饲料转化率	3.01	2.72	2.76	2.99
Carcass traits 胴体品质				
Carcass yield, %[NS] 屠宰率	69.59	70.19	69.57	70.25
Lean meat, %[NS] 瘦肉率	57.01	56.9	57.13	56.93
Backfat, mm[NS] 背膘	14.24	13.5	13.37	13.78
Feed cost/pig, $ (70-100 kg) **饲料成本/头猪**	23.03	20.04	21.55	20.72
Feed cost/kg BW gain 增重成本	0.72	0.63	0.62	0.66
Carcass value, $ (70-100 kg)[a] **胴体价值**	36.74	36.90	39.73	36.26
Income over feed cost/pig, $ 利润	13.71	16.86	18.18	15.53
N-balance 氮平衡				
N intake, kg/pig 氮摄入	2.77	2.28	2.28	2.01
N excretion, kg/pig[b] 氮排出	1.85	1.60	1.35	1.10
N excretion, MT (1000 place[c]) 氮排出，吨（千头猪场）	5.19	4.49	3.79	3.09

[NS] The effect of dietary CP level was not significant (P<0.05); [a] Pig prices (57% lean meat; http://www.schweine.net, 24.04.2018).
[B] Based on 33% N retention in 80 kg pigs (Leek et al., 2005); 9%-pt less N output by 1% CP reduction; [c] 2.8 rotations/year.
[NS]日粮低蛋白水平的影响差异不显著(P<0.05)；[a]猪肉价格 (57% 瘦肉率; http://www.schweine.net, 24.04.2018)；[b]80kg猪的氮沉积按33% (Leek 等人, 2005);降低1%的粗蛋白至少降低9%的氮排放；[c]每年2.8的周转率。

Conclusion and implication
结论与展望

- Lys requirement of today’s high lean finishing pigs has increased over time with increases in lean gain capacity. 随着现在高瘦肉生产能力的高瘦肉型育肥猪的猪增加，猪对赖氨酸的需求也越来越高。

- Optimal AA:Lys ratios are higher than previously assumed values which may be affected by differences in health status associated with AGP ban.氨基酸和赖氨酸的的最佳比例高于先前预估的值，这可能受机体的健康状况和日粮中禁用抗生素生长促进剂的影响。

- Optimal dietary NE content (9.9 MJ/kg) for 60-100 kg high lean pigs is slightly lower partly due to reduced energy need for pigs with less body fat.对于60-100kg高瘦肉型的猪日粮最佳的净能含量为9.9 MJ/kg，有些许的下降，这可能是因为猪的体脂少了对能量的需求也有所降低。

- On average, 1%-unit dietary CP ↓ » ~ 9% ↓ N excretion.通常，猪的日粮降低1%的粗蛋白，氮排出量降低9%。

- Based on current raw materials prices, lowering dietary CP and supplementing with AA up to L-Val in finisher diets can be cost effective. 参照目前的原料价格，通过额外补充L-缬氨酸来降低育肥猪日粮的蛋白水平，是经济有效的。

- Lowering dietary CP and balancing with AA is effective in reducing N excretion. 降低日粮粗蛋白，平衡饲粮中的氨基酸，会有效的减少氮的排放量。

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Any questions?

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