



HAL
open science

Concept and application of ideal protein for pigs

Jaap J. van Milgen, Jean-Yves Dourmad

► **To cite this version:**

Jaap J. van Milgen, Jean-Yves Dourmad. Concept and application of ideal protein for pigs. Chinese Swine Industry Symposium, Oct 2014, Shanghai, China. hal-01210720

HAL Id: hal-01210720

<https://hal.science/hal-01210720>

Submitted on 5 Jun 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



猪理想蛋白的概念及应用

Concept and application of ideal protein for pigs



Jaap VAN MILGEN
Jean-Yves DOURMAD



大纲

Outline

❖ 氨基酸的结构与功能

Structure and roles of amino acids

❖ 理想蛋白

Ideal protein

❖ 氨基酸需要量(生长猪及母猪):

Amino acid requirements for growing pigs and sows:

❖ 试验方法 Experimental methods

❖ 模型推导方法 Model-derived methods

❖ 结论

Conclusions

中国养猪网国际论坛技术资料



大纲

Outline

❖ 氨基酸的结构与功能

Structure and roles of amino acids

❖ 理想蛋白

Ideal protein

❖ 氨基酸需要量(生长猪及母猪):

Amino acid requirements for growing pigs and sows:

❖ 试验方法 Experimental methods

❖ 模型推导方法 Model-derived methods

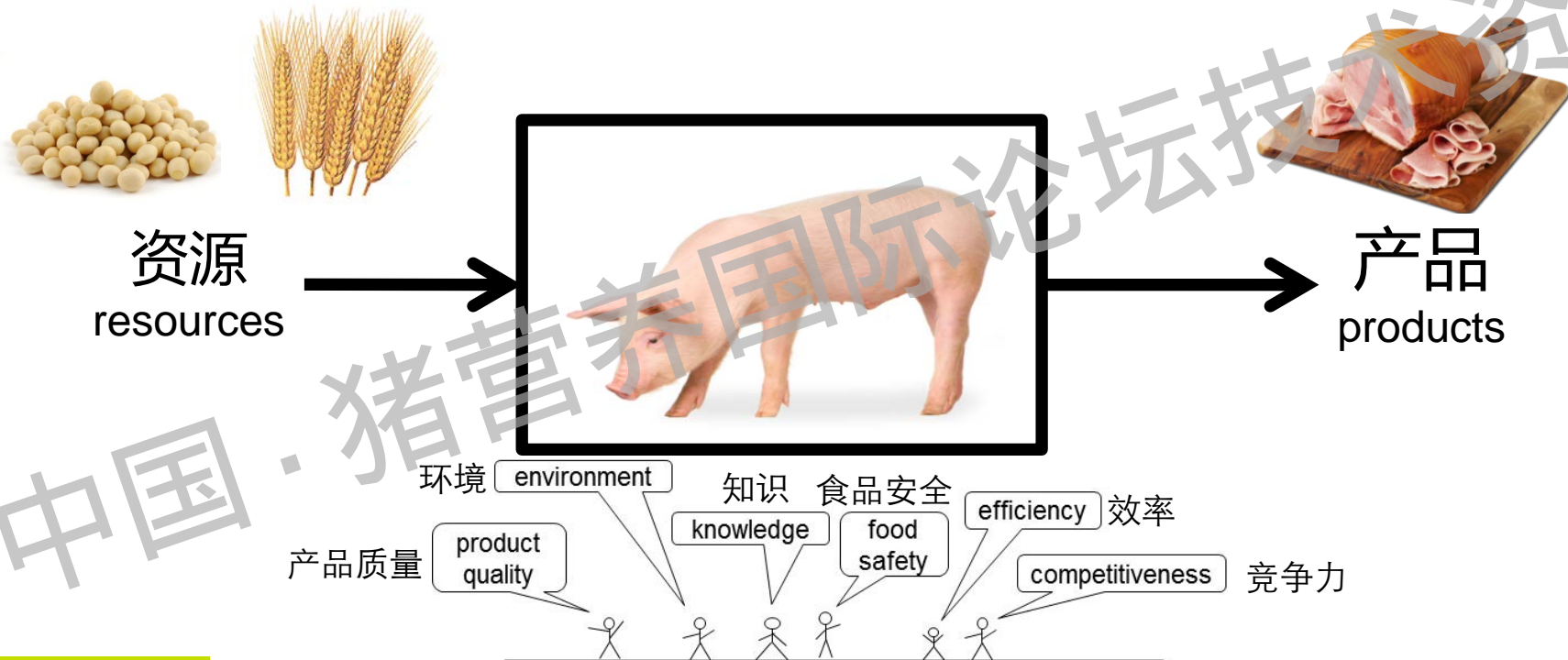
❖ 结论

Conclusions

中国猪营养国际论坛技术资料

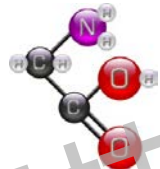
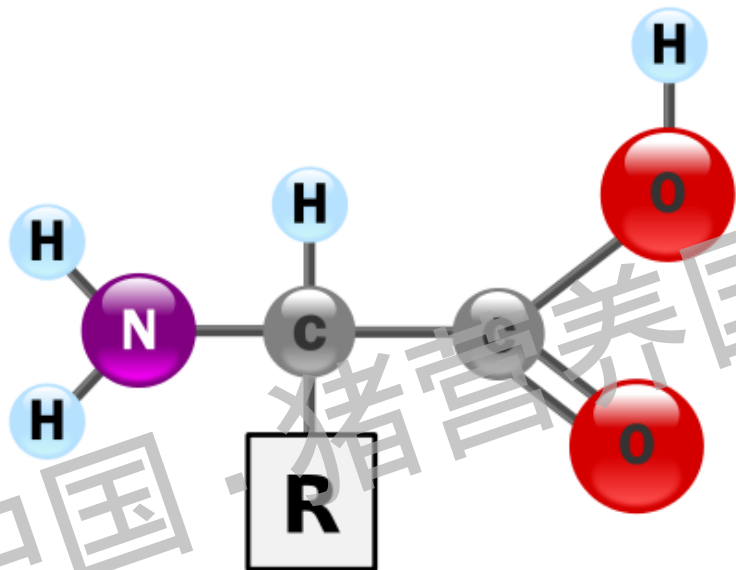
提高养猪业可持续发展能力

Enhancing the sustainability of the pork industry

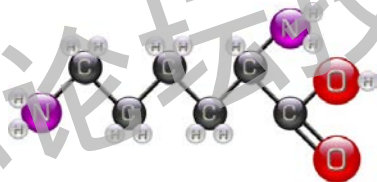


氨基酸结构

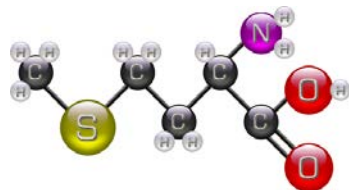
Structure of amino acids



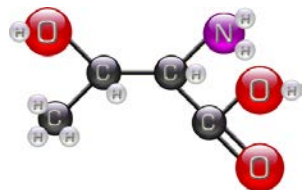
甘氨酸
Gly



赖氨酸
Lys



蛋氨酸
Met



苏氨酸
Thr



氨基酸结构

Structure of amino acids

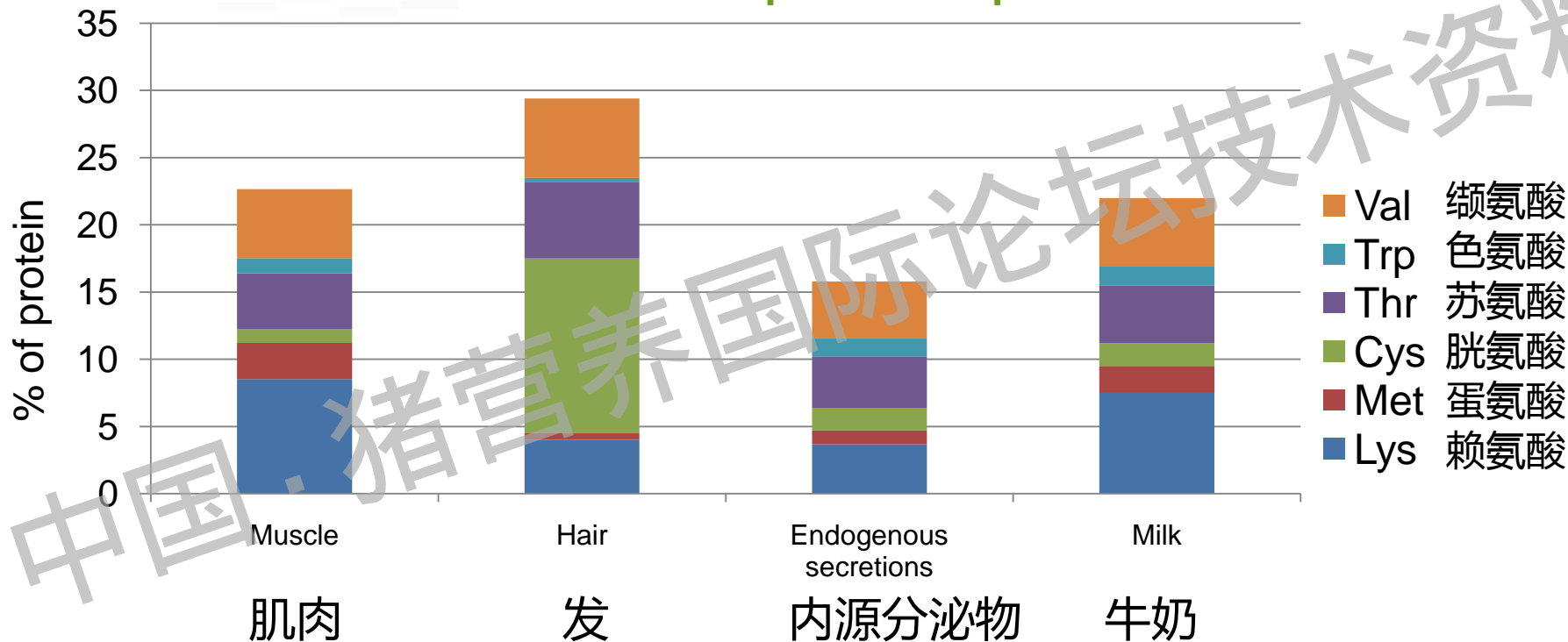
蛋白中的一些元素是饲料中必不可少的成分

“Some elements in proteins are essential constituents of the diet” (William Rose, 1932)

必须氨基酸 Essential	半必须氨基酸 Semi-essential	非必须氨基酸 Non-essential
赖氨酸 Lys	胱氨酸 (来自蛋氨酸) Cys (from Met)	精氨酸 Arg
蛋氨酸 Met	酪氨酸 (来自脯氨酸) Tyr (from Phe)	丙氨酸 Ala
苏氨酸 Thr		丝氨酸 Ser
色氨酸 Trp		甘氨酸 Gly
缬氨酸 Val		脯氨酸 Pro
异亮氨酸 Ile		谷氨酸 Glu
亮氨酸 Leu		谷氨酰胺 Gln
苯丙氨酸 Phe		天门冬氨酸 Asp
组氨酸 His		天冬酰胺 Asn

蛋白质的氨基酸组成

Amino acid composition of proteins





大纲

Outline

❖ 氨基酸的结构与功能

Structure and roles of amino acids

❖ 理想蛋白

Ideal protein

❖ 氨基酸需要量(生长猪及母猪):

Amino acid requirements for growing pigs and sows:

❖ 试验方法 Experimental methods

❖ 模型推导方法 Model-derived methods

❖ 结论

Conclusions

中国猪营养国际论坛技术资料

理想蛋白

Ideal protein (Mitchell et al., 1964)

- ❖ 所有必须氨基酸都同样的会限制生长性能：

All essential amino acids are equally limiting for performance:

- ❖ 不能缺乏 no deficiency
- ❖ 不能过量 no excess

- ❖ 通常以相对赖氨酸量进行表达：

Usually expressed relative to Lys:

- ❖ 赖氨酸通常是饲料中第一限制性氨基酸

Lys is typically the first-limiting amino acid in the diet

- ❖ 生长期间赖氨酸需要量(克/千克 日粮)变化，则其他氨基酸需要量相对于赖氨酸成比例的变化(假定)

The Lys requirement (g/kg diet) changes during growth, but the requirements of other amino acids change proportionally to Lys (assumption)

- ❖ 使用方便：每种氨基酸只需记住一个数据(例如 苏氨酸/赖氨酸=65%)

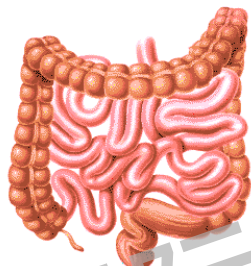
Simple to use: only 1 value for each amino acid to remember (e.g., Thr:Lys = 65%)



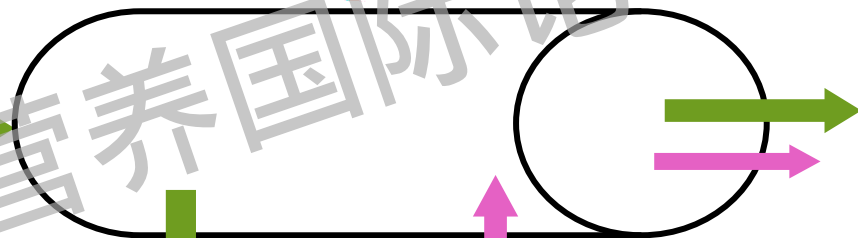
Law of the minimum
(von Liebig, 1850)

氨基酸值和需要量的表示

Expressing amino acid values and requirements



营养摄入
nutrient intake



营养排出
nutrient output

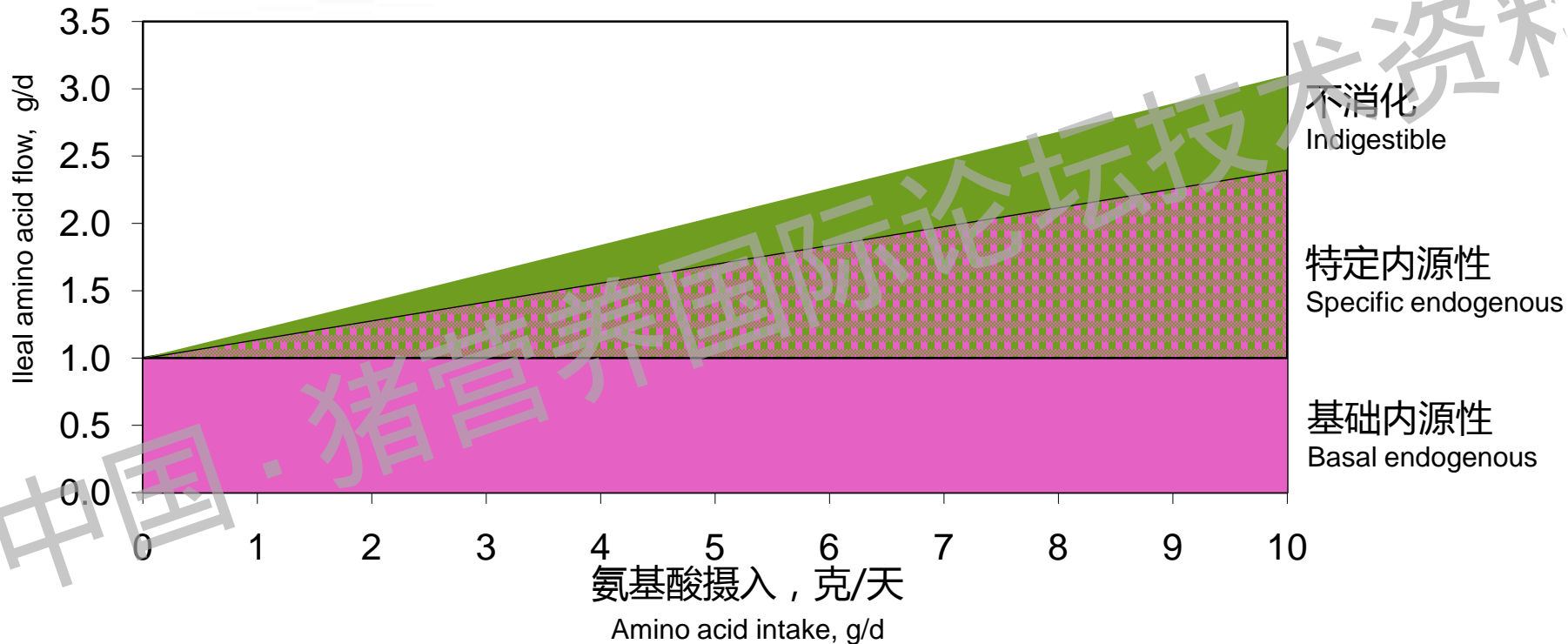
营养消化
nutrient absorption

内源分泌
endogenous secretions

随着氨基酸摄入的增加，内源性损失也增加

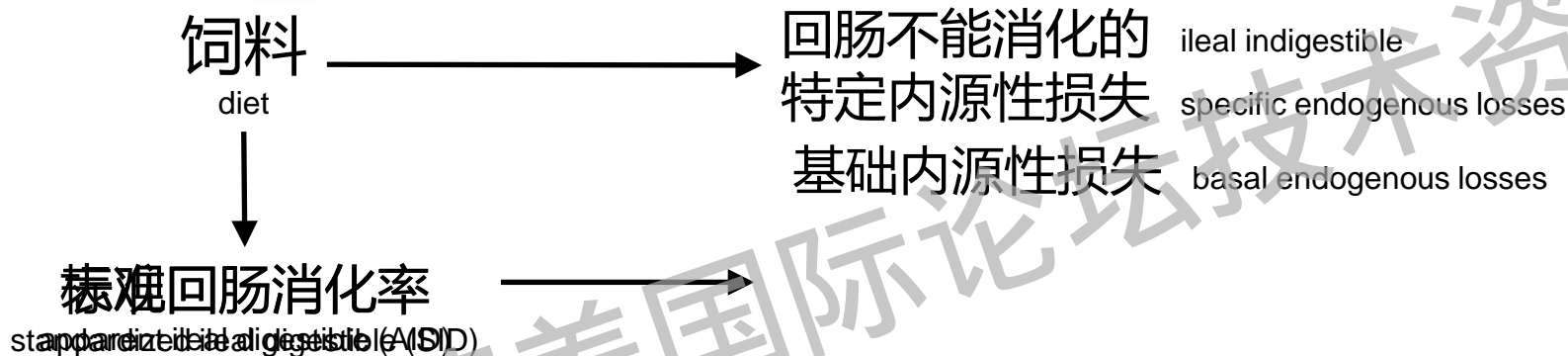
Endogenous losses increase with increasing amino acid intake

回肠氨基酸流量，克/天



氨基酸值和需要量的表示

Expressing amino acid values and requirements

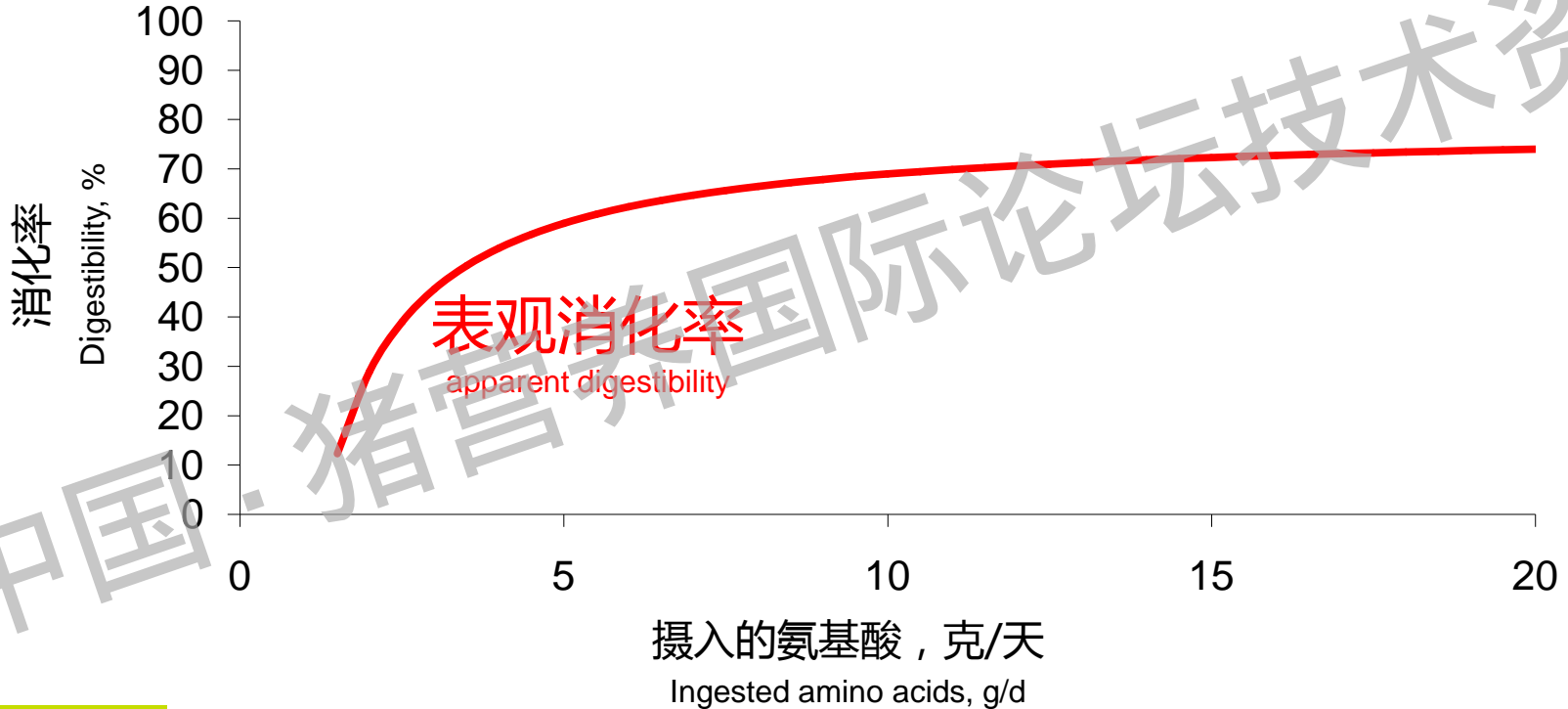


基础内源性损失是：
表观回肠消化率系统中饲料价值的一部分
标准回肠消化率系统中需要量的一部分

Basal endogenous losses are:
part of the feed value in an AID system
part of the requirement in an SID system

随着氨基酸摄入的增加，表观回肠消化率也会增加

The apparent ileal digestibility increases with increasing amino acid intake



标准回肠消化率校正了基础内源损失

The standardized ileal digestibility is corrected for basal endogenous losses



氨基酸值和需要量的表示

Expressing amino acid values and requirements

	赖氨酸 Lys			苏氨酸 Thr		
	含量 Content, g/kg	表观消化率 AID, %	标准消化率 SID, %	含量 Content, g/kg	表观消化率 AID, %	标准消化率 SID, %
豆粕 Soybean meal	27.8	87	90	17.7	82	87
玉米 Corn	2.4	70	80	3.0	74	83
小麦 Wheat	3.1	74	81	3.2	75	83

氨基酸值和需要量的表示

Expressing amino acid values and requirements

❖ 表观回肠消化率：

Apparent ileal digestibility (AID):

❖ 表观回肠消化率是不可加的

AID values are not additive

❖ 基础内源性损失是氨基酸表观消化率值的一部分 (例如：表观回肠消化率数据较低)

Basal endogenous losses are part of the AID amino acid value (i.e., the value is lower)

氨基酸值和需要量的表示

Expressing amino acid values and requirements

❖ 标准回肠消化率：

Standardized ileal digestibility (SID):

❖ 标准回肠消化率校正了基础内源性损失

SID values are corrected for basal endogenous losses

❖ 标准回肠消化率是可加的

SID values are additive

❖ 基础内源性损失是标准回肠可消化氨基酸需要量的一部分 (例如：需求量会更高)

Basal endogenous losses are part of the SID amino acid requirement (i.e., the requirement is higher)

❖ 标准回肠消化率体系效果更好

SID is the preferred mode of expression



大纲

Outline

❖ 氨基酸的结构与功能

Structure and roles of amino acids

❖ 理想蛋白

Ideal protein

❖ 氨基酸需要量(生长猪及母猪):

Amino acid requirements for growing pigs and sows:

❖ 试验方法 Experimental methods

❖ 模型推导方法 Model-derived methods

❖ 结论

Conclusions

中国猪营养国际论坛技术资料

氨基酸需要量量的评估

Estimating amino acid requirements (NRC, 2012)

❖ 基础日粮中待测氨基酸缺乏

Basal diet deficient in the test amino acid

❖ 被测氨基酸至少有4个水平梯度

At least 4 graded levels of the test amino acid

❖ 除被测氨基酸外其他营养不缺乏

Adequate levels of nutrients other than the test amino acid

❖ 足够长的试验期，以使动物表现差异

Adequate duration of the experiment in relation to the response criterion

❖ 适当的统计模型来描述动物对于氨基酸添加的反应

Adequate statistical model to describe the response of the animal to the amino acid supply



试验的限制性因素

Knowledge of the limiting factors

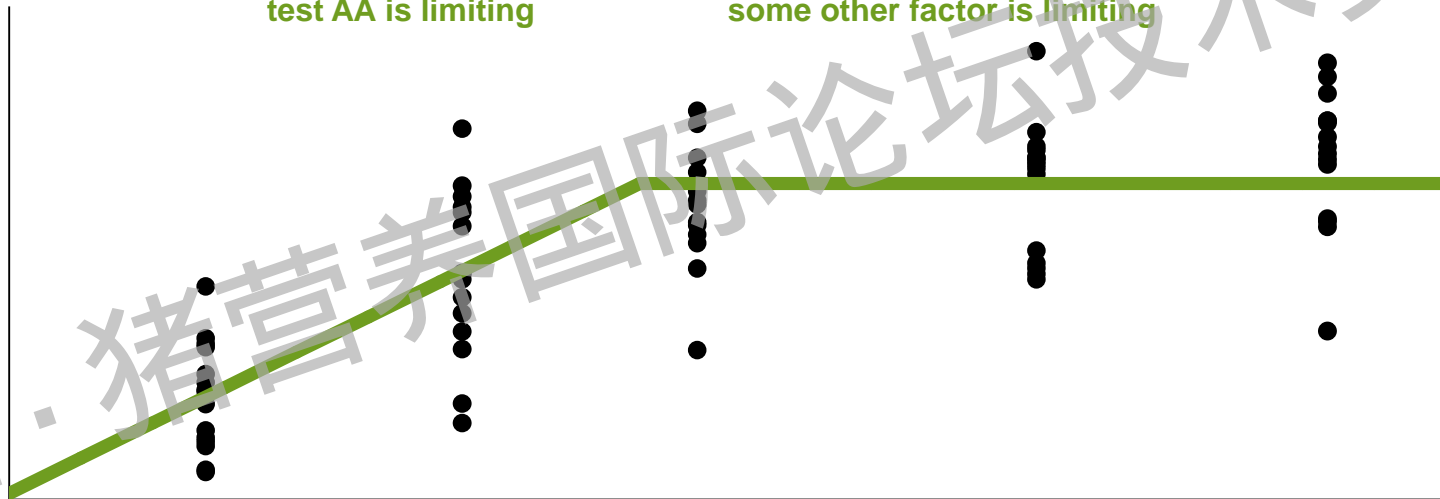
待测氨基酸
test AA is limiting



其他限制因素

some other factor is limiting

反应
Response

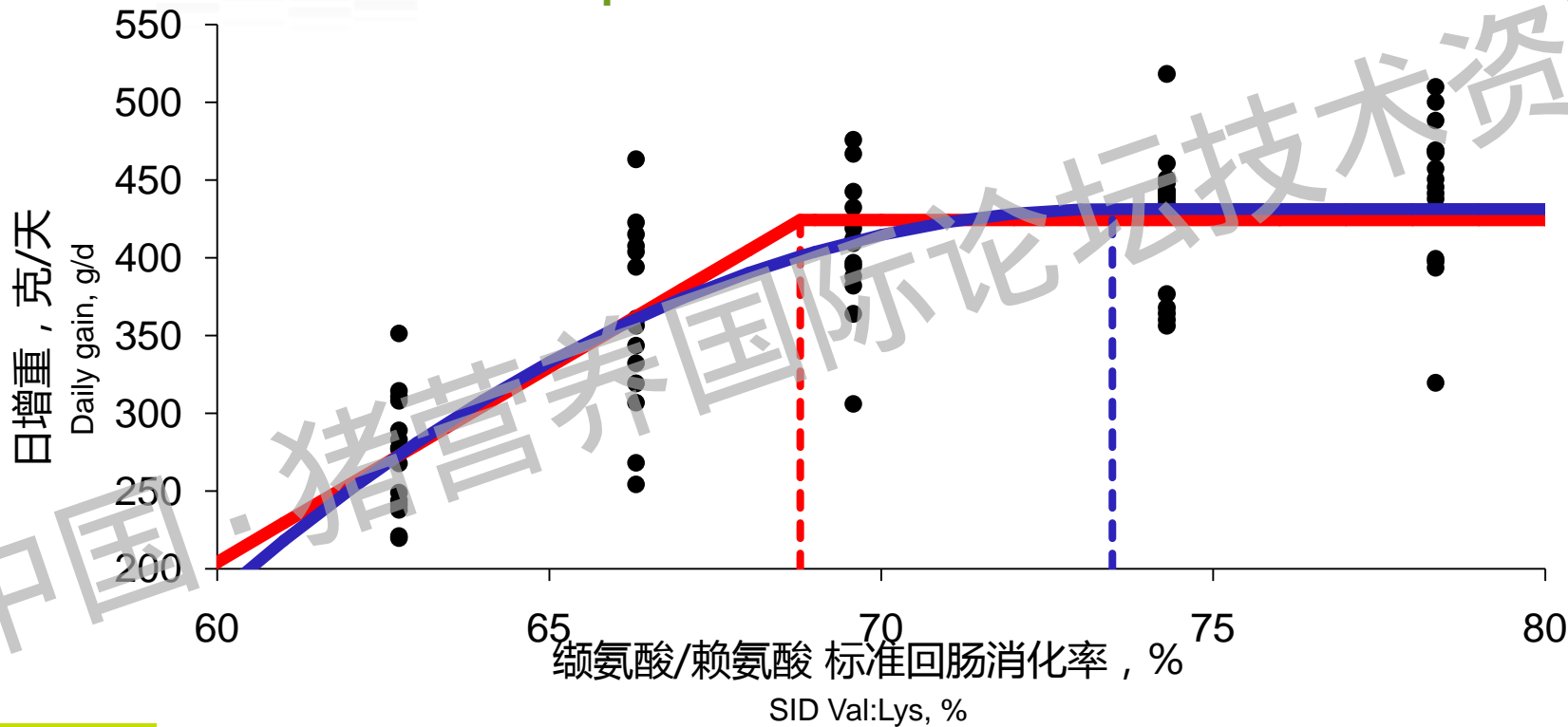


氨基酸含量

Amino acid content

合适的统计方法

Adequate statistical model



NRC (2012) 中氨基酸需要量的试验数量

Amino acid dose-response studies considered by the NRC (2012)

	生长猪 Growing pigs	妊娠母猪 Gestating sows	哺乳母猪 Lactating sows
赖氨酸 Lys	42	4	10
蛋氨酸 Met	19	-	-
蛋氨酸+胱氨酸 Met + Cys	13	2	2
苏氨酸 Thr	13	4	3
色氨酸 Trp	19	3	2
缬氨酸 Val	7	1	2
异亮氨酸 Ile	11	1	-
亮氨酸 Leu	1	-	-
苯丙氨酸 Phe	-	-	-
苯丙氨酸+酪氨酸 Phe + Tyr	-	-	-
组氨酸 His	1	-	-
精氨酸 Arg	1	-	-



大纲

Outline

❖ 氨基酸的结构与功能

Structure and roles of amino acids

❖ 理想蛋白

Ideal protein

❖ 氨基酸需要量(生长猪及母猪):

Amino acid requirements for growing pigs and sows:

❖ 试验方法 Experimental methods

❖ 模型推导方法 Model-derived methods

❖ 结论

Conclusions

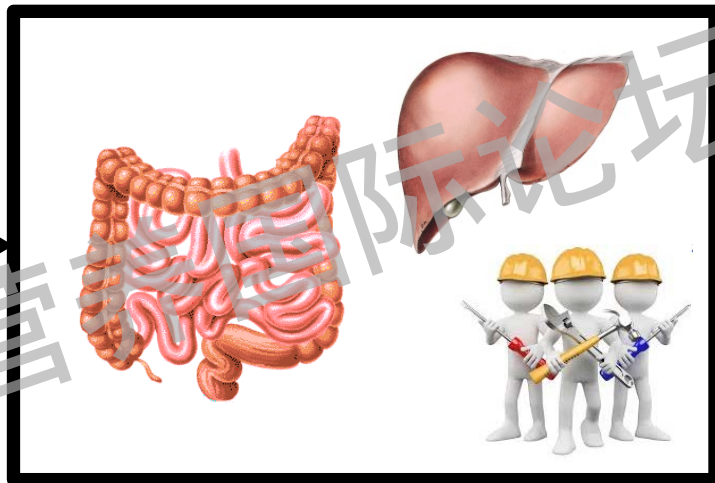
中国

析因法评估生长猪的需要量

Factorial calculation of requirements for growing pigs



来源
resources

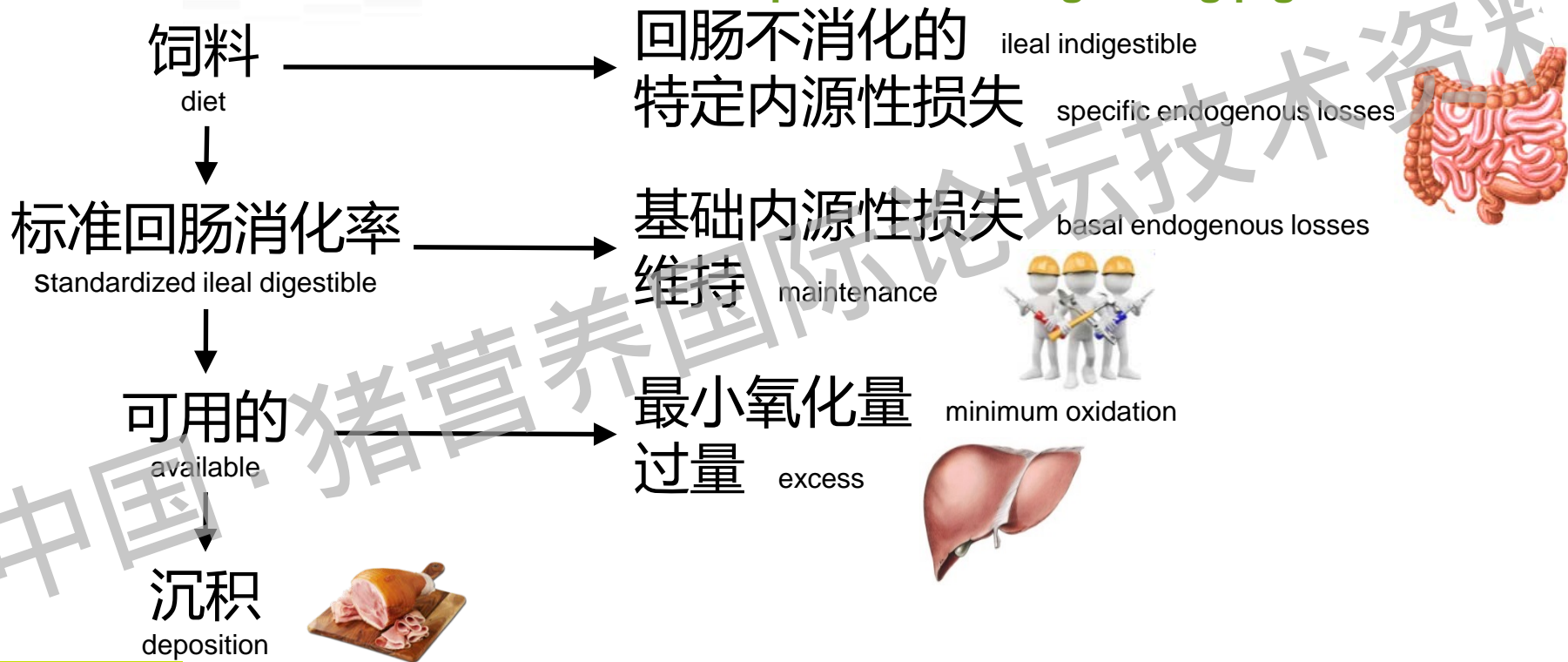


产品
products



析因法评估生长猪的需要量

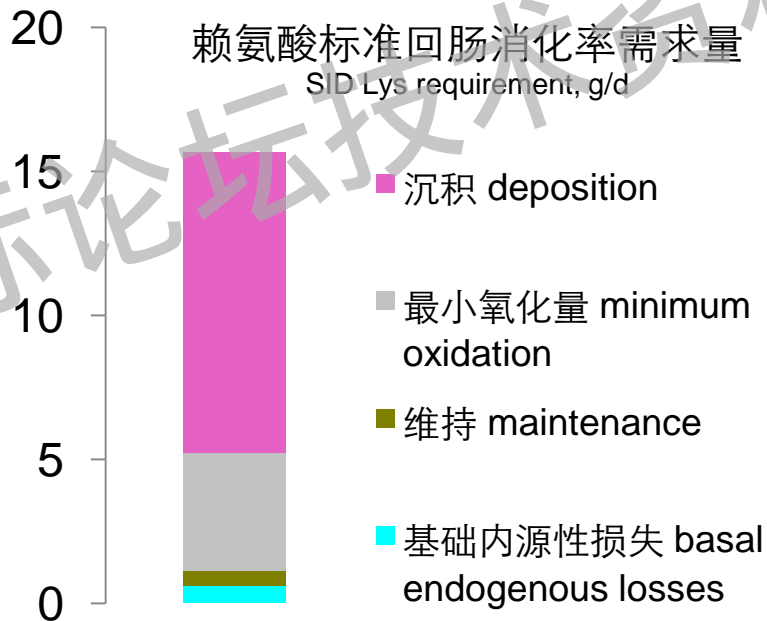
Factorial calculation of requirements for growing pigs



析因法评估生长猪的需要量

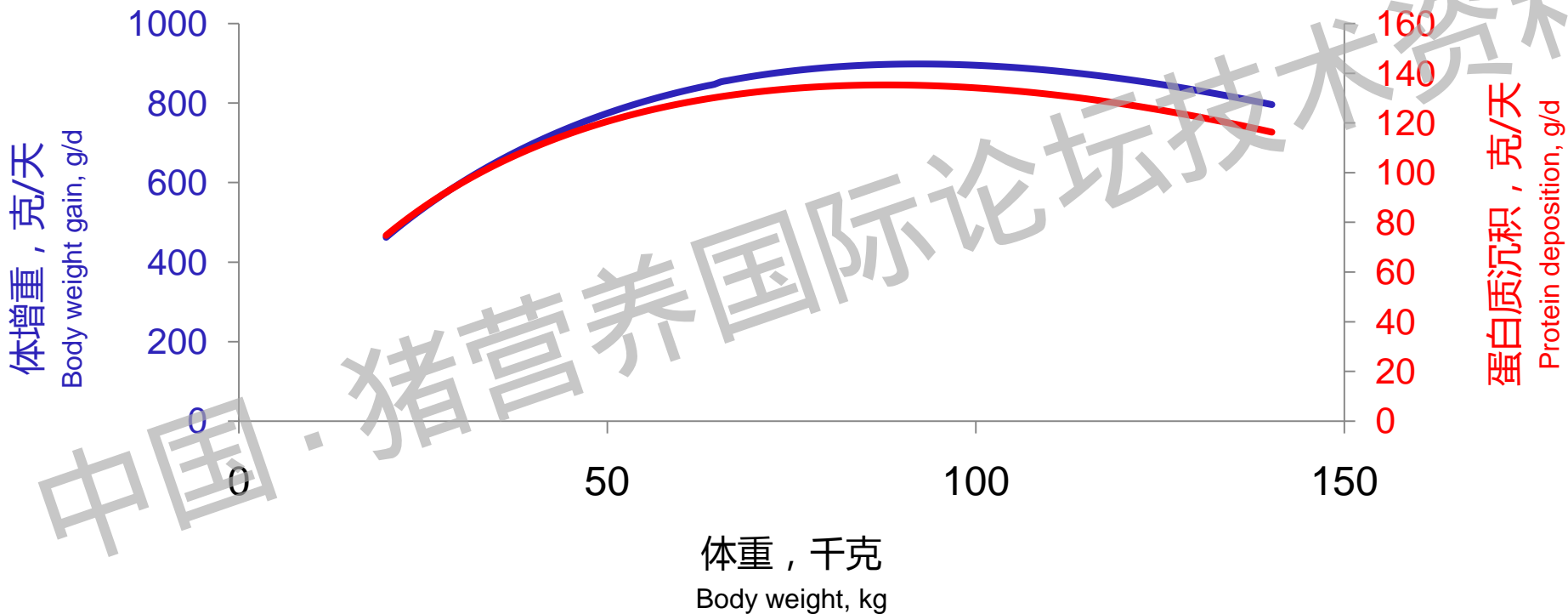
Factorial calculation of requirements for growing pigs

项目 Item	值 Value
体重 Body weight, kg	50
摄入的干物质 DM intake, kg/d	2
蛋白质沉积 Protein deposition, g/d	150
赖氨酸占体蛋白的百分数 Lys content in body protein, %	6.96
赖氨酸最小氧化量 Minimum oxidation of Lys, %	28
赖氨酸维持需求量 Maintenance Lys requirement, mg/(kg BW ^{0.75})/d	28.4
基础内源性损失 Basal endogenous losses, mg/kg DM intake	313



生长过程中体增重和蛋白质沉积的变化非常相似

Body weight gain and protein deposition change in a similar way during growth ...



...蛋白质沉积和采食量的变化不同

... but protein deposition and feed intake vary differently





Home Overview Download License Support Publications

InraPorc is a model and software tool to analyze performance and to evaluate

- **翻译成7种语言(暂无中文)**
Translated into 7 languages (no Chinese yet)
- **500欧元；教育版免费**
500 € free for educational use

The screenshot shows the InraPorc software interface with several panels:

- Simulation**: Options for 'Single simulation' and 'Standard'.
- Sow profile**: Includes 'Animal profile', 'Feed sequence plan', 'Feed rationing plan', 'Initial state', and 'Age (d)'.
- Feed compos**: A section for feed composition.
- Graphs**: A bar chart showing values for Litter 1 through Litter 8, and a line graph for 'Parity 1-3 (28 d)'.
- Simulation list**: A table listing simulation types and feed sequences.

- **生长猪，妊娠母猪和哺乳母猪**

Growing pigs, gestating and lactating sows

- **使用析因法测定氨基酸需要量**

Factorial approach to determine amino acid requirements

- **分析养分利用率**

Analysis of nutrient utilization

- **营养评估方案(假设分析...?)**

Evaluation of nutritional scenarios (what if ...?)

Growing pig profile

Animal profile

NRC2

Farm conditions

Ad libitum feed intake and growth

Model parameters

Ad libitum intake

Unit

NE (MJ/d)

Equation

Gamma (maintenance)

Parameters

Feed intake

a

3.9008

50 kg

18.41

b

0.0137

100 kg

28.02

Growth potential

Mean PD (g/d)

120.00

Precocity (/d)

0.01000

Maintenance

1.000

BW PDmax (kg)

70



Response curve

Reference simulation

Feed sequence plan

Bi-phase standard

Feed rationing plan

Ad libitum



Calibration

Simulation results

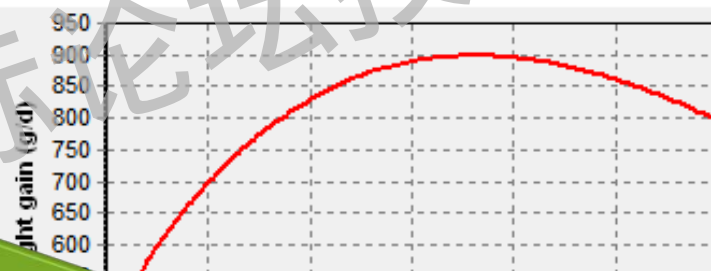
Graph type

Dynamic view

Y-axis

Body

Weight gain



采食量和蛋白质沉积曲线的构建

Construction of feed intake and protein deposition curves

Body weight (kg)

— Ad libitum

— Feed rationing plan

Gain	Feed usage (wastage)	F:G	PD	LD	Backfat	Lean meat
784	2238 (0%)	2.85	120	236	21.4	54.7
784	2238 (0%)	2.85	120	236	21.4	54.7

Growing pig profile

Animal profile

NRC2



或者自动
... or automatically ...

Farm conditions Ad libitum feed intake and growth

Model parameters

Ad libitum intake

Unit NE (MJ/d)

Equation Gamma (maintenance)

Parameters Feed intake

a 3.9008 50 kg 18.41

b 0.0137 100 kg 28.02

Growth potential

Mean PD (g/d) 120.00

Precocity (/d) 0.01000

Maintenance 1.000

BW PDmax (kg) 70

Response curve

Reference simulation

Feed sequence plan Bi-phase standard

Feed rationing plan Ad libitum

Calibration

Simulation results

Graph type

Dynamic view

Y-axis

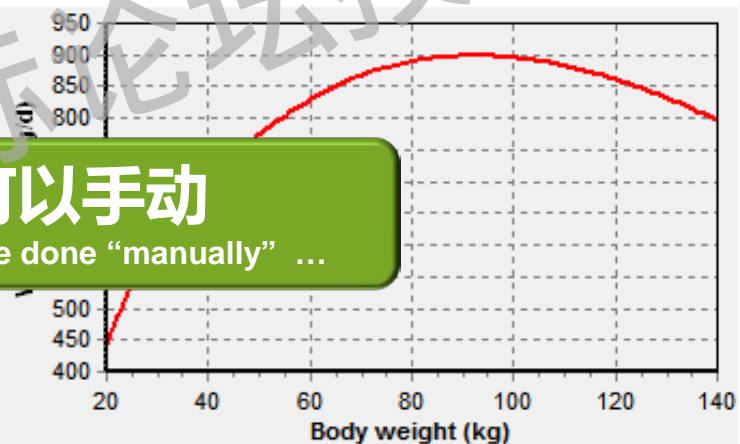
Body

Weight gain

X-axis

Body weight (kg)

可以手动
This can be done "manually" ...




— Ad libitum — Feed rationing plan

Gain	Feed usage (wastage)	F:G	PD	LD	Backfat	Lean meat
784	2238 (0%)	2.85	120	236	21.4	54.7
784	2238 (0%)	2.85	120	236	21.4	54.7


Observed data

Line	Age (d)	Cumulative feed usage (kg)	Body weight (kg)	Backfat thickness (mm)	Lean meat (%)
1	75	0.0	20.0		
2	150	130.0	75.0		
3	230	350.0	140.0		

...通过提供采食量和体重数据
... by providing observed feed intake and body weight data

 Insert

 Delete

 Import

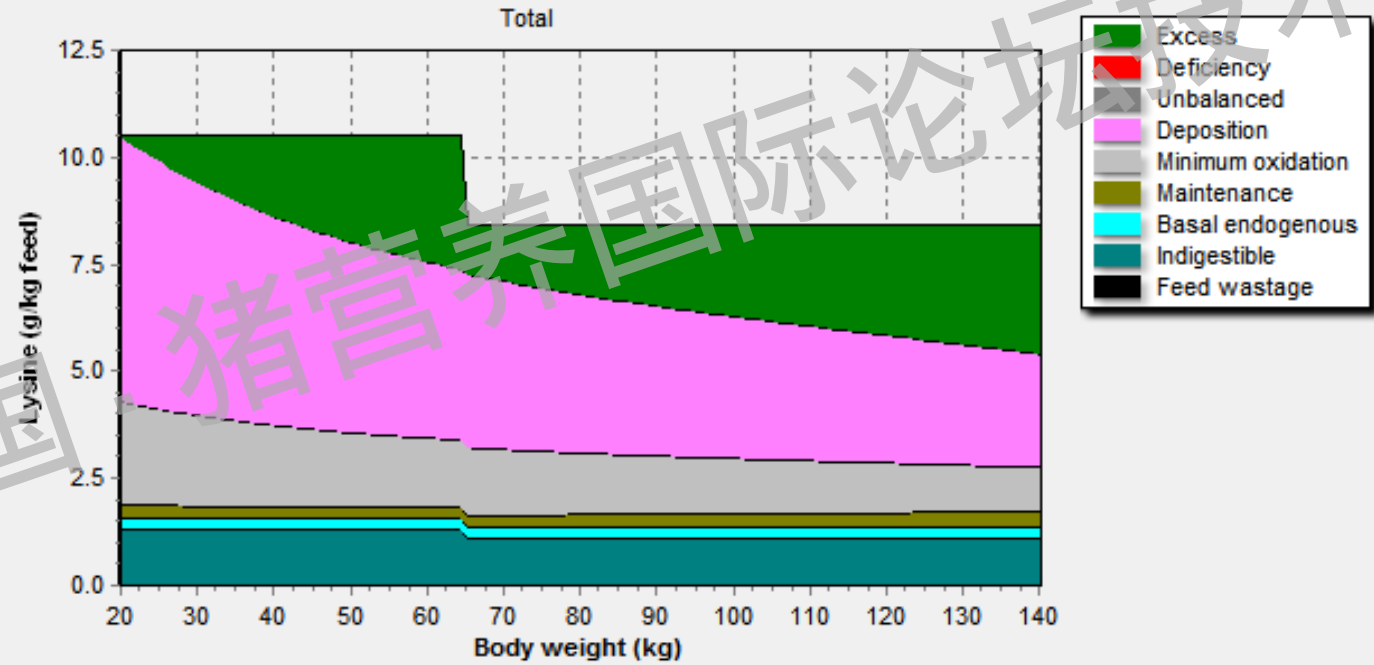
OK

Cancel

中国·猪营养国际论坛技术资料

Graph type: Dynamic partitioning
Y-axis: Lysine
X-axis: Body weight (kg)
Total

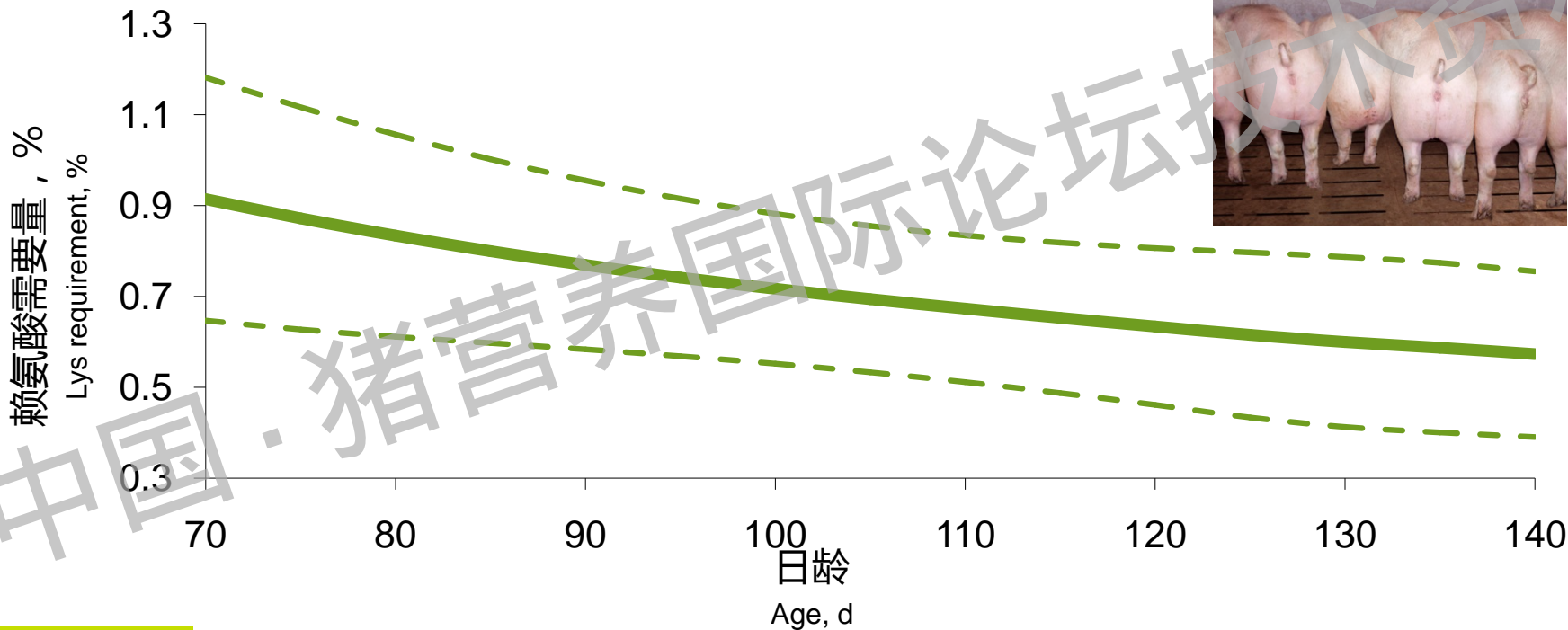
Lysine (Dynamic partitioning) 赖氨酸(动态分布图)



过量
缺乏
不平衡
沉积
最小氧化
维持
可消化
饲料浪费

处理猪只差异：你想饲养哪种猪群？

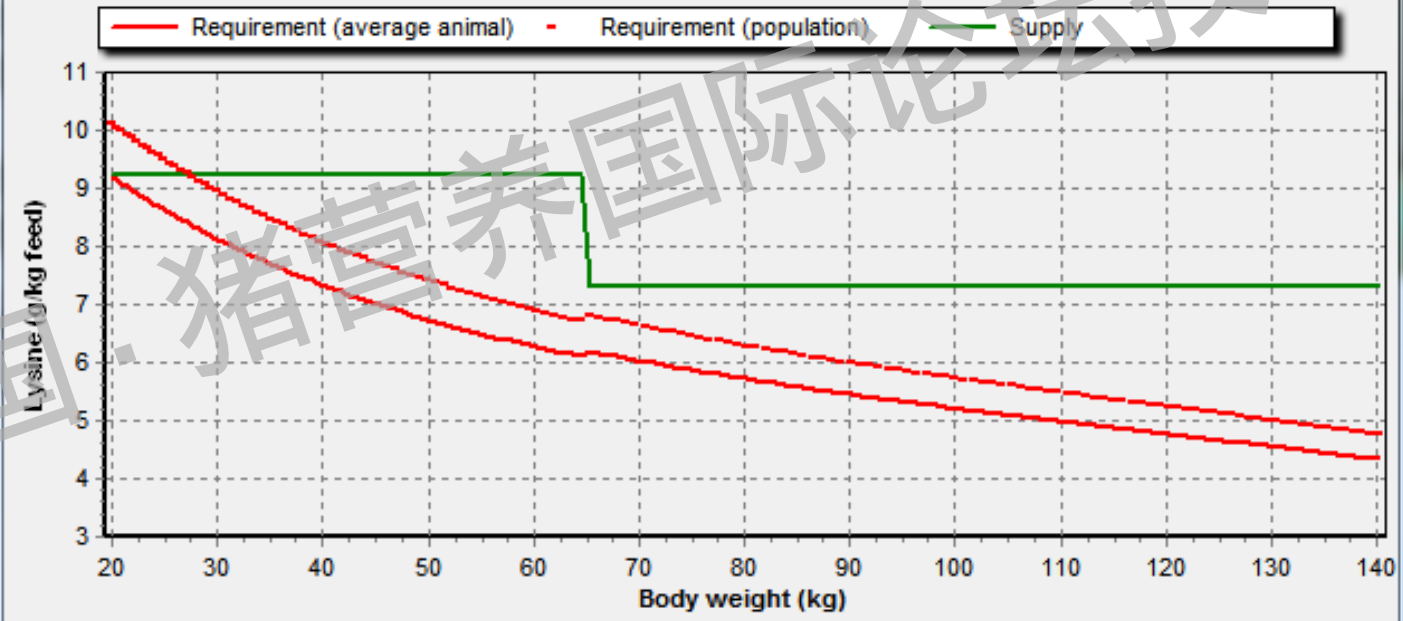
Dealing with variation among pigs: which pig do you want to feed?



Graph type: Requirement and supply
Standardized digestible
Y-axis: Lysine
g/kg feed
X-axis: Body weight (kg)

Lysine (Requirement and supply)

Standardized digestible



Division on Earth & Life Studies of the National Academies

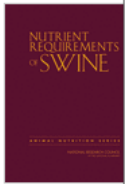


- About Us
- Our Boards
- Reports
- Studies in Progress
- Workshops
- Resources
- Events
- Search

Where the Nation Turns for Independent, Expert Advice

FOLLOW US [Twitter icon] [Facebook icon] GET UPDATES

Expert Report



J'aime 19

- **英语**
English
- **免费软件(出版149.95美元)**
Free software (publication \$149.95)

Each report is prepared by an expert panel and is subject to a rigorous, independent peer review; while the reports represent views of the committee, they also are endorsed by the Academy. [Learn more on our expert consensus reports.](#)

The latest in a series of National Research Council reports provides updated advice on the energy and nutrient requirements of swine to help maintain an efficient, profitable, and environmentally conscious swine industry. Since 1944, there have been 10 editions of the Nutrient Requirements of Swine, a publication that has guided nutritionists and other professionals in developing and implementing feeding programs for swine. However, since the last report in the series in 1998, the swine industry has undergone considerable changes. This eleventh edition evaluates the most recent scientific literature to provide updated information, including a review of the value of corn and soybean-based byproducts from the biofuel industry as food for swine, and revised and revamped nutrient tables. The report also includes updated and expanded computer models to estimate energy, amino acid, calcium and phosphorus requirements for swine at different life stages. A suite of additional resources (see below) is available to complement the report, including the computer model with user guide and a series of case studies to help users understand the scope and limits of the models.

Illinois Corn Marketing Board; The Minnesota Corn Growers Association; The Nebraska Corn Board; The American Feed Industry Association-Institute for Feed Education & Research; DHHS U.S. Food and Drug Administration; internal NRC funds

Related Reports



[Spurring Innovation in Food and Agriculture: A Review of the USDA Agriculture](#)

第一步：选择营养系统

Step I: Select Nutrient Systems

能量

Energy

氨基酸

Amino Acids

磷

Phosphorus

猪营养需要

2012第十一修订版

Step II: Evaluate Feeding Program

第二步：评估饲喂方案

Do you wish to evaluate a feeding program?

你希望评估饲喂方案吗？

第三步：选择评估营养需要量的动物模型

Step III: Select Model for Estimating Nutrient Requirements

Starting Pigs

保育猪

Growing-
Finishing Pigs

生长育肥猪

Gestating Sows

妊娠母猪

Lactating Sows

泌乳母猪

Growing-Finishing Pigs

Net energy (NE) content, kcal/kg 2335
 Fermentable fiber content, % 10.5

Gender

↓
 Gilts & barrows

Feed intake

Feed intake / (feed intake + wastage) 1

Options

Use observed intake as model input

For observed intake define mean intake OR define curve*

Actual mean intake or intake curve Curve

Actual NE intake + wastage curve, kcal/day versus BW

Curve type Polynomial

Actual NE intake + wastage = a + b x BW
 + c x BW² + d x BW³

a -269.2
 b 121.70
 c -0.60909
 d 0.00089043

Options Specify Pd curve; Polynomial function

Polynomial

a 26.16
 b 2.9937
 c -0.0252252
 d 0.0000607

$Pd = a + b \times BW + c \times BW^2 + d \times BW^3$

使用默认或用于自定义的公式用于采食量和蛋白质沉积

Using default or user-defined equations for feed intake and protein deposition

中国

用于生长猪需要量评估的InraPorc和NRC模型

The InraPorc and NRC models for growing pigs

❖ 概念上非常相似，但通过不同的方式实现

Conceptually very similar, but different approaches towards:

❖ 基础内源性损失

basal endogenous losses

❖ 氨基酸的利用效率

efficiency of amino acid use

❖ 动物间的个体差异

variation among animals

❖ 影响大吗？

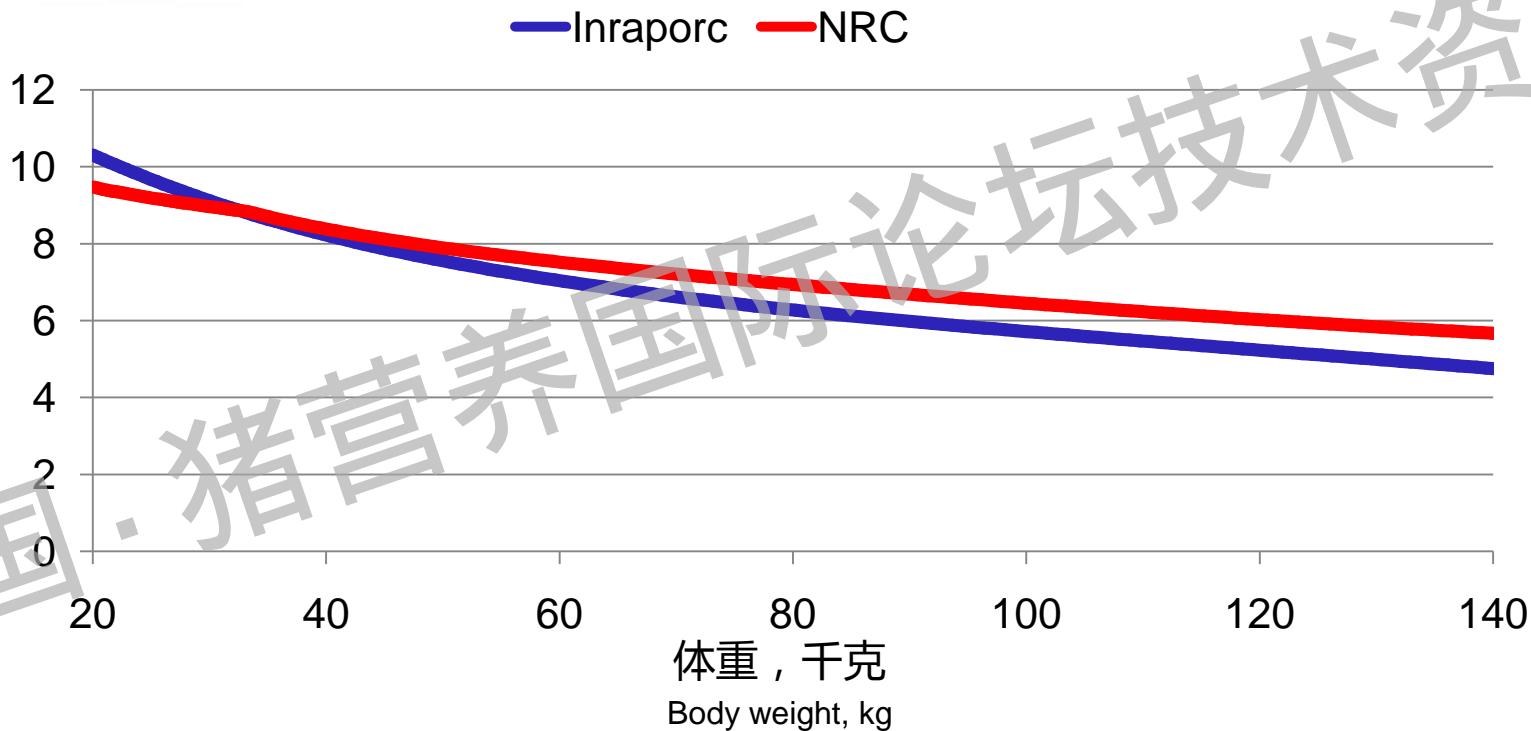
Does it matter?

生长猪赖氨酸需要量的模型推荐量

Model-derived Lys requirements for growing pigs

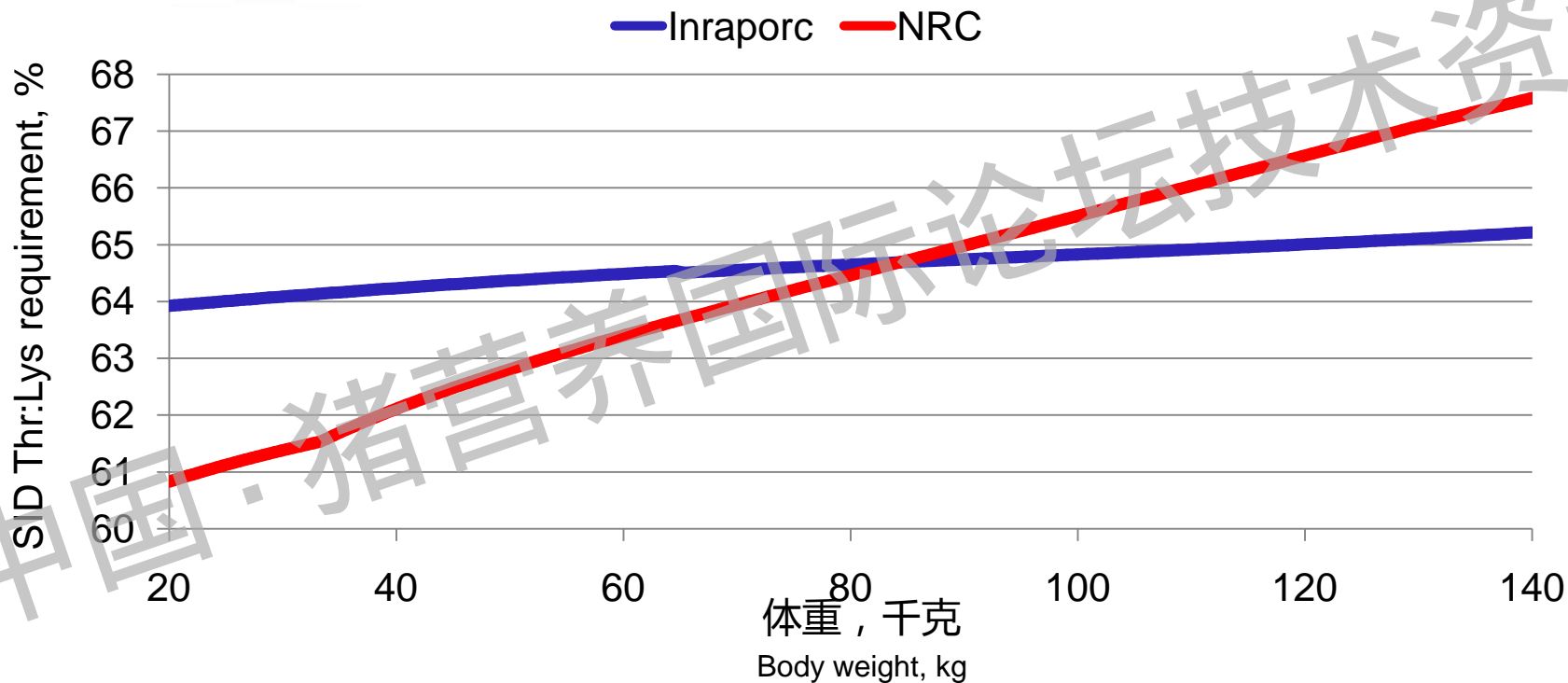
标准回肠可消化赖氨酸需要量

SID Lys requirement, g/kg diet



生长猪标准回肠可消化苏氨酸/赖氨酸模型推荐比值

Model-derived SID Thr:Lys requirements for growing pigs



生长猪的平均理想氨基酸组成

Average ideal amino acid profile for growing pigs

氨基酸 Amino acid	InraPorc	NRC
蛋氨酸 Met	30	29
蛋氨酸+胱氨酸 Met + Cys	60	58
苏氨酸 Thr	65 (64-65)	64 (61-68)
色氨酸 Trp	18	18
缬氨酸 Val	70	66 (65-68)
异亮氨酸 Ile	55	53
亮氨酸 Leu	100	101
苯丙氨酸 Phe	50	61
苯丙氨酸+酪氨酸 Phe + Tyr	95	95
组氨酸 His	32	34
精氨酸 Arg	42	46

模型推荐的母猪氨基酸需要量

Model-derived amino acid requirements for sows

妊娠 Gestation:

- 限饲
Restrictively fed
- 在头胎怀孕期间仍然生长
Still growing during the first parities
- 哺乳后恢复身体储备
Recovery of body reserves after lactation

哺乳期 Lactation:

- 自由采食
Ad libitum fed
- 营养负平衡
Negative nutrient balance
- 动员身体储备
Mobilization of body reserves



模型推荐的母猪氨基酸需要量

Model-derived amino acid requirements for sows

❖ 析因法和经验法模型输入的值基于以下各个指标：

Factorial and empirical approach with model inputs based on:

❖ 采食量：限饲和自由采食

Feed intake: restricted and ad libitum

❖ 孕体生长：产窝仔数，初生重

Conceptus growth: litter size, birth weight

❖ 母体增重

Maternal body weight gain

❖ 奶产量：窝仔猪生长率

Milk production: litter growth rate

❖ 动员体内储备：背膘厚，失重

Mobilization of body reserves: backfat thickness, weight loss

Graph type

Dynamic view

Y-axis

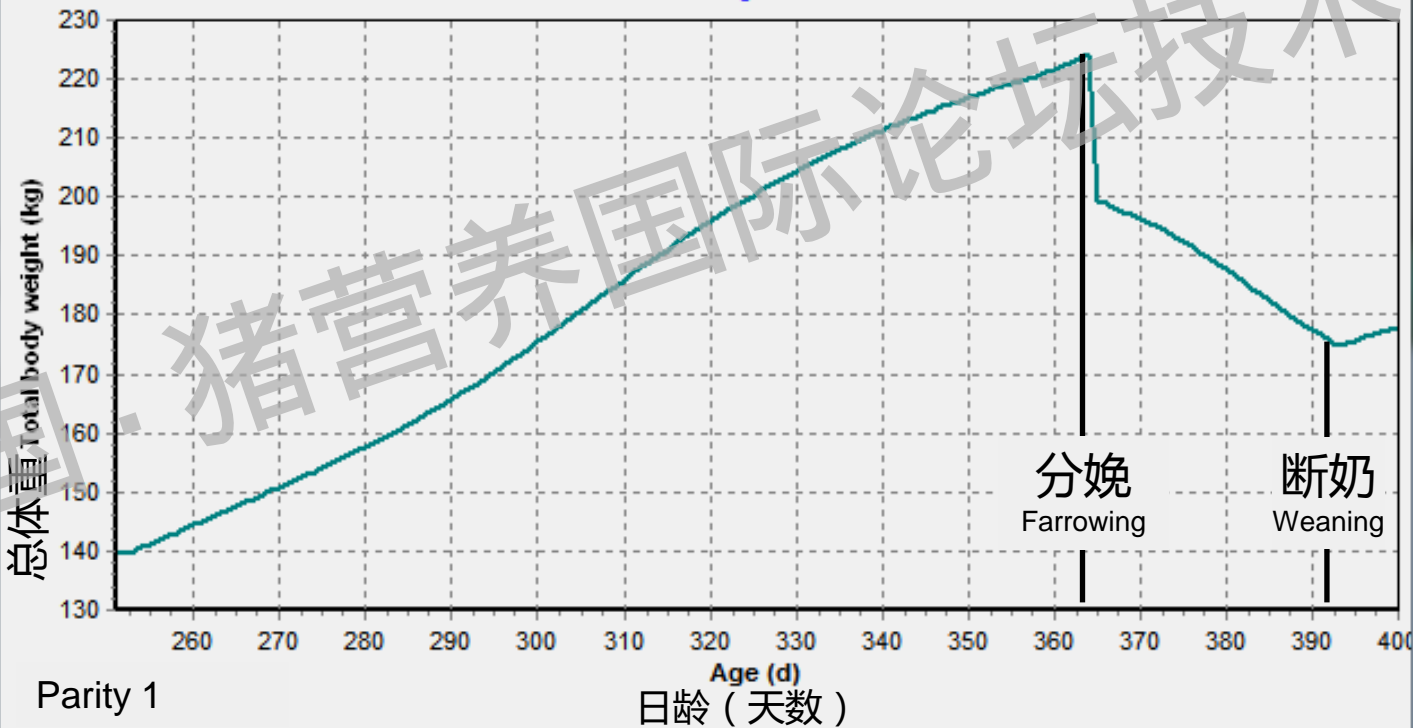
Total body weight

kg

X-axis

Age (d)

生长性能：动态图 Performance : Dynamic view



中国猪营养国际论坛技术资料

Graph type

Dynamic partitioning

Total

Y-axis

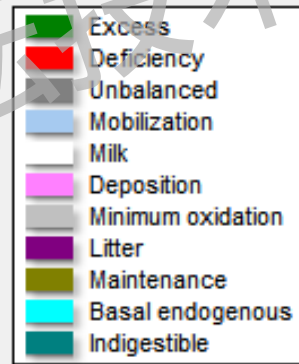
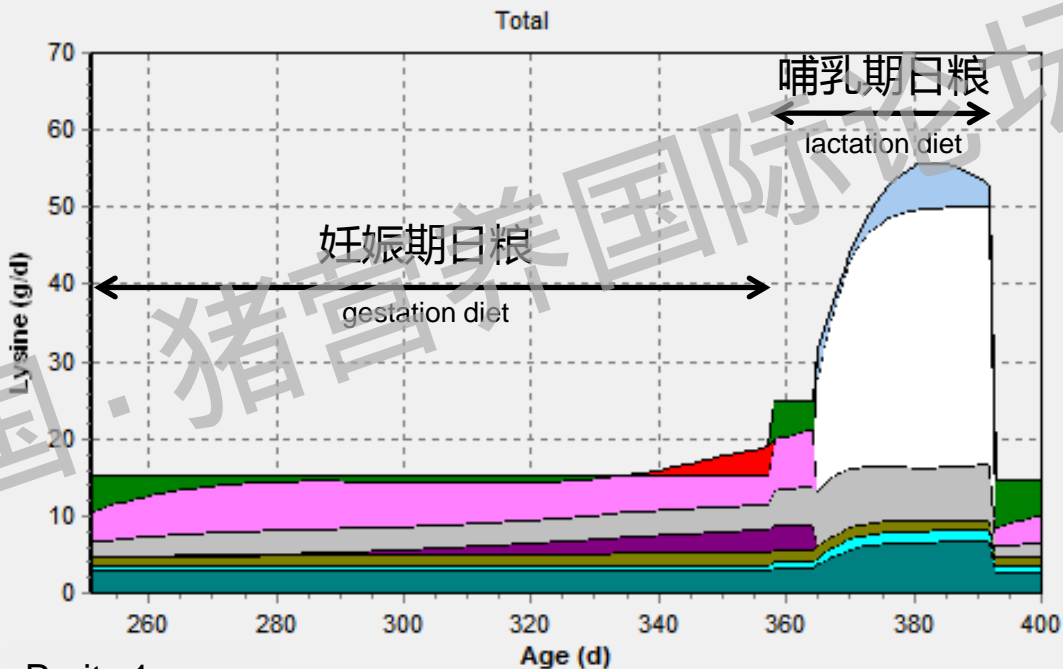
Lysine

g/d

X-axis

Age (d)

Lysine : Dynamic partitioning 赖氨酸：动态分布图



过量
缺乏
不平衡
动员
母乳
沉积
最小氧化
窝产仔
维持
基础内源性
不消化的

Parity 1

中国·猪营养师国际论坛技术资料

Graph type

Requirement and supply

Standardized digestible

Y-axis

Lysine

g/d

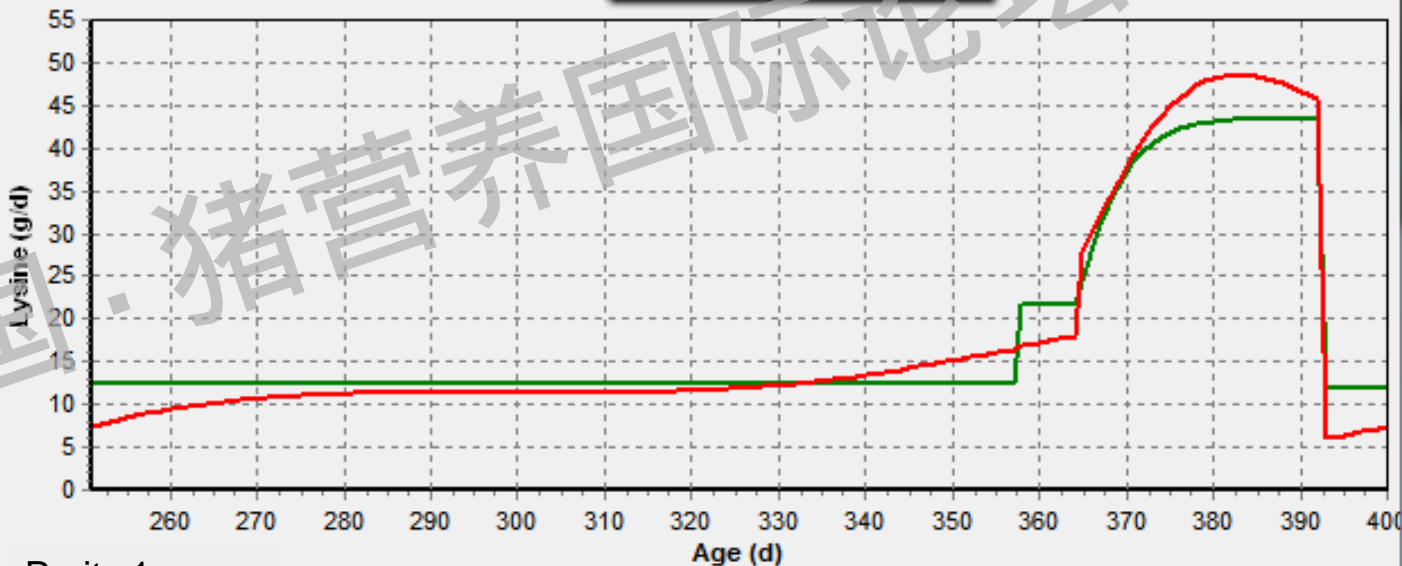
X-axis

Age (d)

Lysine : Requirement and supply 赖氨酸：需要和供应

Standardized digestible 标准可消化

— Requirement — Supply

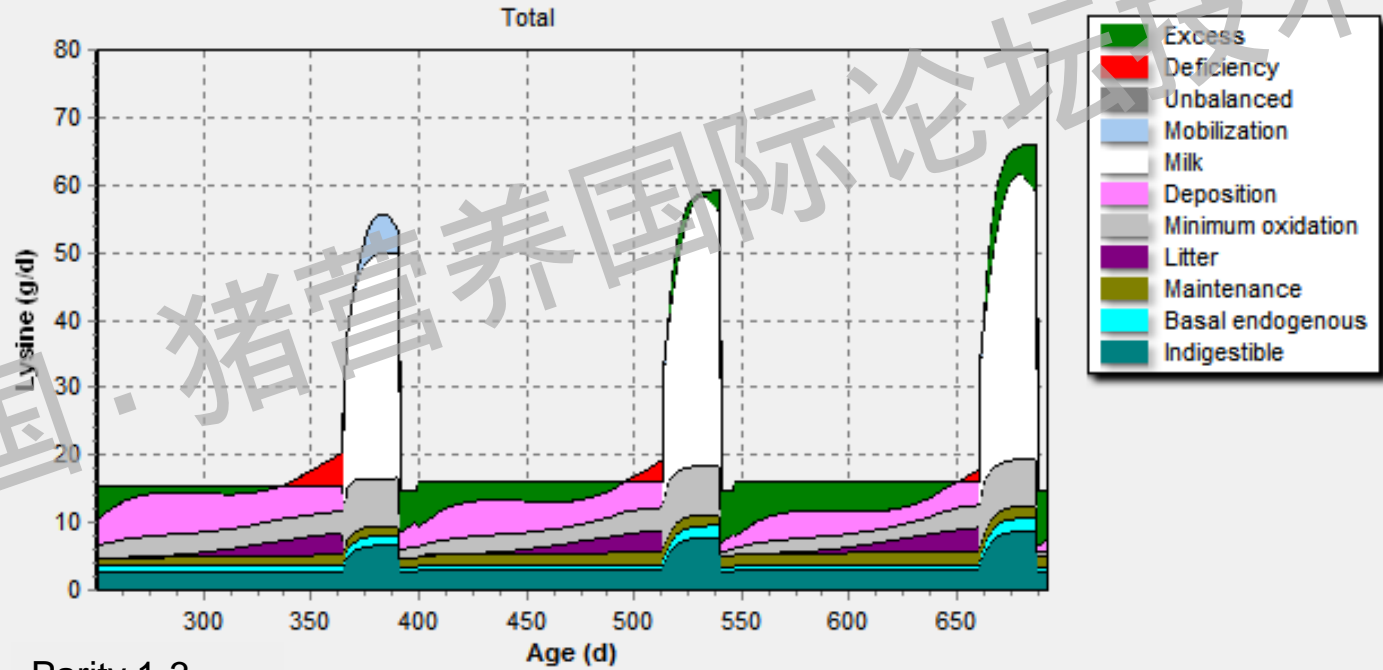


Parity 1

中国·猪营养国际论坛技术资料

Graph type: Dynamic partitioning
 Y-axis: Lysine
 X-axis: Age (d)
 Total

Lysine : Dynamic partitioning 赖氨酸：动态分布图



过量
 缺乏
 不平衡
 动员
 母乳
 沉积
 最小氧化
 窝产仔
 维持
 基础内源性
 不消化的

中国猪营养国际论坛技术资料

Graph type

Requirement and supply

Standardized digestible

Y-axis

Lysine

g/kg feed

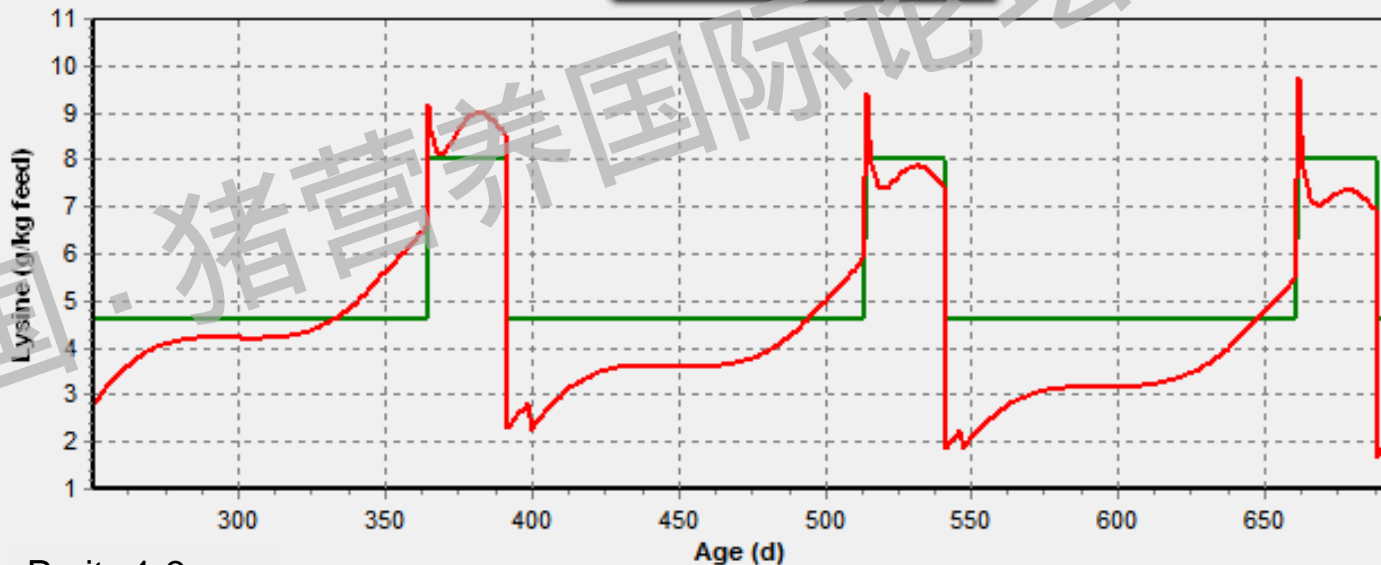
X-axis

Age (d)

Lysine : Requirement and supply 赖氨酸：需要和供应

Standardized digestible 标准可消化

— Requirement — Supply



Parity 1-3

中国猪营养国际论坛技术资料

母猪的InraPorc 和NRC模型

The InraPorc and NRC models for sows

❖ 概念上非常相似，但方法稍微不同：

Conceptually very similar, but slightly different approaches towards:

❖ 蛋白池

protein pools

❖ 基础内源性损失

basal endogenous losses

❖ 氨基酸利用效率(例如，理想氨基酸组成)

efficiency of amino acid use (i.e., ideal amino acid profiles)

❖ 影响大吗？

Does it matter?

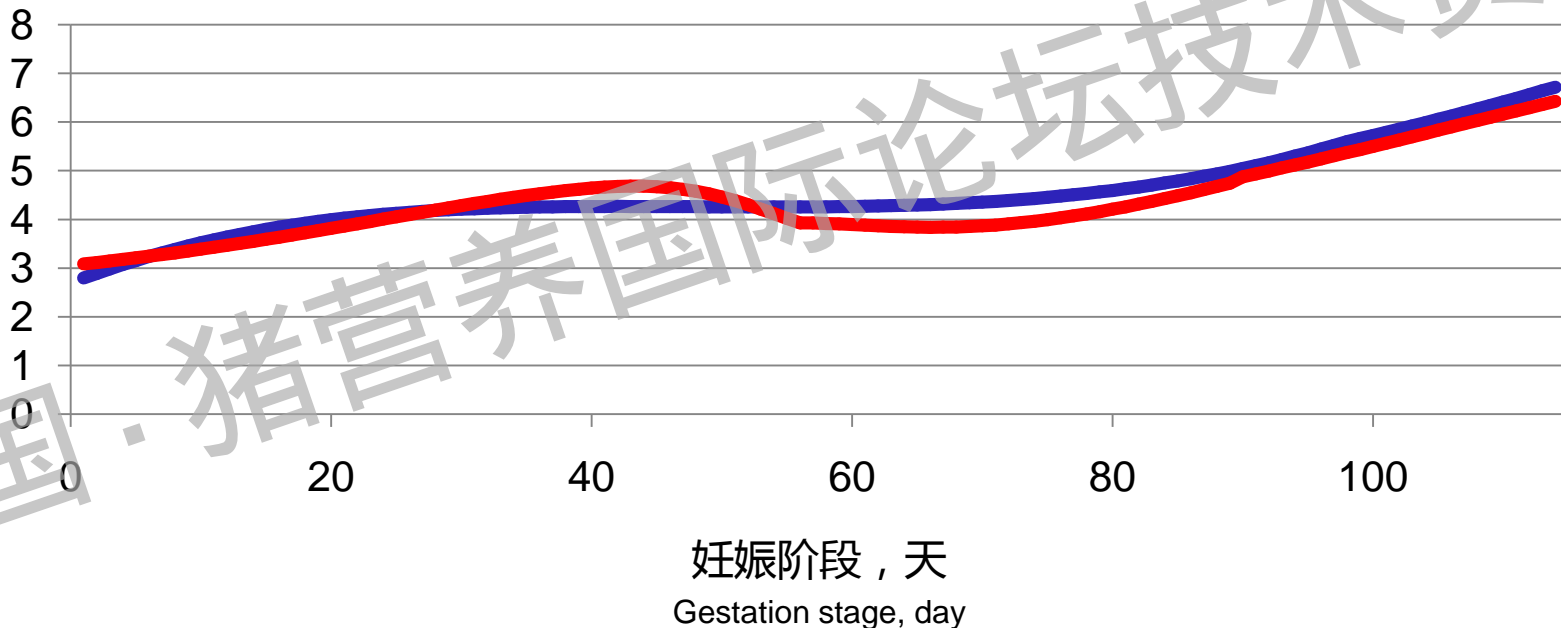
模型推荐的妊娠母猪赖氨酸需要量

Model-derived Lys requirements for gestating sows

回肠消化赖氨酸需求量, 克/千

克饲料

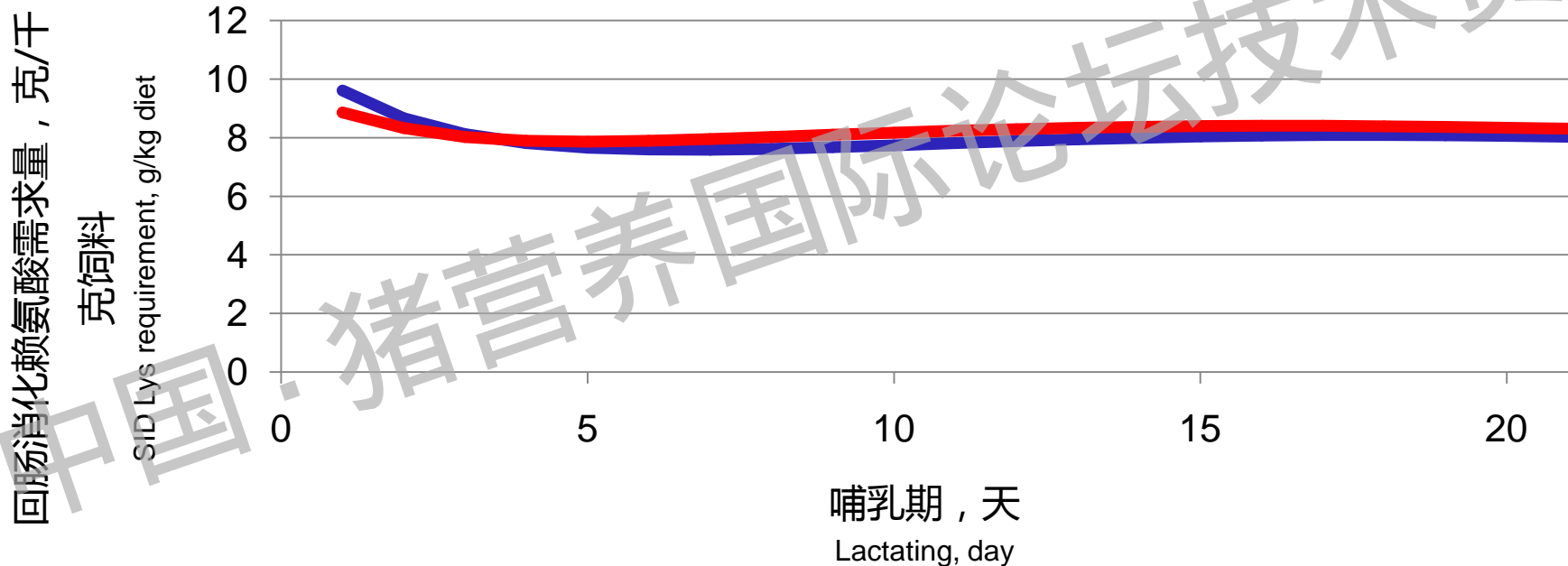
SID Lys requirement, g/kg diet



妊娠阶段, 天
Gestation stage, day

模型推荐的妊娠母猪赖氨酸需要量

Model-derived Lys requirements for gestating sows



回肠消化赖氨酸需求量，克/千

克饲料

SID Lys requirement, g/kg diet

哺乳期，天
Lactating, day

母猪平均理想氨基酸组成模式

Average ideal amino acid profile for sows

氨基酸 Amino acid	妊娠 Gestation		哺乳 Lactation	
	InraPorc	NRC	InraPorc	NRC
蛋氨酸 Met	28	28	30	26
蛋氨酸+胱氨酸 Met + Cys	65	69	60	53
苏氨酸 Thr	72	76	66	63
色氨酸 Trp	20	20	19	19
缬氨酸 Val	75	74	85	85
异亮氨酸 Ile	65	55	60	55
亮氨酸 Leu	100	95	115	113
苯丙氨酸 Phe	60	57	60	54
苯丙氨酸+酪氨酸 Phe + Tyr	100	98	115	112
组氨酸 His	30	32	42	40
精氨酸 Arg	-	53	-	56

结论

Conclusions

❖ 不同生长阶段期间的氨基酸供应对猪生长性能的影响会发生变化

The response of the animal to the amino acid supply changes during the different production stages

❖ 考虑“动物表现”而不是“需要量”

Think “response” rather than “requirement”

❖ 氨基酸供应对猪生长性能的影响有差异

There is variation among pigs in the response to the amino acid supply

致谢：

Acknowledgements:

Roberto BAREA¹

Ludovic BROSSARD¹

Alberto CONDE¹

Kees DE LANGE²

Serge DUBOIS¹

Michel ÉTIENNE¹

Mathieu GLOAGUEN¹

Nathalie LE FLOC'H¹

Jean NOBLET¹

Bernard SÈVE¹

Alain VALANCOGNE¹

¹INRA-Agrocampus Ouest

²University of Guelph