



## Concept and application of ideal protein for pigs

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QUEST

# 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



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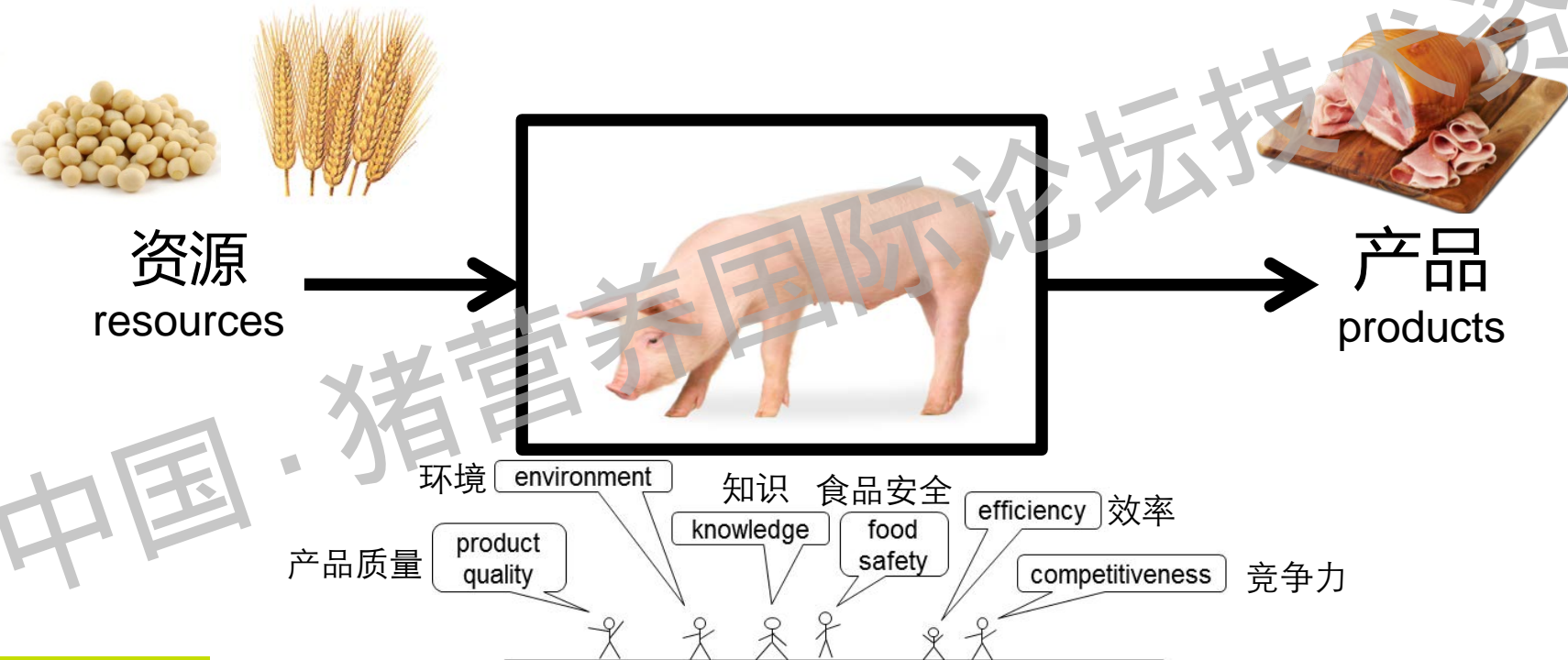
#### ❖ 模型推导方法 Model-derived methods

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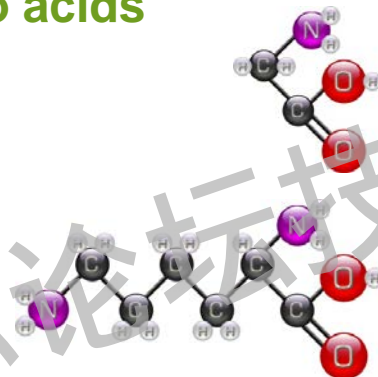
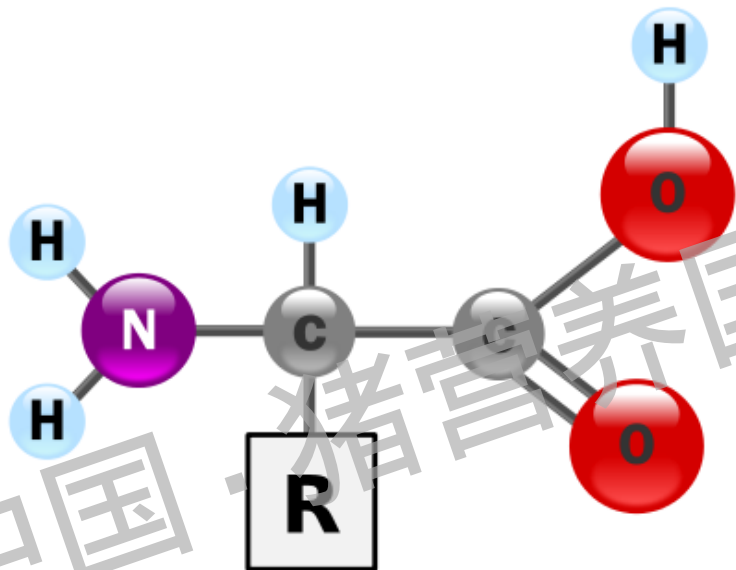
# 提高养猪业可持续发展能力

## Enhancing the sustainability of the pork industry



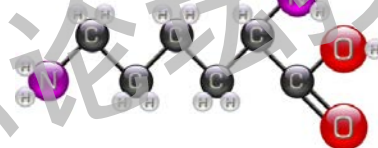
# 氨基酸结构

Structure of amino acids



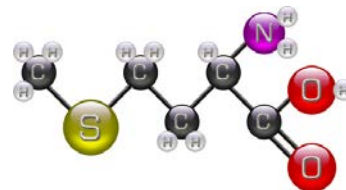
甘氨酸

Gly



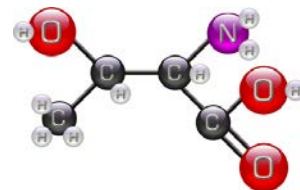
赖氨酸

Lys



蛋氨酸

Met



苏氨酸

Thr

# 氨基酸结构

## Structure of amino acids

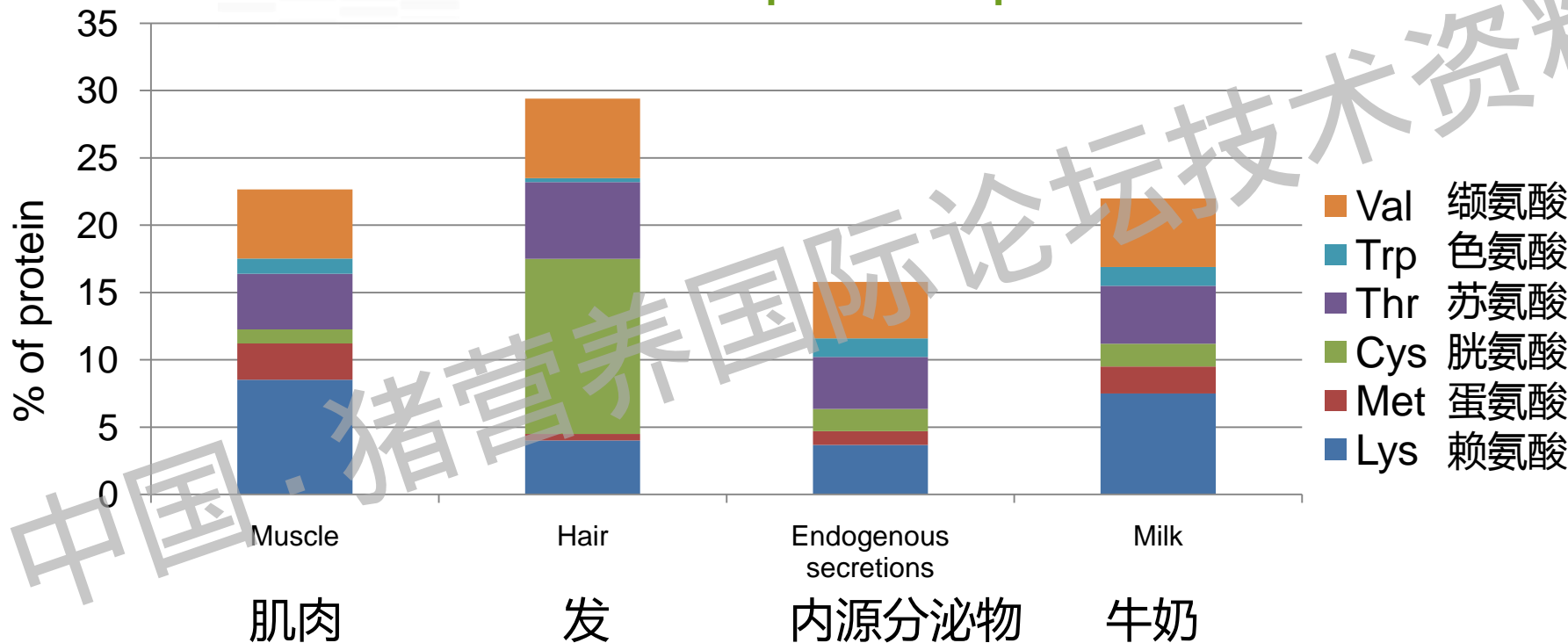
### 蛋白中的一些元素是饲料中必不可少的成分

“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







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# 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%)

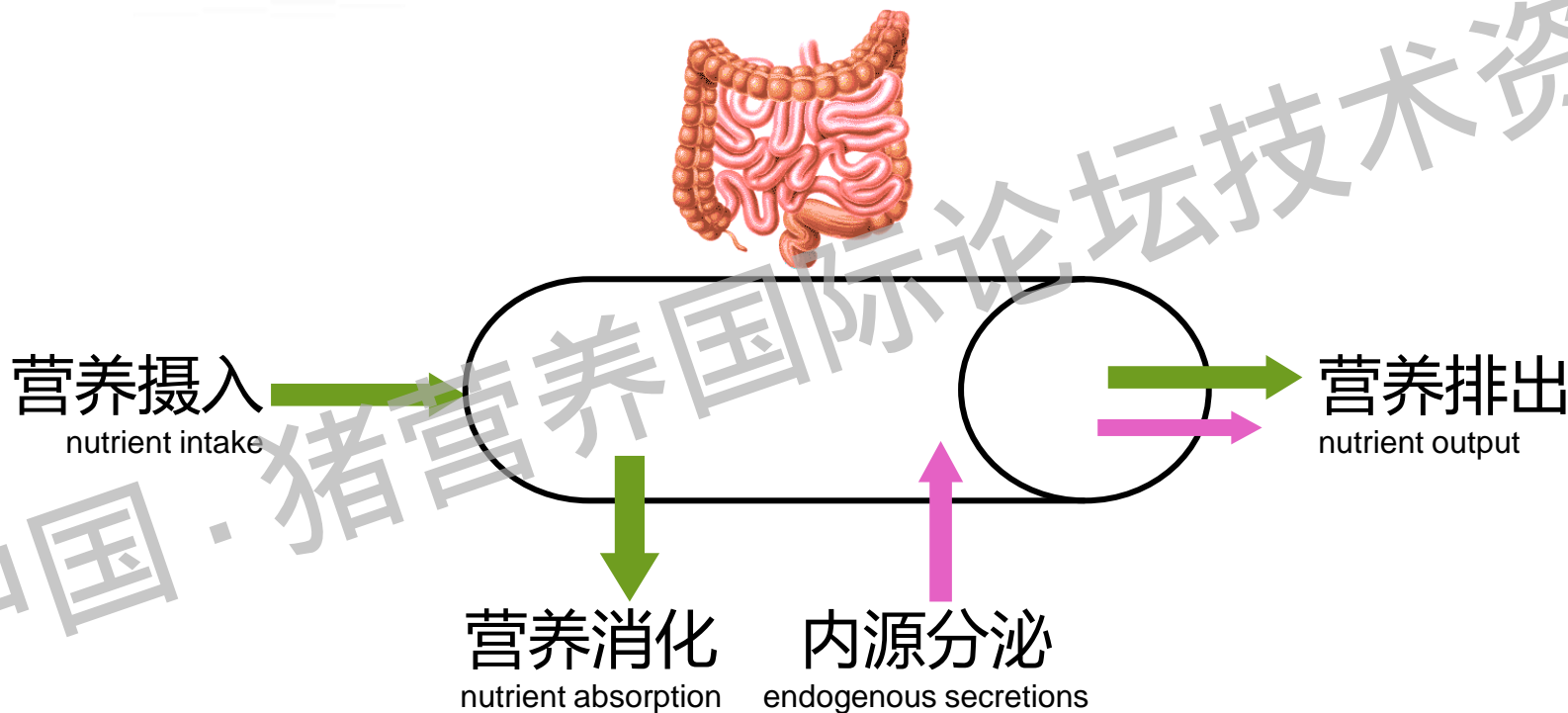
Simple to use: only 1 value for each amino acid to remember (e.g., Thr:Lys = 65%)



Law of the minimum  
(von Liebig, 1850)

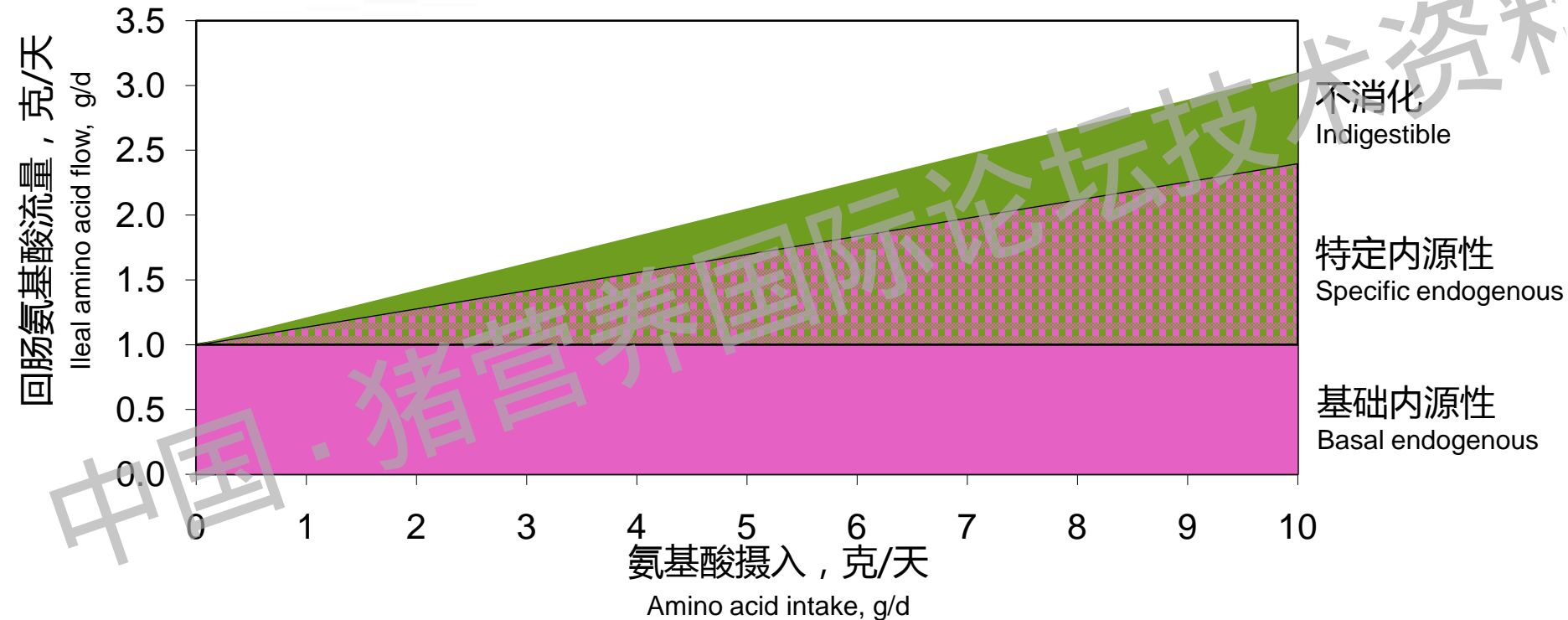
# 氨基酸值和需要量的表示

Expressing amino acid values and requirements



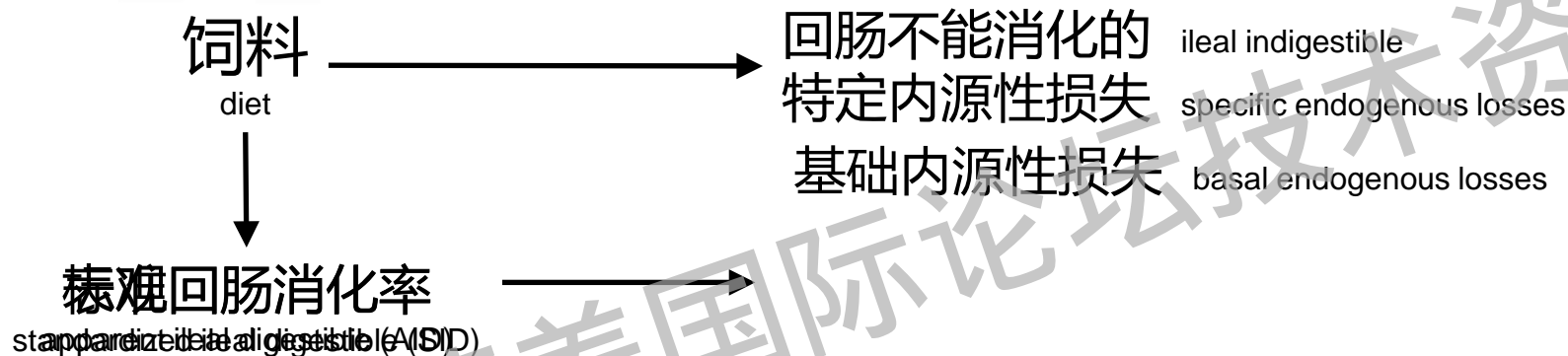
# 随着氨基酸摄入的增加，内源性损失也增加

Endogenous losses increase with increasing amino acid intake



# 氨基酸值和需要量的表示

## Expressing amino acid values and requirements

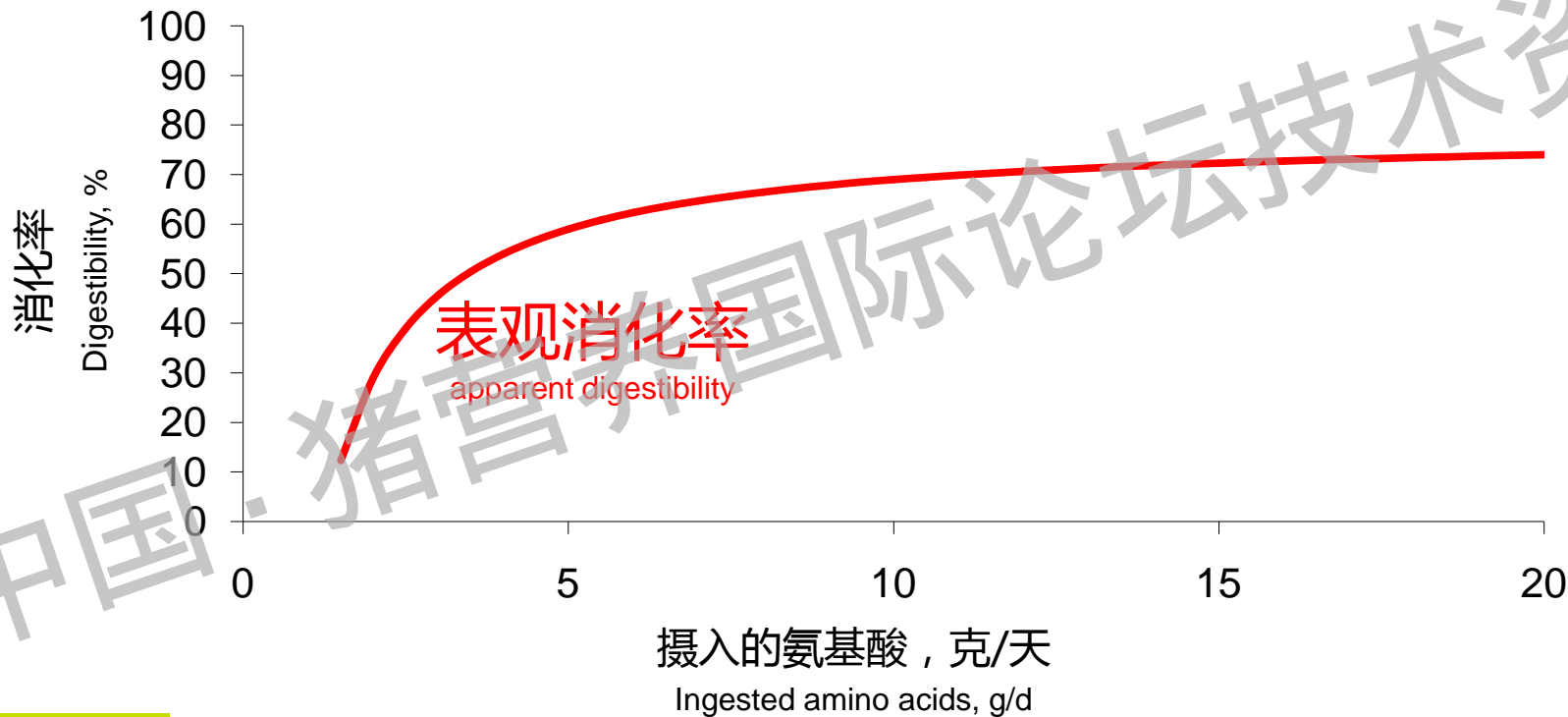


基础内源性损失是：  
表观回肠消化率系统中饲料价值的一部分  
标准回肠消化率系统中需要量的一部分

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



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# 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

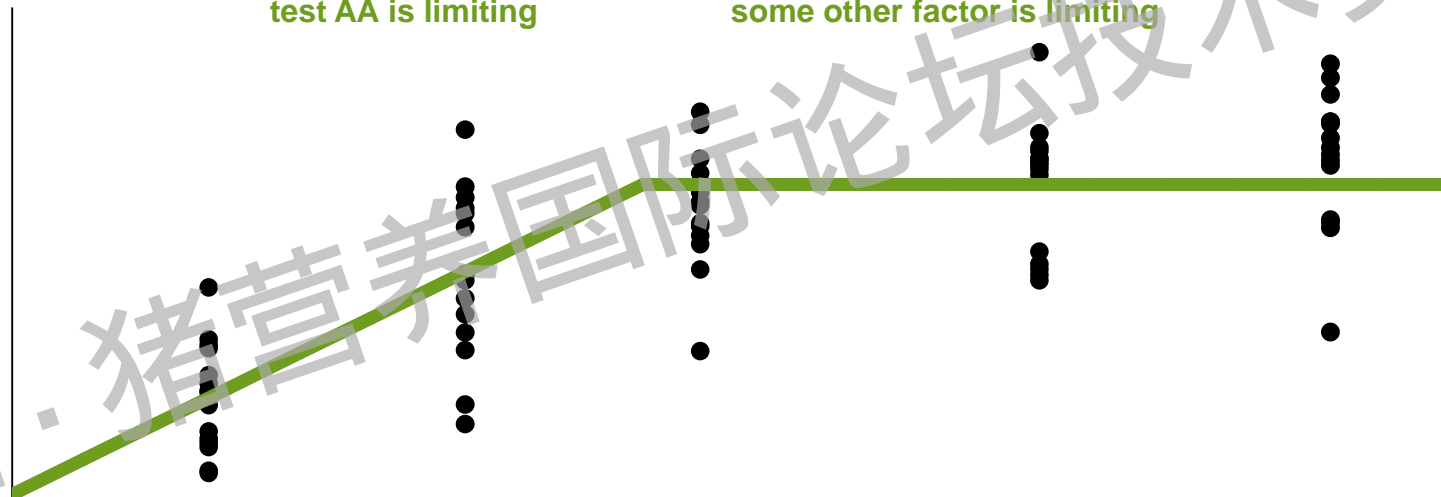
Knowledge of the limiting factors

待测氨基酸  
test AA is limiting



其他限制因素  
some other factor is limiting

反应  
Response

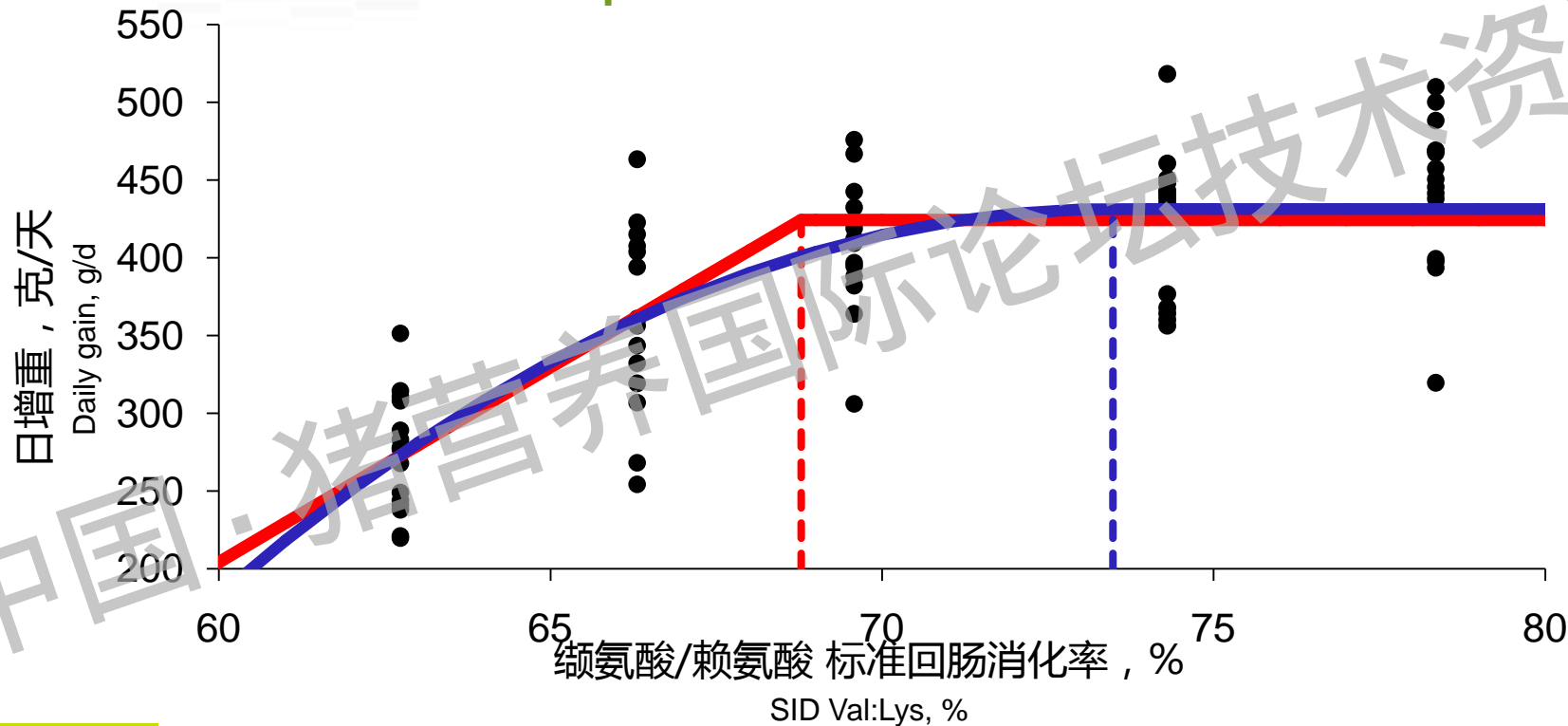


氨基酸含量

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	-	-





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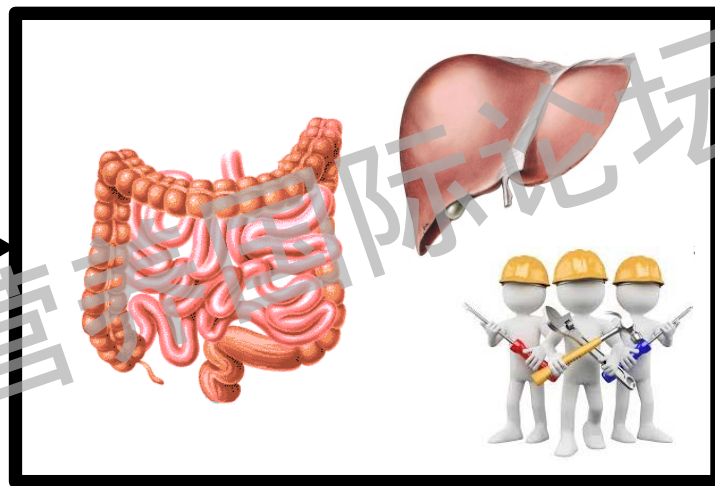


# 析因法评估生长猪的需要量

Factorial calculation of requirements for growing pigs



来源  
resources

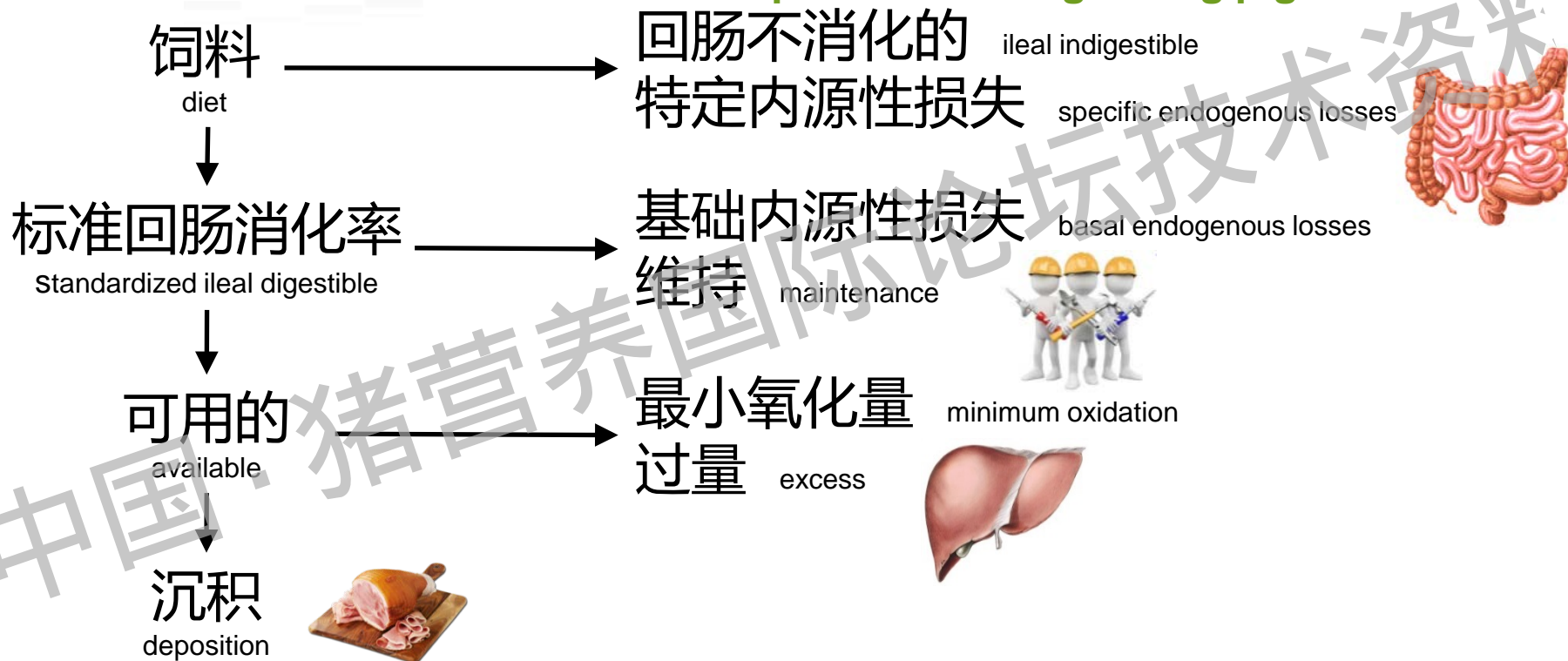


产品  
products



# 析因法评估生长猪的需要量

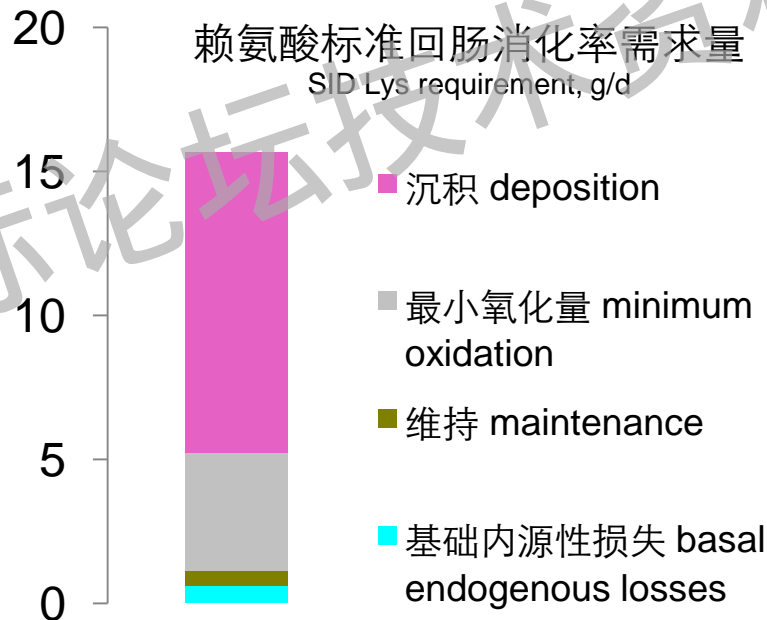
Factorial calculation of requirements for growing pigs



# 析因法评估生长猪的需要量

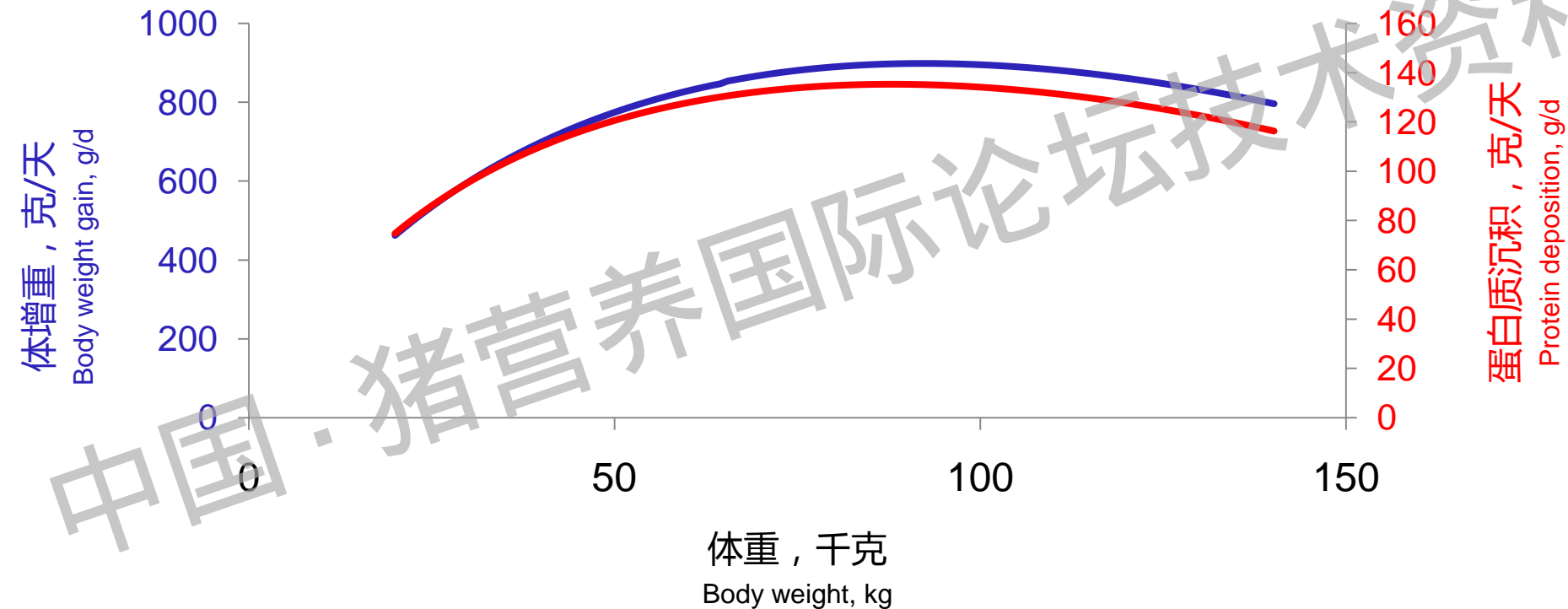
## Factorial calculation of requirements for growing pigs

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 <sup>0.75</sup> )/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





http://w3.rennes.inra.fr/inraporc/index\_en.html



InraPorc: Home page



# InraPorc<sup>®</sup>

Home Overview Download License Support Publications

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

Simulation Performance | Feed | Growth | Economic part

France

**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

Simulation Single simulation | Comparison Single simulation Standard Sow profile Animal profile Feed sequence plan Feed rationing plan Initial state Age (d) Sow Pigslets Feeder Feed composition

INRA

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Institut National de la Recherche Agronomique

Litter	1	2	3	4	5	6	7	8	Herd
2.84	2.84	2.85	2.82	2.83	2.80	2.80	2.77	2.80	
2 000	2 000	1 000	0	0	0	0	0	0	
200 200 3	200 200 3	200 200 3	200 200 3	200 200 3	200 200 3	200 200 3	200 200 3	200 200 3	

Parity 1-3 (28 d)

Simulation 1: "Standard" - feed sequence  
Simulation 2: "Standard" - feed sequence  
Simulation 3: "Standard" - feed sequence  
Simulation 4: "Standard" - feed sequence

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Institut National de la Recherche Agronomique

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UMR PEGASE, 35590 Saint-Gilles, France, phone. +33 (0)2 23 48 52 00  
Publication director: Jaap van Milgen

Site administrators: Jean-Yves Dourmad, Alain Valencongne, Ludovic Brossard and Jaap van Milgen

- **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

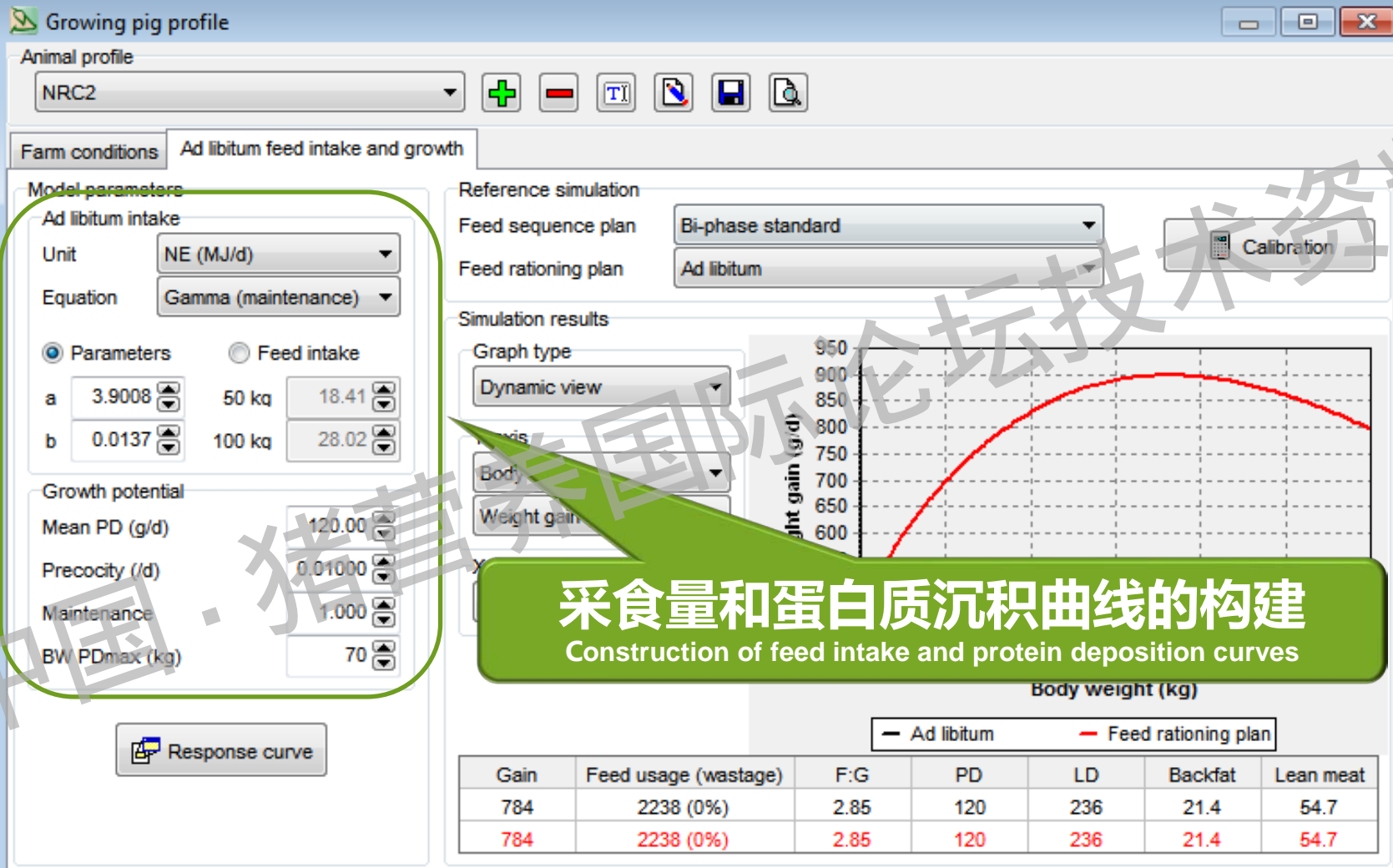
- **分析养分利用率**

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



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

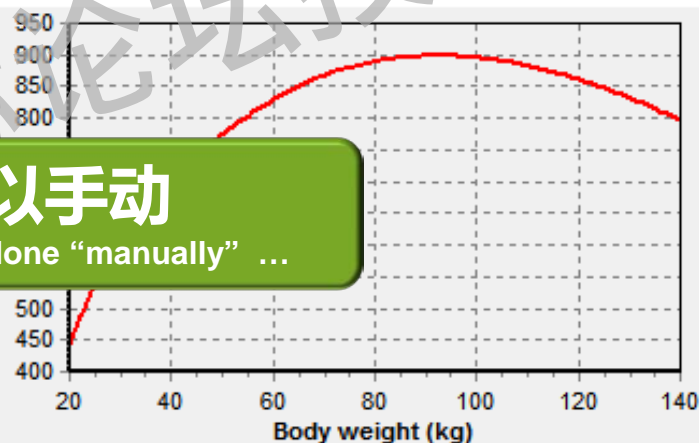
Weight gain

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



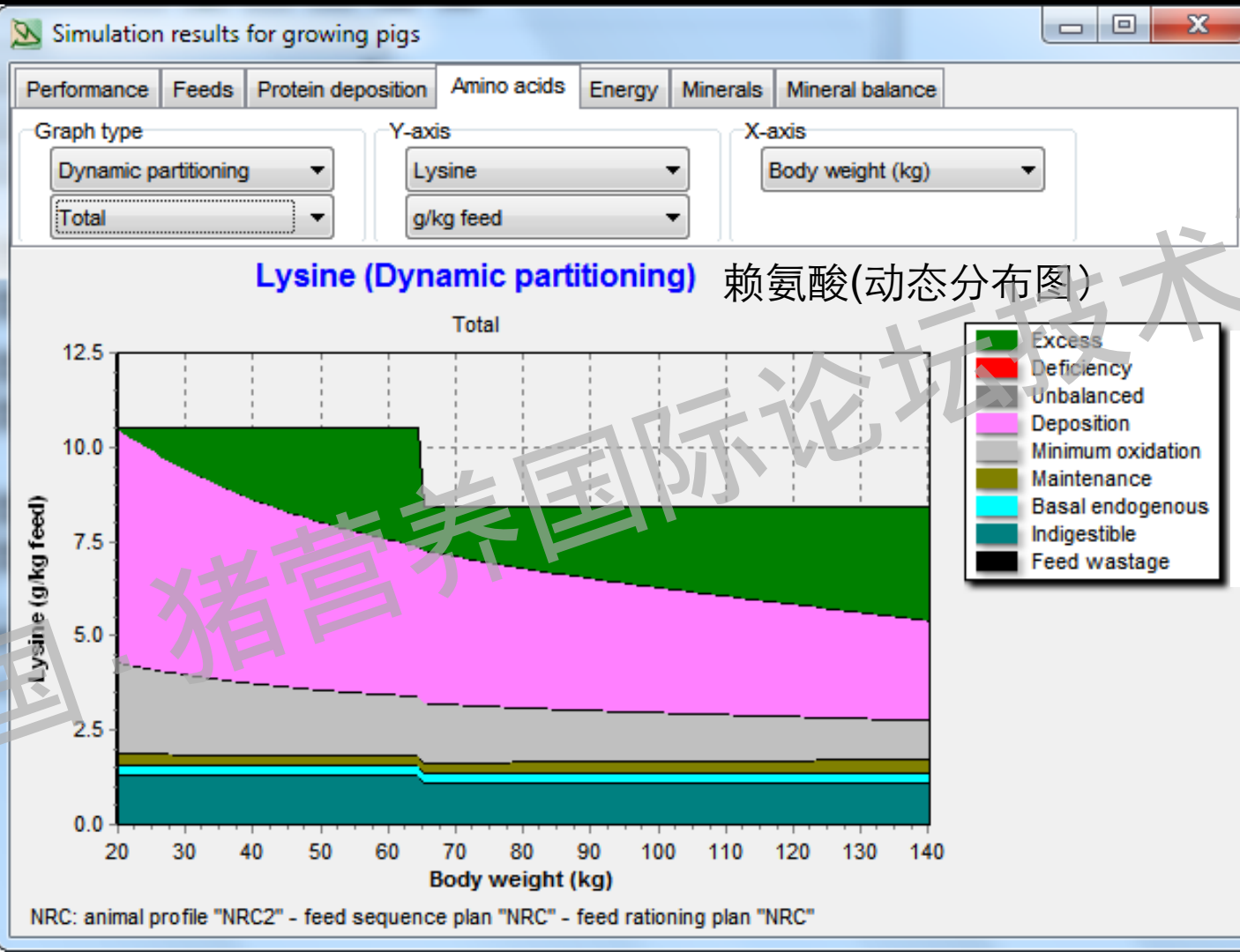
Delete



Import

OK

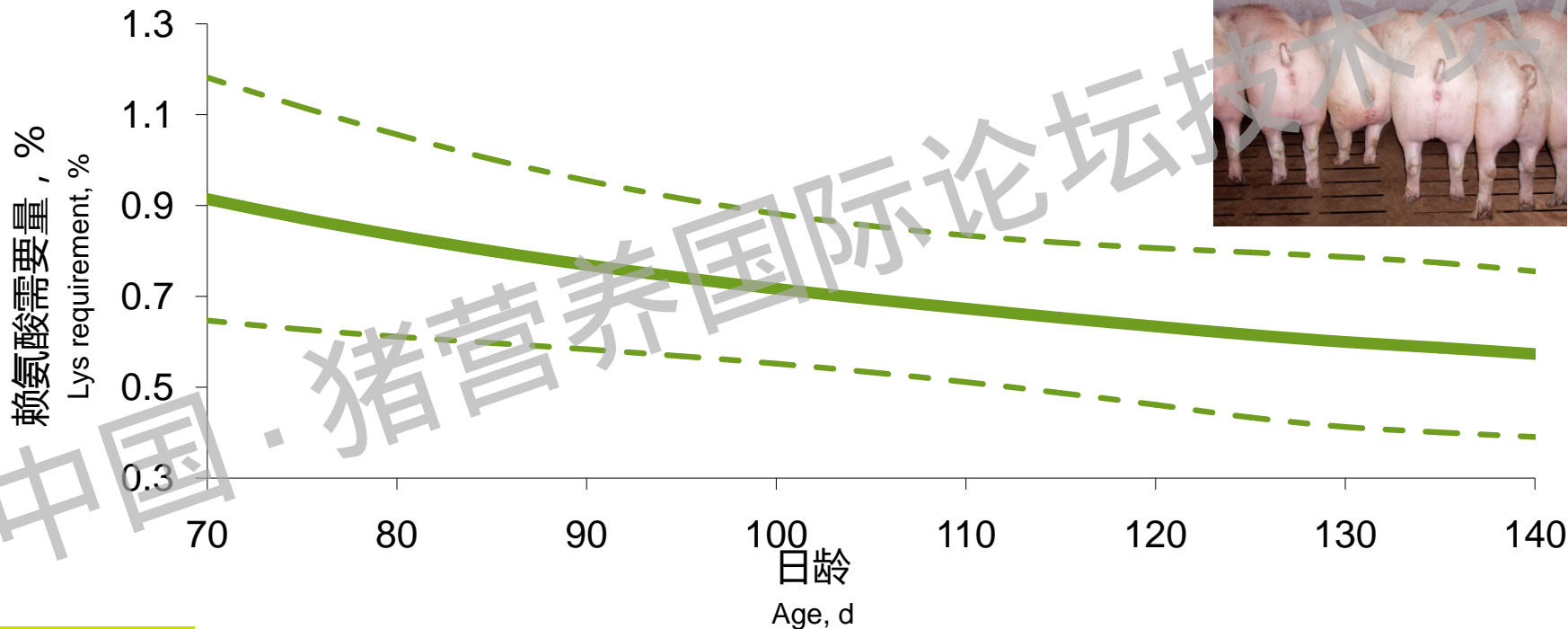
Cancel



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?



# Simulation results for growing pigs

Performance Feeds Protein deposition Amino acids Energy Minerals Mineral balance

Graph type

Requirement and supply

Standardized digestible

Y-axis

Lysine

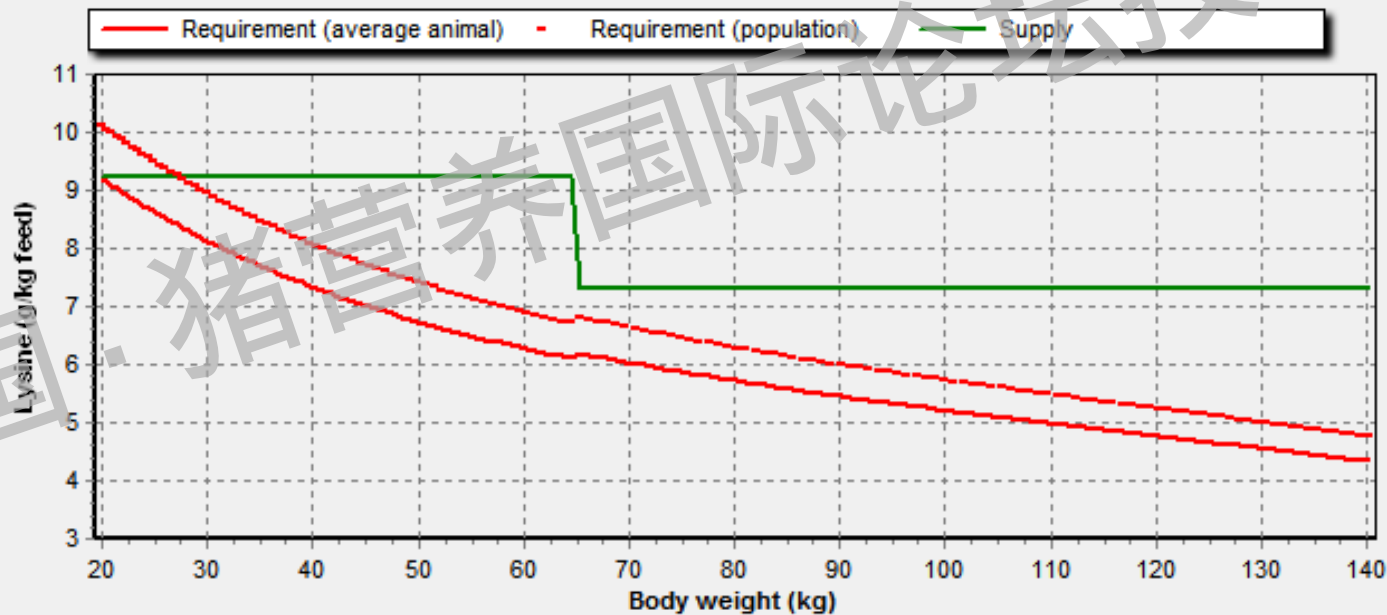
g/kg feed

X-axis

Body weight (kg)

## Lysine (Requirement and supply)

Standardized digestible



NRC: animal profile "NRC2" - feed sequence plan "NRC" - feed rationing plan "NRC"

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## Expert Report



f J'aime 19

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English

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Each report is prepared by a committee of experts 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

Net energy (NE)

氨基酸

Amino Acids

Standardized ileal digestible (SID)

磷

Phosphorus

Standardized total tract digestible (STTD)

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? No

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 &amp; 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 =  $a + b \times BW$   
+  $c \times BW^2 + d \times BW^3$

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



# 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？

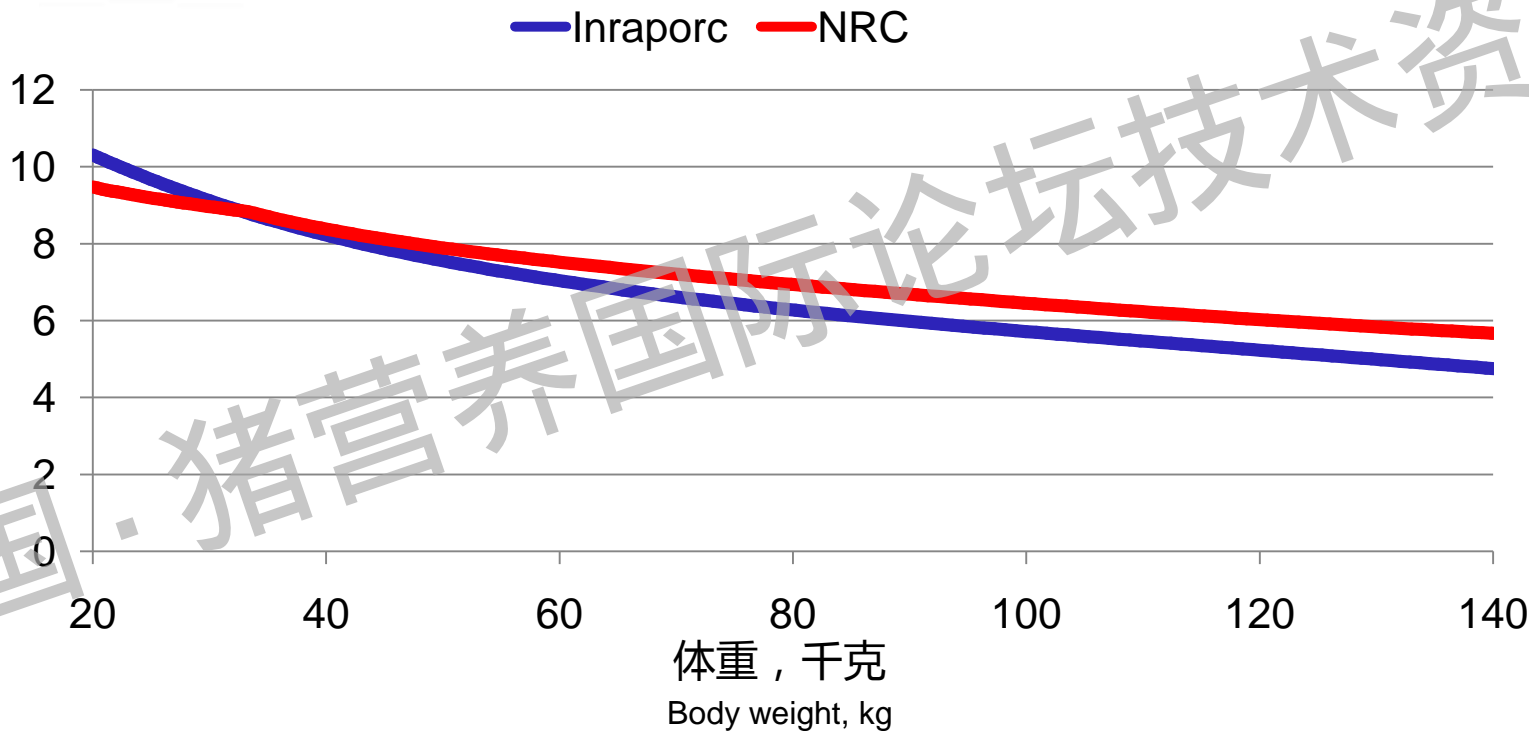
Does it matter?

# 生长猪赖氨酸需要量的模型推荐量

Model-derived Lys requirements for growing pigs

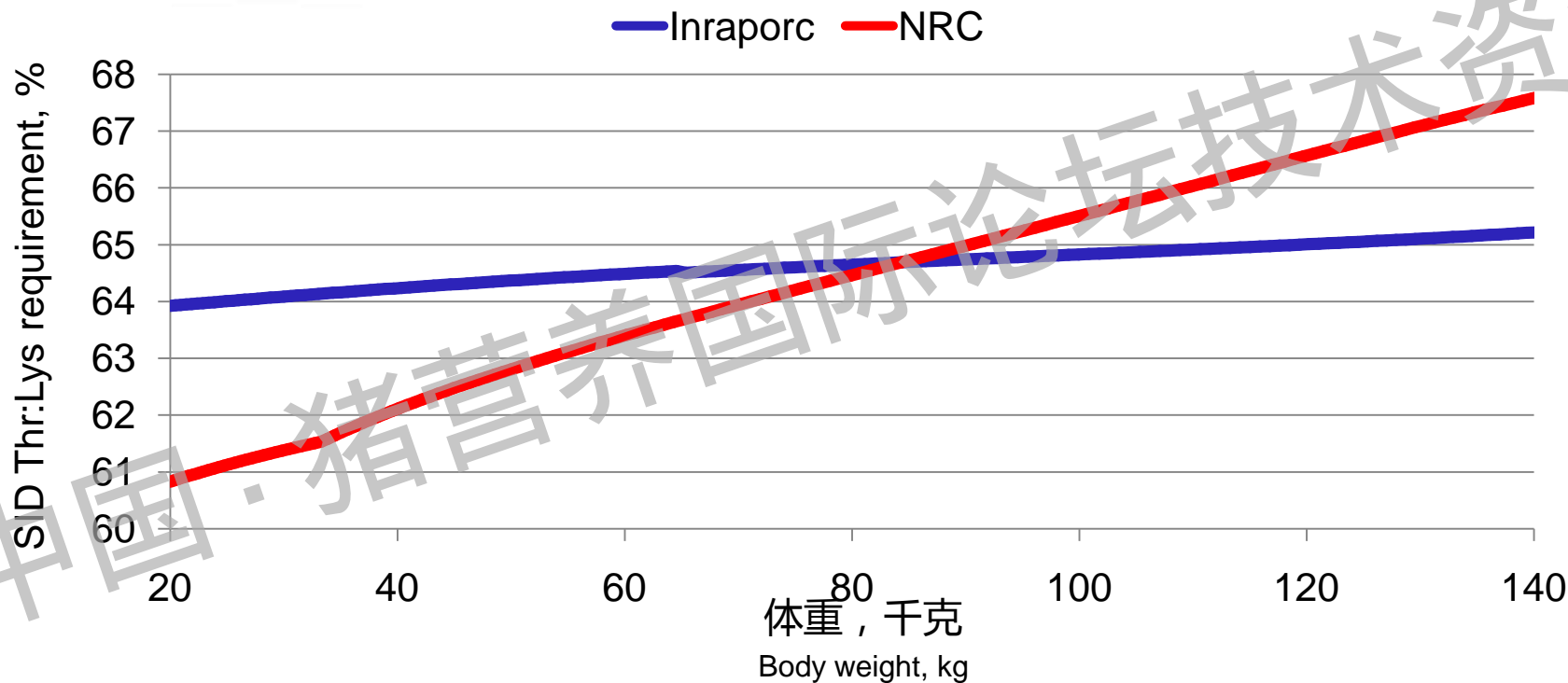
标准回肠可消化赖氨酸需要量

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

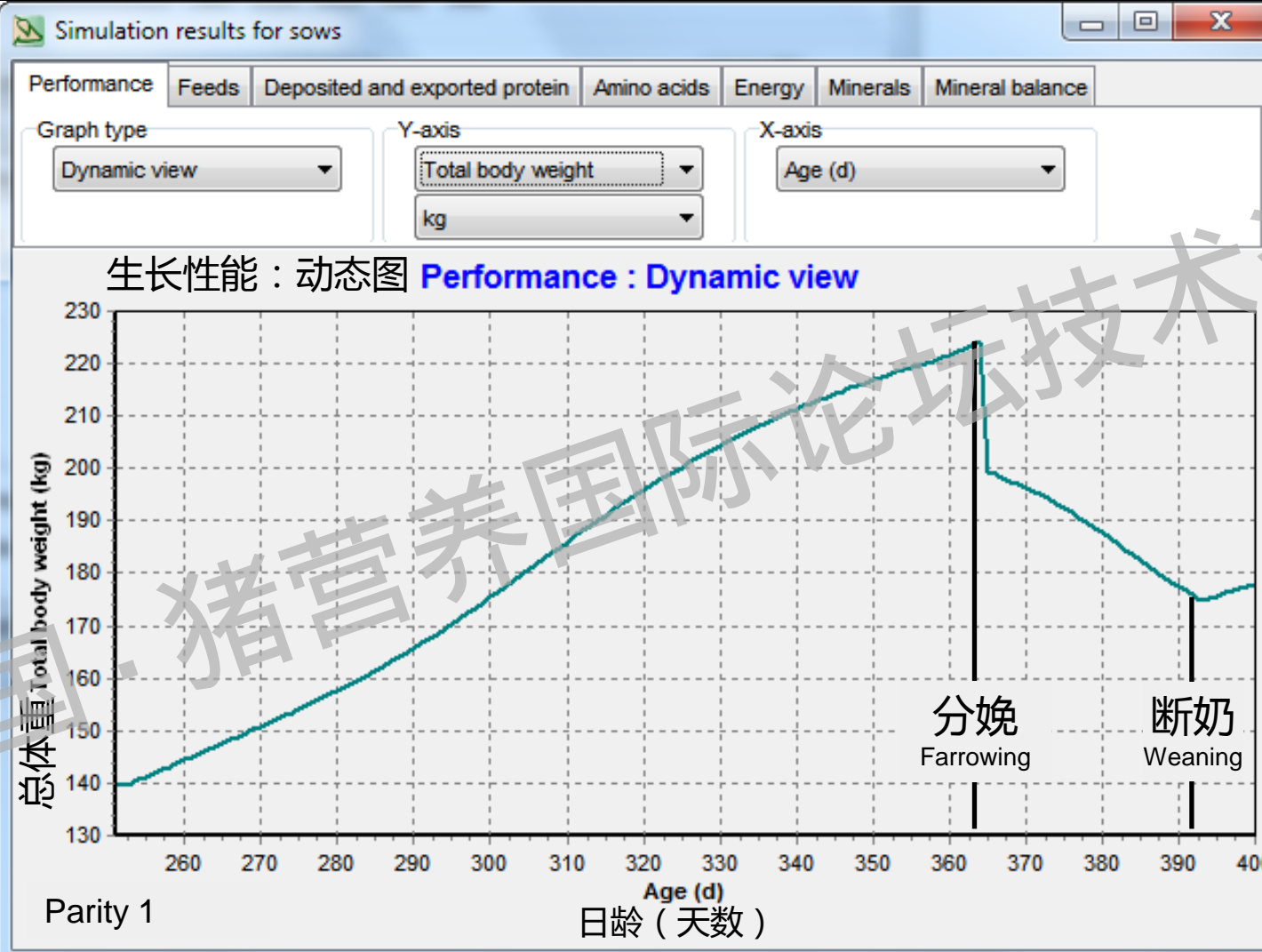
Maternal body weight gain

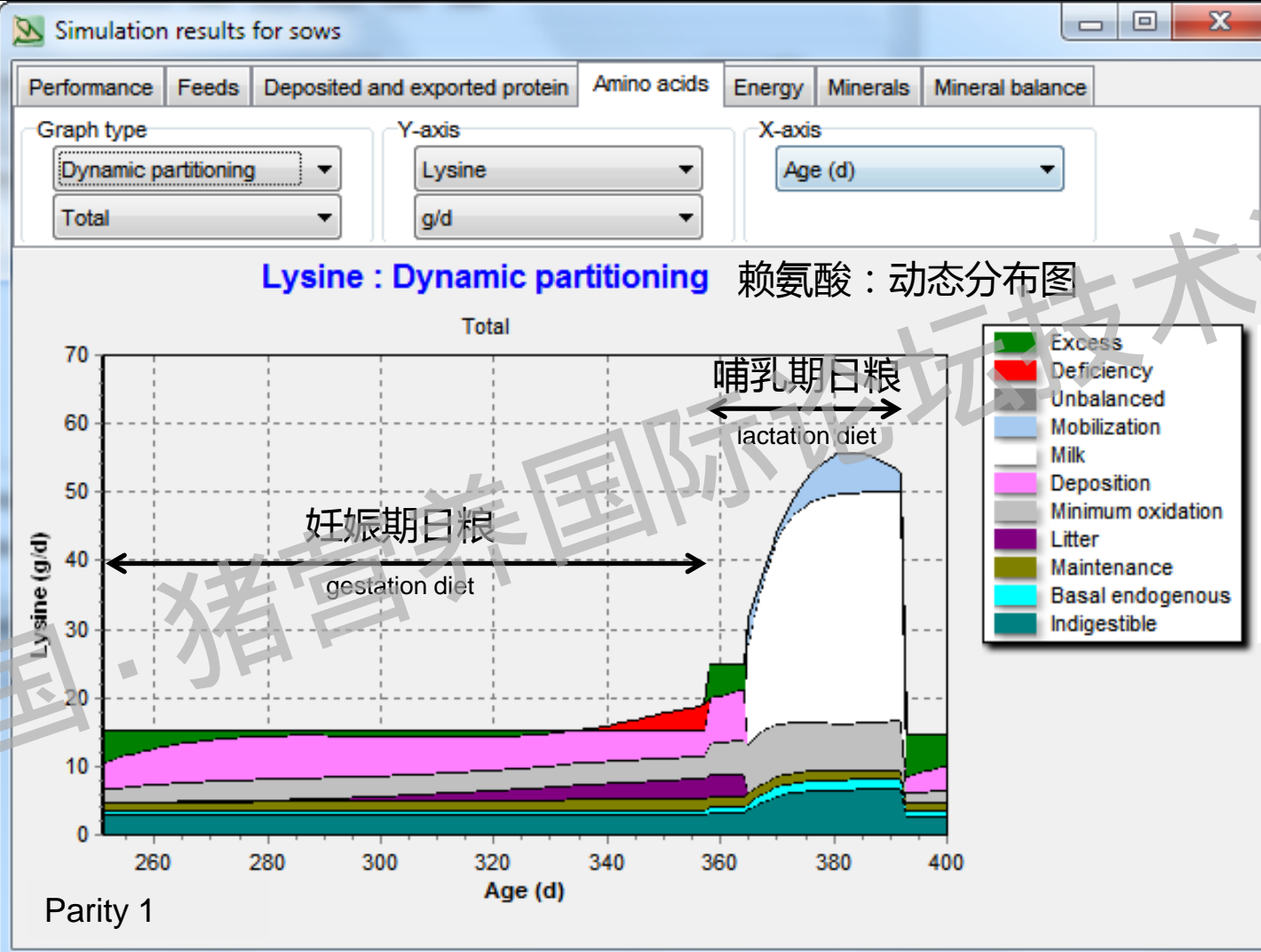
#### ❖ 奶产量：窝仔猪生长率

Milk production: litter growth rate

#### ❖ 动员体内储备：背膘厚，失重

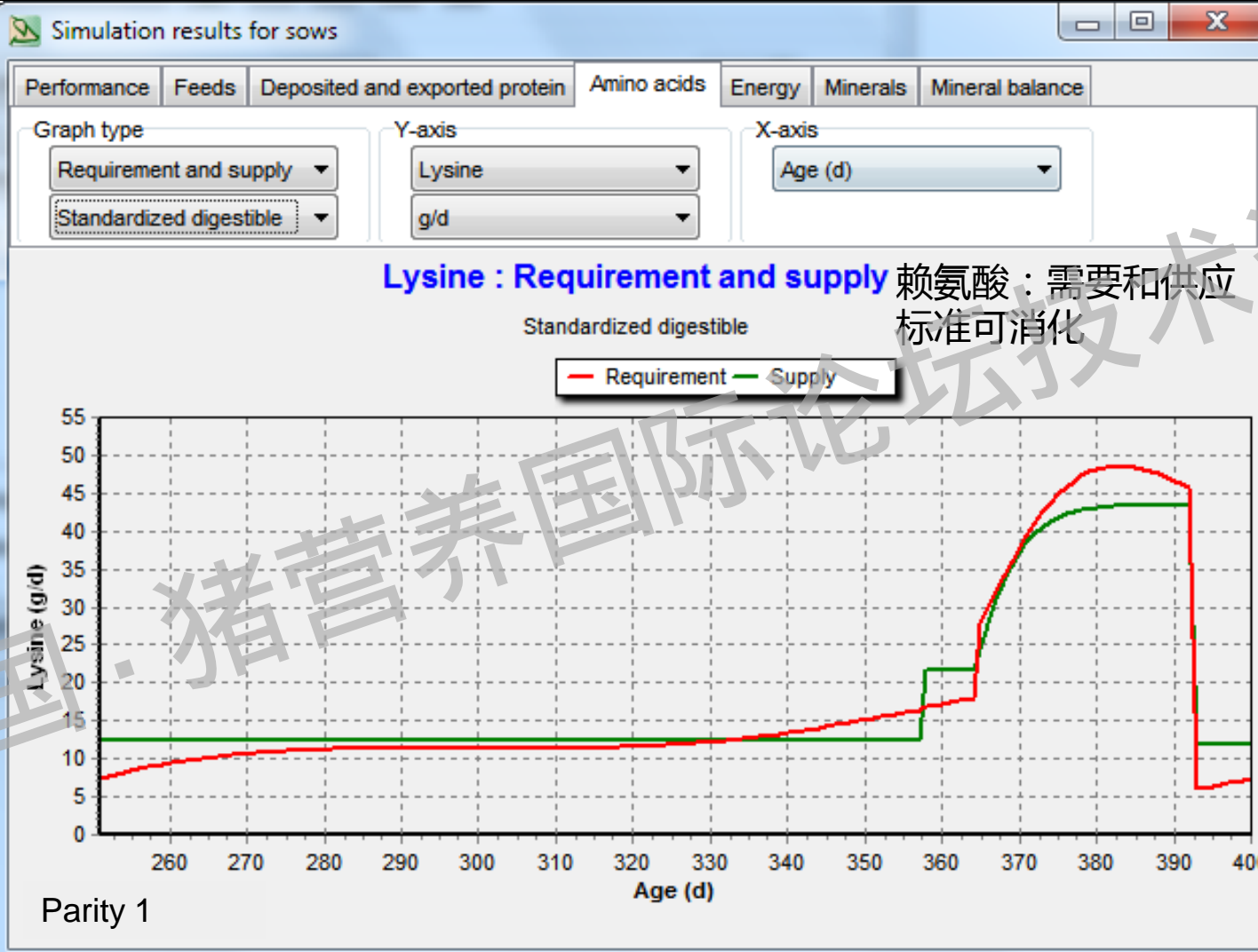
Mobilization of body reserves: backfat thickness, weight loss

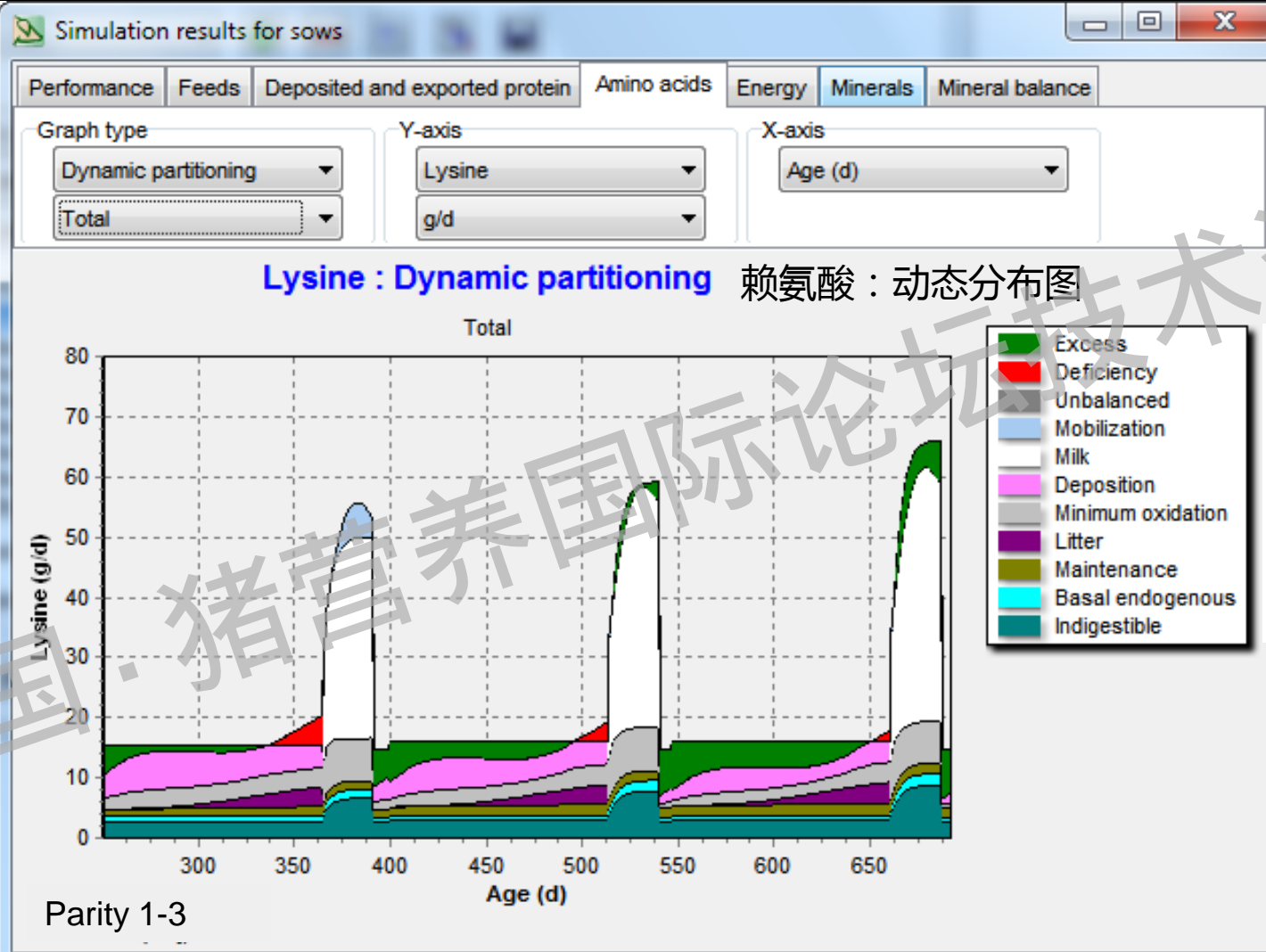




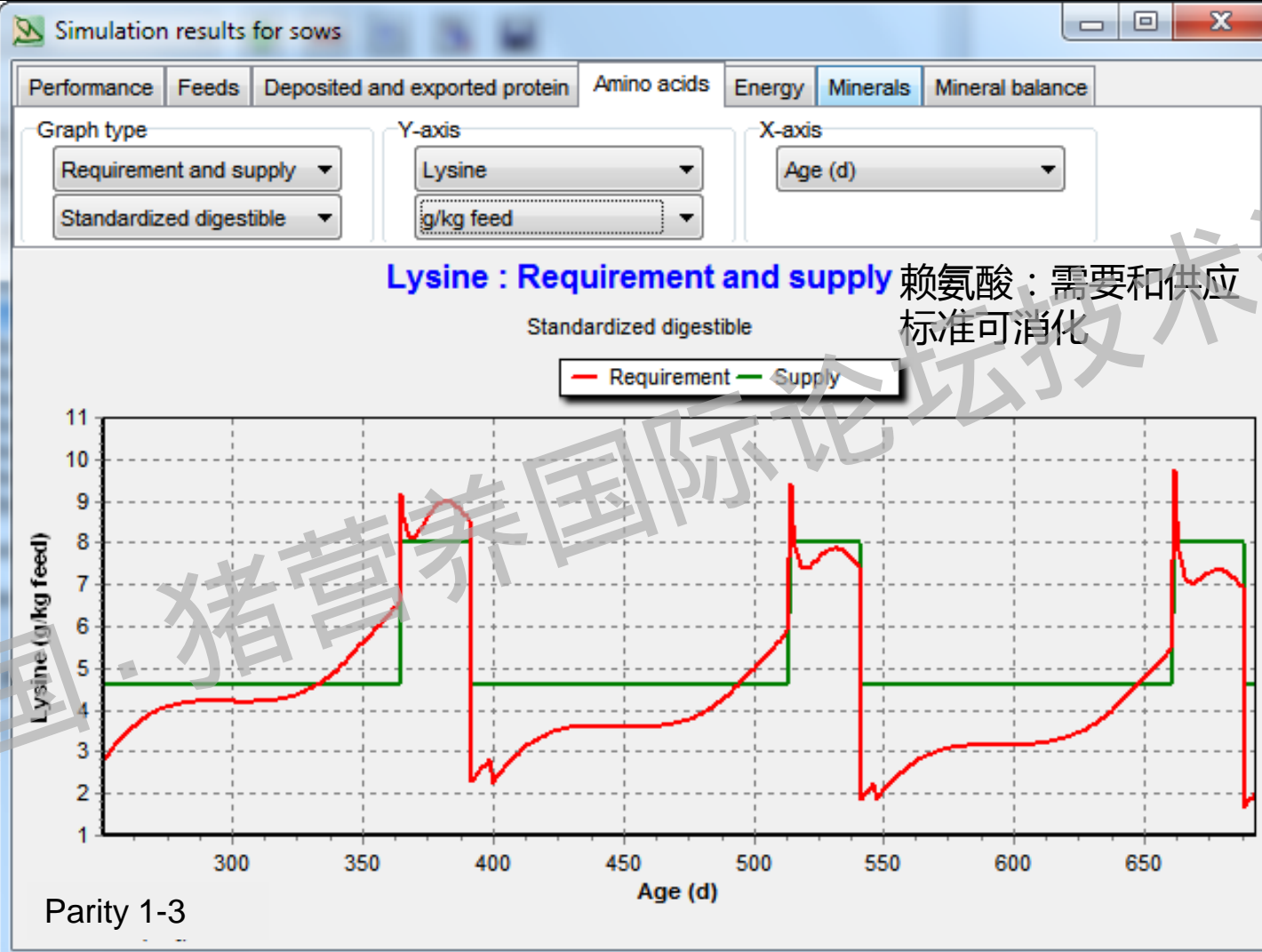
过量  
缺乏  
不平衡  
动员  
母乳  
沉积  
最小氧化  
窝产仔  
维持  
基础内源性  
不消化的







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



# 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?

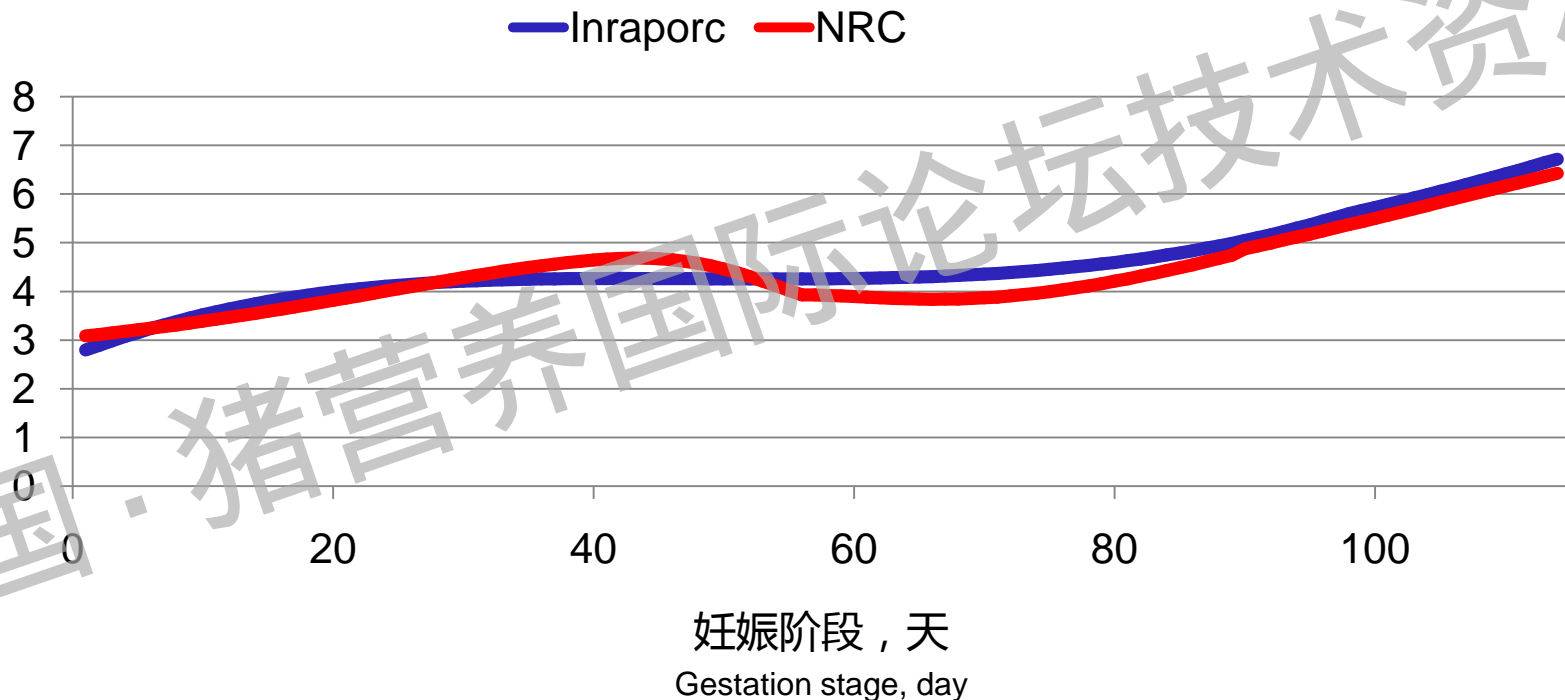
# 模型推荐的妊娠母猪赖氨酸需要量

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



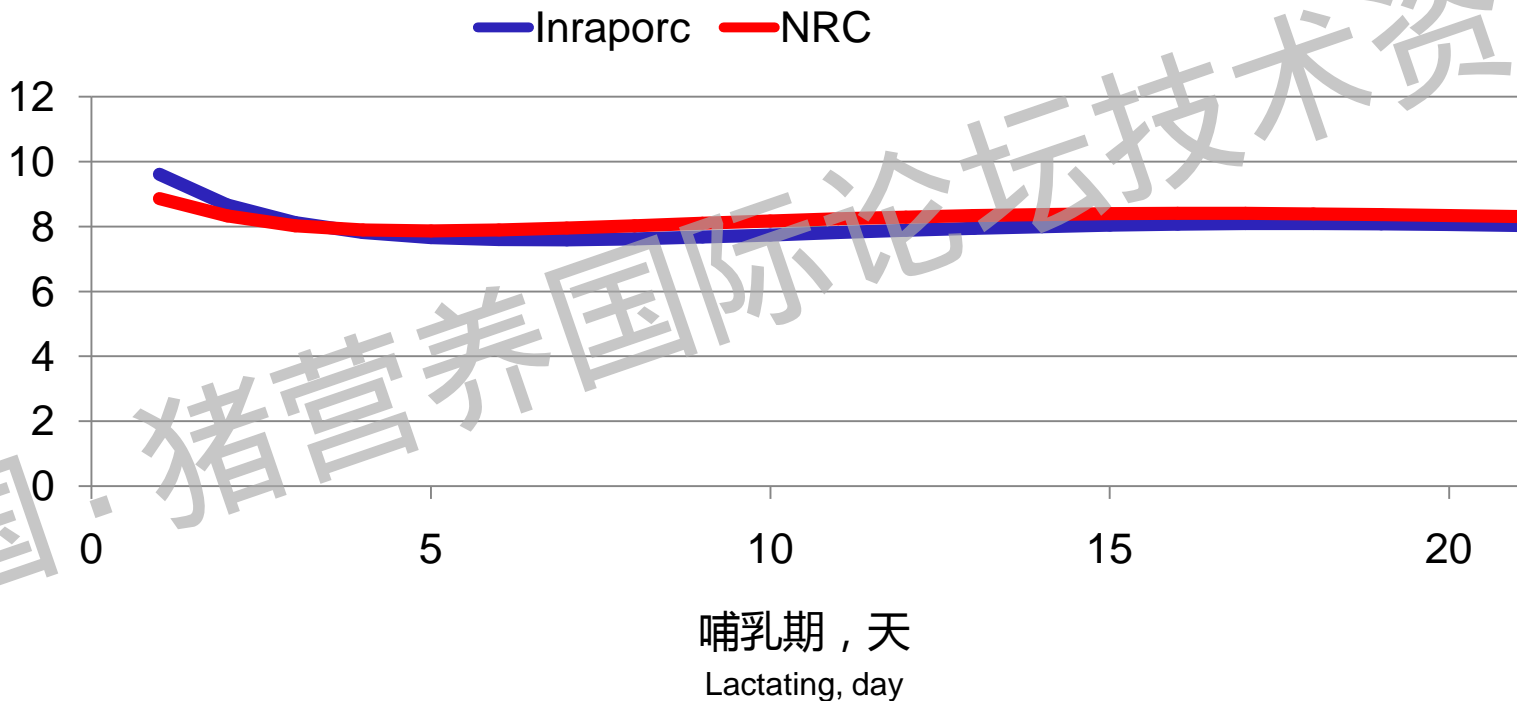
# 模型推荐的妊娠母猪赖氨酸需要量

Model-derived Lys requirements for gestating sows

回肠消化赖氨酸需求量，克/干

克饲料

SID Lys requirement, g/kg diet



# 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

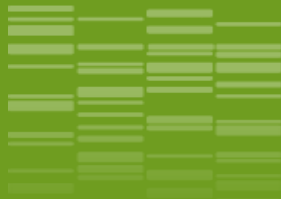
### ❖ 考虑“动物表现”而不是“需要量”

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





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