INRA
SCIENCE & IMPACT

AGRO CAMPUS OUEST

通过精准饲养技术优化生猪养殖

Optimization of pig production through precision livestock feeding

Jaap VAN MILGEN

Outline大纲

- 营养价值和营养需要的变异
- 预测猪只对营养供给产生的反应
- 精准猪肉生产
- 结论

- Variation in nutrient values and requirements
- Predicting the response of pigs to the nutrient supply
- Precision pork production
- Conclusions

Feed formulation is based on “values” and “requirements”
饲料配方基于“营养价值”和“营养需要”

TABLE 17-1 Continued

Ingredient: Soybean Meal, Dehulled, Expelled
AAFCO #: 84.71, AAFCO 2010, p. 392

原料：压榨去皮豆粕

Proximate Components, % 近似组分%			
	$\bar{x}$	n	SD
干物质 Dry matter	95.57	4	1.56
粗蛋白 Crude protein	45.13	4	3.60
粗纤维 Crude fiber	3.30	1	
乙醚提取物 Ether extract	6.64	2	1.10
酸性乙醚提取物 Acid ether extract			
灰分 Ash	6.24	1	
碳水化合物组分 Carbohydrate Components, %			
乳糖 Lactose			
蔗糖 Sucrose			
棉籽糖 Raffinose			
水苏糖 Stachyose			

Amino Acids, % 氨基酸%										
	Total 总值			Digestibility 消化率						
				AID			SID			
	$\bar{x}$	n	SD	$\bar{x}$	n	SD	$\bar{x}$	n	SD
Essential										
CP	45.13	4	3.60	81	3	4.20	89	3	0.55
Arg	3.02	4	0.4	90	3	3.07	95	3	0.39
His	1.14	4	0.15	86	3	3.39	90	3	1.49
Ile	1.90	4	0.33	85	3	3.94	89	3	1.81
Leu	3.21	4	0.51	85	3	3.35	88	3	1.77
Lys	2.79	4	0.22	86	3	4.05	90	3	2.45
Met	0.60	4	0.07	80	3	7.82	85	3	4.84
Phe	2.15	4	0.31	86	3	3.52	89	3	2.51
Thr	1.73	4	0.14	76	3	3.62	84	3	1.82
Trp	0.69	2	0.04	87	1		89	1	
Val	2.01	4	0.36	83	3	4.00	88	3	1.49

NRC, 2012

Feed formulation is based on “values” and “requirements”
饲料配方基于“营养价值”和“营养需要”

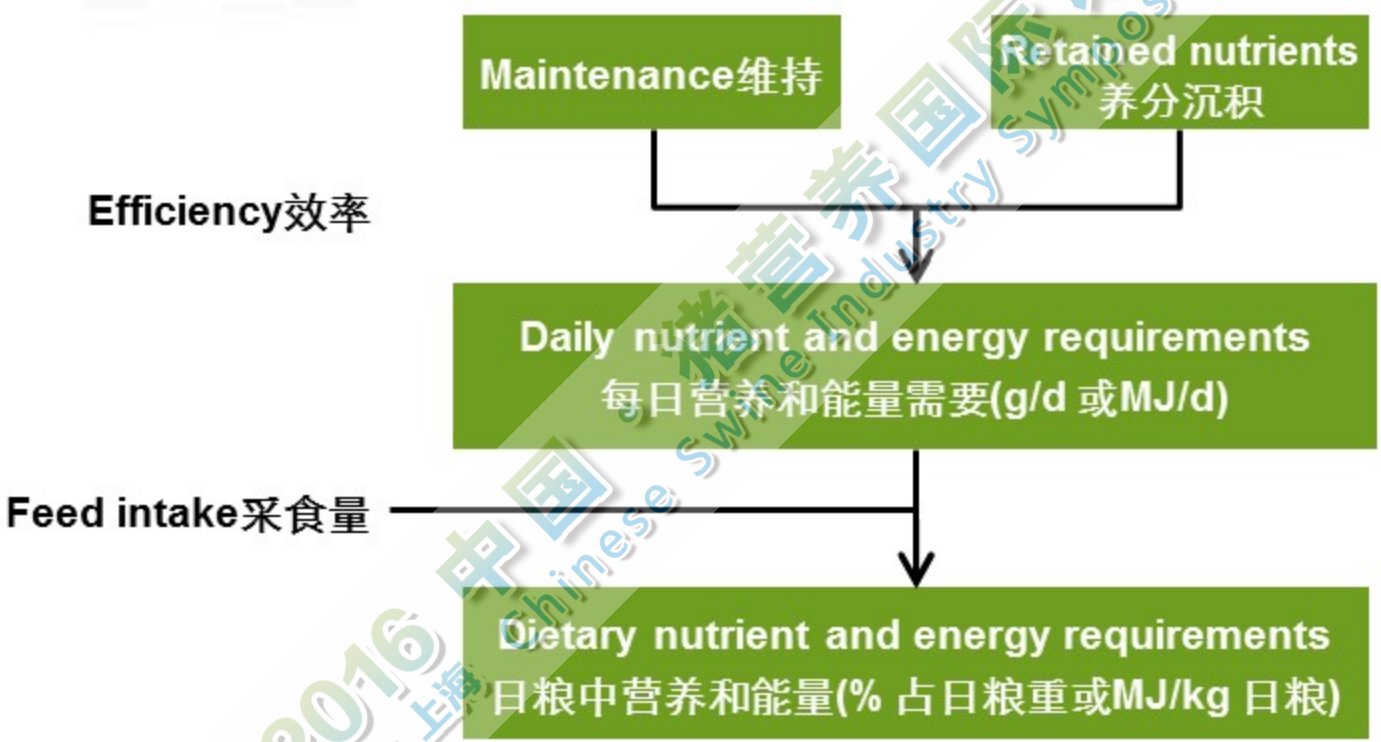


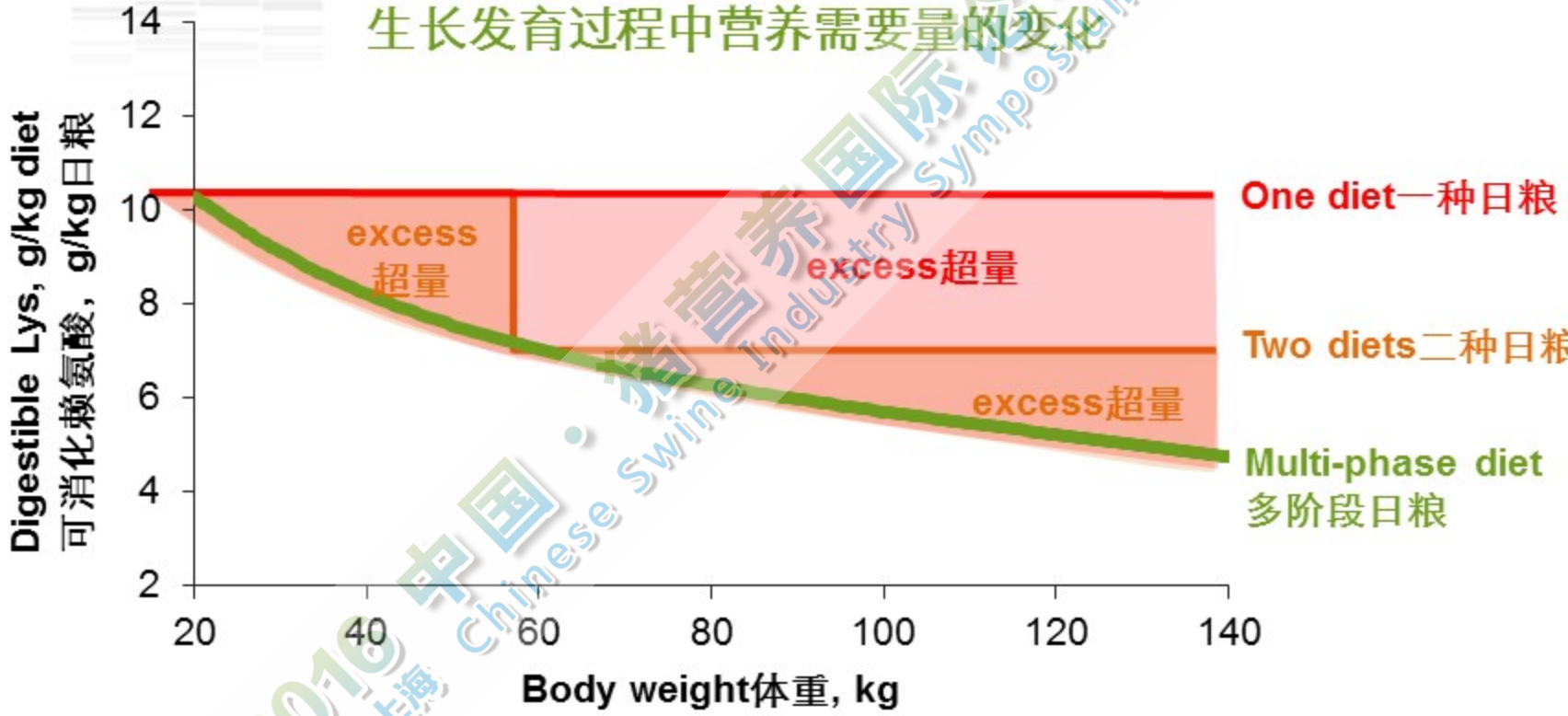
表16-1A 自由采食条件下生长猪日粮中钙、磷和氨基酸需要量(90%干物质)

TABLE 16-1A Dietary Calcium, Phosphorus, and Amino Acid Requirements of Growing Pigs When Allowed Feed Ad Libitum (90% dry matter)[a]

	Item	Body Weight Range (kg) 体重范围 (kg) 5-7	7-11	11-25	25-50	50-75	75-100	100-135
日粮净能	NE content of the diet (kcal/kg)[b]	2,448	2,448	2,412	2,475	2,475	2,475	2,475
日粮有效消化能	Effective DE content of diet (kcal/kg)[b]	3,542	3,542	3,490	3,402	3,402	3,402	3,402
日粮有效代谢能	Effective ME content of diet (kcal/kg)[b]	3,400	3,400	3,350	3,300	3,300	3,300	3,300
估计的有效代谢能摄入	Estimated effective ME intake (kcal/day)	904	1,592	3,033	4,959	6,989	8,265	9,196
估计的采食量+浪费量	Estimated feed intake + wastage (g/day)[c]	280	493	953	1,582	2,229	2,636	2,933
体增重	Body weight gain (g/day)	210	335	585	758	900	917	867
体蛋白沉积	Body protein deposition (g/day)	—	—	—	128	147	141	122
	Calcium and phosphorus (%) 钙和磷 (%)							
总钙	Total calcium	0.85	0.80	0.70	0.66	0.59	0.52	0.46
磷的标准全肠道消化率	STTD phosphorus[d]	0.45	0.40	0.33	0.31	0.27	0.24	0.21
磷的表观全肠道消化率	ATTD phosphorus[e,f]	0.41	0.36	0.29	0.26	0.23	0.21	0.18
总磷	Total phosphorus[f]	0.70	0.65	0.60	0.56	0.52	0.47	0.43
	Amino acids[g,h] *Standardized ileal digestible basis (%)* 氨基酸 占标准回肠消化率%							
精氨酸	Arginine	0.68	0.61	0.56	0.45	0.39	0.33	0.28
组氨酸	Histidine	0.52	0.46	0.42	0.34	0.29	0.25	0.21
异亮氨酸	Isoleucine	0.77	0.69	0.63	0.51	0.45	0.39	0.33
亮氨酸	Leucine	1.50	1.35	1.23	0.99	0.85	0.74	0.62
赖氨酸	**Lysine**	**1.50**	**1.35**	**1.23**	**0.98**	**0.85**	**0.73**	**0.61**
蛋氨酸	Methionine	0.43	0.39	0.36	0.28	0.24	0.21	0.18

Accounting for changes in nutrient requirements during growth

生长发育过程中营养需要量的变化



There is variation among pigs in nutrient requirements

不同猪只营养需要量的差异

Outline大纲

- Variation in nutrient values and requirements
- **Predicting the response of pigs to the nutrient supply**
- Precision pork production
- Conclusions

- 营养价值和营养需要的变化
- **预测猪只对营养供给产生的反应**
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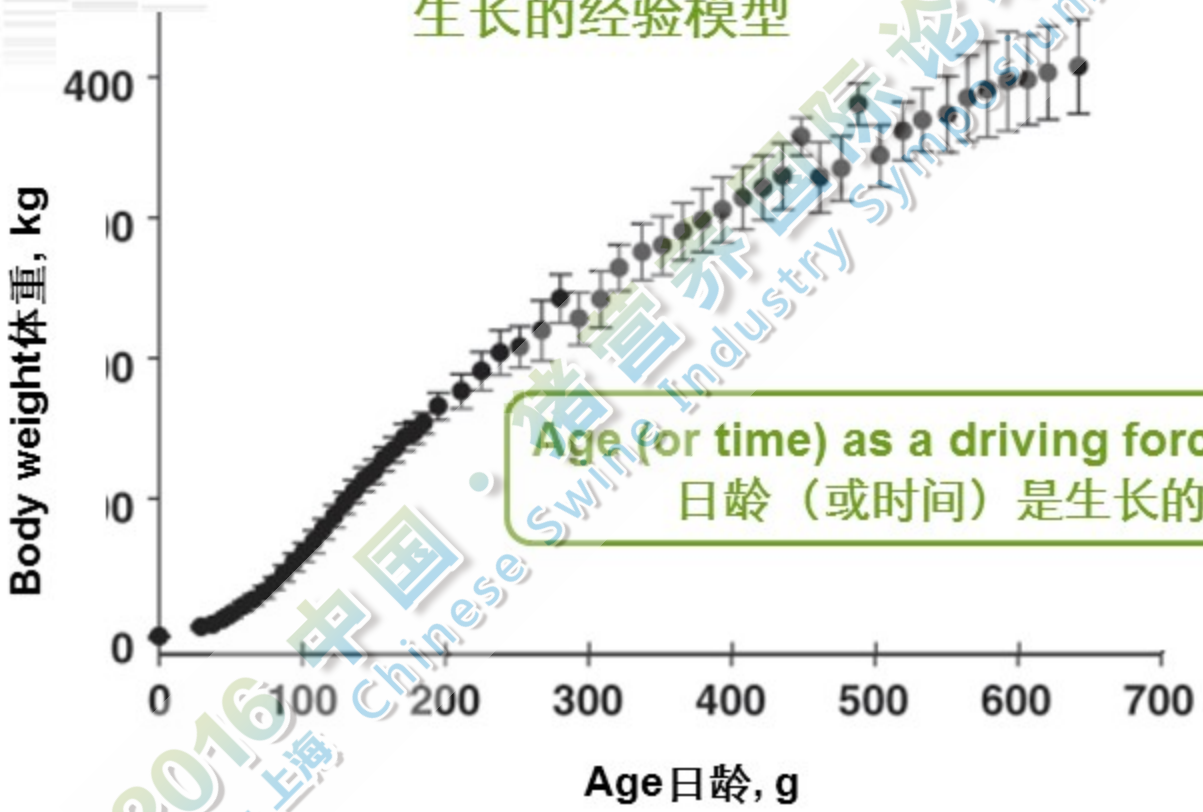
- 结论

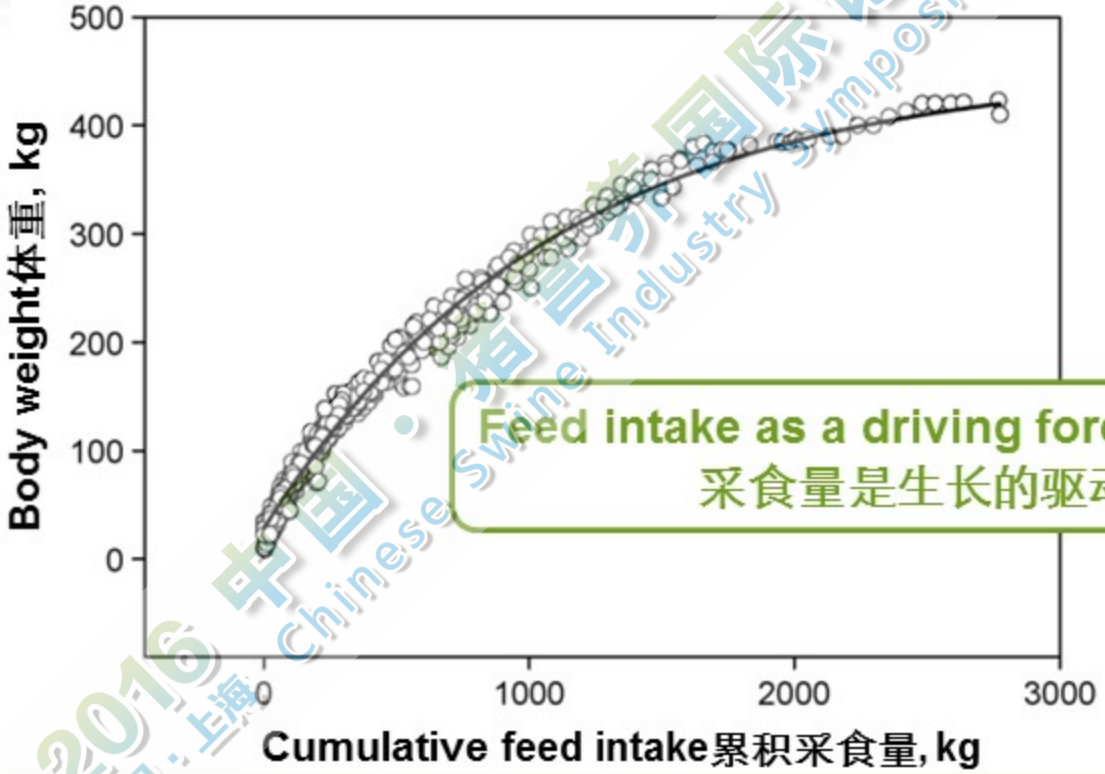
Empirical modeling of growth
生长的经验模型



Age (or time) as a driving force for growth
日龄（或时间）是生长的驱动力

Strathe *et al.*, 2010

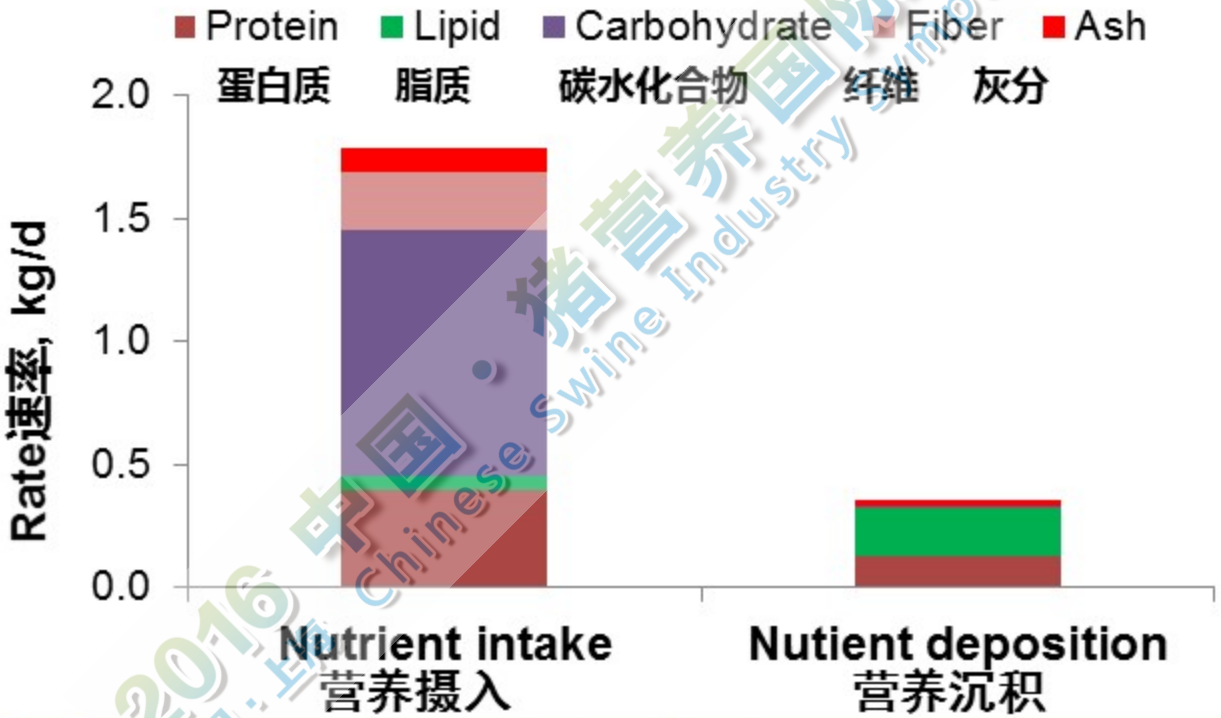
Empirical modeling of growth
生长的经验模型



Feed intake as a driving force for growth
采食量是生长的驱动力

Schulin-Zeuthen *et al.*, 2008

The transformation of feed into a pig
饲料向猪肉的转化



Nutritional modeling of growth
生长的营养模型

Anim. Prod. 1974, **19**: 221–231

MODEL RESPONSES OF THE GROWING PIG TO THE DIETARY INTAKE OF ENERGY AND PROTEIN

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School of Agriculture, University of Edinburgh, West Mains Road, Edinburgh EH9 3JG

SUMMARY

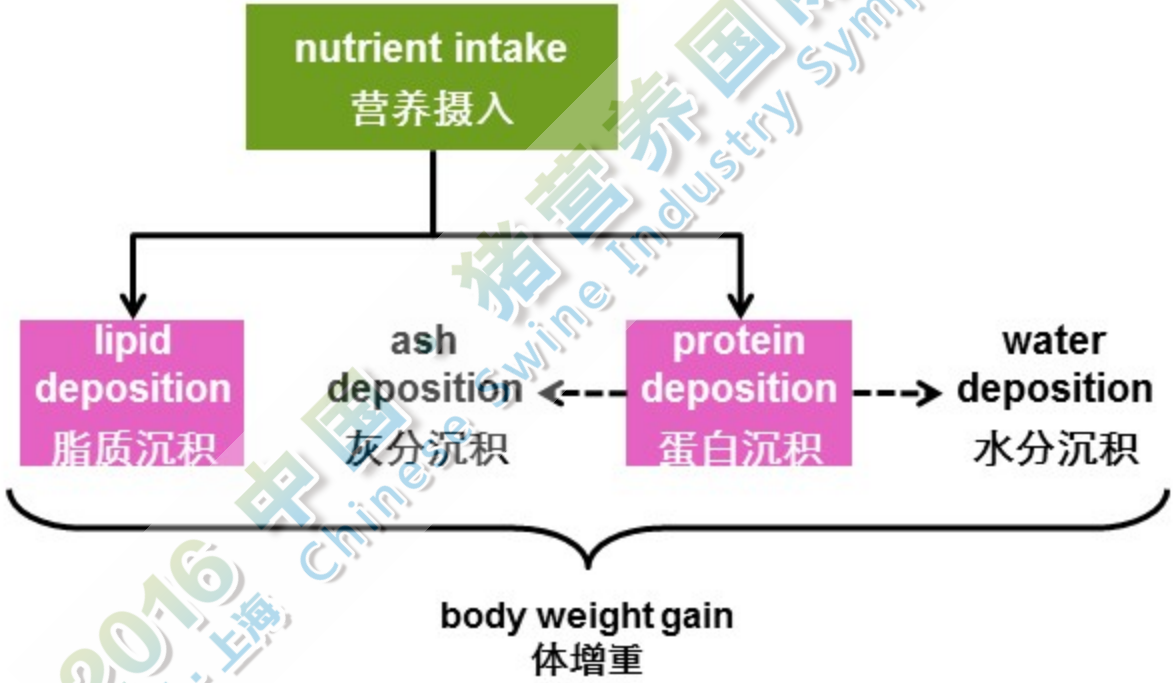
A simple model is described which enables the prediction of the magnitude and direction of the responses of growing pigs to different energy and protein intakes. The model calculates daily live-weight gain from the conversion of the dietary supply of crude protein and energy into protein, lipid and ash in the body of the growing pig. Values were also determined for the energy and protein balances, the composition of the body and the efficiency of feed conversion. The model was formulated with factors drawn from published findings and validated by comparison with independent feeding trials.

通过模型将生长猪对日粮能量和蛋白摄入所产生的反应进行预测

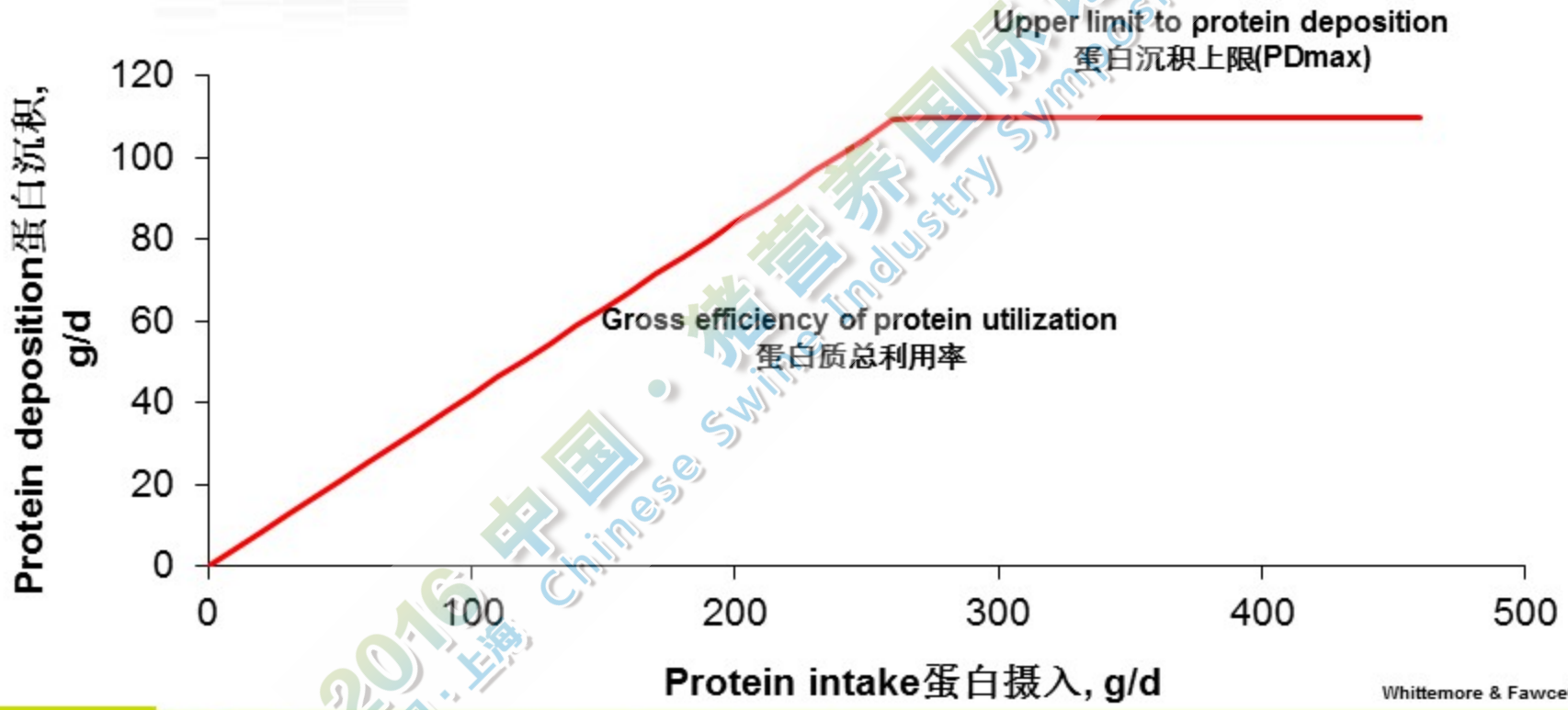
摘要

这里描述了一个简单的模型能够对生长猪摄入不同能量与蛋白质后产生反应的量级和方向进行预测。这个模型计算了日粮供给的粗蛋白和能量转换为生长猪体内的蛋白质、脂质和灰分后产生的活体日增重。这些值也与能量与蛋白质平衡、机体组成和饲料转化率有关。这个模型是基于已发表文献提到的因素并通过独立的饲喂试验间的比较得到证实。

Concepts used in nutritional growth models
营养生长模型中用到的概念

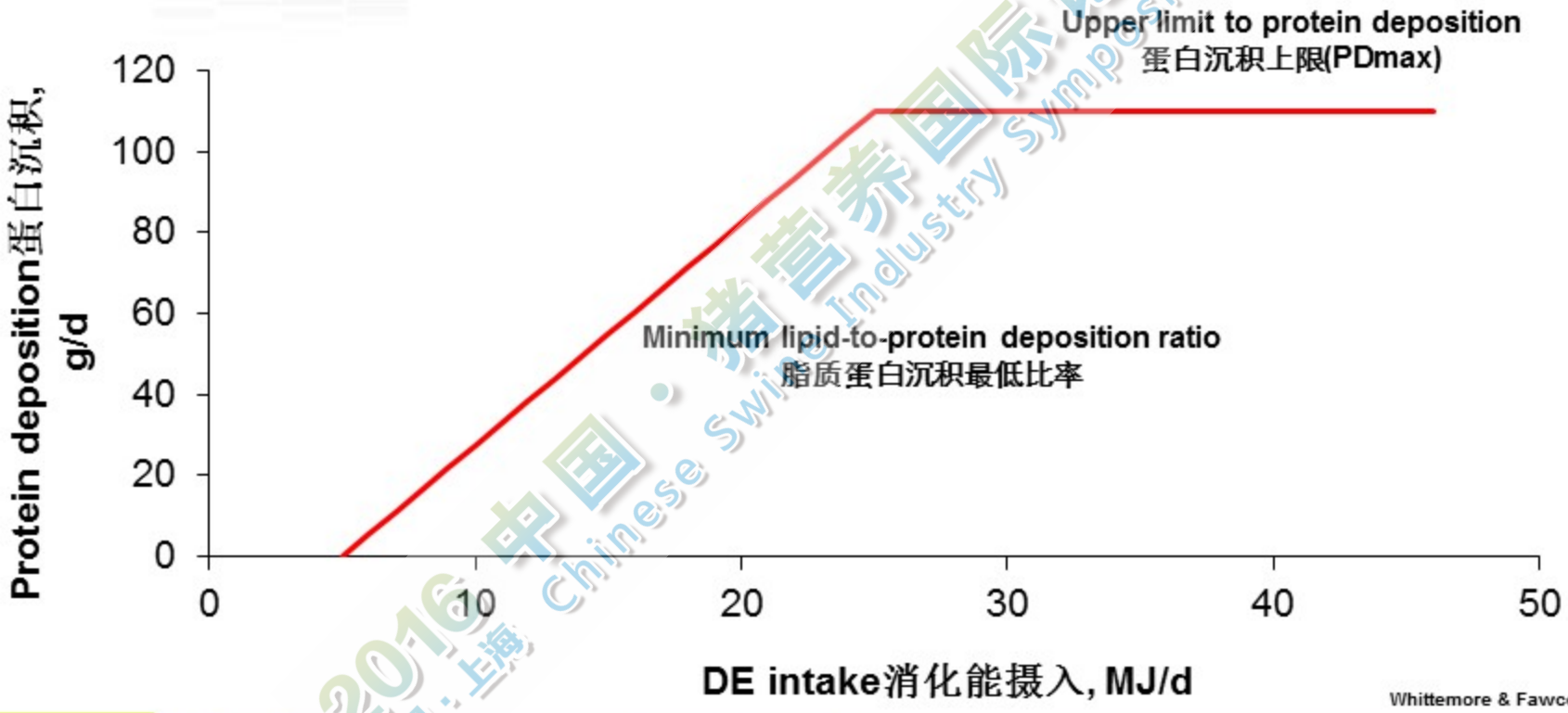


Protein deposition depends on protein intake
蛋白沉积取决于蛋白摄入



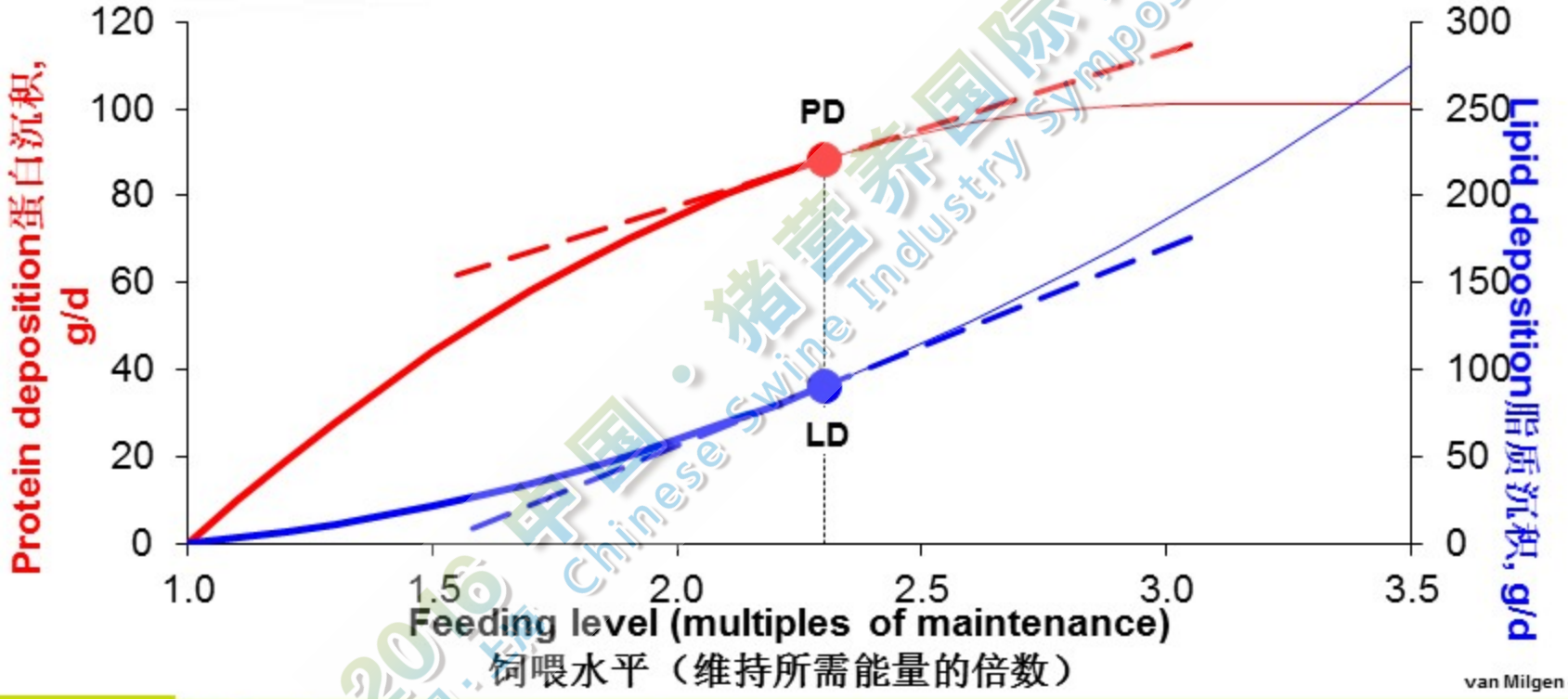
Whittemore & Fawcett, 1974

Protein deposition also depends on energy intake
蛋白沉积取决于能量摄入



Whittemore & Fawcett, 1974

Protein and lipid deposition depend on energy intake
蛋白和脂质沉积取决于能量摄入



van Milgen *et al.*, 2008

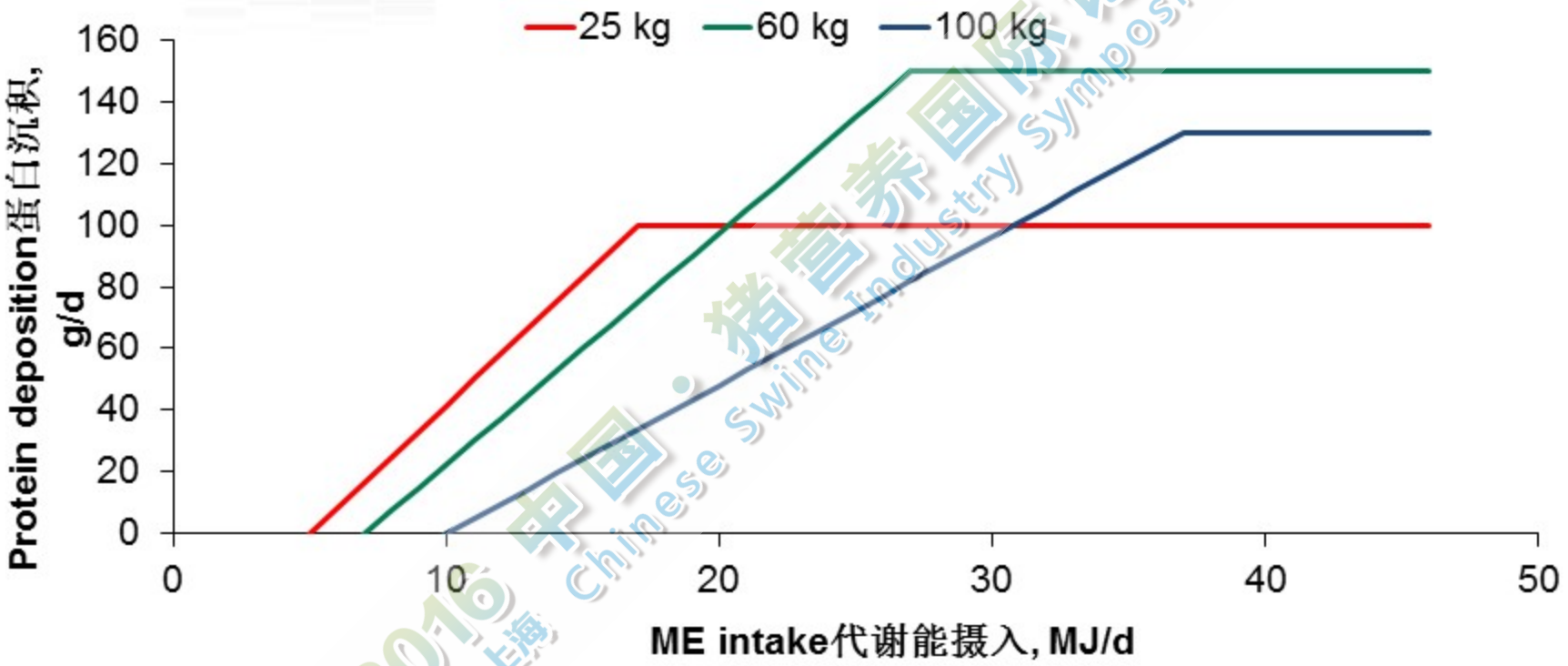
Key concept in these models
模型中的关键概念

- Weight gain is determined by protein deposition (PD) and lipid deposition (LD)
- There is an upper limit to PD (PDmax)
- There is energy partitioning rule between PD and LD
- Protein quality affects PD

- 增重由蛋白沉积(PD)和脂质沉积(LD)决定
- 蛋白沉积有一个上限(PDmax)
- 蛋白沉积和脂质沉积间存在能量分配规律
- 蛋白质量影响蛋白沉积

How do these change during growth?
生长过程中这些如何变化?

The response of the pig changes over time
猪只对能量摄入的反应随时间变化



Black *et al.*, 1986

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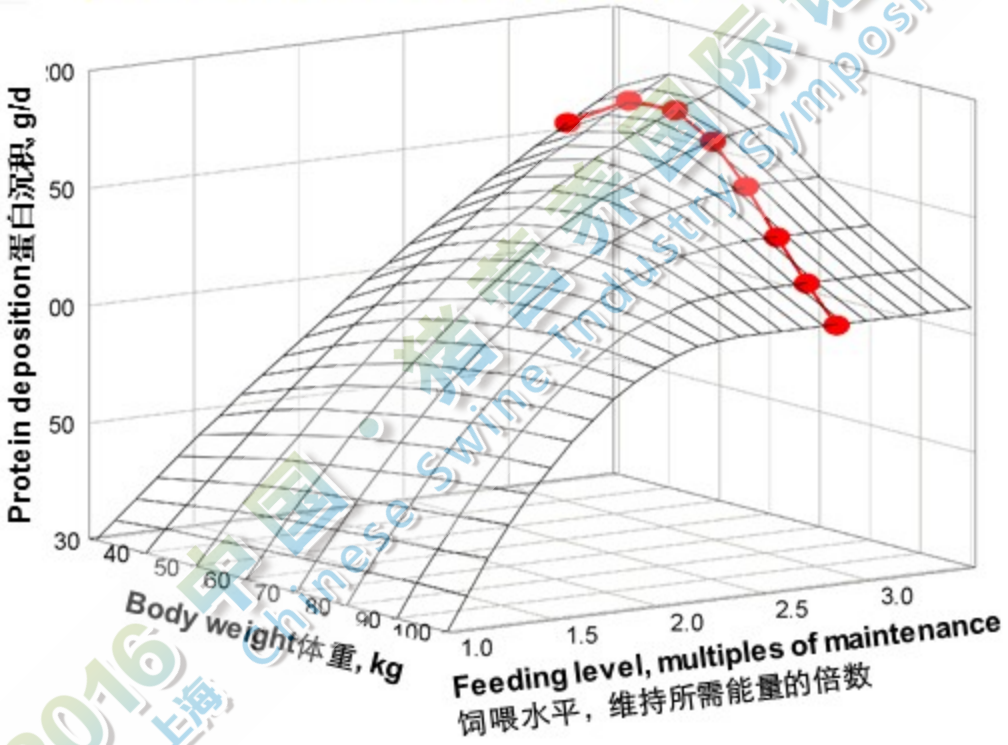
猪只对能量摄入的反应随时间变化



van Milgen *et al.*, 2006

Models have been used to develop decision support tools

已被用于开发决策支持工具的模型

Available online at www.sciencedirect.com
ScienceDirect
Animal Feed Science and Technology
143 (2008) 387–405
ANIMAL FEED SCIENCE AND TECHNOLOGY
www.elsevier.com/locate/anifeedsci

InraPorc: A model and decision support tool for the nutrition of growing pigs☆

Jaap van Milgen*, Alain Valancogne, Serge Dubois, Jean-Yves Dourmad, Bernard Sève, Jean Noblet

Available online at www.sciencedirect.com
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ANIMAL FEED SCIENCE AND TECHNOLOGY
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InraPorc: A model and decision support tool for the nutrition of sows☆

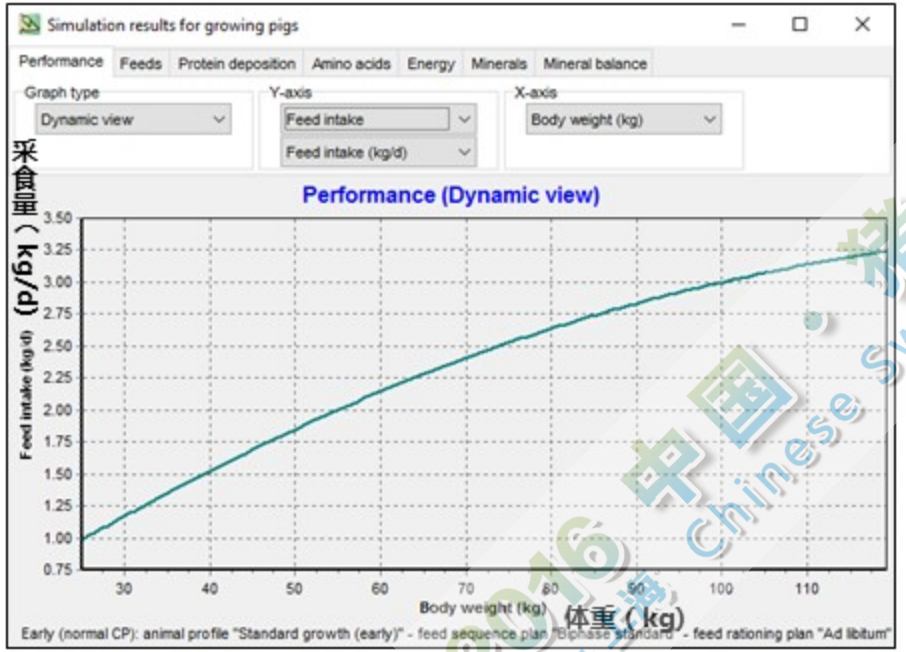
Jean-Yves Dourmad*, Michel Étienne, Alain Valancogne, Serge Dubois, Jaap van Milgen, Jean Noblet

inraporc.inra.fr

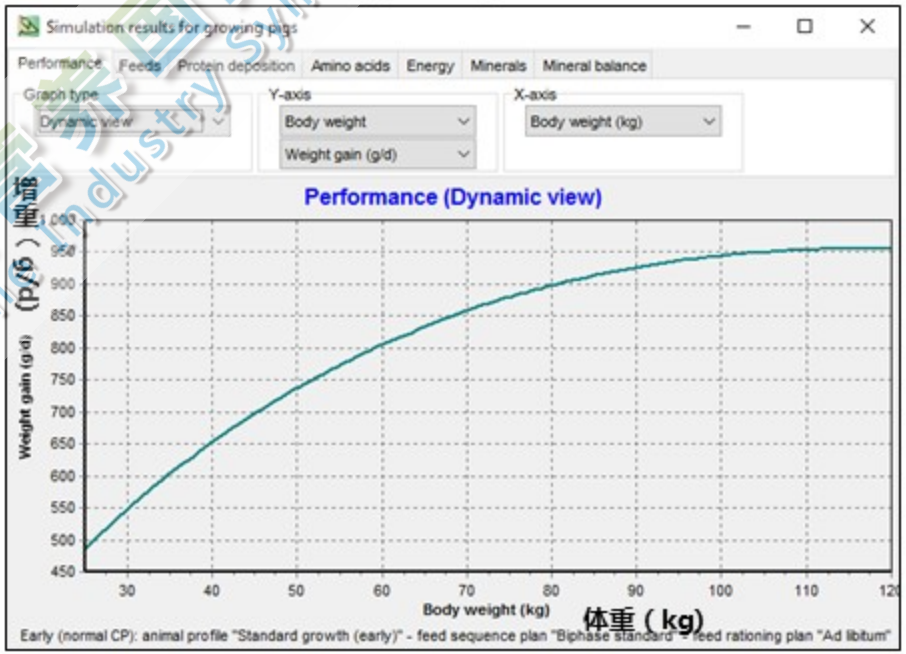
In simulation modeling, pigs follow a phenotypic trajectory …

模拟模型中，猪只遵循表型轨迹…

Feed intake采食量



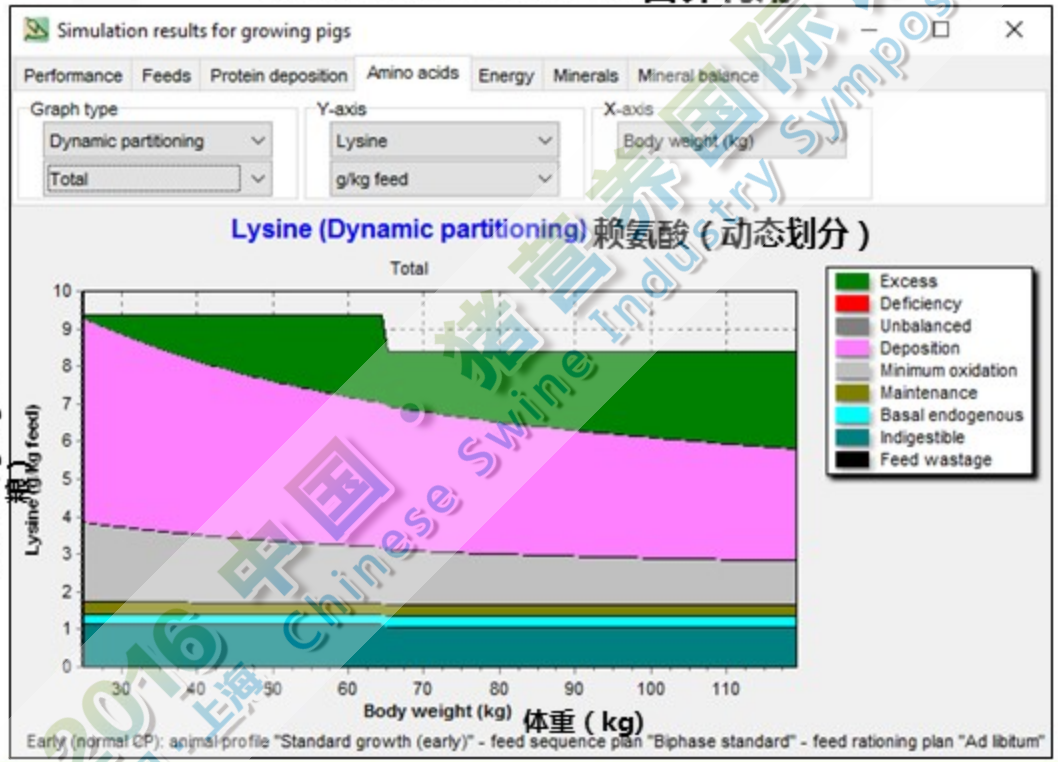
Weight gain增重



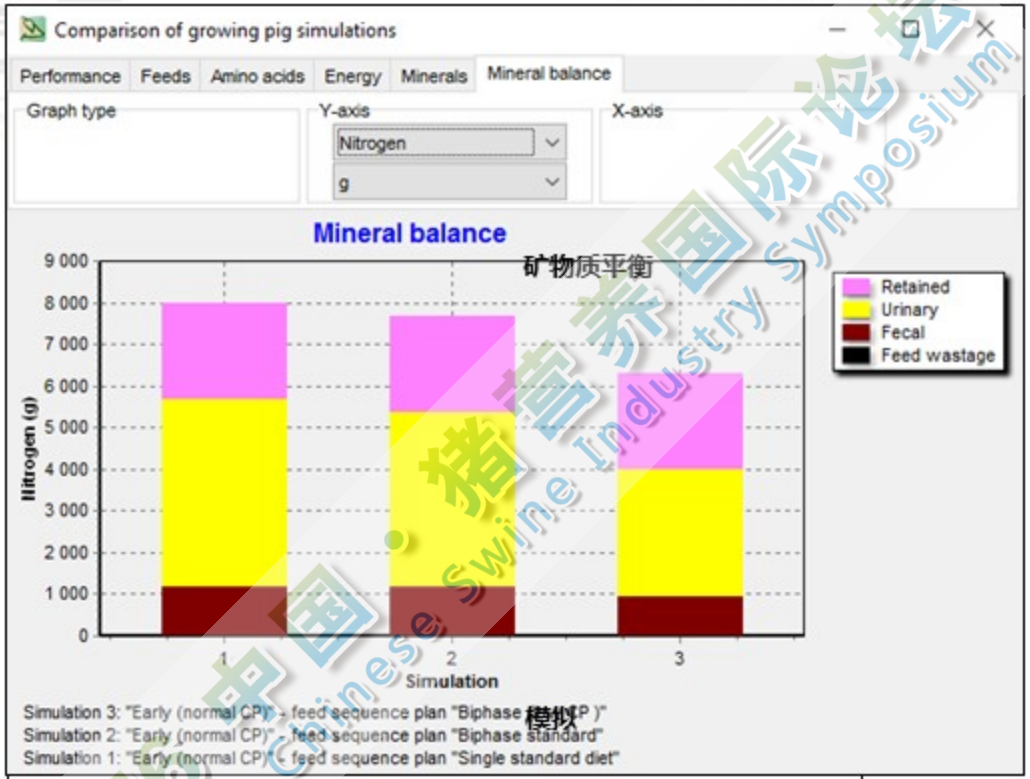
… allowing to analyze results in different ways

…允许用不同的方式分析结果

Nutrient utilization 营养利用



What-if scenarios假定场景分析



沉积的
尿中的
粪便中的
饲料浪费的

模拟3：“早期（正常蛋白）” -饲喂顺序计划 “双相（低蛋白）”
模拟2：“早期（正常蛋白）” -饲喂顺序计划 “双相标准”
模拟2：“早期（正常蛋白）” -饲喂顺序计划 “单标准日粮”

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Definition of precision livestock farming
精准畜牧业的定义

"Management of livestock production systems using the principles and technology of process engineering" (Wathes et al., 2008)

基于过程工程学的原理与技术对家畜生产系统进行管理(Wathes et al., 2008)

1. **Continuous monitoring of the process response or outcome**
2. **Mathematical model predicting the process outcome from inputs**
3. **The desired outcome**
4. **A mechanism to control inputs**

1. **对过程响应或结果进行持续监测**
2. **预测投入的处理结果的数学模型**
3. **预期的结果**
4. **控制投入的机制**

How do I feed a pig so that it will attain 110 kg at 6 months of age?
如何饲养一头猪让它在六个月内达到110公斤?

Precision livestock feeding and farming. Why?
精准畜牧业

- The number of animals per farm and per farmer is increasing
- A need to become more efficient with feed resources that are less or not in competition with other uses
- A possibility to make better use of biological variation among animals
- A rapid development in monitoring technologies
- New methods for data analysis (e.g., real-time, big data)

- 每个农场每个农民饲喂的动物数量在增加
- 对于饲料原料资源的利用更高效，使其与其他用途有竞争更少甚至不竞争
- 对动物间的生物变异可能有更好的利用
- 监测技术的迅速发展
- 数据处理的新方法(如实时分析技术, 大数据)

General concepts of precision livestock farming
精准畜牧业的基本概念

Inputs输入

(e.g., type and/or quantity of feed, heating, ventilation)（如饲料种类和/或数量、供暖设备、通风设施）

Outputs输出

(e.g.,feed intake, weight gain, room temperature, air quality)（如采食量、增重、室温、空气质量）

Sensors
传感器

Data collection
数据收集

Prediction model
预测模型

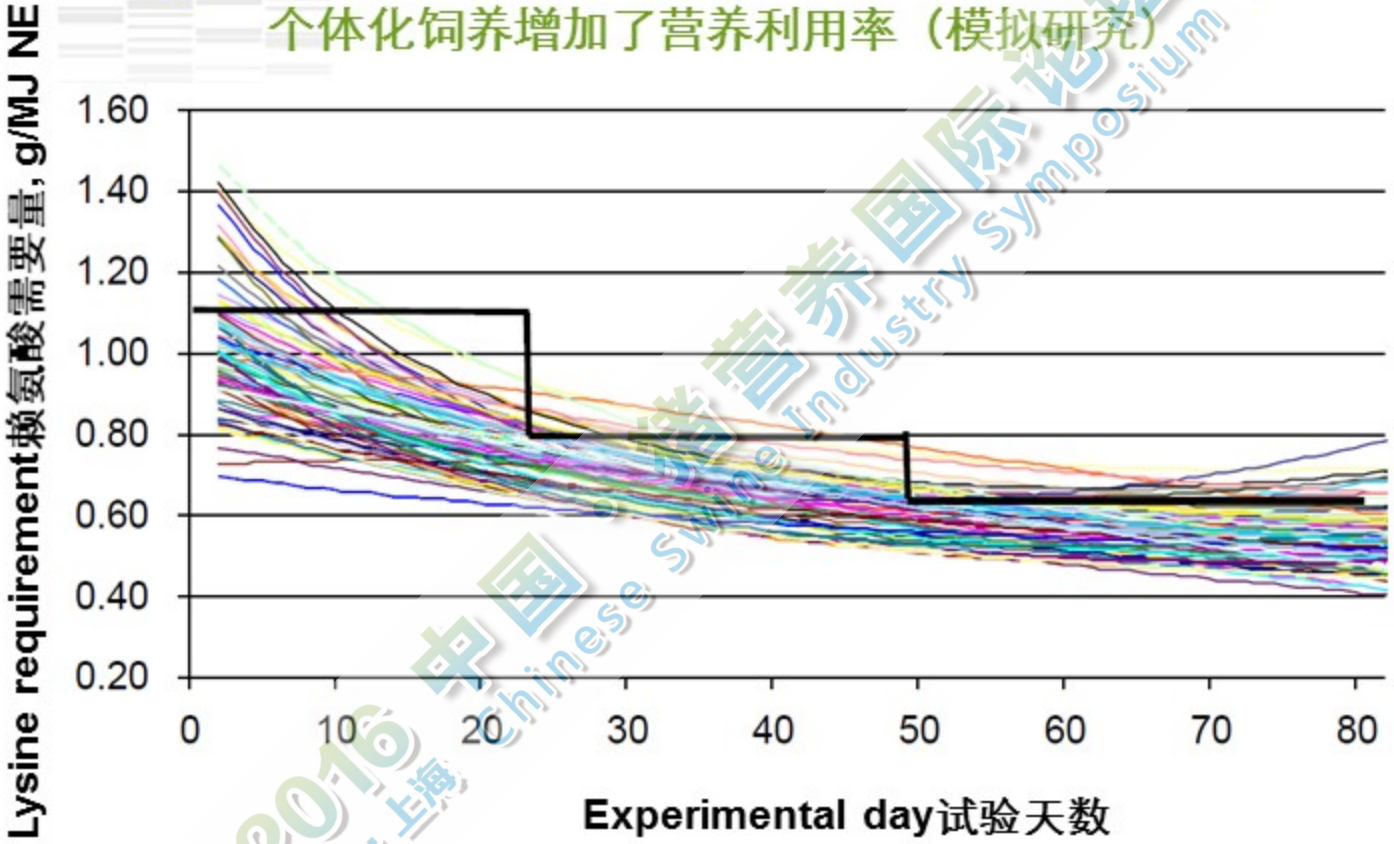
Controller
控制器

Desired output
期望的输出值

Wathes *et al.*, 2008

Individual feeding increases the efficiency of nutrient utilization (simulation study)

个体化饲养增加了营养利用率（模拟研究）



Pomar et al., 2010

Individual feeding increases the efficiency of nutrient utilization (simulation study)
个体化饲养提高营养利用率（模拟研究）

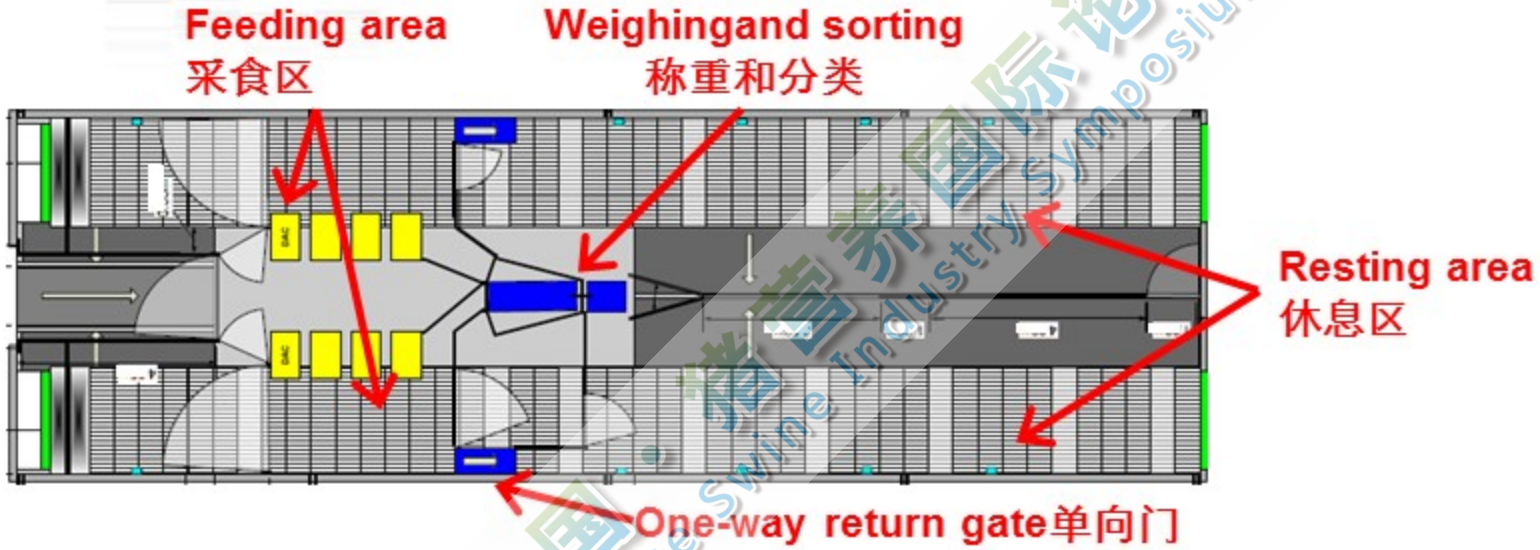
	3-phase feeding 三阶段饲养	individual feeding 个体化饲养
Feed intake采食量,kg/d	2.49	2.49
Weight gain增重 ,g/d	0.97	0.97
Feed cost/ADG,$/kg 饲料成本/平均日增重	1.02	**0.97**
Nitrogen intake氮摄入,kg	**5.69**	**4.29**
Nitrogen retention氮沉积,kg	2.08	2.08
Nitrogen excretion氮排泄,kg	**3.61**	**2.21**
Nitrogen efficiency氮利用率,%	**37**	**48**

Pomar et al., 2010

Monitoring feed intake and weight gain in real time

实时监测采食量和增重

Monitoring feed intake and weight gain at the INRA facilities
采用INRA设备实时监测采食量和增重



- Animal identification by RFID
- Access to the feeding area through the weighing station
- Automatic feeders distribute small portions of feed
- Possibility to mix up to 4 diet

- 通过射频识别技术识别动物
- 通过称台进入采食区
- 自动进料器分配小份饲料
- 可混合四种日粮

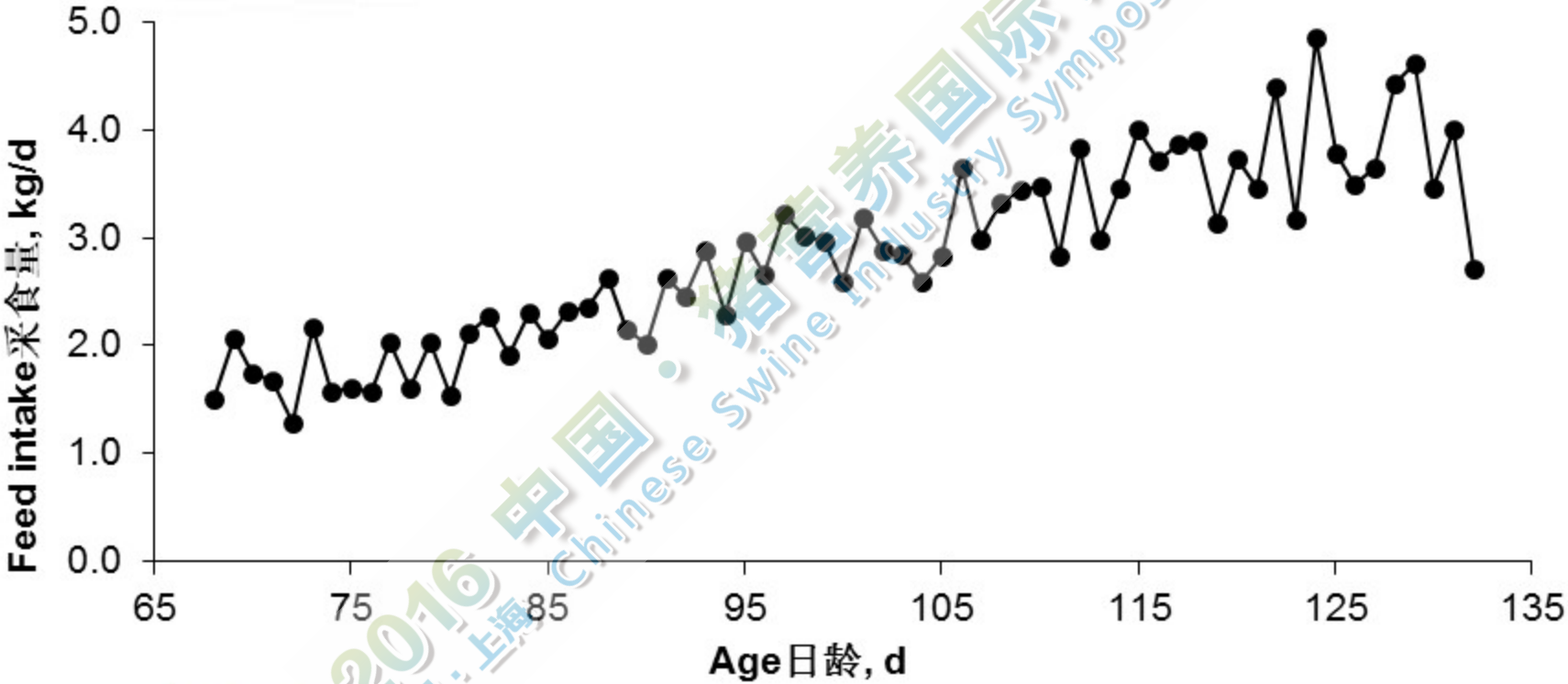
Monitoring feed intake and weight gain at the INRA facilities
采用INRA设备实时监测采食量和增重

Resting area休息区

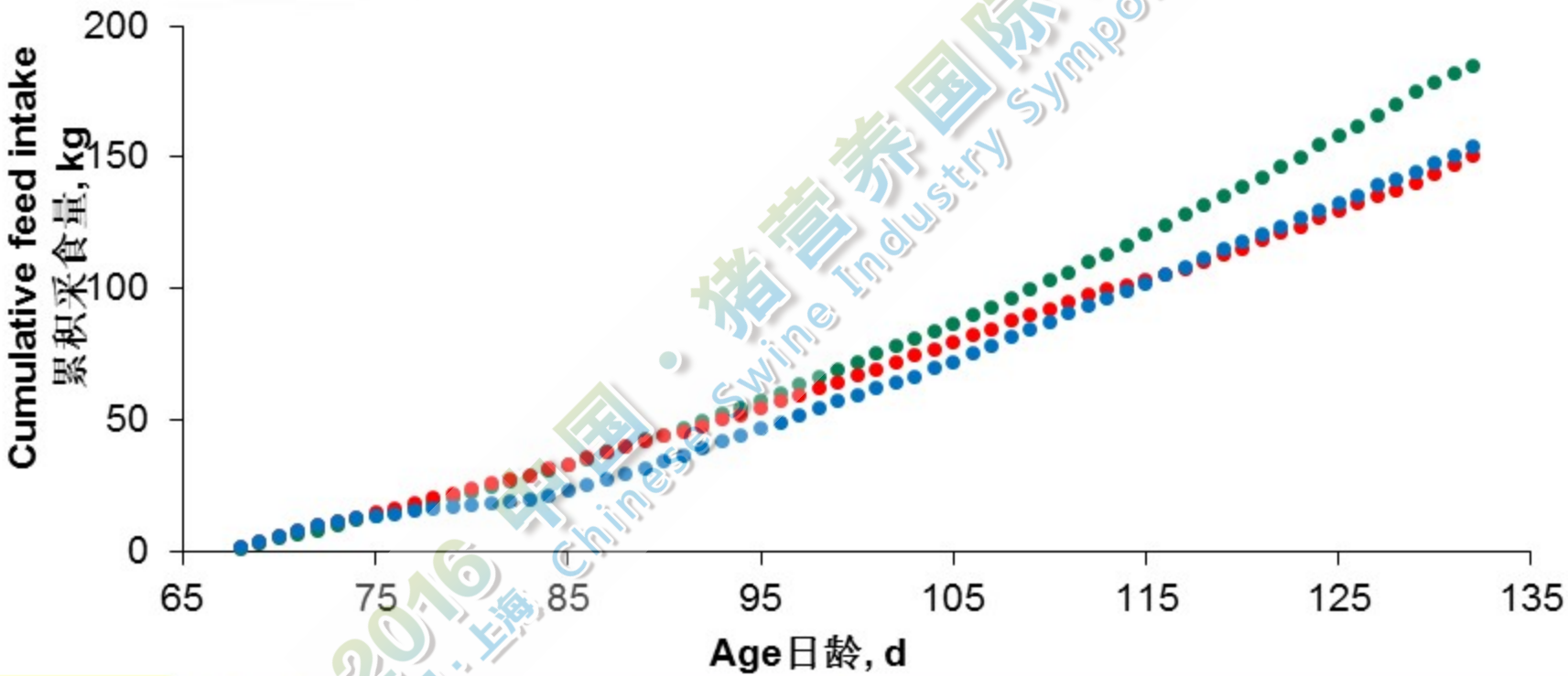
Weighing/sorting
称重/分类

Feeding area
采食区

Daily feed intake is variable
日采食量是变化的



Pigs can have different feed intake trajectories
猪只可以有不同的采食量轨迹



Experimental validation of precision feeding
精准饲养的试验验证

	3-phase group 三阶段群体	Commercial group 商业化群体	Multi-phase group 多阶段群体	Multi-phase多阶段 individual个体
Diets and ingredients 日粮组分	Blend of 2 diets 混合2种日粮	Commercial 商业化日粮	Blend of 2 diets 混合2种日粮	Blend of 2 diets 混合2种日粮
Feeding program 饲喂程序	3-phase 三阶段	3-phase 三阶段	Multiphase 多阶段	Multiphase 多阶段
Duration of each phase 各阶段持续时间	28 d	28 d	1 d	1 d
Feeding type饲养类型	Group群体	Group群体	Group群体	Individual个体
Requirement target at the start of the phase 阶段开始时的要求目标	80%	80%	80%	100%

Andretta et al., 2014

Individual feeding increases the efficiency of nutrient utilization (simulation study)
个体化饲养提高营养利用率（试验研究）

	3-phase group 三阶段群体	Commercial group 商业化群体	Multi-phase group 多阶段群体	Multi-phase individual 多阶段个体
Feed intake采食量, kg/d	3.05[a]	2.73[b]	3.07[a]	3.05[a]
Weight gain增重, kg/d	1.11	1.07	1.11	1.10
Gain:feed 肉料比	0.38[b]	0.40[a]	0.37[b]	0.37[b]
Protein deposition蛋白沉积, g/d	161	155	155	154
Lipid deposition脂质沉积, g/d	343	326	366	369

Andretta et al., 2014

Individual feeding can reduce feed cost and nutrient excretion
个体化饲喂可降低饲料成本和营养物质排泄

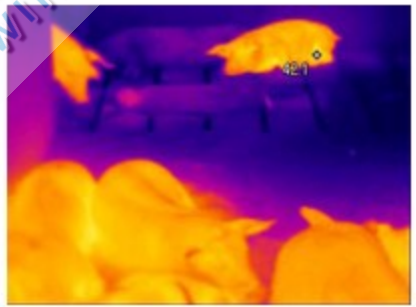
	3-phase group 三阶段群体	Commercial group 商业化群体	Multi-phase group 多阶段群体	Multi-phase individual 多阶段个体
Lys intake赖氨酸摄入, g/d	23.8[a]	23.9[a]	19.7[b]	17.4[c]
Nitrogen intake氮摄入, g/d	76.8[a]	69.1[b]	69.3[b]	64.8[b]
Nitrogen excretion氮排泄, g/d	48.1[a]	41.9[b]	42.1[b]	37.7[b]
Nitrogen efficiency氮利用率, %	33.8[a]	35.1[b]	35.8[b]	38.0[b]
Warm left carcass鲜左侧胴体, kg	50.5	49.4	51.1	51.7
Loin area眼肌面积, cm^2	57.4	55.1	54.3	55.5

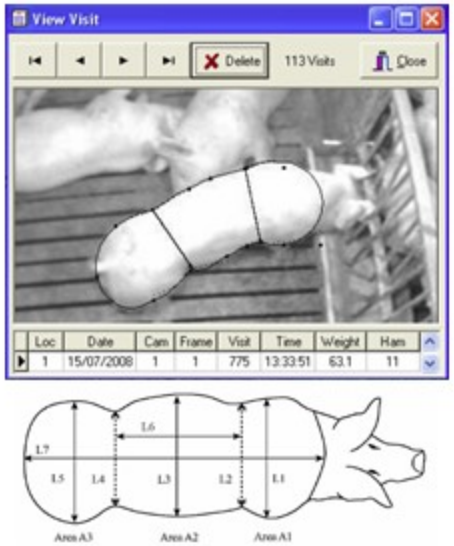
Andretta et al., 2014

Other examples of real-time monitoring and precision livestock farming
实时监控和精准畜牧业的其它例子

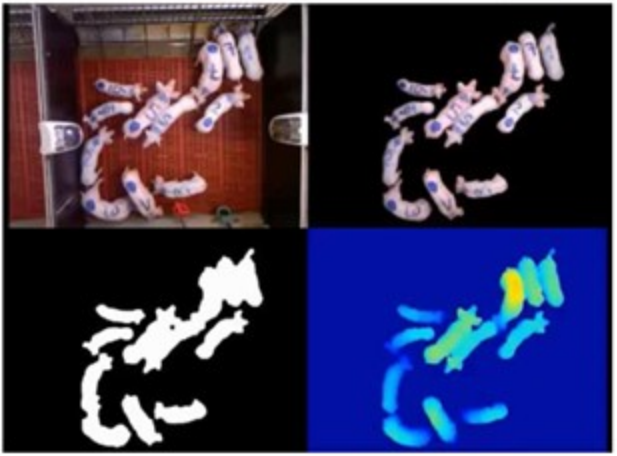
- Weight: weigh platform, scales, image
- Body composition: image, ultrasound
- Behavior: video, accelerometer
- Health: infrared image, sound, feeding and drinking behavior

- 体重：称重台、刻度、影像
- 体组成：影像、超声波
- 行为：视频、加速器
- 健康：红外影像、声音、采食和饮水行为





Other examples of real-time monitoring and precision livestock farming
实时监控和精准畜牧业的其它例子



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通过自动影像记录仪分析猪只的攻击性行为

Analysis of aggressive behaviours of pigs by automatic video recordings

Maciej Oczak [a,b,*], Gunel Ismayilova [c], Annamaria Costa [c], Stefano Viazzi [b], Lilia Thays Sonoda [d], Michaela Fels [d], Claudia Bahr [b], Jörg Hartung [d], Marcella Guarino [c], Daniel Berckmans [b], Erik Vranken [a,b]

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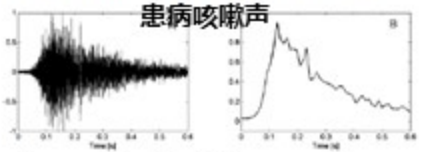
Other examples of real-time monitoring and precision livestock farming
实时监控和精准畜牧业的其它例子

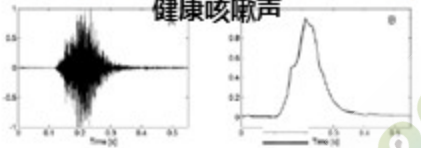
Example Sick cough sound

患病咳嗽声



Example Healthy cough sound

健康咳嗽声



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Cough sound analysis to identify respiratory infection in pigs

分析咳嗽声音识别猪呼吸道感染

Sara Ferrari[a,*], *Mitchell Silva*[b], *Marcella Guarino*[a], *Jean Marie Aerts*[b], *Daniel Berckmans*[b]

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Precision livestock farming …
精准畜牧业

- Is still in its infancy
- Requires to transform data into information, which needs to be integrated
- Increases resource efficiency and reduces environmental impact
- Accounts for the needs of individual pigs
- Can change the design of pig production systems

- Will initiate new questions and challenges:
  - Who is in control? The computer, the farmer, the animal?
  - Who owns the data? Need for data integration
  - Perceptions of the farmer, the citizen/consumer?

- 仍处于初始阶段
- 需要将数据整合转化为信息
- 提高了资源利用率且降低了对环境的影响
- 考虑了猪只的个体化需要
- 可改变生猪生产系统的设计

- 将面临新的问题和挑战:
  - 到底在谁的控制之下？计算机、农民、动物?
  - 谁拥有这些数据？数据整合的需要
  - 农民、公民/消费者的认知水平?

Precision livestock farming …
精准畜牧业

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Is precision livestock farming an engineer's daydream or nightmare, an animal's friend or foe, and a farmer's panacea or pitfall?

精准畜牧业是工程师的白日梦还是噩梦，是动物的朋友还是敌人，是农民的灵丹妙药还是陷阱？

C.M. Wathes[a,*], H.H. Kristensen[b], J.-M. Aerts[c], D. Berckmans[c]

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