猪饲料原料净能研究进展

Research in China pig net energy system

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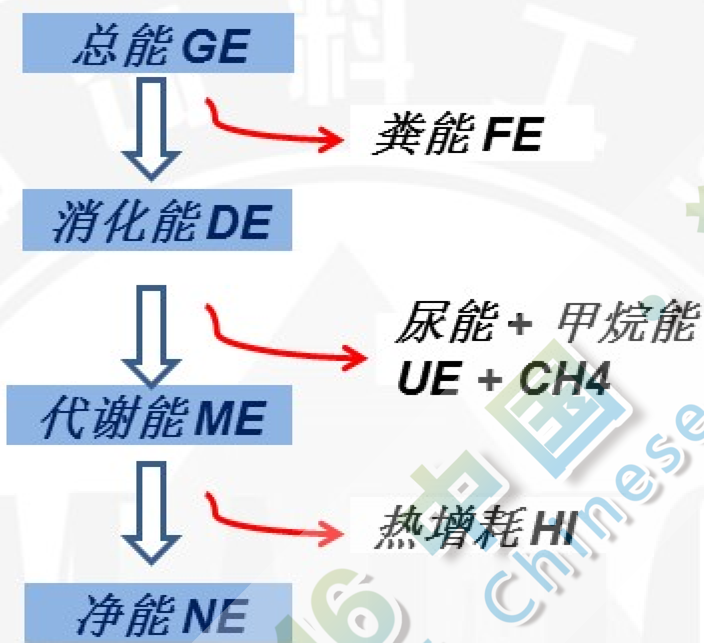
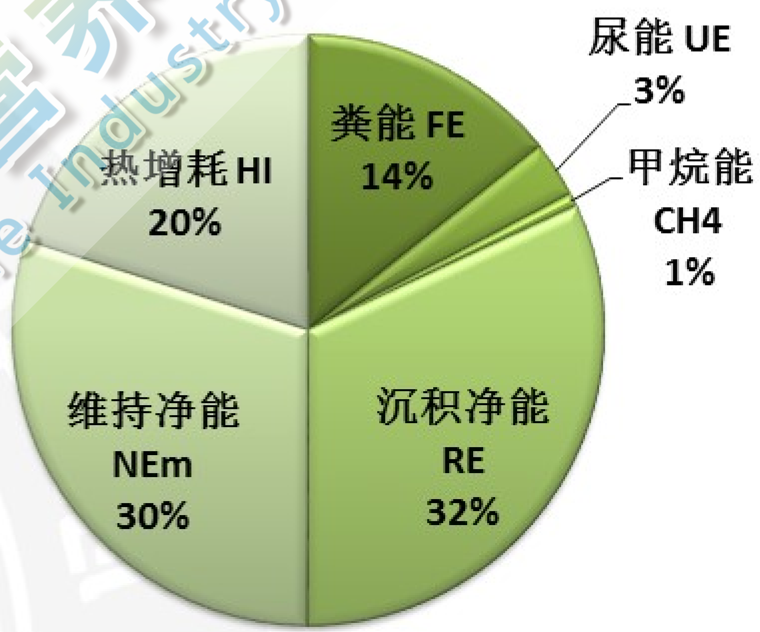
October 20, 2016. ShangHai

1. 什么是净能 What is NE?

净能 = 总能 – 粪能 – 尿能 – 甲烷能 – 热增耗
NE = GE – FE – UE – CH4 – HI





数据来源于农业部饲料中心Data from MAFIC

2.1 为什么用净能—更准
Why using NE—Accurate

更精确地评价饲料的有效能值

The most accurate estimate of the energy actually available to the animal

	原料 Ingredients	Energy (MJ/kg DM) DE	ME	NE
常用原料 Common ingredients	玉米 Corn	96	99	124
	豆粕 SBM	100	100	100
	麸皮 Wheat Bran	66	66	73
玉米副产物 Corn-products	DDGS	92	87	96
	玉米胚芽粕 Corn germ meal	74	73	82
	玉米麸质饲料 Corn gluten feed	62	56	69
杂粕 oil-seed meal	菜粕 Rapeseed meal	74	71	78
	棉粕 Cottonseed meal	63	61	69
	花生粕 Peanut meal	95	85	99
	葵花粕 Sunflower meal	60	57	59

不同能量体系对饲料原料有效能值评价

Mafic 数据，豆粕能值为100

2.2 为什么用净能——结合实际生产
Why using NE——Pig industry

同时测定维持、生产和热增耗，使供需在同一基础上

Determination energy for maintenance, production and HI at the same time

2.3为什么用净能——结合实际生产
Why using NE——Pig industry

可以更好的预测生长性能 Predict the growth performance

不同能量体系对猪生长性能的影响
Effect of increasing levels of dietary fat on energy system

牛油添加水平 Levels of tallow, %	0	1.75	3.5	5.25	SEM	P值
日增重ADG (g/d)	598	622	634	642	8.00	0.001
消化能采食量 DE intake (MJ/d)	20.65	21.31	21.57	21.83	0.25	0.002
代谢能采食量 ME intake (MJ/d)	19.97	20.62	20.88	21.14	0.24	0.002
净能采食量 NE intake (MJ/d)	14.81	15.36	15.64	15.86	0.18	0.001
消化能采食量/增重 DE intake/gain (MJ/kg)	34.55	34.28	34.04	34.02	0.14	0.009
代谢能采食量/增重 ME intake/gain (MJ/kg)	33.41	33.16	32.95	32.94	0.14	0.012
净能采食量/增重 NE intake/gain (MJ/kg)	24.79	24.71	24.70	24.68	0.10	0.573

单位增重消耗的DE、ME不一致，NE值是一致 Energy intake per BW gain is significant different for DE and ME system, but the NE intake per BW gain is not affected by levels of dietary fat

Wu, 2007

2.4 为什么用净能——副产物
Why using NE——By products

玉米副产物Corn-product:

玉米DDGS：6百万吨(李, 2014)

Corn DDGS: 6 million T (Li, 2014)

玉米麸质饲料: 4百万吨 (王, 2014)

Corn gluten feed: 4 million T (Wang, 2014)

玉米胚芽粕: 2百万吨(刘, 2014)

Corn germ meal: 2 million T (Liu, 2014)

小麦副产物: (2千万吨)

Wheat-product: (20 million T)

麦麸Wheat bran

小麦细麸Wheat middlings

小麦次粉Wheat shorts

杂粕Oilseed meal: 菜粕Rapeseed meal; 棉粕cottonseed meal;

花生粕peanut meal; 葵花粕sunflower meal

副产物的应用，增加了日粮中纤维的含量，热增耗相应增加

2.5 为什么用净能——副产物
Why using NE——By products

添加DDGS后采用ME体系和NE体系对胴体增重和胴体日增重的影响
Carcass characteristics of pigs fed diets containing DDGS and formulated using the ME or the NE system

项目 Item	玉米-豆粕 Corn-SBM	代谢能-DDGS ME-DDGS	净能-DDGS NE-DDGS	p-value
胴体增重 Carcass gain	100[a]	97.45[b]	99.40[a]	0.01
胴体日增重 Carcass ADG	100[a]	97.47[b]	99.44[a]	0.02

注：共计1,233头猪，分为3个处理，每个处理19个重复，每个重复19-24头猪
Note: 1,233 pigs, 3 treatments, 19 replicates per treatment, 19-24 pigs per replicate

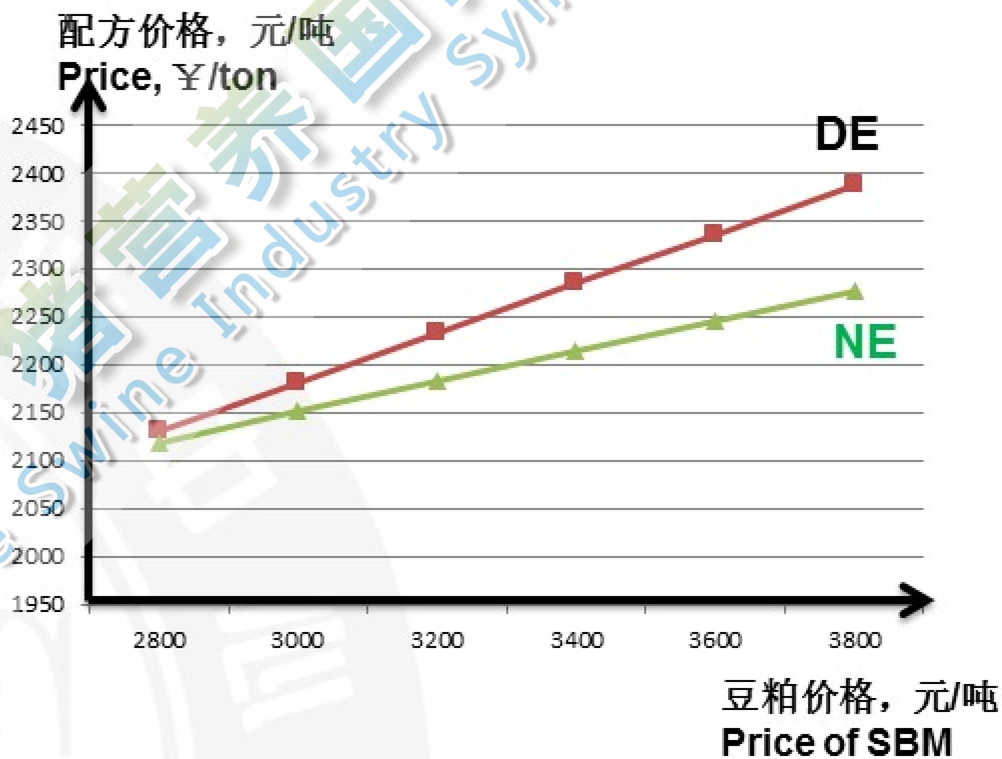
J. Acosta et al，2016

2.6 为什么用净能——降低成本
Why using NE——Decrease feed cost

Decrease feed cost and N output

原料名称 Ingredients	DE	NE
玉米Corn	67.44	68.78
豆粕SBM	24.91	15.16
麦麸Wheat bran	5.00	5.00
菜粕 RSM	0.00	5.00
DDGS	0.00	2.69
磷酸氢钙DCP	0.73	0.64
石粉Limestone	0.71	1.17
食盐Salt	0.30	0.30
预混料premix	0.50	0.50
赖氨酸L-lys-HCl	0.32	0.53
蛋氨酸Met	0.03	0.05
苏氨酸Thr	0.02	0.10
色氨酸Trp	0.00	0.02
缬氨酸Val	0.00	0.06
营养成分:		
DE	3413	3343
NE	2500	2481
CP	17.73	16.50
SID lys	0.98	0.98
SID Met	0.28	0.28
SID Thr	0.59	0.59
SID Trp	0.20	0.17
SID Val	0.64	0.64
成本（元/吨）	2181	2151

用不同能量体系做配方成本比较
Comparison of price of formula using DE and NE system



当豆粕的价格越高时，用净能做配方越经济 The higher price of SBM, the more feed cost be decreased

￥: Corn1840; WB 1040; SBM 3000; RSM 2400; DDGS 1800

2.7 为什么用净能
Why using NE

净能为合理利用副产物和低蛋白日粮提供了理论支撑

More benefits when combined by-products and low-protein diets

3.1 如何测定 How to measure

两个主要方法 Two methods to measure the NE

- 比较屠宰法 Comparative slaughter
- 间接测热法 Indirect calorimetry

3.2 如何测定净能——自动喂料
How to measure——Feed pigs automatically

整体
whole

电机
Electronic

计时器
Timer

3.3 如何测定净能——记录活动
How to measure——Physical activity

小室 Chamber	0~6	6~8	8~10	10~12	12~14	14~16	16~18	18~24	Total	$HP_{activity}$	THP	$HPa_{ctivity}$/THP, %
A1	0	3	109	8	6	26	63	0	215	1.04	11.04	9.45
A2	0	0	95	43	12	34	94	20	298	1.36	12.20	11.11
B1	2	0	94	7	47	53	26	16	245	1.15	11.59	9.94
B2	0	0	78	2	21	53	46	23	223	1.06	13.74	7.71
C1	6	5	43	39	26	42	94	20	275	1.16	11.74	9.85
C2	3	0	74	1	18	83	36	19	234	1.03	11.97	8.63

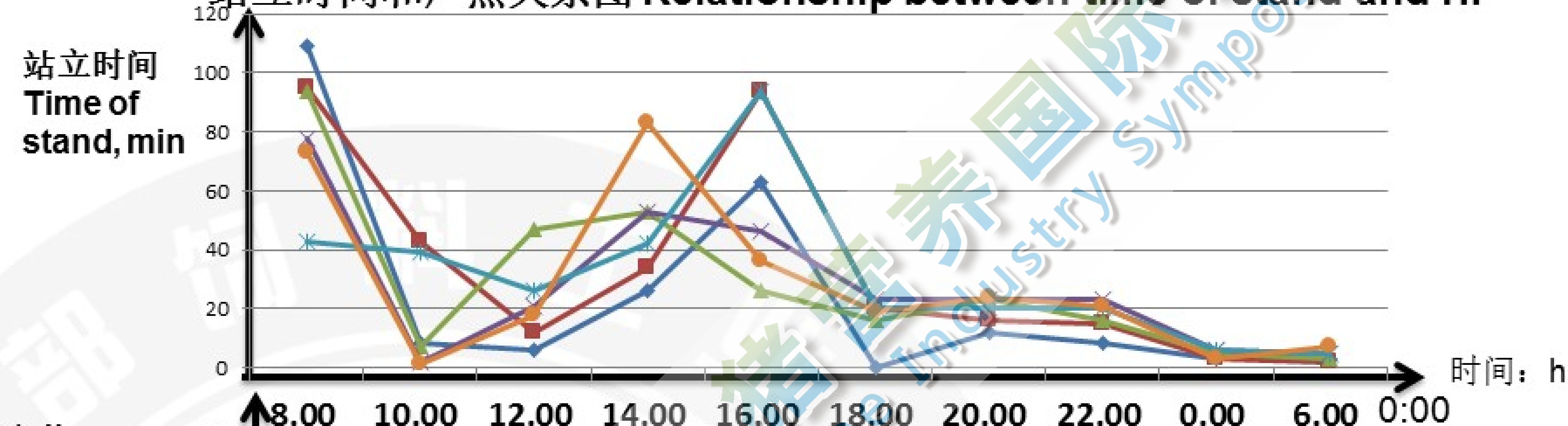
注：一天的数据，时间, min；HP, MJ/d
Note: data for 1d; Unit: min, HP, MJ/d

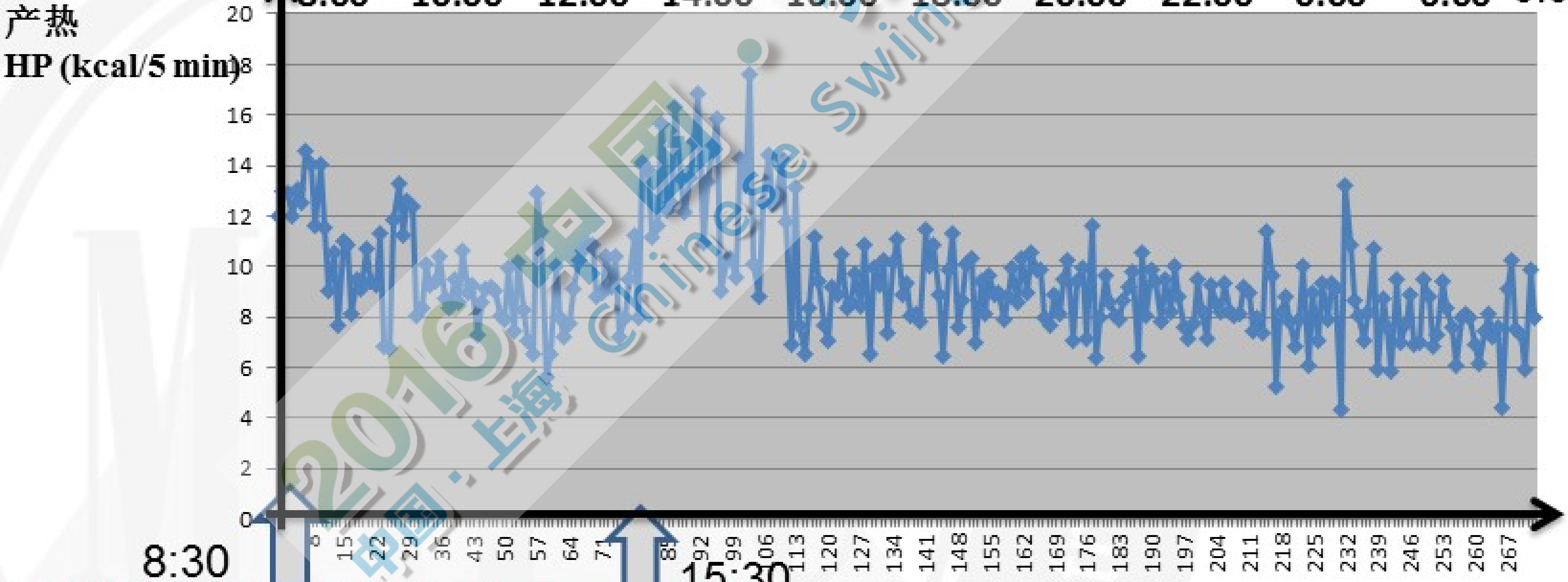
通过视频记录猪每天活动时间，净能计算更加准确
Record the time of pig's physical activity

3.3 如何测定净能——记录活动

How to measure——Physical activity

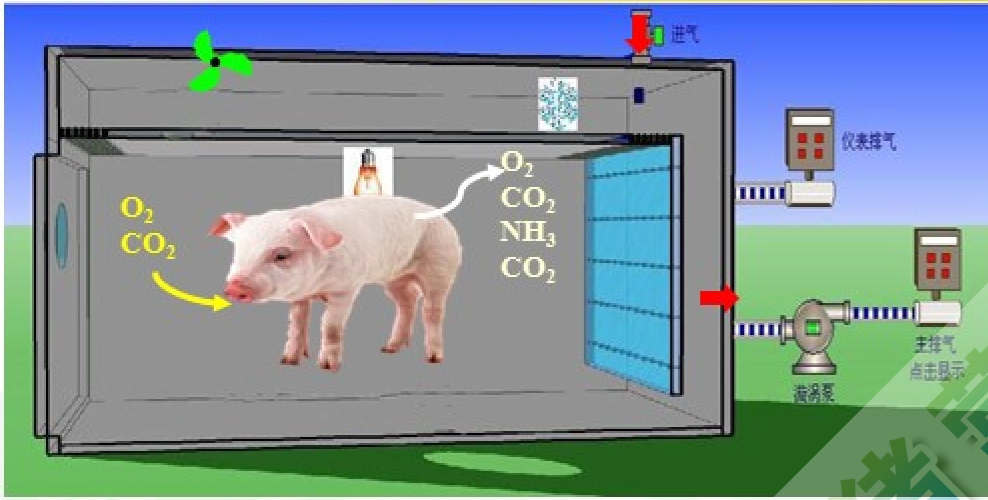
站立时间和产热关系图 Relationship between time of stand and HP



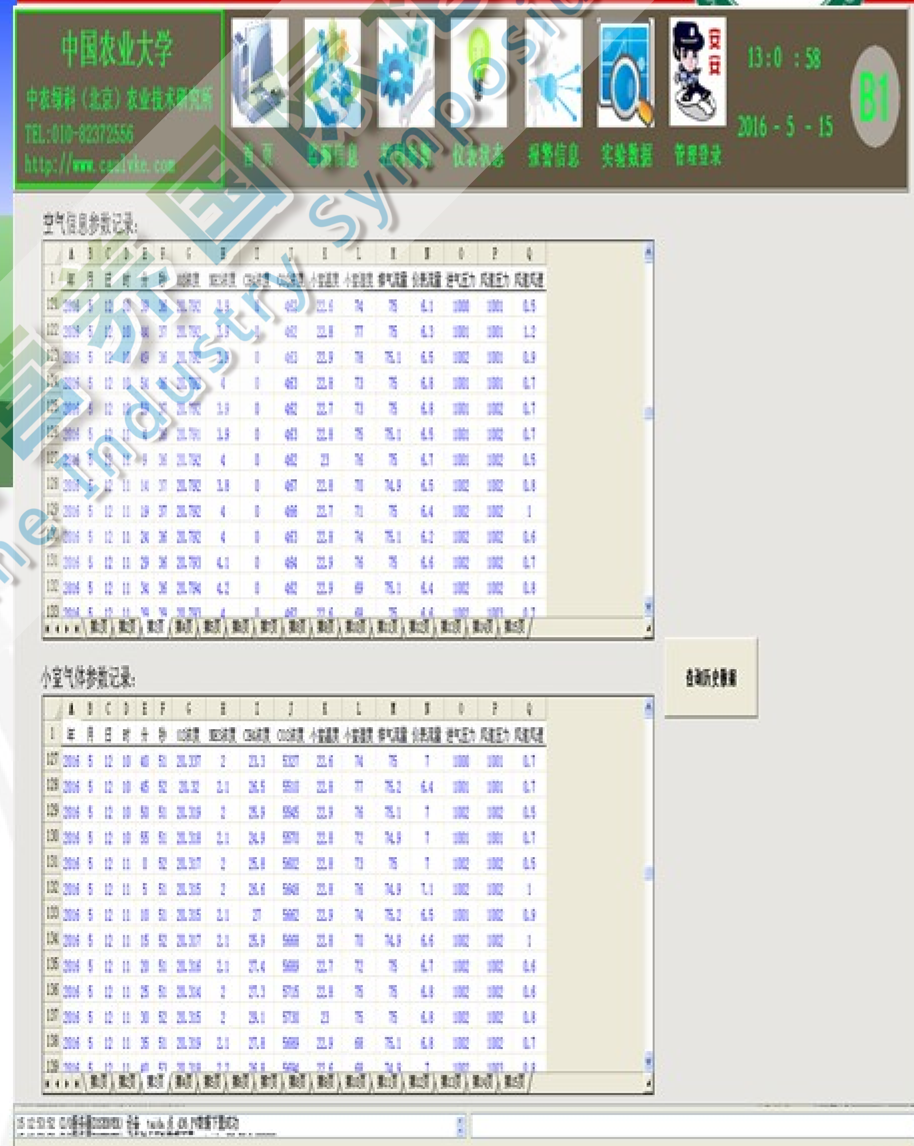


3.4 如何测定净能——庞大的数据量

How to measure——Complicated



1. 数据量大：每5分钟分别记录室内、外气体、气压、温湿度、风速等大量原始数据，每天产生9504个原始数据（不包括粪尿数据）
   Plenty of data： O_2, CO_2, CH_4, T, pressure, humidity for outside and inside, about 9504 data
2. 周期长：燃烧试验、猪产热试验、正式试验15天，每个试验饲养时间3个月以上
   Long period：Pre-trials(2 weeks)，15 d per period, 3 months per experiment



净能体系建立的难点

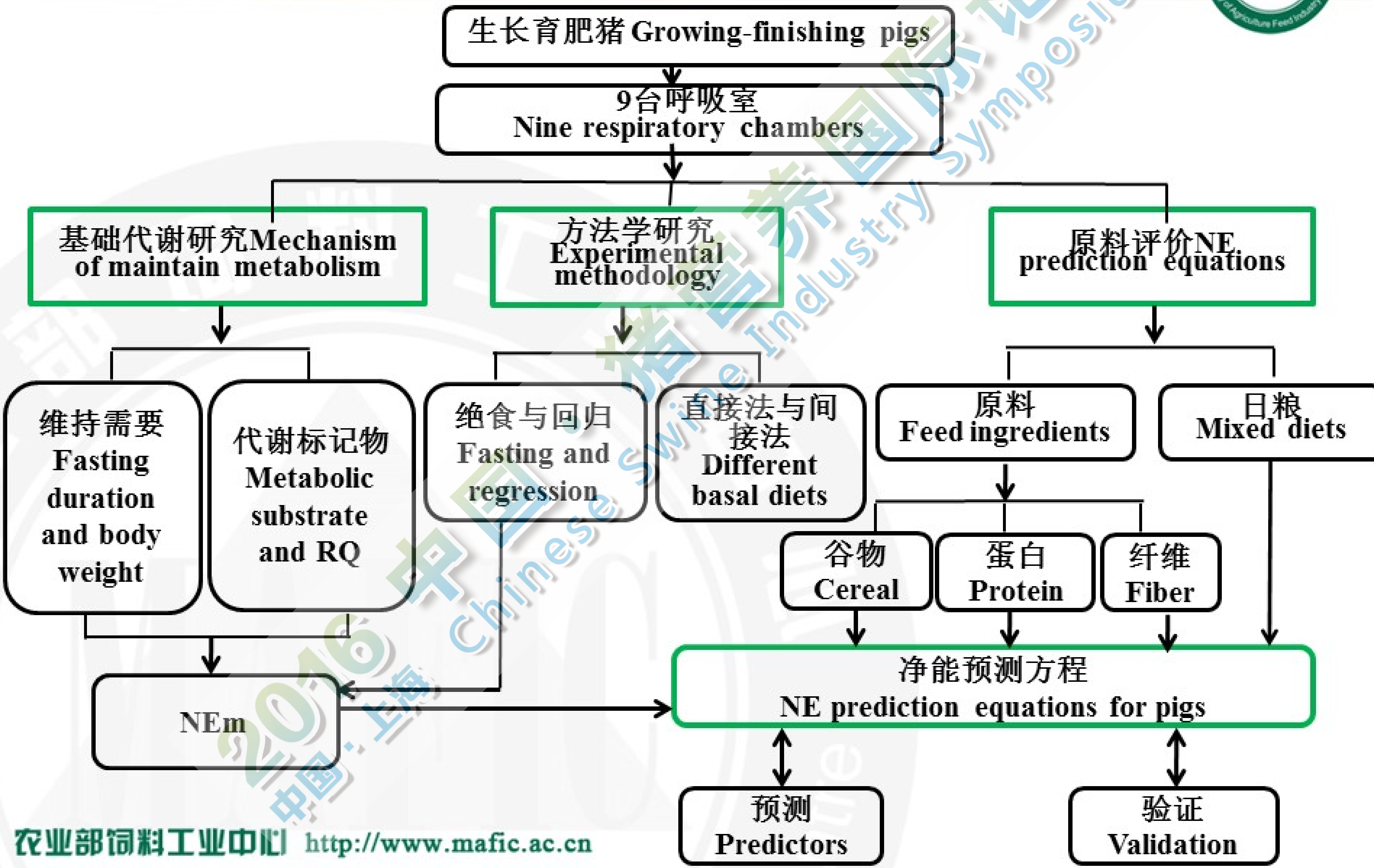
Difficulty when measured NE

1. 产热的剖分 Partition heat product

2. 从日粮到原料，更加复杂 From diets to ingredients

3. 原料净能预测模型的建立
   NE predicted equations for ingredients

4.1 中心净能体系研究框架
Summary of NE research at MAFIC



4.2 已做工作——猪能量分配规律 Finished work

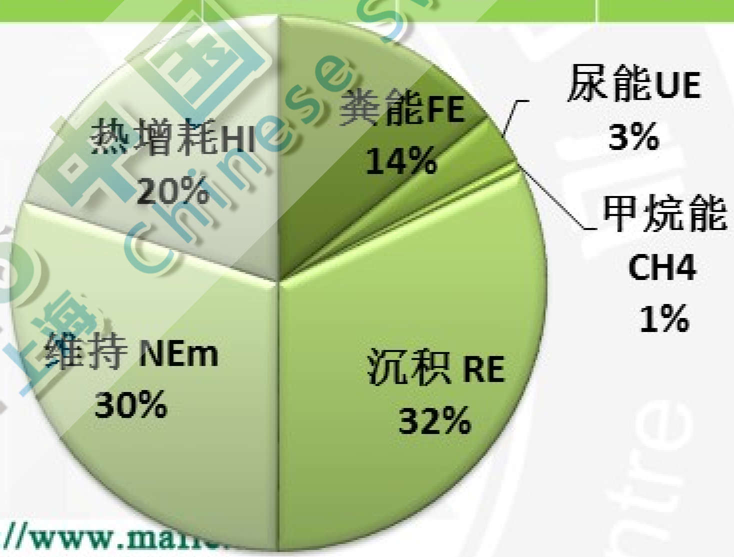
猪排泄基本信息 Information of intake and output for pigs

体重BW, kg	采食量Feed intake, g/d	鲜粪重 Weight of feces, g/d	尿量Urine, L/d	耗氧O_2, L/d	产甲烷CH_4, L/d	产二氧化碳CO_2, L/d	尿氮UN, g/d
45	1500	558	2.89	605	4	655	17

注:1、本数据来源于净能试验 (n =168)；2、日粮涵盖玉米豆粕、杂粕、DDGS、麸皮、小麦等；3、采食量比正常情况稍低；4、代谢笼饲养

Note:1. data from NE trials in MAFIC(n = 168); 2. pigs were fed in crates; feed intake was lower than Ad libitum; 3. diets included corn-SBM, oil-seed meal DDGS, wheat bran, wheat

食入总能GE intake	粪排出能FE output	尿排出能 UN output	甲烷能 Energy for CH4	产热量 Total HP	沉积净能 RE	维持能量NEm	热增耗 HI
25.22	3.62	0.78	0.18	12.61	8.08	7.53	5.08



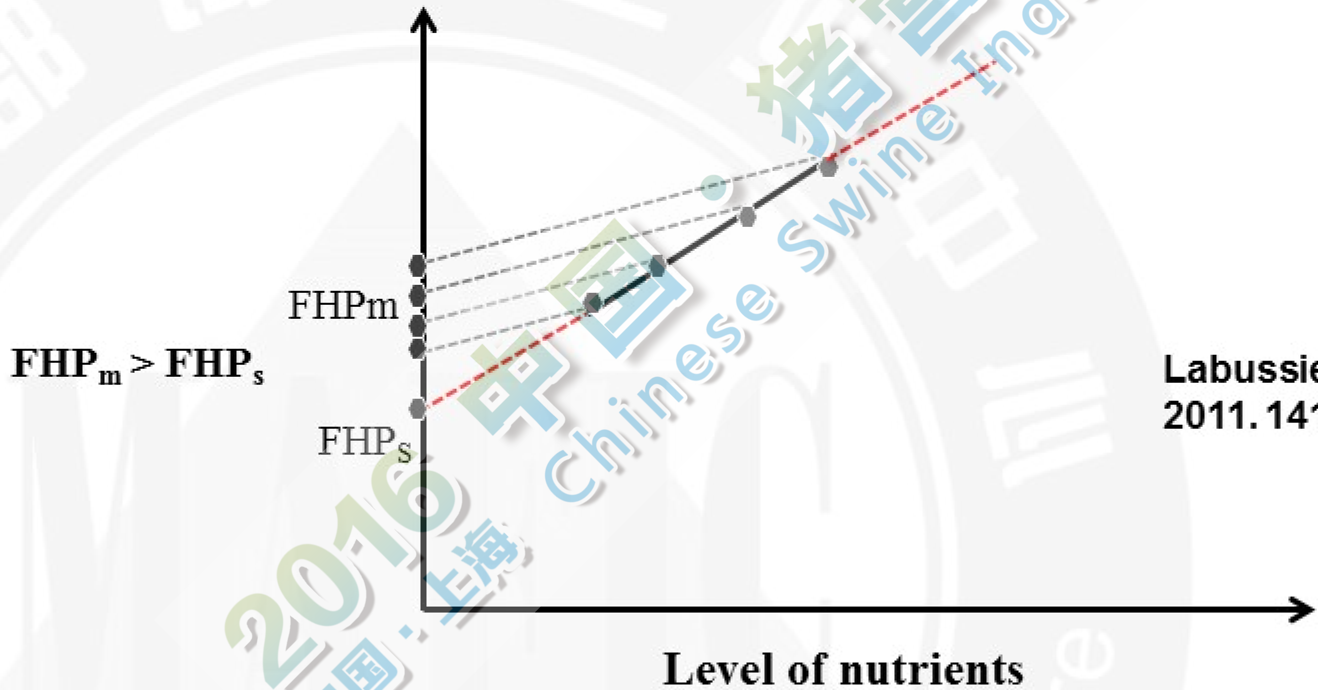
4.3.1 已做工作——维持需要研究
Finished work——Energy for maintenance

评估维持净能的经典方法—直线回归：

Extrapolating HP measured at different ME intake levels above maintenance to zero ME intake

缺陷：用于维持（Km）和生长（Kg）的效率不一样

Limitation: The efficiencies of energy utilization for maintenance (Km) and growth (Kg) are different



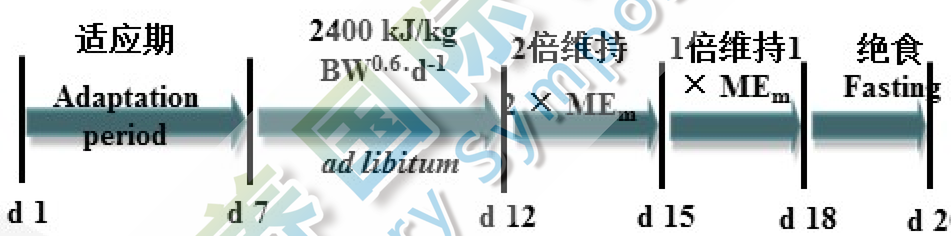
Labussiere, E, Journal of Nutrition, 2011. 141:1855-1861

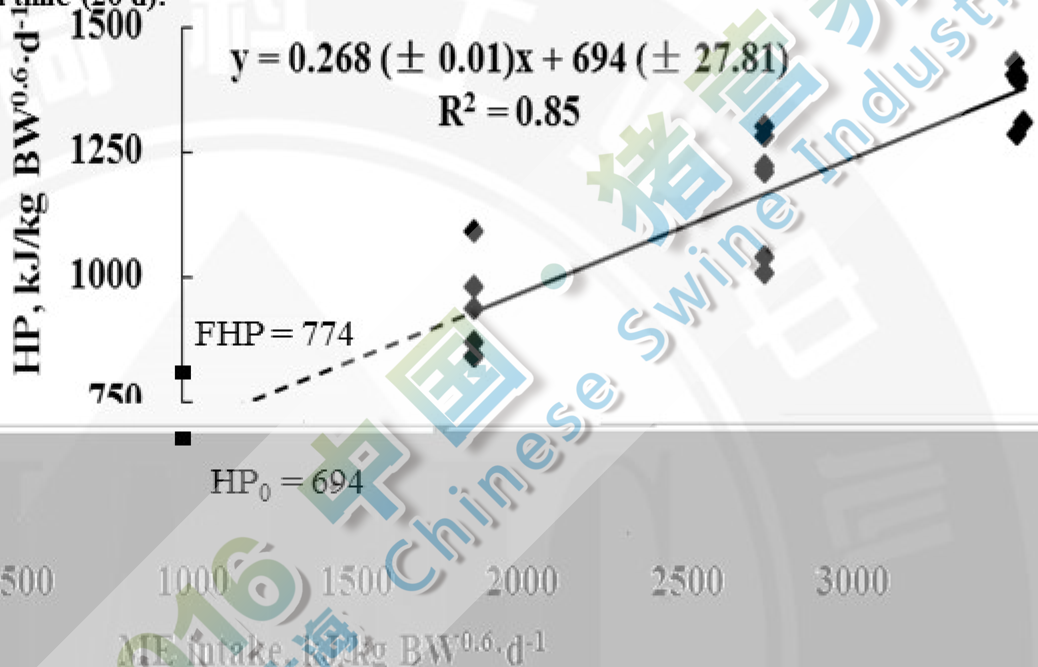
$$\mathbf{NE} = \mathrm{NEm} + b \times RE_p + c \times RE_f$$

4.3.1 已做工作——维持需要研究

Finished work——Energy for maintenance

- 6头猪Six barrows (43.0 ± 1.4 kg)
- 一个玉米豆粕日粮One corn-soybean meal diet
- 维持代谢能 ME_m: 893 kJ/kg $BW^{0.6}\cdot d^{-1}$ （Zhang et al., 2014)
- 试验期Trial time (20 d):





实测绝食产热量> 回归得到的产热量，表明用于维持的效率>生长的效率

FHP > HP0, indicated km > kg

(Liu et al., 2014)

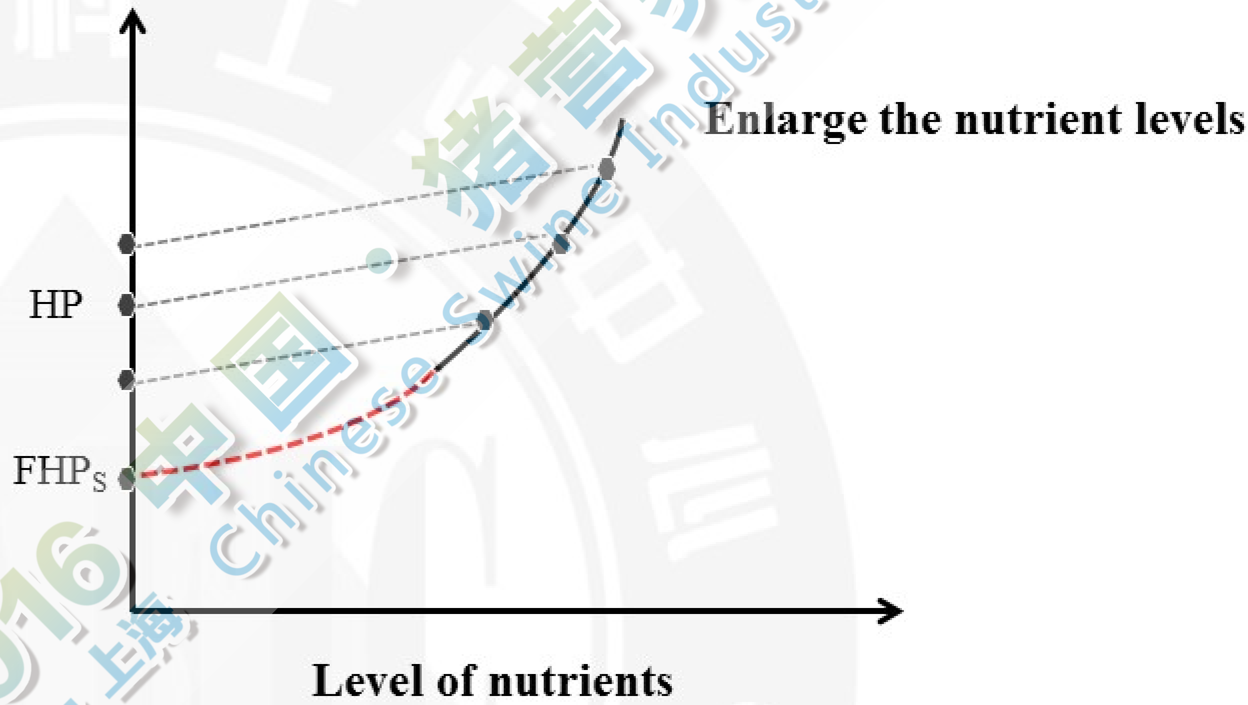
4.3.2 已做工作——维持需要研究
Finished work——Energy for maintenance

评估维持净能的新方法—指数回归：

Exponential regression analyses to estimate the energy requirement

优点：增加采食梯度，随着采食水平的变化产热呈指数变化

Advantage: a wide range of ME intakes both above and below maintenance



Zhang, G.F., et al. J Anim Sci, 2014. 92: 2987-2995

4.3.2 已做工作——维持需要研究

Finished work——Energy for maintenance

玉米豆粕日粮
Corn-SBM diet

36头生长猪和36头肥育猪
36 growing and 36 finishing pigs

6台开放式呼吸测热室6 open circuit respiration chambers

处理组: 6个饲喂水平分别为自由代谢能采食水平 (2400 kJ/kg $BW^{0.6} \cdot d^{-1}$) 的 0, 20, 40, 60, 80, 或 100% 。

Treatments: Six feeding levels were calculated as 0, 20, 40, 60, 80, or 100% of their estimated ad libitum ME intake (2400 kJ/kg $BW^{0.6} \cdot d^{-1}$)

指数回归分析
Exponential regression analyses

NE_m

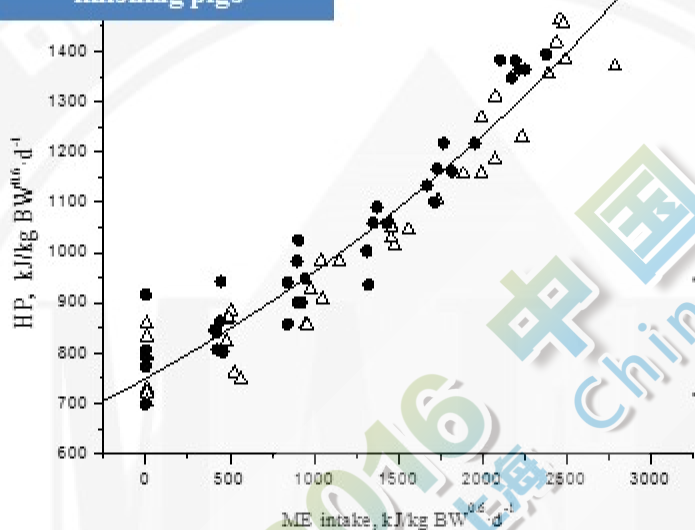


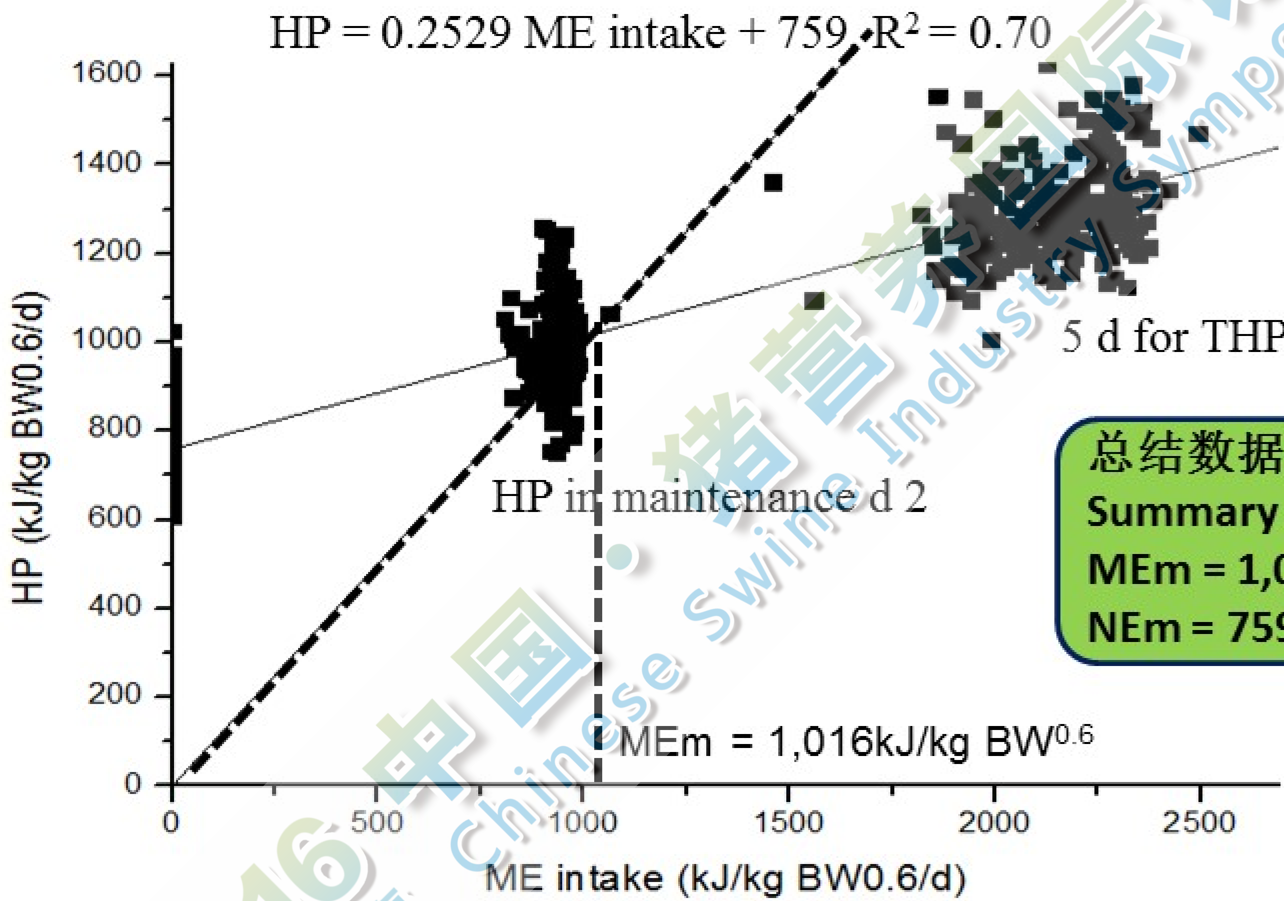
表2 不同代谢能采食水平的对数回归和维持能量需要Table 2. Regression of logarithm of heat production (kJ/kg $BW^{0.6} \cdot d^{-1}$) on ME intake (kJ/kg $BW^{0.6} \cdot d^{-1}$) and the calculated maintenance energy requirement

Body weight, kg	Intercept	Slope × 10,000	r^2	SEM	ME_m	NE_m	K_m, %
30-60	2.88	1.08	0.91	0.024	973	758	77.9
60-90	2.86	1.10	0.92	0.025	921	732	79.5

产热和ME采食水平的指数回归关系
Exponential relationship between heat production and ME intake

(Zhang et al., 2014)

4.3.3 已做工作——维持需要研究
Finished work——Energy for maintenance



总结数据
Summary data(kJ/kg $BW^{0.6}$)
MEm = 1,016
NEm = 759

注：34日粮, 12原料, 204 重复, 408 产热数据， 204 绝食产热数据

Note: 34 diets, 12 ingredients, 204 replications, 408 heat production data and 204 fasting heat production data

已做工作-维持需要研究
Finished work——Energy for maintenance

小结：Conclusion:

1. 维持的效率大于生长 (Km > Kg)
   Energy for maintenance (Km) > for growth (Kg)

2. 指数回归更能反映维持与生长的区别
   Exponential regression maybe better reflect the different between maintenance and growth

3. 总结已有工作得到的生长猪维持净能为759，维持代谢能为1,016（单位：kJ/kg $BW^{0.6}$）
   Summary the data in MAIFC, NEm = 759, MEm =1,016 (unit: kJ/kg $BW^{0.6}$)

4. 下一步研究维持能量的用途，即从呼吸熵，血液组学中找到能代表维持的标记底物
   Next work: research the energy utilization in maintenance according to the RQ, and metabolic substrate

4.4.1已做工作——方法学
Finished work——Methodology

直接法与间接法测定玉米能值比较

Energy content (MJ/kg, DM) of corn in growing pigs determined directly or by difference

	直接法 Determined directly	间接法 Determined by difference	SEM	*P*- value
能值 Energy content				
消化能DE	16.65	16.42	0.08	0.24
代谢能 ME	16.31	16.15	0.08	0.39
净能 NE	13.21	13.69	0.20	0.52
能量利用效率 Energy utilization				
代谢能/消化能 ME/DE	97.96	98.36	0.08	0.13
净能/代谢能 NE/ME	80.99	84.77	1.14	0.35

(Liu et al., 2014)

4.4.2 已做工作——方法学
Finished work——Methodology

玉米基础日粮和玉米豆粕基础日粮对测定豆粕能值的影响
Effects of different basal diets on energy content (MJ/kg, DM) of soybean meal

	玉米基础日粮 Corn-Basal Diet	玉米豆粕基础日粮 Corn-SBM-Basal Diet	SEM	*P*-value
能值Energy content				
消化能 DE	17.94	17.36	0.12	0.42
代谢能ME	17.31	16.52	0.09	0.60
净能NE	10.04	10.62	0.49	0.97
能量利用效率 Energy utilization				
代谢能/消化能 ME/DE	96.49	95.16	0.42	0.36
净能/代谢能 NE/ME	58.00	64.29	4.01	0.87

(Liu et al., 2014)

4.4.3 已做工作——方法学
Finished work——Methodology

小结Conclusion:

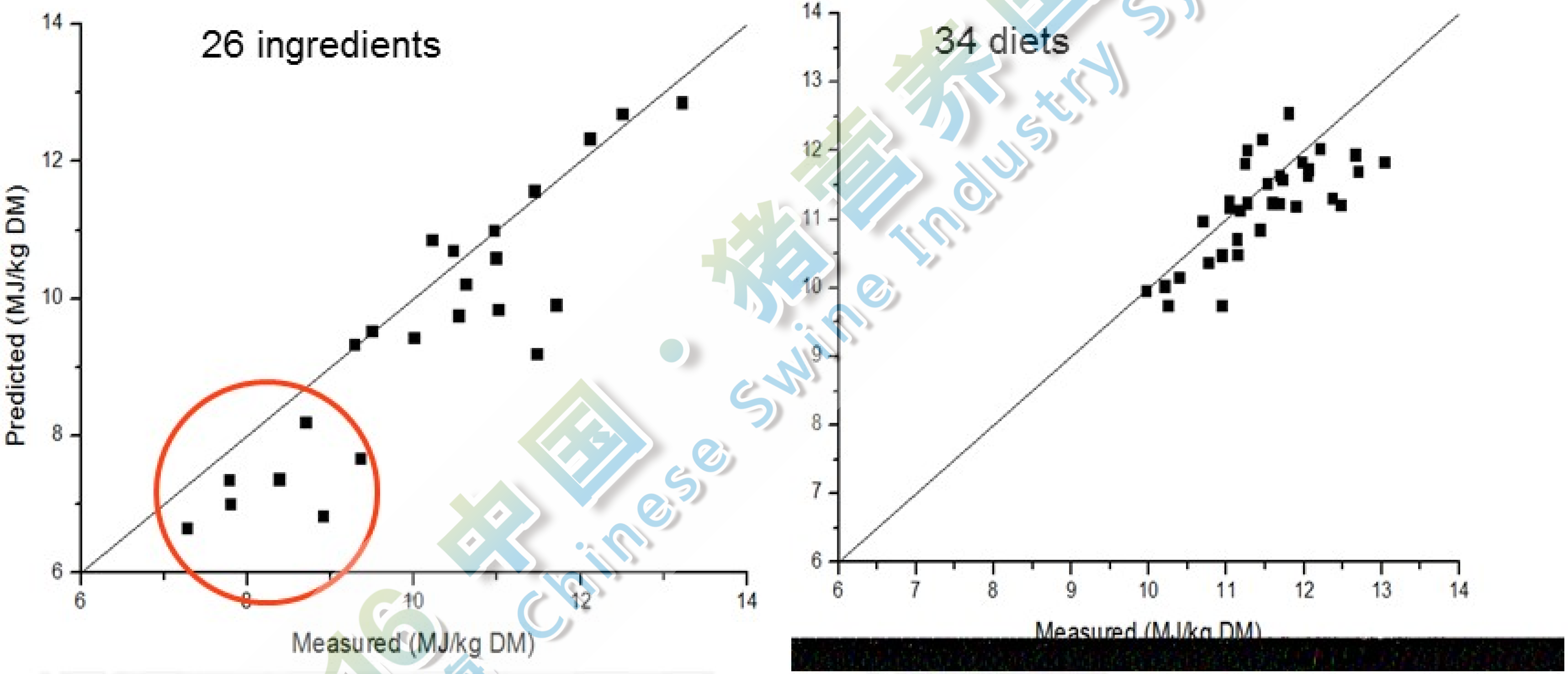
1. 测定玉米能值可以用直接法
   Determination the NE of corn using direct method

2. 测定豆粕及杂粕能值可以用玉米豆粕做基础日粮
   Determination the NE of protein ingredients using corn-SBM diet

4.5.1已做工作——原料净能
Finished work——NE for ingredients

与INRA方程对比

Comparison of NE values of 26 ingredients or 34 diets from measured in MAFIC and predicted based on INRA prediction equation



Prediction equation (NE = (0.70 × DE) + [(1.61 × EE) + (0.48 × Starch) - (0.91 × CP) - (0.87 × ADF)]/1000 × 4.184)

4.5.2 已做工作——原料净能
Finished work——NE for ingredients

No.	预测方程（22个原料） Equations (22 ingredients)	R^2	RSD	p-value
1	NE = 0.25 + 0.62 DE + 0.03 St	0.91	0.49	< 0.01
2	NE = 0.91 + 0.63 ME + 0.02 St	0.88	0.56	< 0.01
3	NE = 13.63 + 0.15 EE - 0.10 NDF - 0.28 Ash	0.84	0.66	< 0.01

No.	预测方程（34个日粮） Equations (34 diets)	R^2	RSD	P value
1	NE = -2.45 + 0.64 DE + 0.08 NDF + 0.05 starch	0.65	0.48	< 0.01
2	NE = -5.66 + 0.85 ME + 0.06 NDF + 0.15 ADF + 0.05 Starch	0.69	0.43	< 0.01
3	NE = -9.36 + 0.96 GE + 0.07 Starch	0.60	0.46	< 0.01

Ingredients 原料分类	预测方程Equations	R^2	RSD	*P* value
蛋白原料Protein (n=16)	NE = 0.035 + 0.64 DE	0.87	0.52	< 0.01
谷物原料Cereal (n= 3)	NE = 15.32 - 0.23 NDF	0.98	0.14	0.09
纤维原料Fiber (n=3)	NE = 9.15 - 0.24 Ash	0.99	0.01	< 0.01

非最终的方程：随着试验数据的增多还在进一步优化，并通过生长试验来验证最合适的方程

Not the final equations，which is need to be continued according new work in MAIFC

5.1.1 下一步工作——验证

Next work——Validation

验证
Validation

repeat

方程Equation – 重复验证repeat – 新方程new equation

Cross-validate

文献Literature

Growth trials

1. 能量效率Caloric efficiency
2. 低蛋白日粮 Low-protein diets
3. 生长模型Growth model

胴体组成
Body composition

5.1.2下一步工作——验证
Next work——Validation

试验一、蛋白原料净能预测方程的验证

Exp.1 validation the NE prediction equations for protein ingredients

负责人： 李忠超 **PhD:** Zhongchao Li

试验期： 2016年9月 **Period: Sep.** 2016

地点： 中国农业大学丰宁试验基地

Place: Fengning Swine Research Unit of China Agricultural University (Hebei, China)

试验处理： 玉米豆粕基础日粮，菜粕日粮，DDGS日粮，葵花粕日粮，**Treatments:** Corn-SBM diet, rapeseed meal diet, DDGS diet and sunflower diet

试验动物： 选取360头60kg猪，每个处理15个重复，每个重复6头猪

Animal: 360 pigs (BW = 60kg), 15 replicates per treatment, 6 pigs per pen

试验设计： 各处理组的玉米保持一致，分别以菜粕，DDGS和葵花粕代替基础日粮中豆粕的15%，添加合成AA，以满足SID AA需要，且保持各处理组的SID lys/NE一致

Experiment design: keep the consistent of corn among the 4 treatments, replace the SBM in basal diet using the rapeseed meal, DDGS and sunflower, respectively. Add the crystalline AA the consistent of SID lys/NE among the 4 treatments

检测指标： 生长性能，增重净能比，胴体指标，脂肪、肌肉沉积

Measurements: Growth performance, NE intake per gain, carcass, RE_P and RE_L

5.2 下一步工作——方法学
Next work——Methodology

试验二、 氨基酸添加对测定玉米净能的影响
Exp.2 The effect of amino acid on the NE of corn
负责人： 李亚奎 **PhD:** Yakui Li
试验期： 2016年7月 **Period:** July. 2016
地点： 中国农业大学丰宁试验基地
Place: Fengning Swine Research Unit of China Agricultural University (Hebei, China)
试验处理： 玉米、玉米+ (AA 满足理想蛋白模式）、玉米++ (添加 Ile)
Treatments: Corn, corn + (ideal protein), corn ++ (Ile)
Animal: 18 pigs (BW = 40kg), 6 replicates per treatments, 6 chambers

Item	Corn	Corn +	Corn ++
玉米Corn	97.00	96.92	96.64
磷酸氢钙Dicalcium phosphate	1.20	1.20	1.20
石粉Limestone	0.90	0.80	0.80
食盐Salt	0.40	0.35	0.35
预混料Vitamin and mineral premix	0.50	0.50	0.50
98赖氨酸L-Lys-HCl	-	0.20	0.30
蛋氨酸DL-Met	-	-	0.01
苏氨酸L-Thr	-	0.01	0.08
色氨酸L-Trp	-	0.03	0.05
L-Val	-	-	0.02
L-Ile	-	-	0.05

5.3.1 下一步工作——构建模型
Next work——Nutritional Requirement Modeling

猪净能需要量模型建立目的

The Objective Pig Nutritional Requirement Modeling

1. 猪场（养猪人）

   Pig industry (Farmers)

2. 饲料厂（配方师）

   Feed industry

3. 研究单位（发文章）

   Research only (Papers)

5.3.2下一步工作——构建模型

Next work——Nutritional Requirement Modeling

一、生长猪Growing pigs:

1. 理想蛋白 (Lys) 下确定 维持净能 (NE_m), 能量转化为蛋白和脂肪的效率 (K_p, K_f) NEm, Kp, Kf…. Ideal protein (Lysine)
2. 日增重，瘦肉增重与体蛋白和体脂肪的关系 Protein, fat----ADG, Lean gain
3. 能量和Lys供应与蛋白增重和脂肪增重的关系 Protein fat, gain----Energy supply, Lysine….
4. 蛋白水平、环境温湿度对产热的影响
   Effect of protein, temperature, humidity on heat production…
5. 猪的数量对产热和生长性能的影响
   Variability of pigs

育肥猪 (> 120 kg体重)
Finishing pigs: (> 120 kg)
母猪Sow:

5.3.3 构建模型——蛋白水平、环境温湿度对产热的影响
Next work——Protein, temperature on HP

Heat stress in pigs is accompanied by adipose tissue-specific responses that favor increased triglyceride storage

JAS, 2016. H. Qu, Purdude University

20 ℃ vs 35 ℃； 母猪 vs 公猪Gilts vs boars

1. 热应激诱导脂肪组织内PCK1表达（6.79 vs 0.63)

   Heat stress induced PEPCK expression in adipose tissue

2. 上调脂肪合成过程

   Elevated glyceroneogenesis can increase fat storage in pigs under heat stress

3. 猪对热应激有组织特异性反应

   Pigs have tissue-specific differences in response to heat stress

4. 热应激猪脂肪酸激酶（FAS和脂蛋白酶（LPL）高

   FAS and LPL are higher in heat stress pigs

5.3.4 构建模型——蛋白水平、环境温湿度对产热的影响
Next work——Protein, temperature on HP

试验三、 自然条件下，蛋白水平和环境温度对产热和净能值的影响

Exp.3 Effect of Climate and protein level on NE values

负责人： 刘虎 **PhD:** Hu Liu

试验期： 2016年7月和2017年1月**Period:** Summer (July. 2016) vs Winter (Jan. 2017)

地点： 中国农业大学涿州试验基地

Place: Zhuozhou Swine Research Unit of China Agricultural University (Hebei, China)

Nature climate: Temp. out side house, Inside house

Max. Min. Average, rectal temperature, skin and respiration rates.

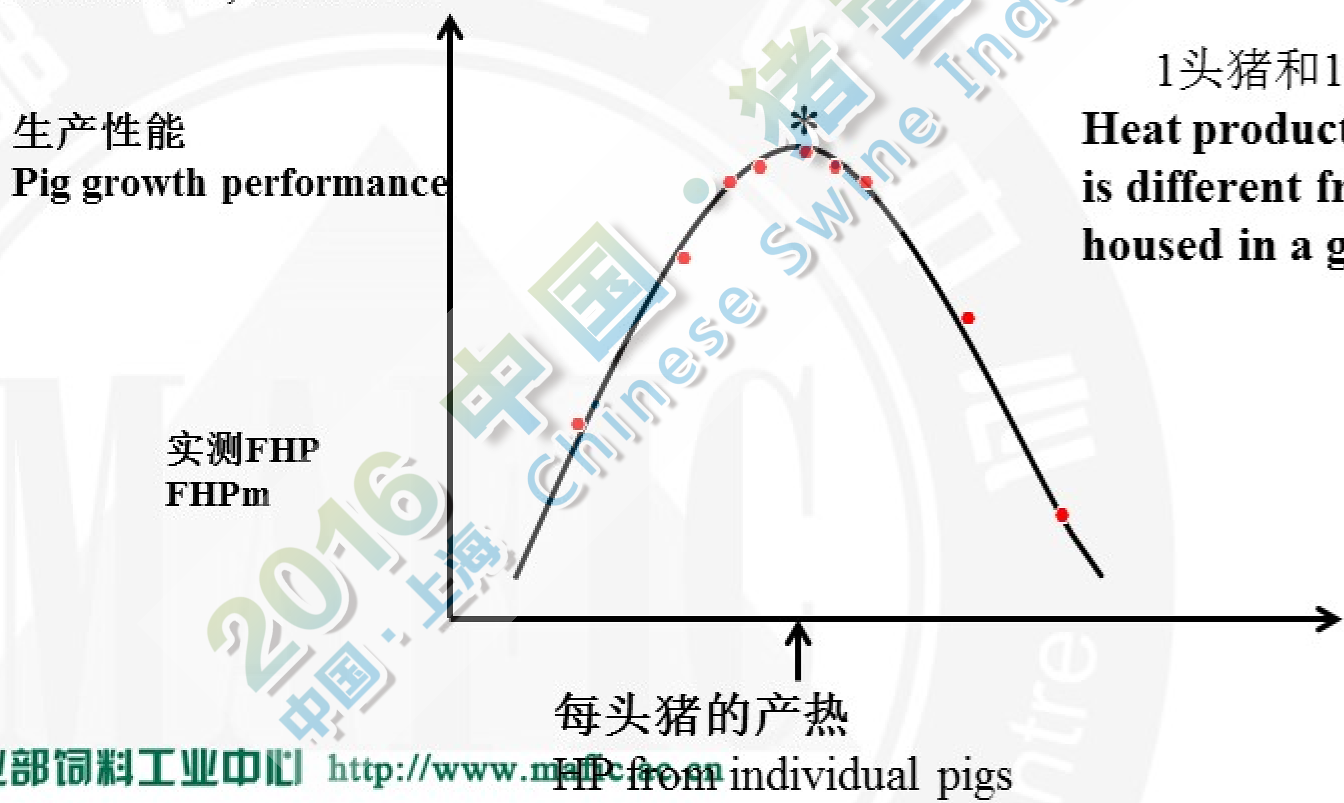
试验处理 Experiment design: 2*2双因子（高低温V.S 正常和低蛋白日粮）2 by 2 factors (High vs low temperature and Normal diets vs low protein diet

检测指标： 生长性能、胴体指标，脂肪、肌肉沉积，相关生化指标

Measurements: Growth performance, carcass (fat, muscle, bone deposition), REP, REL, biochemical parameters which participation of fat and muscle influenced by temperatures

5.3.5 构建模型——猪的数量对产热和生长性能的影响
Next work——Effect of Pig Numbers on NE

1. **1头猪 v.s 10头猪** Response from pigs differently one vs 10 pigs together
2. 猪个体差异（体重不同），导致采食量等发生变化
Body weight different, response differ a lot, such as feed intake
3. **精确饲喂：**不同阶段，G:F，初产、妊娠、哺乳母猪，公猪...
Precision nutrition: Different phases, G-F, replacement gilt, gestation sows, lactation sows, boars….



1头猪和10头猪产热不同
Heat production from one pig is different from that ten pigs housed in a group

5.4.1 下一步工作——维持的测定

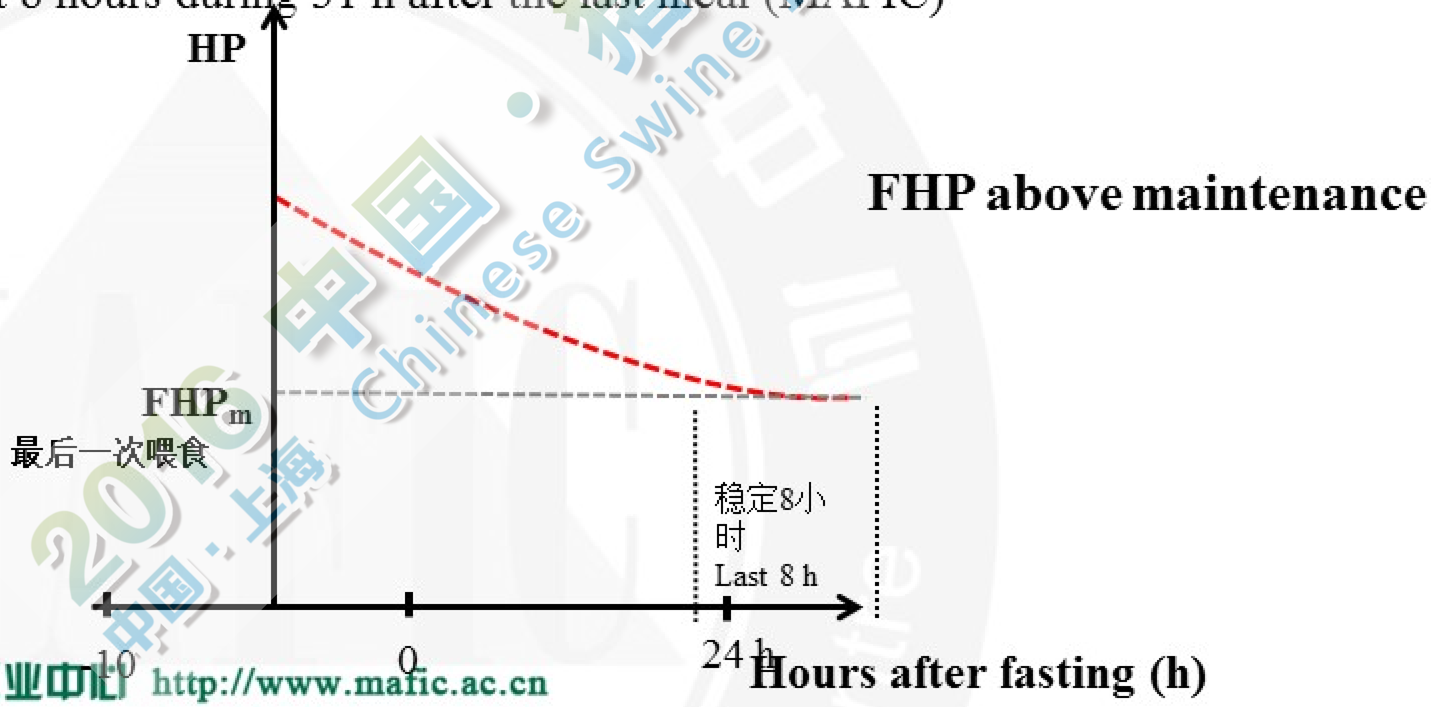
Next work——Energy for maintenance

绝食产热量（FHP）的测定：FHP:

1. 用绝食24h的产热，渐进线的方式评估FHP (**INRA** 方法）

The FHP is estimated as the asymptotic nocturnal heat production after a period of food deprivation of 24 h (INRA)

2. 最后一次喂食31h到38h的夜间稳定的8h产热评估FHP (**MAFIC** 方法）The FHP is estimated last 8 hours during 31 h after the last meal (MAFIC)



5.4.2 下一步工作——维持的测定
Next work——Energy for maintenance

Exp. 4 不同采食水平下维持能量代谢规律的研究

The Mechanism of maintain metabolism at different feed levels

负责人： 刘虎 **PhD:** Hu Liu

试验期： 2016年9月 **Time:** Sep. 2016

地点： 中国农业大学代谢室

Place: Metabolism room in China agricultural university

试验处理： 自由采食， 80%、60%、40%自由采食

Treatments: Ad libitum, 80%, 60% and 40% ad libitum

试验动物： 选取24头30kg生长猪，每个处理6个重复，每个重复1头猪

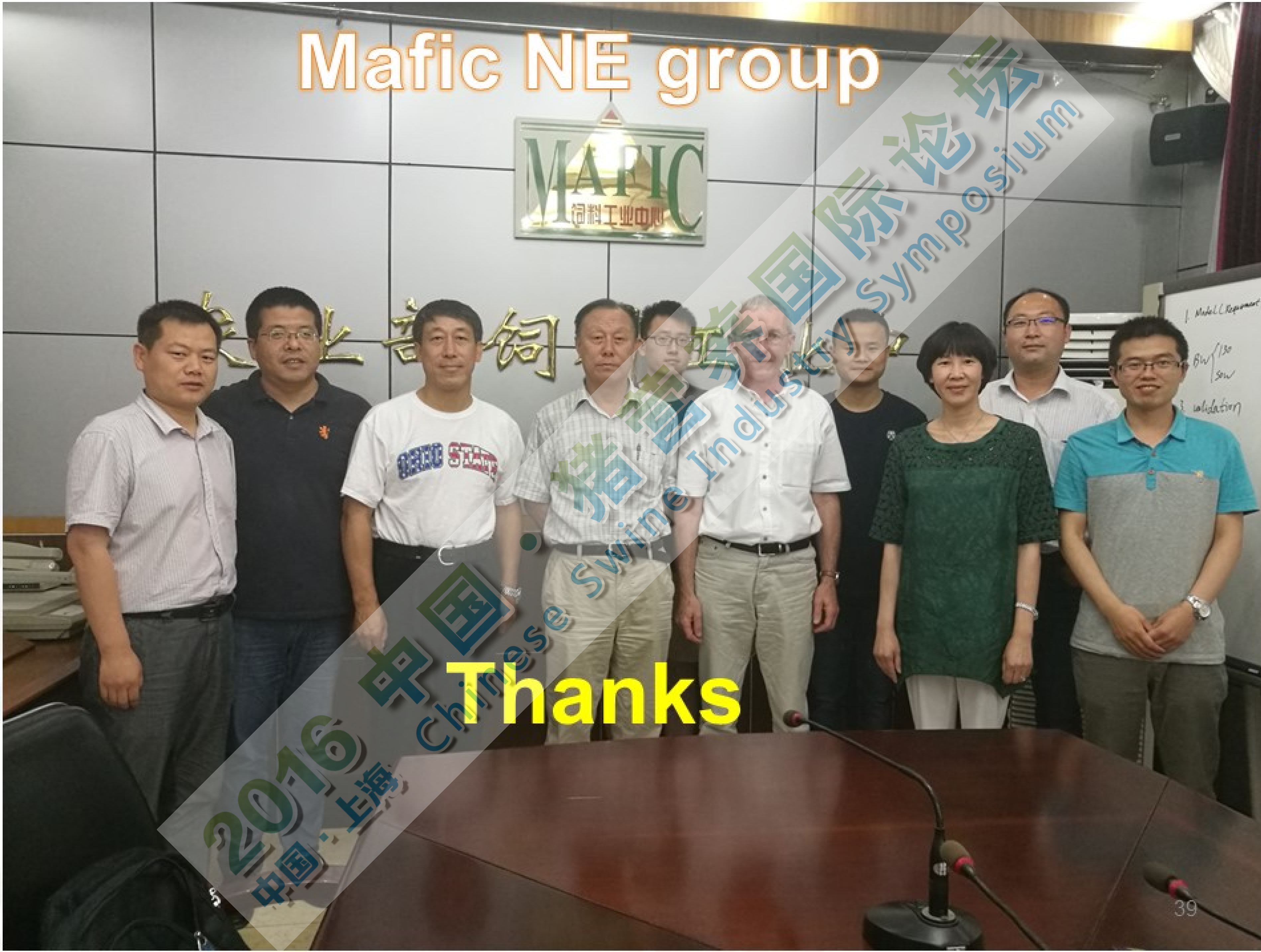
Animal: 24 growing pigs (30 kg)， 6 replicates per treatments

试验设计 Experimental design:

检测指标： O_2, CO_2, CH_4, RQ, 血生化，酶活，基因表达、代谢图谱

Measurements: O_2, CO_2, CH_4, RQ, biochemical parameters, enzyme activity, gene expression, metabonomics

Mafic NE group



Thanks