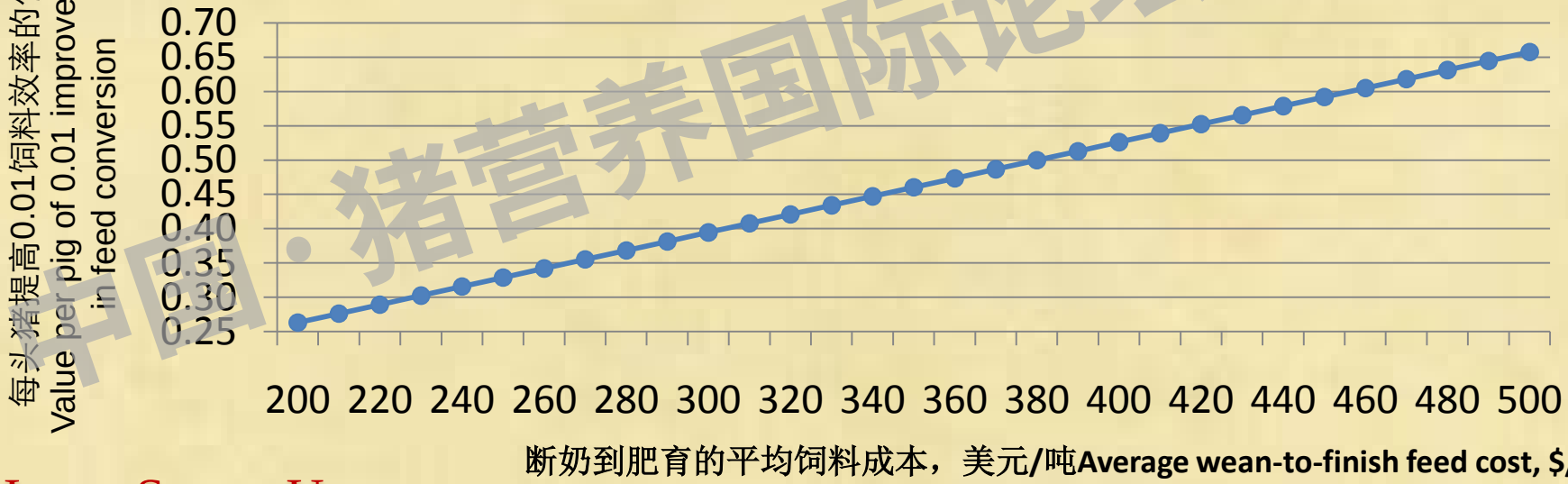
国际饲料效率项目：我们该如何行动？

INTERNATIONAL FEED EFFICIENCY PROJECT: WHAT ARE WE LEARNING?

John F. Patience
爱荷华州立大学动物科学系
应用猪营养学研究
Applied Swine Nutrition
Dept. of Animal Science
Iowa State University

饲料效率概念 Feed efficiency concepts

- 优化饲料效率大大提高猪场的整体经济效益 Optimizing feed efficiency contributes greatly to overall farm success
  - 根据现在美国的饲料价格，每头猪饲料效率（料重比）中的一个点大约值0.26美元 One point in feed conversion (feed:gain) is worth about $0.26 per pig at today's feed prices (US)



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- 优化饲料效率大大提高猪场的整体经济效益
  Optimizing feed efficiency contributes greatly to overall farm success

- 饲料效率是一个非常复杂的课题
  Feed conversion is a very complex subject
  - 从管理的角度看，不能准确理解此课题，将付出沉重的代价
    Failure to understand the subject can lead to costly management mistakes

饲料效率概念 Feed efficiency concepts

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- 饲料效率是一个非常复杂的课题

  Feed conversion is a very complex subject

- 饲料效率不应作为一个孤立存在的管理目标。

  Feed conversion must not be a management target used in isolation.

  – 在评估饲料效果时，必须同时考虑到其它成效和经济效益

    It must be considered in the context of other performance and financial outcomes

饲料效率受许多因素的影响
Feed efficiency is influenced by many factors

- **饲料组成 Feed composition**
  - 能量、氨基酸浓度、营养平衡 Energy, amino acid concentration, nutrient balance
  - 其他营养素的缺乏 Gross deficiencies of other nutrients
  - 饲料加工：粉碎、制粒、酶 Feed processing: grinding, pelleting, enzymes
  - 饲料添加剂 Feed additives
- **环境因素 Environmental factors**
  - 温度 Temperature
  - 健康（影响巨大）Health (huge),
  - 采食状况 Access to feed
- **猪 Pig**
  - 生长速度、蛋白质脂肪比、 初重和末重、死亡率
    Growth rate, protein:lipid ratio, starting and final weight, mortality

限饲与饲料效率 Feed restriction and feed efficiency

	自由采食百分比 Percent of ad lib					
	100	93	86	79	72	P-值 P-value
末重，lb Final wt., lb	264.7	262.1	261.6	262.3	264.5	0.1074
增重，lb/d Gain, lb/d	2.23	2.03	1.68	1.72	1.45	<0.0001
胴体脂肪，%干基 Carcass fat, % DM	**58.2**	**55.0**	**51.9**	**51.2**	**49.6**	**0.0058**
胴体蛋白质，%干基 Carcass protein, %DM	**34.4**	**35.8**	**39.8**	**41.8**	**43.7**	**0.0011**

Patience et al., 2002

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脂质/蛋白质比 Lipid:protein ratio	**1.72**	**1.58**	**1.36**	**1.25**	**1.16**	**0.0004**
代谢能摄入，Mcal/d ME intake, Mcal/d	8.24	7.61	7.04	6.43	5.84	0.001

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Patience 等, 2002
Patience et al., 2002

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上市天数 Days to market	**95.5**	**102.3**	**123.4**	**120.8**	**144.3**	

Patience等, 2002
Patience et al., 2002

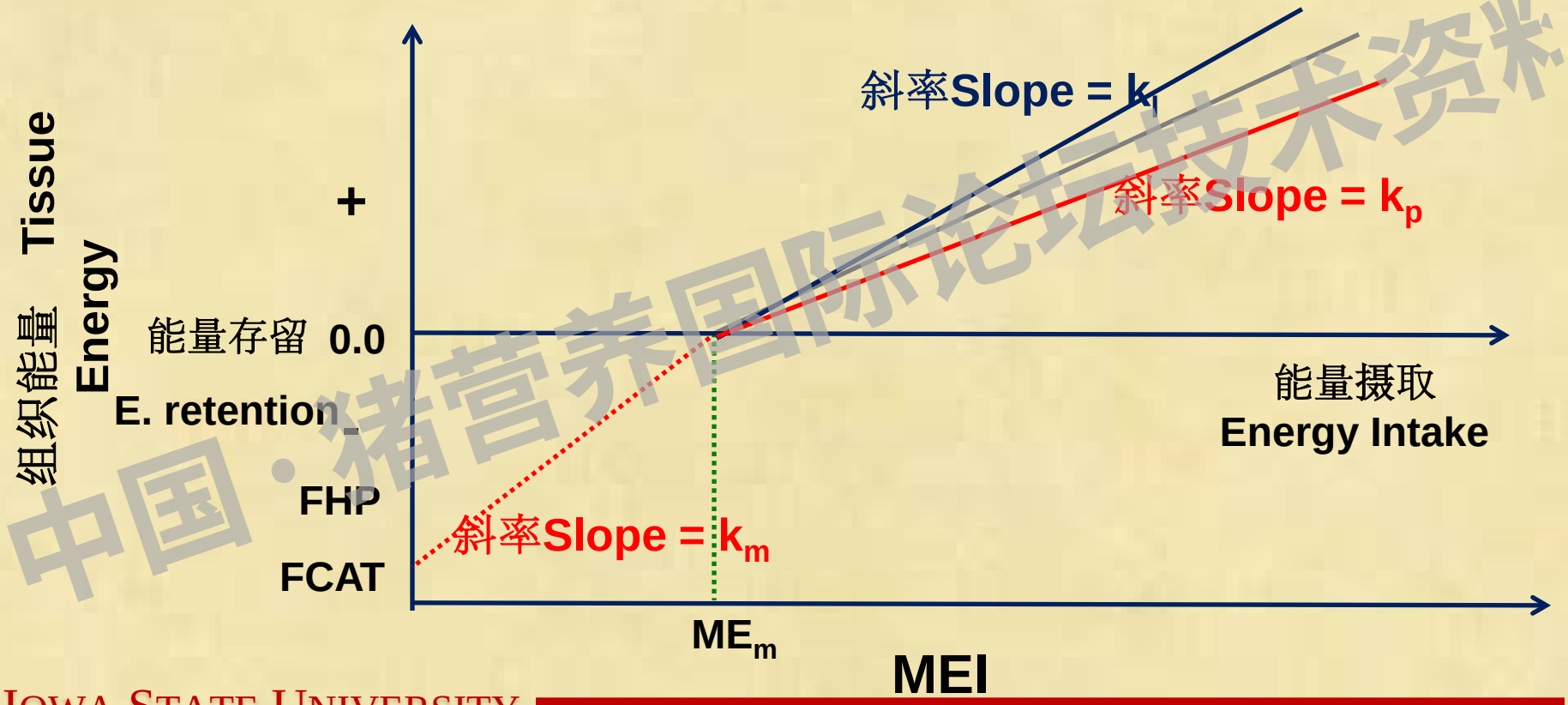
维持和增重之间如何分摊每日能量摄入
How daily energy intake is divided between maintenance and gain

功能 Functions	增重 Gain	代谢能摄入，Mcal/d ME intake, Mcal/d
维持 Maintenance	-	2.52 (34%)
蛋白质（瘦肉）增重 Protein (lean) gain	138 g/d (16%)	1.46 (20%)
脂肪增重 Fat gain	267 g/d (31%)	3.36 (46%)
合计Total	862 g/d	7.3 (100%)

假设每公斤日粮中含有代谢能3.31 Mcal和SID赖氨酸0.85%。猪体重为70kg左右，每天大约增重900g（总的育肥平均日增重= 840g/d),每天消耗2.20kg饲料，饲料效率为2.58（总采食量与育肥 猪增重比即总的饲料转化率为2.85 :1）。

Assume the diet contains 3.31 Mcal ME/kg and 0.85% SID lysine. The pig weighs about 70 kg, is gaining about 900 g/d (total growout ADG = 840 g/d) and is eating 2.20 kg of feed/day, giving a feed conversion of 2.58 (total feeder to finish growout FC is 2.85:1).

能量利用效率 Efficiency of energy use



de Lange and Birkett, 2005

国家猪饲料效率项目：总体目标

National Program on Swine Feed Efficiency: Overall objective：

提高生猪生产中的

营养利用率和**饲料效率，**

从而加强养猪业的竞争力，并通过积极、重点和综合的研究和推广降低养猪业对谷物和蛋白质的需求

Increase **nutrient utilization**

and **feed efficiency**

in pork production,

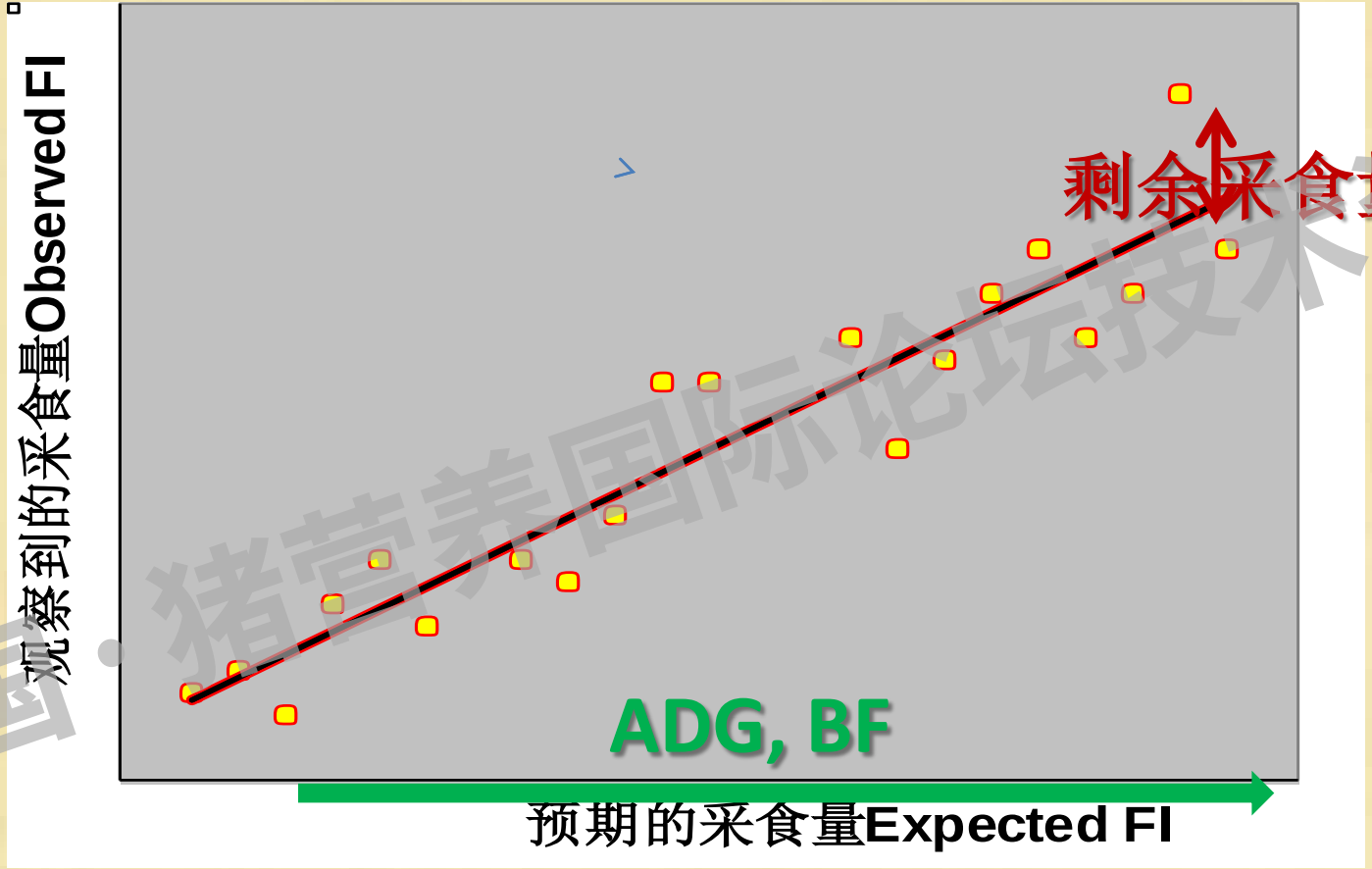
thereby strengthening the competitiveness of the pork industry and reducing its demand on grains and proteins, through focused and integrated initiatives in research and extension.

具体目标 Specific objectives

1. 评估猪只（在玉米豆粕型日粮情况下针对饲料效率选育后的猪只）在非常规原料日粮下的生长表现 To quantify the performance of pigs selected for increased feed efficiency under corn-soybean diets when fed lower quality by-product ingredients (higher fiber, lower fat).

2. 评估选育后的猪只应对行为、生理和免疫应激的能力。To evaluate the ability of pigs selected for increased efficiency to cope with behavioral, physiological and immunological stressors.
3. 进一步开发行业现有的工具，以轻松有效地确定和选择效率更高的猪。 To develop industry-ready tools to easily and effectively identify and select more efficient pigs.

4. 提高养猪生产者对饲料效率影响因素以及现有的饲料效率提高策略的认识 To increase pork producers' awareness of the factors influencing feed efficiency and strategies available to achieve improvement.
5. 确保快速、有效地实施国内和国际上提高饲料效率的新技术。 To ensure the rapid and effective implementation of new technologies to improve feed efficiency both nationally and internationally.



选择低剩余采食量(RFI)为育种目标，经超过8代选育后其生长性能的变化情况　Impact of selection for reduced RFI over 8 generations

- 剩余采食量RFI = -241 g/d
- 平均日采食量ADFI = -376 g/d
- 饲料转化率FCR = -0.22
- 背膘BF = -2.5 mm
- 眼肌面积LEA = +1.5 mm
- 平均日增重ADG = -79 g/d

Young & Dekkers (2012)

1.在高能日粮情况下选育的低RFI品系猪在饲喂低能日粮情况下生长性能是否仍然具有优势？

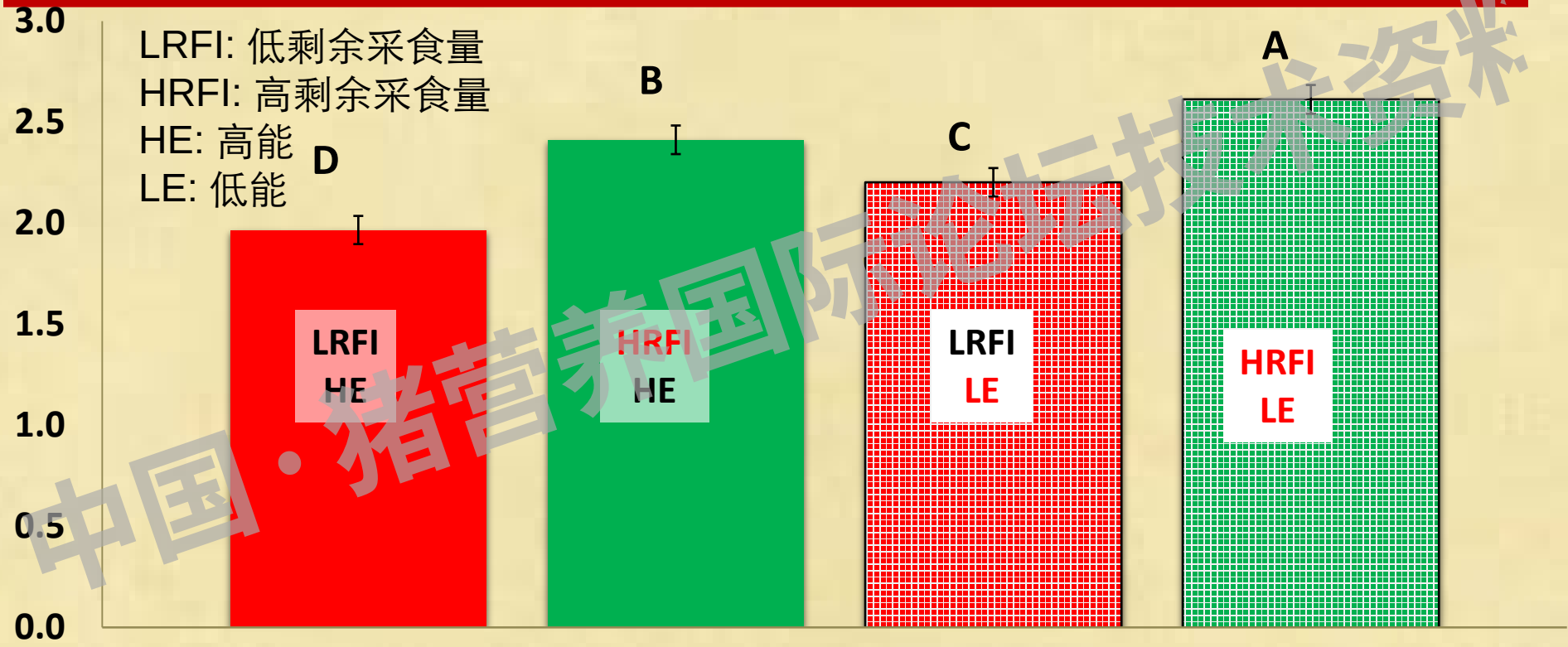
Are pigs that are selected for low RFI on higher energy diets still superior when fed lower energy diets?

高能（HE）和低能（LE）日粮的原料和营养成分 Ingredient and nutrient composition of higher (HE) and lower (LE) energy diets

原料Ingredient (%)	高能High Energy	低能Lower Energy
黄色马齿玉米Corn, yellow dent	80.18	42.34
豆粕46.5 %Soybean meal 46.5%	16.72	7.99
大豆皮Soybean hulls	-	20.00
玉米皮Corn bran	-	7.00
次粉Wheat middlings	-	20.00
L-赖氨酸L-Lysine	0.25	0.25
DL-蛋氨酸DL-Methionine	0.01	0.01
L-苏氨酸 L-Threonine	-	0.06
L-色氨酸 L-Tryptophan	0.05	-
磷酸二氢钙Monocalcium Phos.	1.06	0.71
石粉Limestone	0.93	0.83
食盐Salt	0.50	0.50
维生素预混料Vitamin Premix	0.15	0.15
矿物质预混料Mineral Premix	0.15	0.15

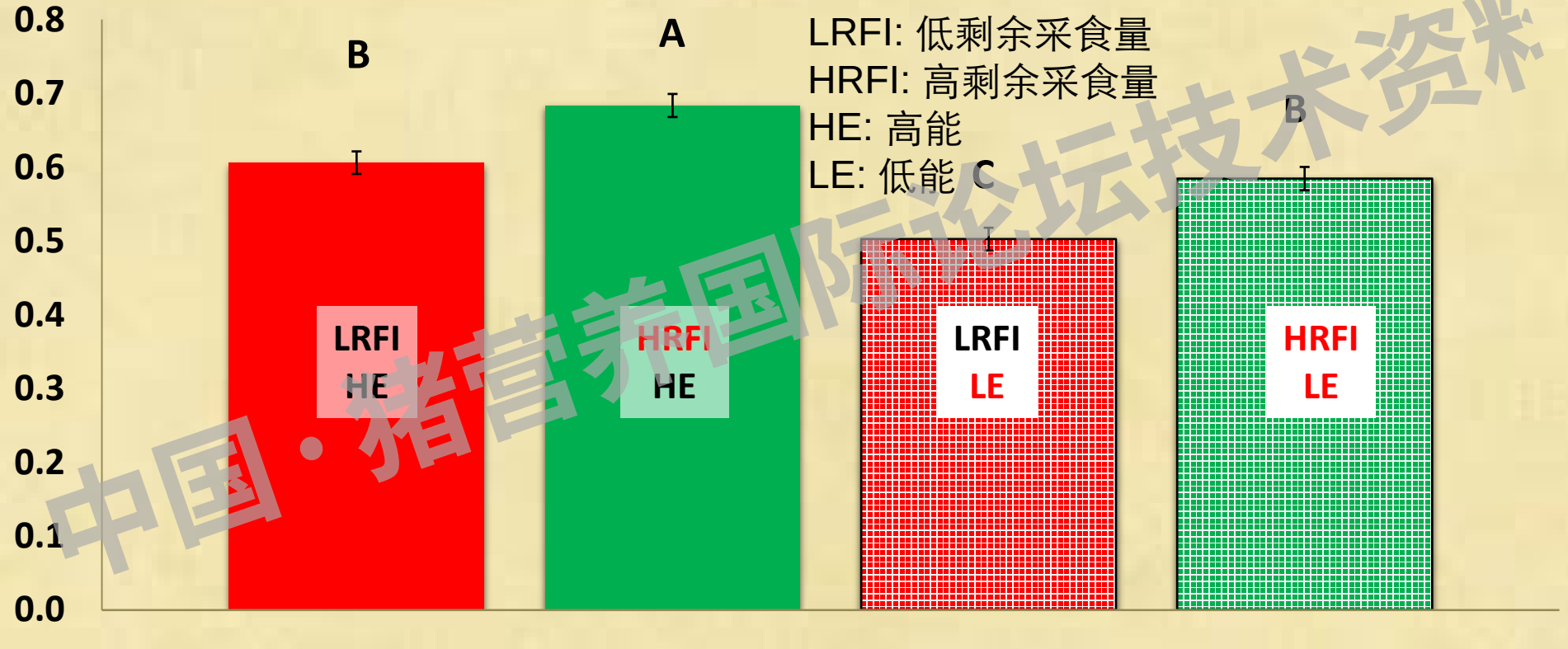
营养Nutrient	高能High energy	低能Lower energy
干基DM, %	89.4	89.3
代谢能ME, Mcal/kg	3.32	2.87
净能NE, Mcal/kg	2.47	2.03
粗蛋白CP, %	14.7	13.8
中性洗涤纤维NDF, %	9.4	25.9
粗纤维Crude Fiber, %	2.6	10.5
粗脂肪Crude Fat, %	3.6	3.5
总磷Phos % total	0.56	0.55
可利用磷Phos %, available	0.28	0.28
赖氨酸Lysine %, SID	0.80	0.70
苏氨酸Threonine %, SID	0.50	0.44
蛋氨酸Methionine %, SID	0.23	0.20

品系和日粮对平均日采食量的影响 Effect of line and diet on average daily feed intake, kg/day



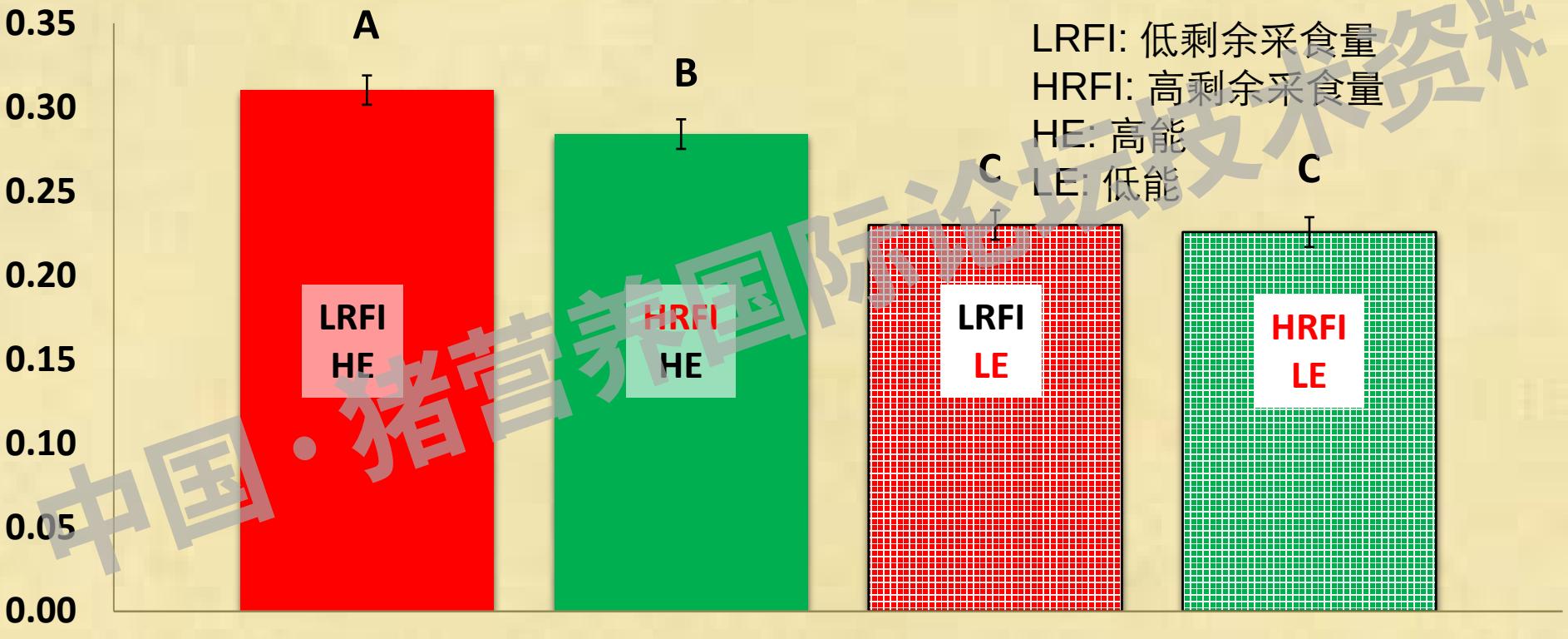
Mauch et al. (2014)

品系和日粮对平均日增重的影响 Effect of line and diet on average daily gain, kg/day



Mauch et al. (2014)

品系和日粮对饲料效率的影响，kg增重/kg饲料
Effect of line and diet on feed efficiency, kg gain/kg feed



Mauch et al. (2014)

结论 Conclusion #1

- 在饲喂高能日粮下选育的低RFI品系猪在饲喂低能日粮时生长性能可能不具有优势。
  Pigs selected for low RFI on a higher energy diet may not be superior when fed a lower energy diet

2. 低RFI品系猪是否更容易生病？

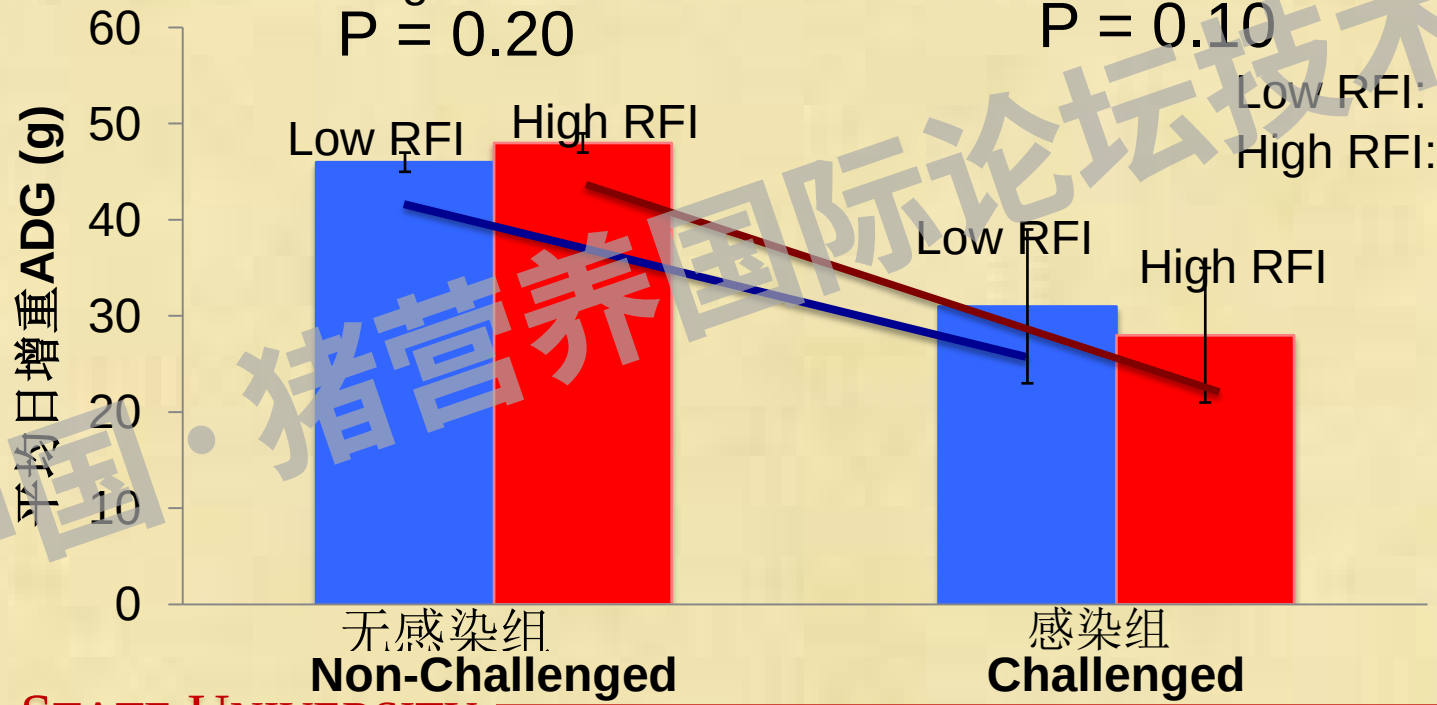
Are pigs that are selected for low RFI more susceptible to illness?

猪品系及蓝耳病(PRRS)病毒对平均日增重的影响

Effect of line and PRRS challenge on average daily gain (g)

感染状况* 剩余采食量品系：P=0.04

Challenge Status*RFI Line: P = 0.04



Low RFI: 低剩余采食量

High RFI:高剩余采食量

Dunkelberger et al. (2013)

抗体分析Antibody analysis

- 感染后第4、7和11天血清样品
  Serum samples on days 4, 7, and 11 post-infection
  - 猪繁殖与呼吸综合征酶联免疫吸附测定：PRRS病毒特异性IgG
    PRRS ELISA assay: PRRSV-specific IgG
  - MAGPIX 试验　MAGPIX Assay:　　总抗体Total antibody

- **结果**：上述两个试验均表明低剩余采食量品系的猪在7至11天之间抗体产生上升幅度较大
  Results: both assays indicate greater increase in antibody production from day 7 to 11 for the Low RFI line
    - ELISA试验: $P < 0.001$
    - MAGPIX试验: $P = 0.007$

结论 Conclusion #2

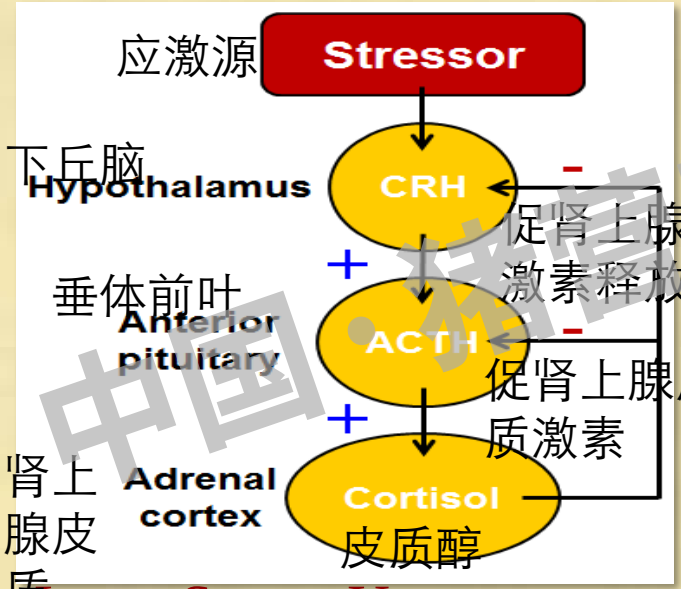
- 在饲喂高能日粮下选育的低RFI品系猪在饲喂低能日粮时生长性能可能不具有优势。
  Pigs selected for low RFI on a higher energy diet may not be superior when fed a lower energy diet
- 低RFI品系猪并未显得更易得传染性疾病。
  Pigs selected for low RFI do not appear to be more susceptible to infectious disease

3. 低RFI品系猪对生理应激是否更敏感？

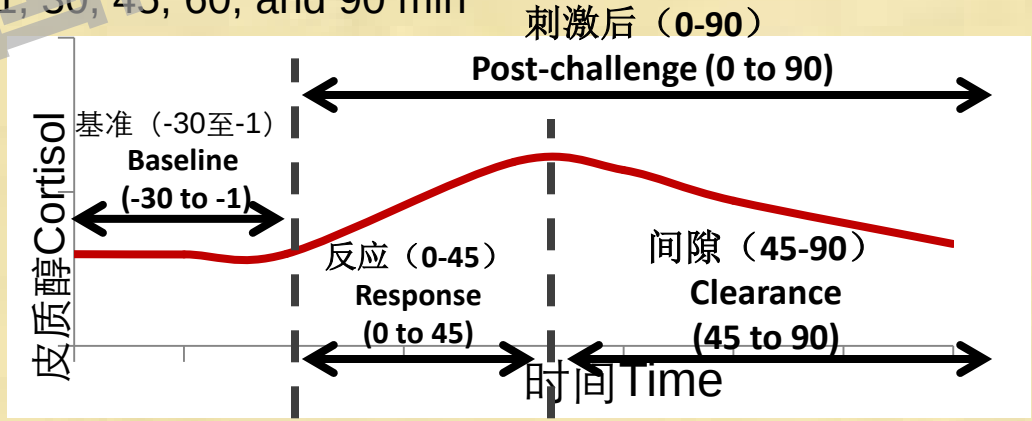
Are pigs that are selected for low RFI more susceptible to physiological stress?

肾上腺皮质激素刺激 ACTH challenge

- 按每公斤体重肌肉注射0.2 IU外源性猪促肾上腺皮质激素 Challenged I.M. with 0.2 IU/kg BW of exogenous porcine ACTH



- 在-30、-15、-1、30、45、60 和 90分钟时，连续采集样品 Serial blood samples collected at -30, -15, -1, 30, 45, 60, and 90 min



Jenkins et al. (2013)

结果：促肾上腺皮质激素刺激 Results: ACTH challenge

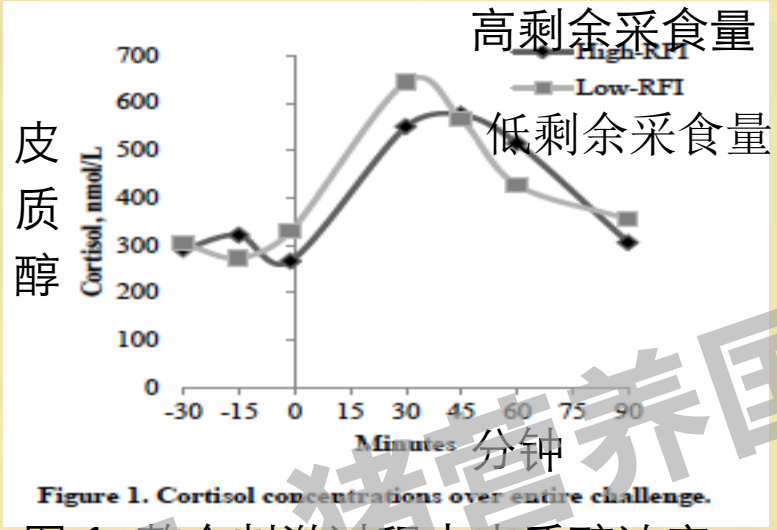


图 1. 整个刺激过程中皮质醇浓度

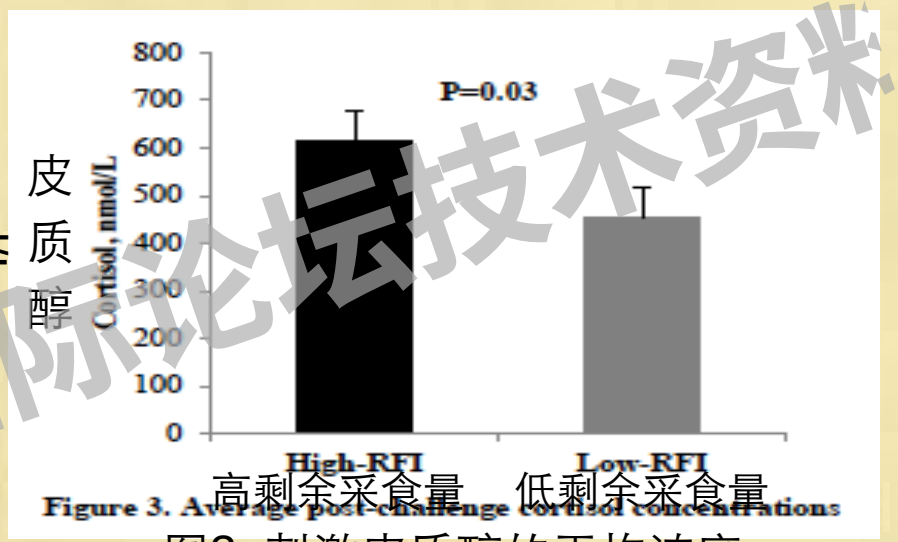


图3. 刺激皮质醇的平均浓度

选择不同的剩余采食量品系猪使得促肾上腺皮质激素刺激前后诱导皮质醇反应发生了改变。高剩余采食量对此应激更敏感，但同样会恢复。Divergent selection for RFI resulted in altered pre-and post ACTH induced cortisol response. High RFI tended to be more responsive to this stress challenge, but recovered equally.

Jenkins et al. (2013)

结论Conclusion #3

- 在饲喂高能日粮下选育的低RFI品系猪在饲喂低能日粮时生长性能可能不具有优势。 Pigs selected for low RFI on a higher energy diet may not be superior when fed a lower energy diet
- 低RFI品系猪并未显得更易得传染性疾病。 Pigs selected for low RFI do not appear to be more susceptible to infectious disease
- 低RFI品系猪并未对生理应激更敏感。
  Pigs selected for low RFI do not appear to be more susceptible to physiological stress

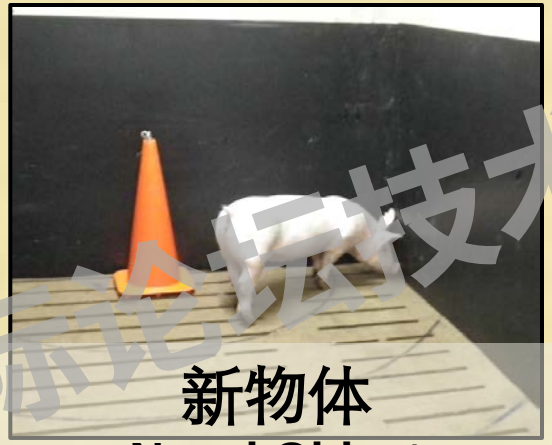
4. 低RFI品系猪对行为应激是否更敏感？

Are pigs that are selected for low RFI more susceptible to behavioral stress?

材料和方法 Materials and Methods

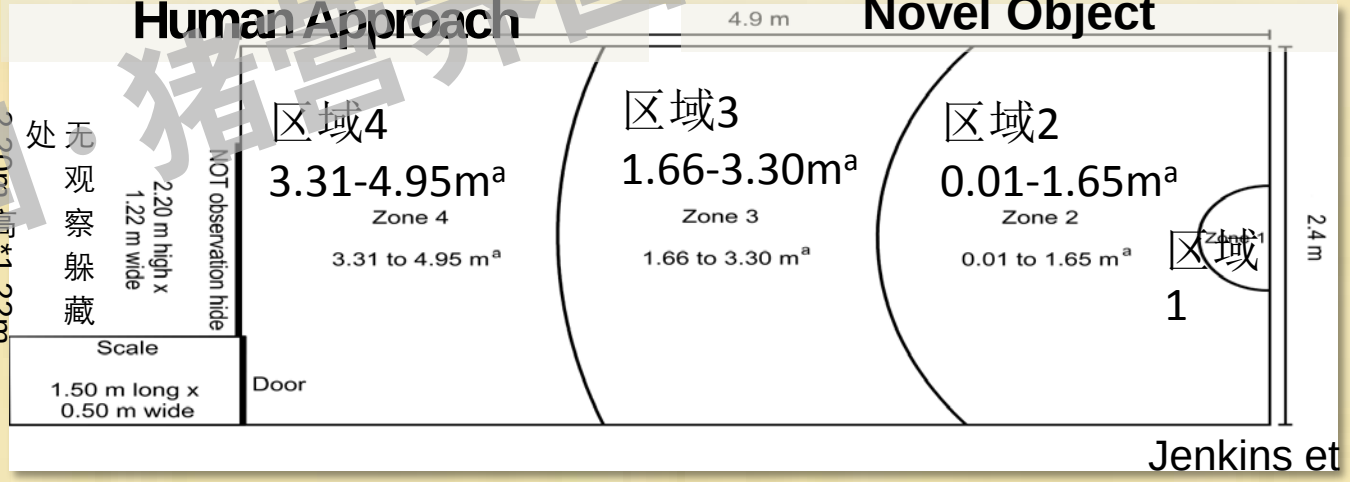
人类靠近

Human Approach



新物体

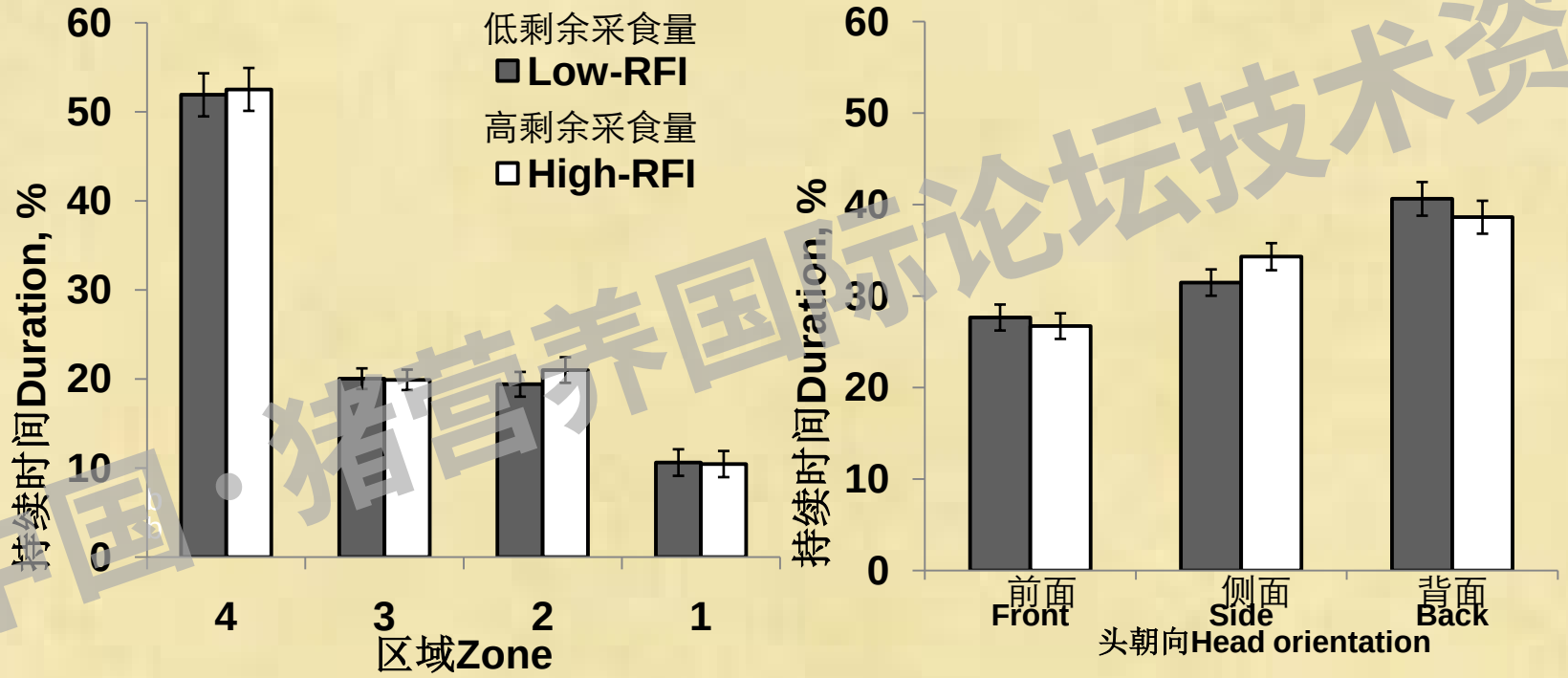
Novel Object



范围：1.50m长*0.50m宽

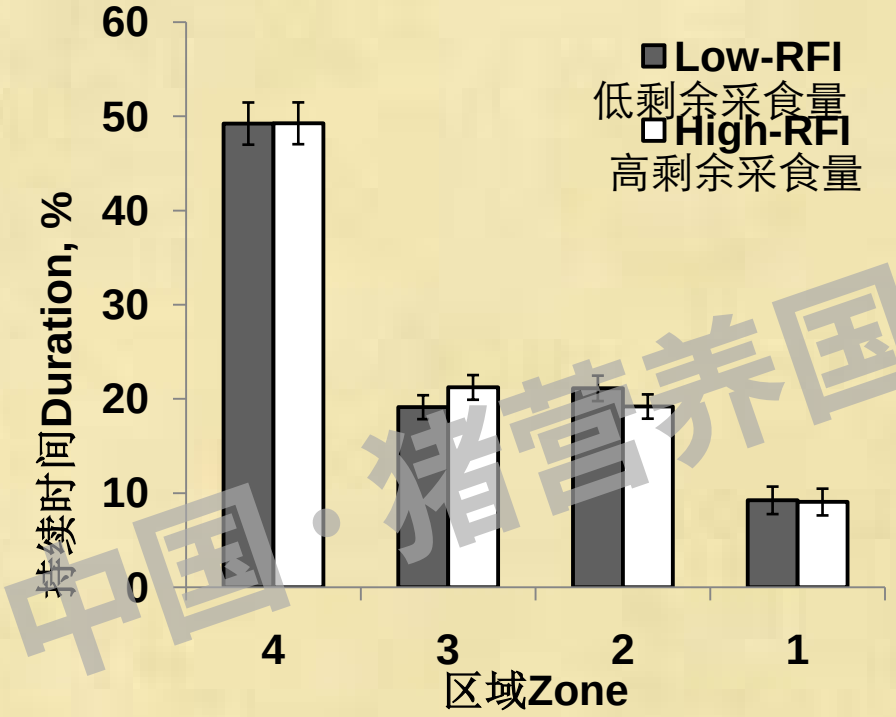
Jenkins et al. (2013)

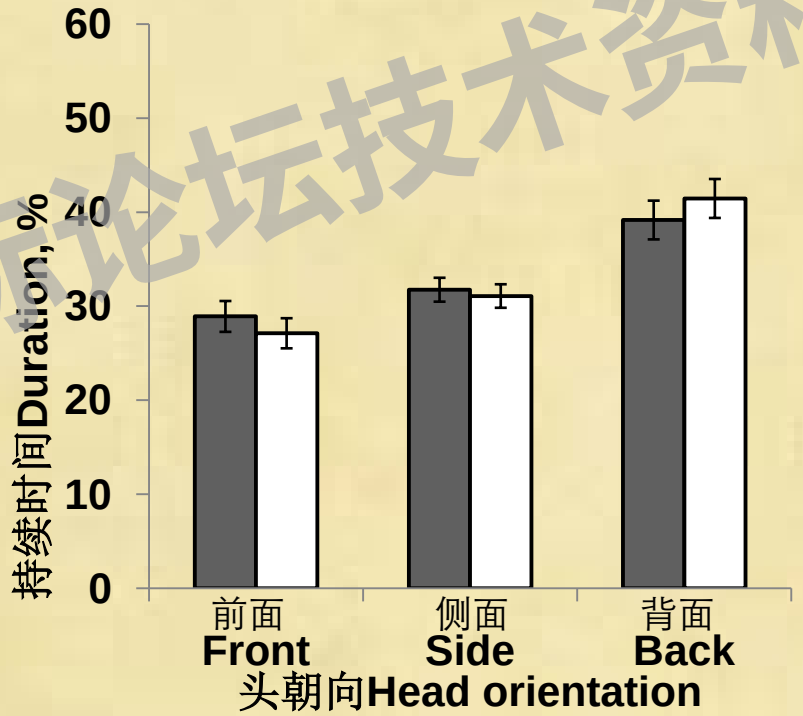
结果：人类靠近猪只试验
Results: Human approach test



Jenkins 等, (2013)

结果：新物体刺激试验 Results: Novel object test





Jenkins et al. (2013)

结论Conclusion #4

- 在饲喂高能日粮下选育的低RFI品系猪在饲喂低能日粮时生长性能可能不具有优势。 Pigs selected for low RFI on a higher energy diet may not be superior when fed a lower energy diet
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- 低RFI品系猪并未对生理应激更敏感。 Pigs selected for low RFI do not appear to be more susceptible to physiological stress
- 低RFI品系猪并未对行为应激更敏感。 Pigs selected for low RFI do not appear to be more susceptible to behavioural stress

5. 低RFI品系猪所产猪肉口感是否更差？

Do pigs that are selected for low RFI produce pork of lower eating quality?

RFI品系对肉质的影响

Impact of RFI line on measures of meat quality

性状Trait	低剩余采食量 LRFI	高剩余采食量 HRFI	P-值 P-value
pH, 48 h	5.65 *(5.60, 5.59)* †	5.64 *(5.59, 5.68)*	0.61
滴水损失 Drip loss, %	1.34 *(1.18, 1.51)*	1.60 *(1.42, 1.80)*	**<0.01**
蒸煮损失Cook loss, %	15.73 (0.41)*	16.44 (0.42)	**0.10**
肌肉颜色Color score	2.0 (0.2)	2.3 (0.2)	**<.0001**
肌肉大理石纹Marbling score	1.3 *(1.15, 1.39)*	1.4 *(1.31, 1.58)*	**<0.05**
硬度评分Firmness score	1.4 *(1.19, 1.56)*	1.5 *(1.26, 1.66)*	0.23

† 95 %置信区间
*标准误差
† 95% Confidence Interval
* Standard Error

Arkfeld et al. (2013)

低RFI品系对猪里脊肉近似分析的影响
Impact of RFI line on proximate analysis of loins

性状Trait	低剩余采食量LRFI	高剩余采食量HRFI	P值P-value
%水分 Moisture	73.68 (0.07)*	73.26 (0.07)	**<0.0001**
% 脂质Lipid	1.30 *(1.01, 1.68)*†	1.70 *(1.32, 2.20)*	**<0.01**
% 蛋白Protein	23.93 (0.10)	23.97 (0.10)	0.63

† 95 %置信区间
*标准误差
† 95% Confidence Interval
* Standard Error

Arkfeld et al. (2013)

低RFI品系对猪里脊肉感官特性的影响
Impact of RFI line on sensory traits of loins

性状Trait	低剩余采食量 LRFI	高剩余采食量 HRFI	P-值 P-value
多汁度Juiciness	9.80 (0.16)*	9.34 (0.16)	**<0.05**
嫩度Tenderness	9.11 *(8.58, 9.65)†*	9.18 *(8.64, 9.74)*	0.84
咀嚼性Chewiness	4.91 *(4.39, 5.49)*	4.89 *(4.36, 5.48)*	0.95
风味Pork flavor	4.34 (0.12)	4.47 (0.12)	0.26
异味Off flavor	0.39 *(0.29, 0.50)*	0.34 *(0.25, 0.44)*	0.42
压缩力 Star probe, Kg	4.75 *(4.56, 4.95)*	4.73 *(4.55, 4.93)*	0.87

† 95 %置信区间
† 95% Confidence Interval
*标准误差
* Standard Error

Arkfeld et al. (2013)

结论Conclusion #5

- 在饲喂高能日粮下选育的低RFI品系猪在饲喂低能日粮时生长性能可能不具有优势。 Pigs selected for low RFI on a higher energy diet may not be superior when fed a lower energy diet
- 低RFI品系猪并未显得更易得传染性疾病。 Pigs selected for low RFI do not appear to be more susceptible to infectious disease
- 低RFI品系猪并未对生理应激更敏感。 Pigs selected for low RFI do not appear to be more susceptible to physiological stress
- 低RFI品系猪并未对行为应激更敏感。 Pigs selected for low RFI do not appear to be more susceptible to behavioural stress
- 用于改善饲料效率而选育的猪在肉质某些方面稍差，尽管存在这些差异，但是很小。 Pigs selected for improved feed efficiency were slightly inferior in some aspects of meat quality, but where those differences exist, they are small.

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Our long term goal is to increase nutrient utilization and feed efficiency in the pig, to strengthen the competitiveness of the pork industry and to reduce its demand on grains and proteins. We will use a truly multi-disciplinary approach in this project, including nutrition, physiology, microbiology, behavior, immunology, quantitative genetics, swine genomics, proteomics, transcriptomics, bioinformatics and statistics. Through this grant, we will develop new knowledge and new tools to benefit our pork industries and agriculture in general.

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Mani, V., Weber, T.E., Baumgard, L.H., and Gabler, N.K. (2012). Endotoxin, Inflammation and Intestinal Function in Livestock. J. Anim. Sci. 90(5):1452-1465.

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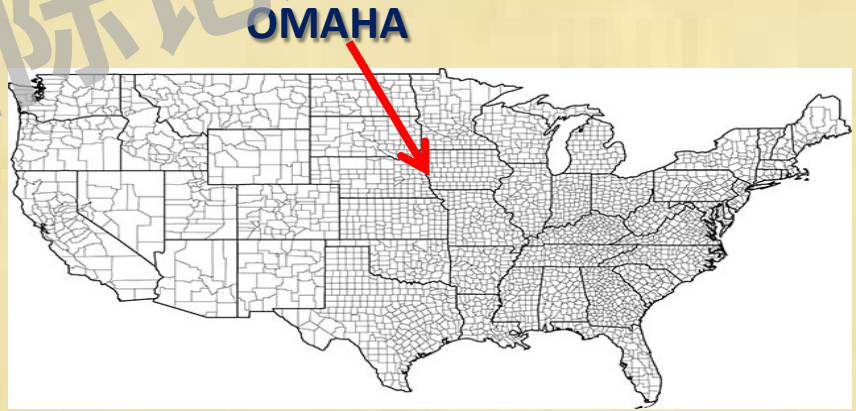

参与教师 Participating faculty

爱荷华州立大学Iowa State University

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John Patience (PI)
Nick Gabler
Brian Kerr (USDA)
Tom Weber (USDA)

遗传学Genetics
Jack Dekkers
John Mabry
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Mike Tokach
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萨斯喀彻温大学University of Saskatchewan

Andrew van Kessel

法国国家农业研究院INRA, France

Helene Gilbert

澳大利亚猪合作研究中心Pork CRC, Australia

Roger Campbell,
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