INRA
SCIENCE & IMPACT

环境及健康应激对生长猪的改变及新营养平衡的调整

Response of Growing Pigs to Environmental and Health Stress Adjustments in Dietary Nutrient Profile and Content

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健康养殖是养猪产业的主要问题

Preserving health status : a major issue for pig production

健康
HEALTH

药物保健
Medication

经济
ECONOMY

生产率 Productivity,
效率 Efficiency
药物成本 Cost of medication

环境
ENVIRONMENT

有机肥生产 Manure production
病原菌排出 Pathogen excretion
药物残留 Drug residues

动物福利
ANIMAL WELFARE

公众认知 Public perception

公共卫生
PUBLIC HEALTH

人畜共患病 Zoonosis
食品安全 Food safety
抗生素耐药性 Antibiotic resistance

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生产率 Productivity,
效率 Efficiency

环境
ENVIRONMENT

集约化养殖 Intensive farming
↘抗生素和药物使用 antibiotic and medication use

药物残留 Drug residues

动物福
ANIMAL WI

其它养殖方式 Alternative farming
环境控制少 Environment less controlled
用药少 Fewer medications

公共卫生
PUBLIC HEALTH

食品安全 Food safety
抗生素耐药性 Antibiotic resistance

健康的定义 Definition of HEALTH

Human

- **WHO 1948:**
  健康不仅仅是没有疾病和虚弱现象，而是生理、心理、社会功能三方面的[illegible]
  « a state of complete physical, mental, and social well-being and no[illegible]se of disease or infirmity."»

家畜 Livestock

- 兽医学中健康和疾病概念
  "The conceptualisation of health and disease in [illegible]e" *Gunnarsson Acta Veterinaria Scandinavica 2006 48:20*

1. 健康呈常态 Health as normality
2. 健康有生物学功能 Health as bio[illegible]
3. 健康是一种动态平衡 He[illegible]
4. 健康指身体和心理[illegible]ysical and psychological well-being
5. 健康生产 [illegible]s productivity including reproduction

- 健[illegible]物效率的水平：无疾病、无心理压力、良好生产性能（动物最大潜能?）
  [illegible]evel of *functional and metabolic efficiency* of a living organism: no disease, no psycho[illegible]ss, good productivity(maximum animal potential?)

重大传染传染病防治不在本演讲范围内
Major Infectious diseases are not in the scope of my lecture

和疾病相关的众多因素中饲料和营养非常重要
Feed and nutrition are major components of multifactorial production diseases

- 畜舍条件 Housing conditions
- 饲料 Feed
- 温度 Temperature
- …

- 病毒 Virus
- 细菌 Bacteria
- 真菌 Fungi
- 粉尘 Dust …

- 遗传 Genetics
- 年龄 Age
- 生理状态 Physiological status
- 营养水平 Nutritional status
- …

从饲料和营养中期望得到什么
What is expected from Feed and Nutrition ?

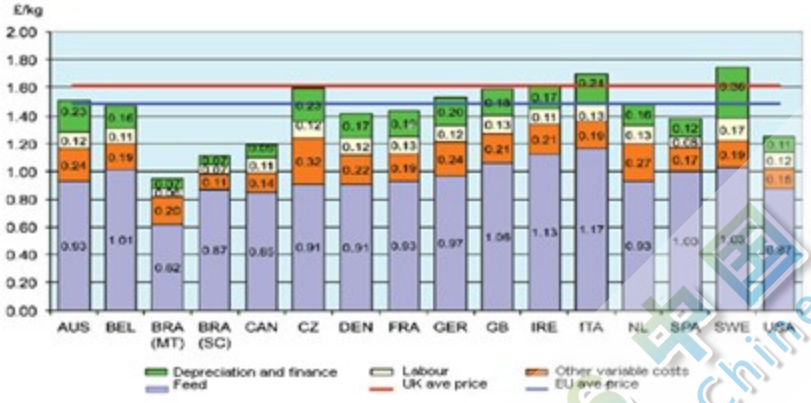
- 为了健康养殖，减少药物使用
  To contribute to health preservation in a context where medication should be reduced

- 为了降低由于健康问题造成的性能影响
  To limit the consequences of health disturbances on performance

饲料、营养、健康紧密相连
Feed, Nutrition and health are interconnected

➔ 良好健康状态应当在维持饲料利用率和生长率的同时节省饲料成本。

a good health status is necessary to maintain feed efficiency, growth rate and to limit feed cost



饲料成本的重大意义

major importance of feed costs

以猪慢性呼吸道疾病为例：

Ex. Chronic respiratory disease in pig :

- 饲料转化率 feed conversion ratio + 0.3
- 生长期增加7-28天 duration of growing phase + 7-28 d

Source: http://www.thepigsite.com/pighealth/article/33/the-costs-of-disease/

饲料、营养、健康紧密相连
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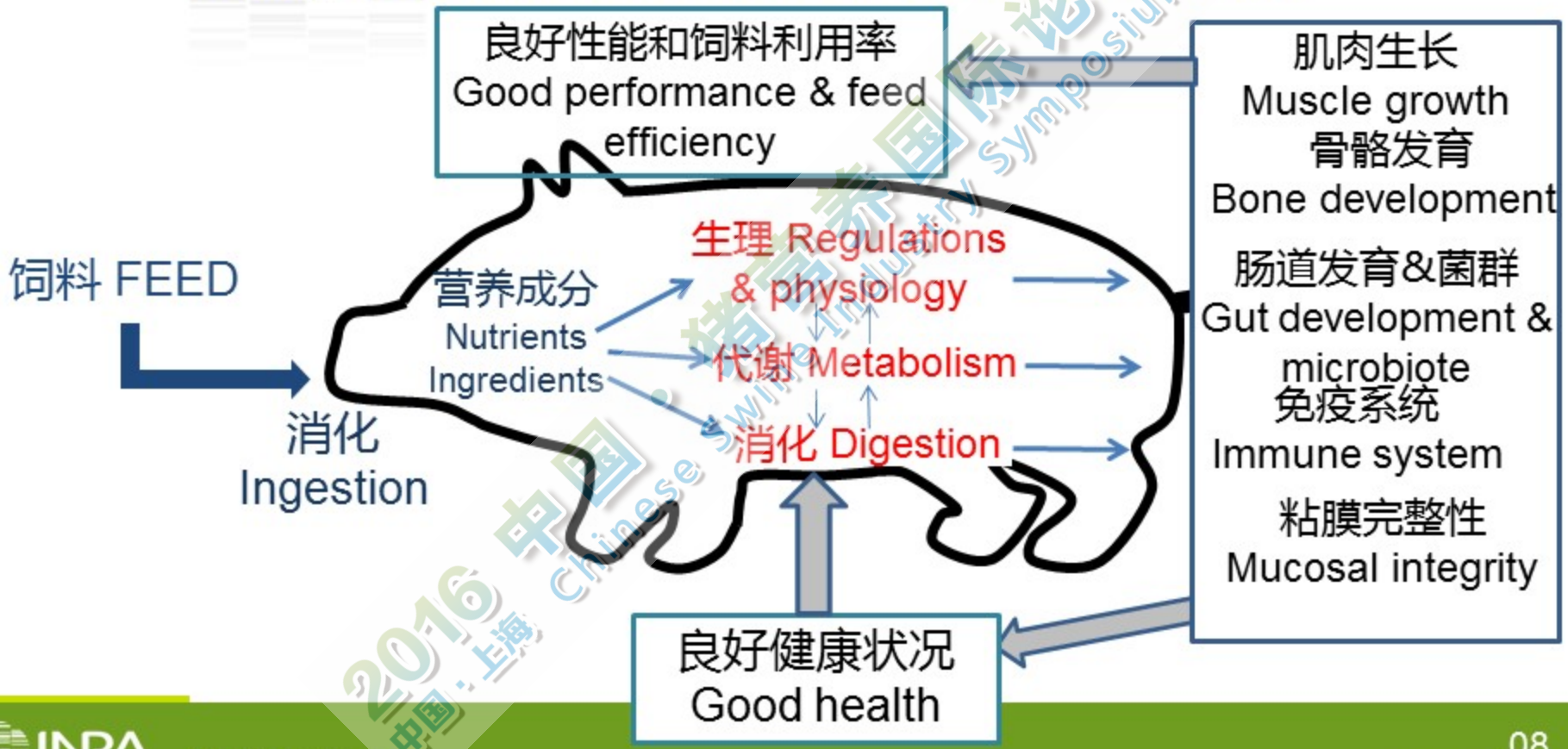

目录 Outlines

- 猪应对健康受损的生理和代谢基础

  Physiological and metabolic basis of the pig response to health disturbances

- 猪应对健康受损能力的影响因素

  Factors impacting the **pig ability to cope with** health disturbances

- 为维持猪健康需要做哪些营养调整？

  Which nutritional adjustments to support pig health ?

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- 猪应对健康受损的生理和代谢基础

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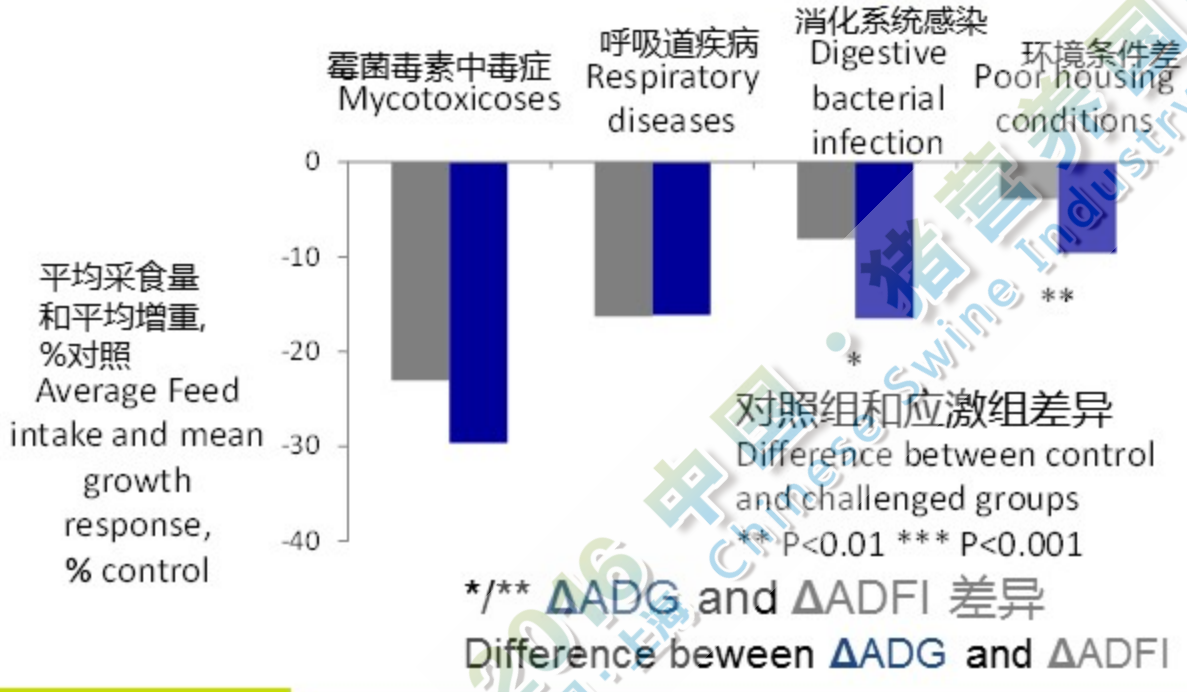
- **Which nutritional adjustments** to support pig health ?

健康受损对采食量和生长的影响-122篇研究汇总

Effect of health disturbances on feed intake and growth - meta-analysis 122 studies -

Pastorelli et al., 2012



应激和研究之间的可变性
Variability between challenges and studies

-不同强度
Various intensities

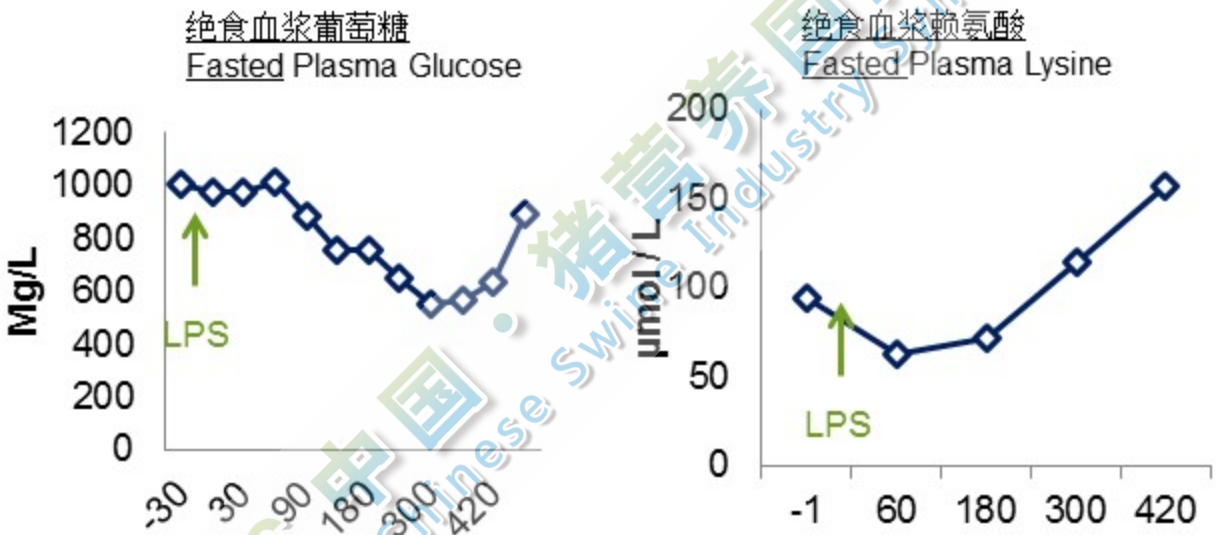
ΔADG ≥ ΔDFI
(-30% à -10%) ≥ (-23% à -4%)

-不同机制
Various mechanisms

↘ 采食量 feed intake
消化紊乱 digestive disturbances
代谢调整 metabolic adaptations

细菌内毒素注射诱导系统性炎症，调节养分利用率
A systemic inflammation caused by bacterial endotoxin (LPS) injection modifies nutrient utilization

Merlot et al, 2013 EAAP

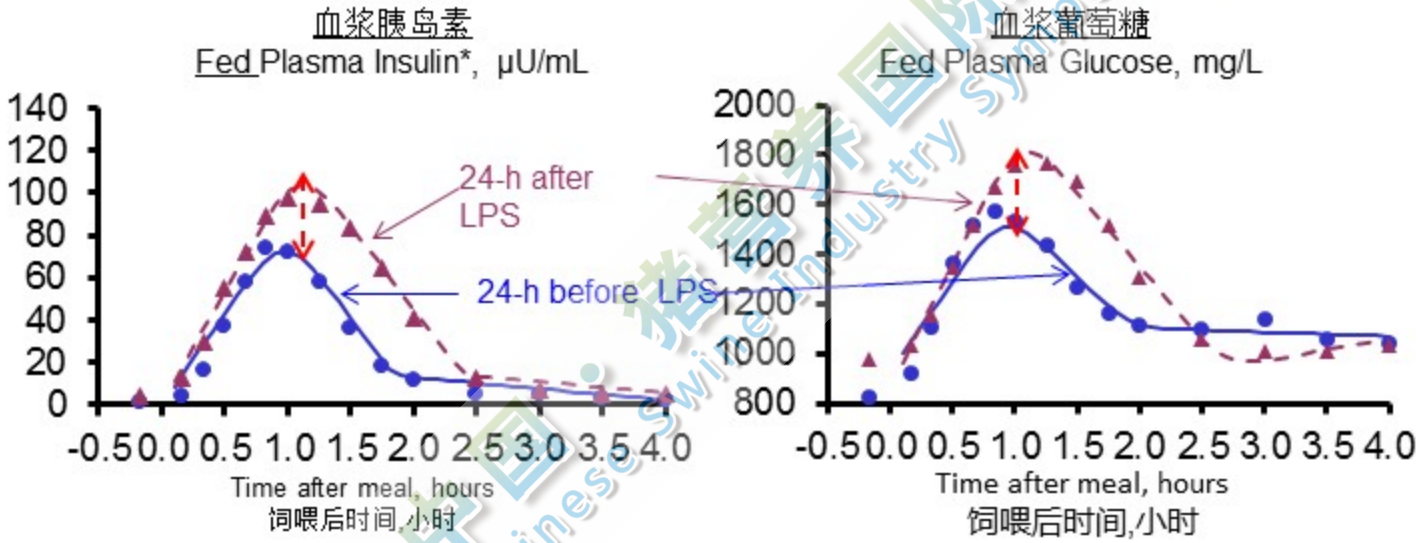


➔ 高能量需要High Energy demand

➔ 增加蛋白质降解Increase in protein breakdown

由细菌内毒素注射引发的系统性炎症降低胰岛素敏感性
A systemic inflammation caused by bacterial endotoxin injection decreases insulin sensitivity

Campos et al, 2015 ESPHM



*Insulin is a hormone that allows the body (muscle, adipose tissue and liver) to use nutrients
胰岛素是促进机体组织（肌肉、脂肪和肝脏）利用养分的激素

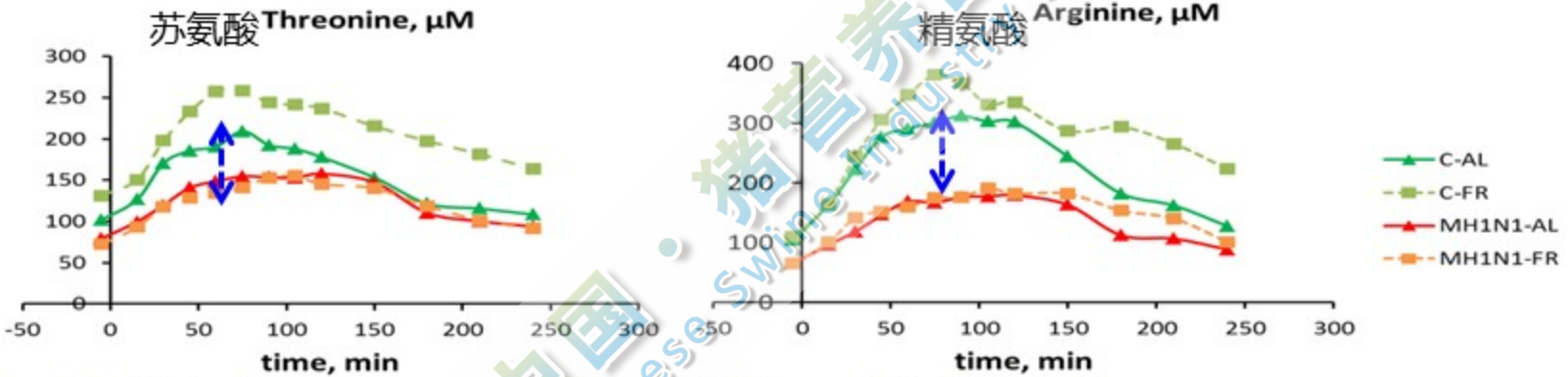
➔ 降低肌肉养分利用率？
➔ Lower nutrient utilization by the muscle?

试验数据表明健康受损影响氨基酸利用率
Experimental evidences showing that amino acid utilization is impacted by health disturbances

Le Floc'h et al PlosOne 2014

支原体-H1N1联合感染的猪采食后血浆氨基酸动力学研究：呼吸道疾病

Plasma postprandial kinetics* of AA in control and co-infected pigs (Mycoplasma and H1N1) : respiratory disease



*禁食24h后（感染支原体23天，H1N1 3天）饲喂相同量的饲料(200g),测定血浆氨基酸水平

Plasma AA were measured after pigs were fed the same amount of feed (200 g) after being fasted overnight (23d post Mycoplasma and 3d post H1N1)

苏氨酸参与到免疫蛋白？

Threonine incorporation into Immune proteins?

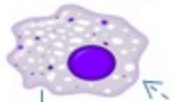
精氨酸用于合成一氧化氮利用率？

Arginine utilization for nitric oxide synthesis?

总结：健康受损影响所有代谢过程

To summarize : all metabolisms are affected by health disturbances

单核细胞Monocytes,
巨噬细胞macrophages..



IL1 - TNF- IL6

↗ACTH

病态行为（发热、食欲减退、冷漠）
sickness behavior (fever, anorexia, apathy…)

\- 糖皮质激素 Glucocorticoids→↗ 糖异生 neoglucogenesis, 蛋白质分解代谢 protein catabolism

\+ 甘油三酯TG
葡萄糖Glucose
尿素Urea
急性期蛋白APP

脂肪组织
Adipose tissue

↗瘦素
leptin

↘ 脂蛋白酶活性
Lipoprotein lipase activity

AA

肌肉Muscle

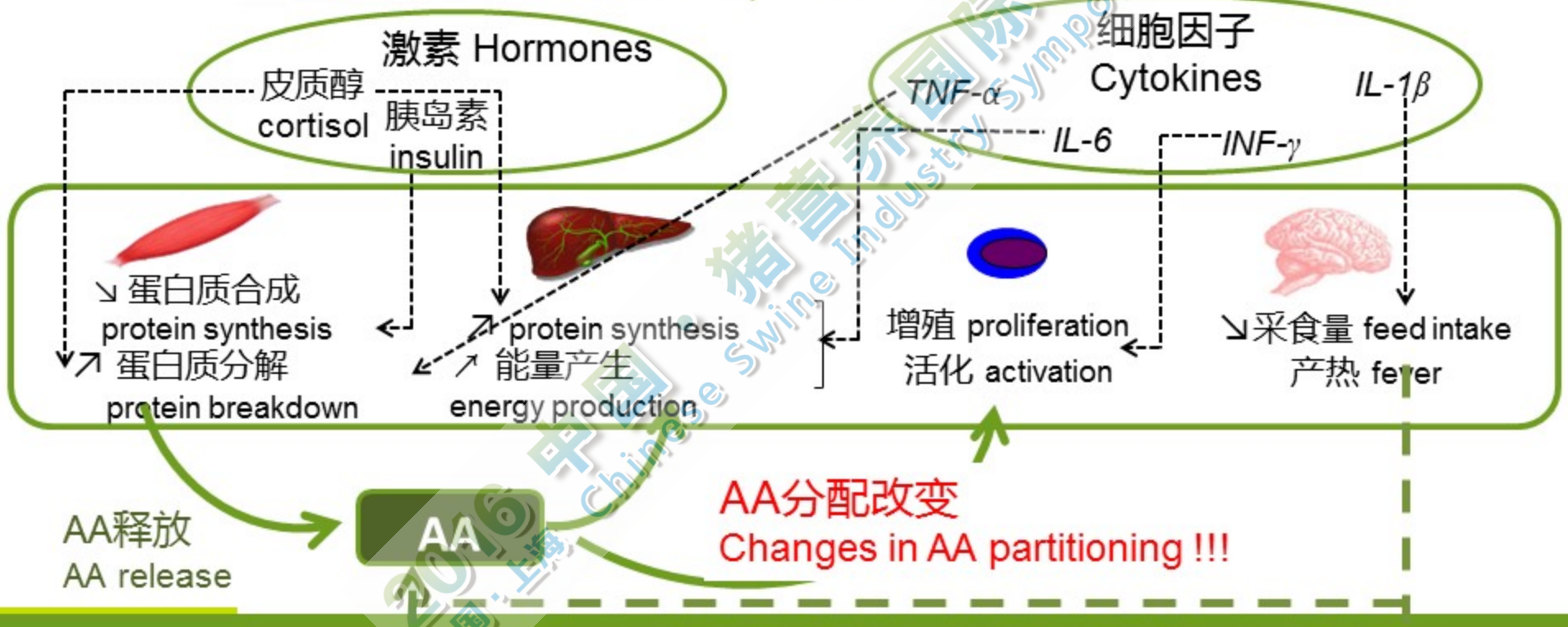
↗TG合成
TG synthesis
↗ 糖原分解-糖异生
Glycogenolysis-neoglucogenesis
↗ APP 合成
APP synthesis
↗ 氮排泄
Nitrogen excretion

免疫细胞
Immune cells

氨基酸AA

↘氨基酸摄入
AA uptake
↗蛋白质降解
protein degradation

免疫系统激活引起的蛋白质代谢紊乱
A focus on protein metabolism disturbances caused by immune system activation



目录 Outlines

- **Physiological and metabolic basis** of the pig response to health disturbances

✓ 猪应对健康受损能力的影响因素

(some) Factors impacting the **pig ability to cope** with health disturbances

- 外因：温度、卫生 External factors : temperature, hygiene
- 内因：基因型、性别 Internal factors : genotype, sexual type

高温是全球猪生产问题

High temperatures is an issue for pig production worldwide

背景 Context

- 发展中国家养猪生产增加-热带和亚热带地区
  Increased pig production in developing countries - tropical and subtropical areas
- 全球变暖 Global warming

对猪生产行业造成的影响 Consequences on pig production ?

- 采食量和性能降低
  Reduced feed intake and performance
- 高温有利于病原体传播
  High temperatures favor pathogen dissemination

- 高温对猪应对公共卫生挑战的影响仍未知？
  Effect of high temperatures on pig ability to cope with a health challenge is unknown ?

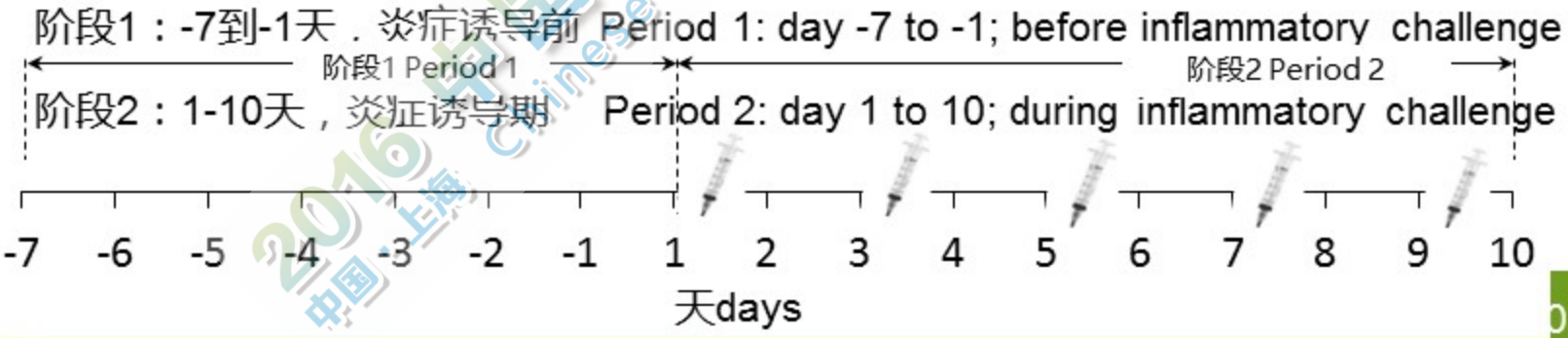
高温对内毒素诱导引起的炎症反应的影响
Effects of high ambient temperature on inflammatory response induced by endotoxin

Campos et al, 2014. Veterinary Journal 200(3), 404-9.

- 30头装有颈静脉导管的猪 30 pigs fitted with a jugular catheter ≈ 50 kg
- 2种温度条件 2 thermal conditions :

  适温(TN):16头猪，24℃；Thermo-neutrality (TN): 16 pigs; 24°C

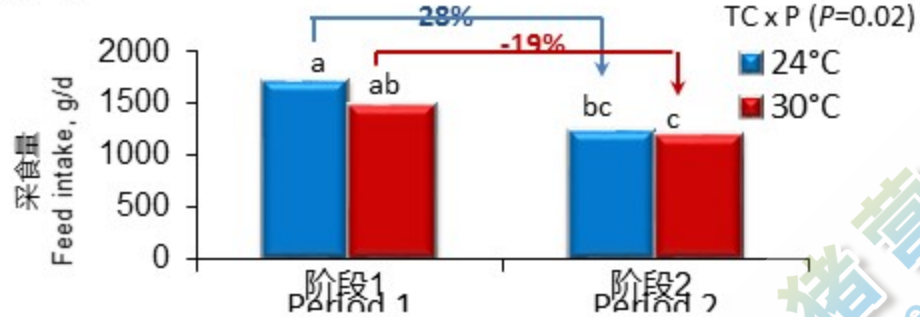
  高温:15头猪，30℃； High temperature : 14 pigs; 30°C
- 2个试验阶段 2 experimental periods

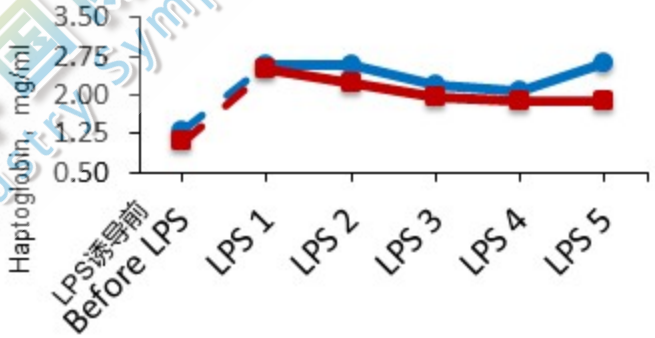


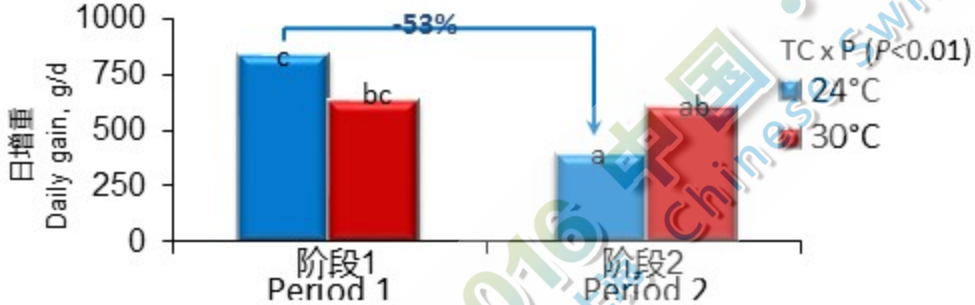
高温减轻内毒素诱导猪的炎症反应和生长抑制

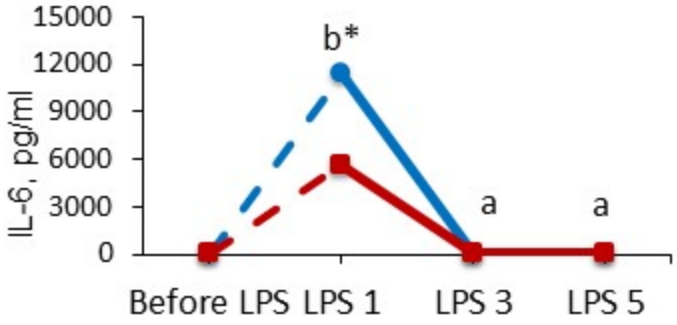
High ambient temperature alleviates inflammatory response and growth depression in pigs challenged with endotoxin

Campos et al, 2014. Veterinary Journal 200(3), 404-9.









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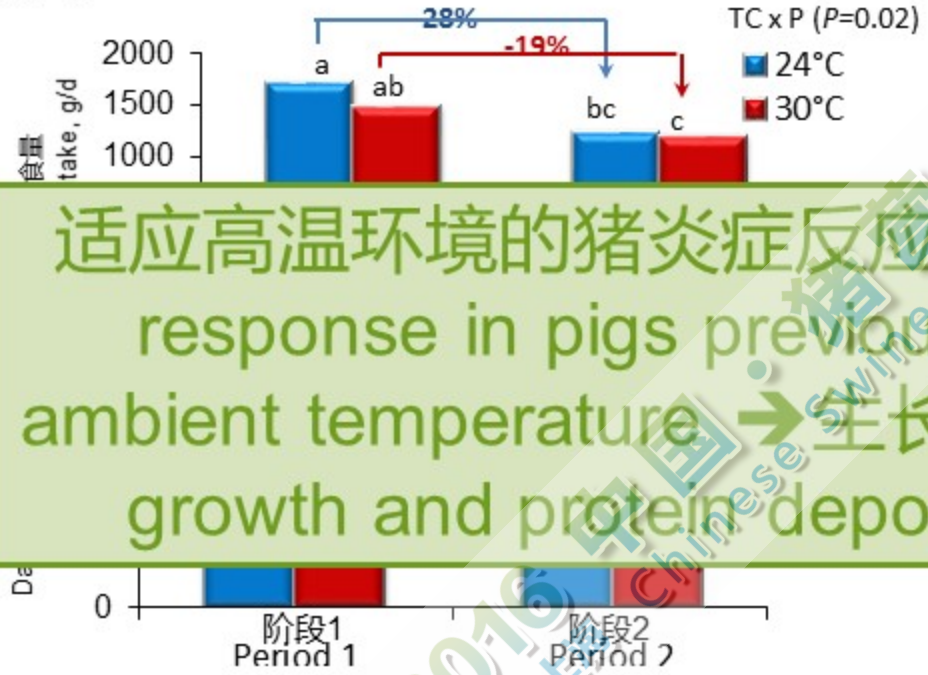
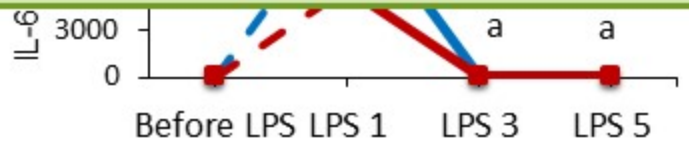




适应高温环境的猪炎症反应较低Lower inflammatory response in pigs previously acclimated to high ambient temperature →生长和蛋白质沉积受影响较低 growth and protein deposition are less affected

基因型的影响
Influence of genotype

遗传选择的高产动物易感生产性疾病？？

Animals genetically selected for high productive traits would be more susceptible and affected by production diseases ???

Rauw, 2009

→ 针对机体免疫力选择 ？
Selection against immune capacity?

→ 降低用于维持健康的营养的能力？
Reduced ability to use nutrients for health maintenance?

本研究目的 Objectives of the study

为了评估 To assess:

Chatelet et al, ICPD 2016

- 应对差环境卫生条件引起的免疫挑战的能力
  Ability **to cope** with an immune challenge caused by poor hygiene housing conditions

- 挑战应激后恢复能力
  Ability **to recover** after the challenge

根据残余采食量（RFI，测定饲料利用率的一种指标）选择两条生产线的生长猪

…of two lines of growing pigs selected on their residual feed intake or RFI (a measure of feed efficiency)

试验设计 Experimental Design

→ 160头生长育肥猪，自由采食，单独饲喂

A total of 160 **growing – finishing** pigs fed ad libitum /individual pens

→ 4个试验组（每组40头猪）4 Experimental groups (40 pigs per group)

生产线Line (L)	**X**	环境Environment (E)

Low RFI (LRFI) → 效率高：采食比预期少

More efficient: eat less than predicted

High RFI (HRFI) →效率低：采食比预期高

Less efficient: eat more than predicted

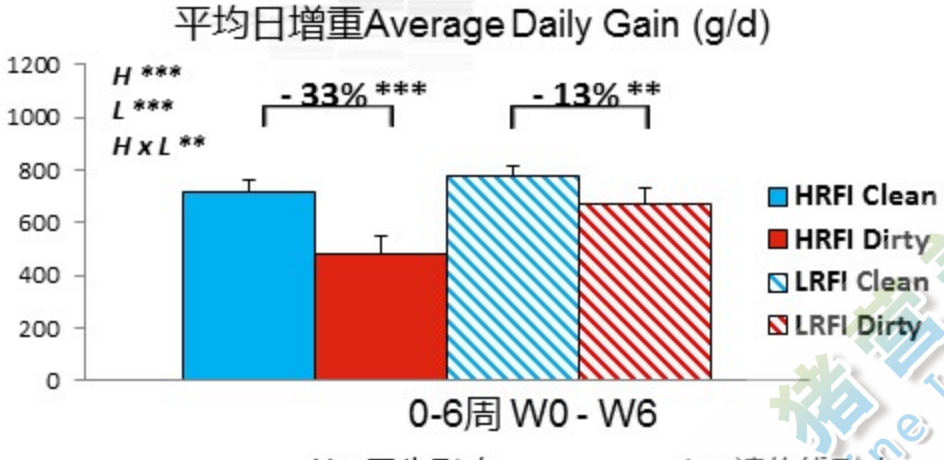
→ 12周，30-115 kg, 2 阶段

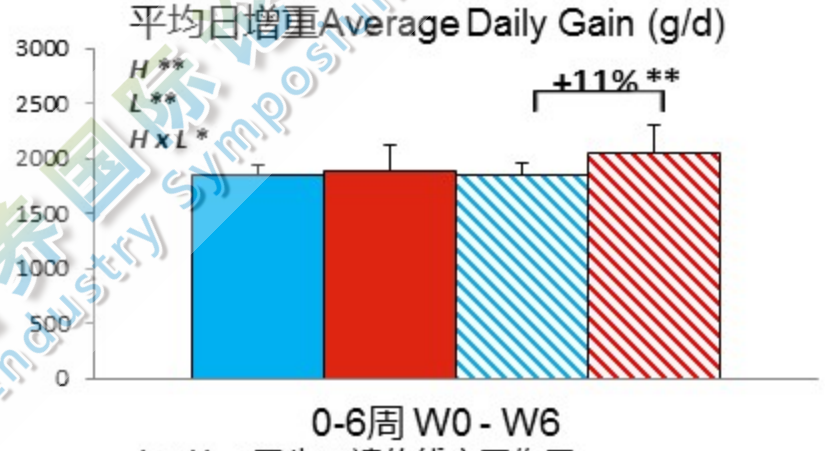
12 Weeks (W) 30-115 kg, 2 periods:

- 阶段1：挑战期(0-6周) 50%清洁/50%脏乱
  Period 1 or challenge (W0 - W6) 50% clean E / 50% dirty E
- Period 2 or recovery (W6 - W12) 100% clean E
  阶段2：恢复期(6-12周) 100% 清洁

Chatelet et al, ICPD 2016

生长率和采食量Growth rate and Feed intake





H：卫生影响
H : effect of Hygiene

L：遗传线影响
L : effect of genetic Line

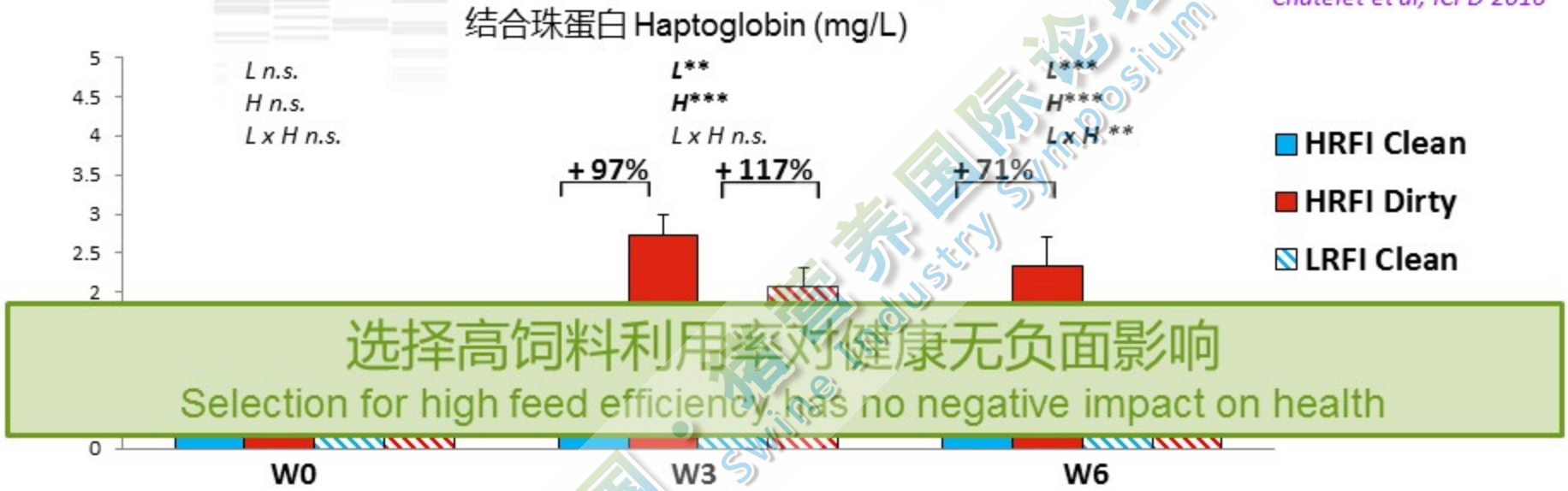
L x H ：卫生 x 遗传线交互作用
L x H : interaction Hygiene x Line

- 差的卫生条件降低生长率：低效率品系（HRFI）受到的影响较大
  Poor hygiene reduced growth rate : greater effect for the less efficient line (HRFI)
- 采食量未减少
  No reduction of feed intake !!!!

Chatelet et al, ICPD 2016

炎症特征 Inflammatory Response

Chatelet et al, ICPD 2016



选择高饲料利用率对健康无负面影响

Selection for high feed efficiency has no negative impact on health

差卫生挑战导致系统炎症反应，且引起肺炎：低效率品系

Poor hygiene induced a systemic inflammation and caused pneumonia : for the less efficient line

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- **Physiological and metabolic basis** of the pig response to health disturbances
- **Factors** impacting the **pig ability to cope** with health disturbances

- 为维持猪健康需要做哪些营养调整？
  → 重点关注氨基酸
- **Which nutritional adjustments** to support pig health ?
  A focus on Amino Acids

免疫系统激活引起的蛋白质代谢紊乱

A focus on protein metabolism disturbances caused by immune system activation

免疫刺激 Immune stimulation
炎症反应 inflammation

↘采食量
↘Feed intake

代谢变化
Metabolic changes

↘生长和蛋白沉积
↘Growth and protein deposition

部分氨基酸参与维持健康相关的代谢过程
Some AA are specifically involved in metabolic processses associated with health maintenance

- 合成特定蛋白
  Incorporation into specific proteins
  粘蛋白，免疫球蛋白，急相期蛋白
  Mucins, immunoglobulins, APP …

苏氨酸，色氨酸，缬氨酸
Thr, Trp, Val

- 氨基酸是肝脏、免疫细胞和肠细胞的营养成分
  AA are nutrients for the liver, immune and intestinal cells
  - 糖原合成 neoglucogenesis
  - 细胞增殖 cell proliferation

色氨酸，谷氨酰胺
Trp, Gln …

- 氨基酸是活性分子合成的前体
  AA are precursors for the synthesis of active molecules
  - 细胞毒性物质 cytotoxic compounds
  - 抗氧化物 antioxidant compounds

半胱氨酸，精氨酸
Cys, Arg

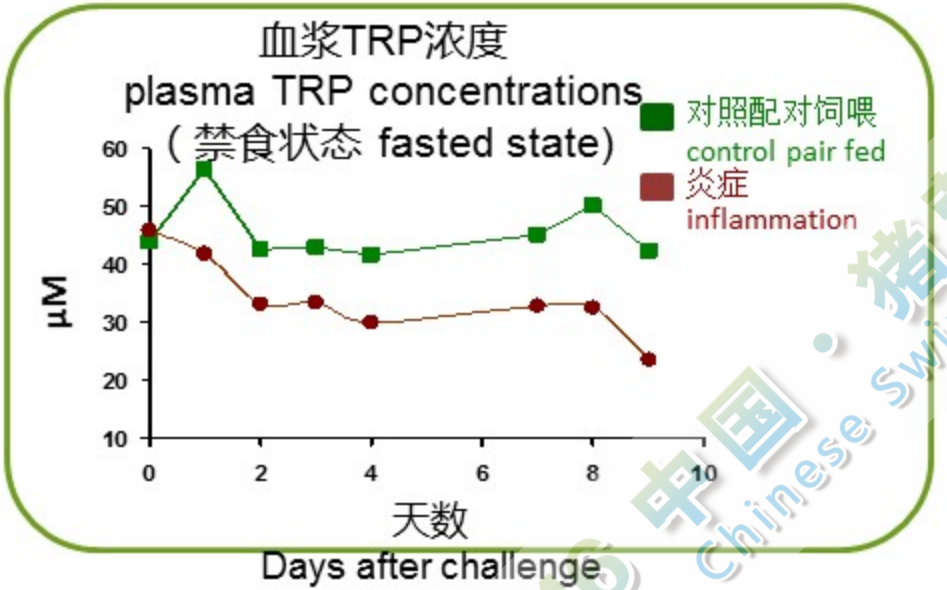
慢性肺炎对色氨酸代谢的影响

Effect of a chronic lung inflammation on TRP metabolism

通过弗氏佐剂注射诱导肺炎

Lung inflammation induced by Complete Freund's adjuvant injection

Melchior et al 2004, 2005



↘ 血浆色氨酸 plasma[TRP]

血浆中色氨酸消失
TRP disappearance from plasma

色氨酸分解代谢增加
Increased Trp Catabolism

合成富含TRP的蛋白
Incorporation into TRP rich-proteins → 急性期蛋白 APP

IDO活性增加Greater IDO activity

结合珠蛋白浓度增加Greater haptoglobin concentration

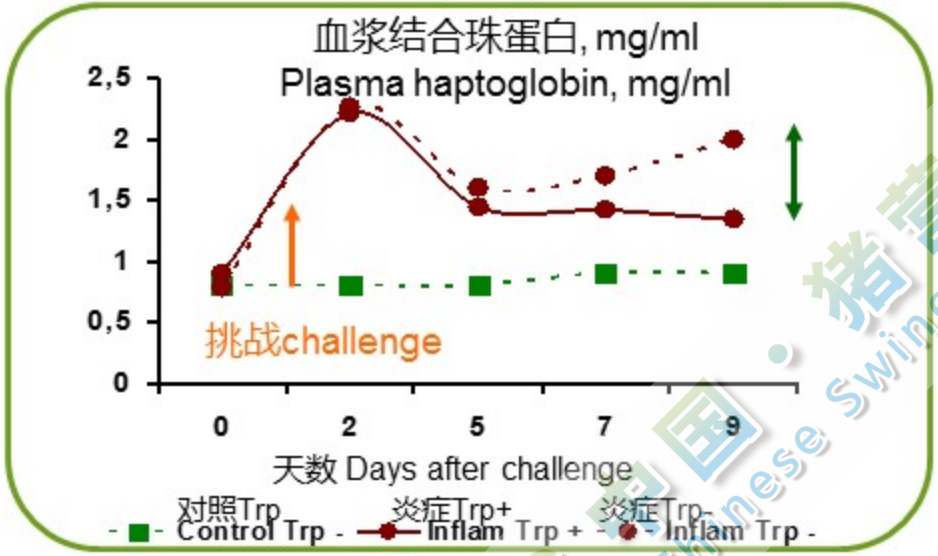
补充色氨酸减轻肺炎的影响

TRP supply alleviates the effect of lung inflammation

Le Floc'h et al 2008,

通过弗氏佐剂注射诱导肺炎

Lung inflammation induced by Complete Freund's adjuvant injection



TRP - : 1.8 g/kg

TRP + : 2.35 g/kg

- 饲喂高色氨酸日粮的猪血浆结合珠蛋白较低，更健康

Pigs fed with the high TRP diet had lower plasma [haptoglobin] and were healthier

抗氧化剂
Antioxidant

控制炎症反应
Control of inflammatory response

补充上述剂量色氨酸可以维持血浆色氨酸浓度，降低炎症

TRP supply above recommendations maintains TRP plasma concentrations and limits the inflammation

补充日粮色氨酸对相关健康参数的影响
Impact of TRP dietary supply on health parameters

- 上述剂量TRP (0.30 vs 0.18%) 降低由注射diquat*造成的仔猪氧化应激
  TRP above recommendations (0.30 vs 0.18%) alleviates oxidative stress induced by diquat* injection in piglets :
  - ↗肝脏SOD* and GPx* ↘血浆MDA*
  - ↗antioxidant SOD* and GPx* in the liver and ↘* plasma MDA*
  - ↘ 血浆尿素 plasma urea
  - 没有减弱氧化应激对生长性能的影响
  - did not attenuate the effect of oxidative stress on growth performance

  Mao et al 2014

- *Diquat : an herbicide known for inducing oxidative stress; SOD and GPx are antioxidative enzymes and MDA is a biomarker of oxidative stress*
- *注: 一种可以诱导氧化应激的除草剂; SODhe GPx是抗氧化酶，MDA是氧化应激状态的生物标记*

- 上述剂量TRP (0.24 vs 0.74%) 降低断奶仔猪应激
  TRP above recommendations (0.24 vs 0.74%) reduced the impact of weaning stress :
  - ↘ 唾液皮质醇反应 salivary cortisol response
  - 维持肠道形态 maintains gut morphology
  - 对生长性能无影响 no effect on growth performance

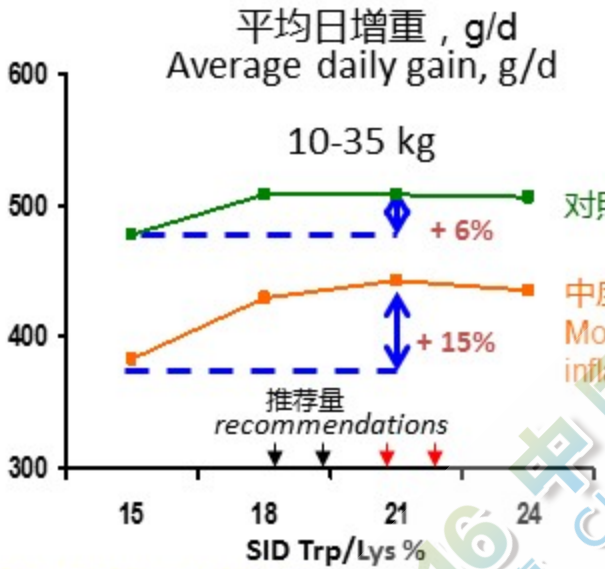
  Koopmans et al 2006

- 胃灌TRP减少由葡聚糖硫酸钠造成的新生仔猪结肠炎病变
  TRP supplied intragastrically reduced colitis lesions caused by DSS* in neonatal piglets
  - ↘ 局部炎症反应 local inflammatory response
  - 猪更健康（减轻腹泻）healthier pigs (less severe diarheas)

  Kim et al J 2010

色氨酸和健康状况对生长性能的影响
Effect of TRP and health status on growth performance

Le Floc'h et al 2010



•较差畜舍卫生引起炎症反应
•Inflammation caused by low hygiene of housing

受炎症的猪：
In pigs suffering from inflammation :

- ↗ 色氨酸：无增长恢复
  ↗ Trp : no growth restoration
- 低色氨酸对生长率影响较大
  greater impact of low TRP supply on growth rate

中度炎症的动物额外添加色氨酸对生长改善较大
The improvement of growth by additional tryptophan is *greater in animals with moderate inflammation*

结论Conclusions (1)

维护农场动物健康：期望从饲料和营养中得到什么？
Preserving health of farm animals: What is expected from feed and nutrition?

降低用药的同时维护健康的策略
a strategy for health preservation with less medication

➔ 功能性营养成分Functional nutrients

降低较差健康状况对性能和营养利用率影响的策略
a strategy for limiting the consequences of poor health status on performance and efficiency of nutrient utilization

➔ 调整营养配方Modification of nutrient profile

结论Conclusions (2)

从研究角度来看 From a research perspective

✓饲料和健康紧密相连，多样性和复杂性
The interactions between feed and health are numerous, diverse and complex

✓仍需要有新的知识 New knowledge are still necessary

- 肠道微生物的作用 Role of digestive microbiota
- 超出生长性能以外的相关营养功能
  Knowledge on nutrient functions beyond performance

全球动物健康
Health results from a global animal response

✓下一步：超越概念认证 The next step : to go beyond the proof of concept

- 生理反应 physiologic response
- 菌群变化 changes in the microflora profile
- 基因表达 gene expression …

结论Conclusions (3)

从农场角度来看From an on-farm use perspective

- ✓ 仍有很多限制因素需克服
  Some limitations are still to overcome

- ✓ 当调整饲料配方和饲喂方式来维持健康和性能时
  When feed formulation and feeding practices could be adapted to preserve both health and performance

  - ➢ 以预防为目的➔鉴别限制性营养组分
    in a preventive way ➔ identification of sub limiting nutrients
  - ➢ 以治疗为目的➔ 采食量低的问题
    in a curative way ➔ problem of low feed intake
  - ➢ 补偿性增长 to sustain compensatory performance

结论Conclusions (4)

从农场角度来看From an on-farm use perspective

✓如何调整饲料配方和饲喂方式来维护健康和性能

How feed formulation and feeding practices could be adapted to preserve both health and performance

- 以个体为群体（关键阶段）VS 群体中的个体
  group of individuals (critical phase) *vs* individual in a group

结论Conclusions (4)

从农场角度来看From an on-farm use perspective

✓ 如何调整饲料配方和饲喂方式来维护健康和性能
How feed formulation and feeding practices could be adapted to preserve both health and performance

- 以个体为群体（关键阶段）VS 群体中的个体
- group of individuals (critical phase) vs individual within a group

✓ 可以从精细化养殖得到什么
What could be expected from Precision Livestock Farming：

- 早期检测健康问题带来的挑战：the challenge of (early) detection of health disturbances：
  咳嗽及腿病检测 cough and lameness detection (Berkmans 2014),
  采食行为的变化 changes in feeding behavior (Maselyne et al 2015),
  饮水行为 drinking behavior (Cornoue et al 2013)
- 通过精细化养殖饲喂群体或个体
  Feed the group or the individual through precision feeding (Andretta et al 2014)

结论Conclusions (4)

从农场角度来看From an on-farm use perspective

- ✓ 如何调整饲料配方和饲喂方式来维护健康和性能
  How feed formulation and feeding practices could be adapted to preserve both health and performance
  - ➢ 以个体为群体（关键阶段）VS 群体中的个体
  - ➢ group of individuals (critical phase) vs individual within a group
- ✓ 可以从精细化养殖得到什么
  What could be expected from Precision Livestock Farming：
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  - ➢ 通过精细化养殖饲喂群体或个体
    Feed the group or the individual through precision feeding (Andretta et al 2014)
- ✓ 日粮需要与其他饲养管理措施结合 Feed should be associated to other management strategies

接下来将会怎样？举例
What is ongoing? An example

欧洲项目——致力于集约化养猪和家禽生产体系中的生产性疾病

An European project dedicated to production diseases* in intensive pig and poultry production systems

项目负责人：纽卡斯尔大学

22个参与者 2013-108

Leader: University of Newcastle (I Kyriazakis)

22 partners - 2013-2018

生产性疾病*：遗传、环境（畜舍、营养、管理）和病原菌相互作用产生的多因素疾病

Production diseases*: multifactorial diseases in which genetics, environment (housing, nutrition, management) and pathogenic challenge show complex interactions

- 掌握基因型（骨骼健康，炎症反应，消化功能紊乱）与畜舍条件（母猪）交互作用的基础生理代谢

To with the genotype (bone health, inflammatory response, digestivdevelop our understanding of the underlying physiological and metabolic mechanisms in interaction e disorders) and housing conditions (sows)

- 验证营养方案能够克服这些疾病的影响

To test nutritional strategies to overcome the impact of these diseases