UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

饲料原料评估
Evaluation of Feed Ingredients

Hans H. Stein
Univ. of Illinois
http://nutrition.ansci.illinois.edu

1867

营养物质分类
Classes of Nutrients

能量不是一种营养素
Energy is Not a Nutrient!

- 水分 Water
- 蛋白质 Protein
- 碳水化合物 Carbohydrates
- 脂质 Lipids
- 维生素 Vitamins
- 矿物质(灰分) Minerals (ash)

饲料原料中灰分的重要性
Importance of ash in feed ingredients

Item	Permeate-1	Permeate-2
灰分 Ash, %	8.96	1.72
ME, kcal/kg DM	3,081	3,593

Kim et al., 2012

肉骨粉Meat and Bone Meal

Item	平均Average	最小Min	最大Max	变异系数CV
蛋白质CP, %	51.9	45.7	57.2	6.2
脂肪AEE, %	13.1	11.6	15.2	10.5
灰分Ash, %	27.3	20.6	33.2	13.8
钙Ca, %	8.6	5.2	11.0	20.7
磷P, %	4.2	2.6	5.3	19.1

% Ca = 0.456 × 灰分ash – 4.015 ($R^2 = 0.97$)

% P = 0.2044 ×灰分 ash – 1.424 ($R^2 = 0.96$)

Sulabo and Stein, 2013

磷和钙的消化率
Digestibility of P and Ca

STTD of P (%) = 66.345 + 4.225 × ash – 13.126 × Ca

(R^2 = 0.83)

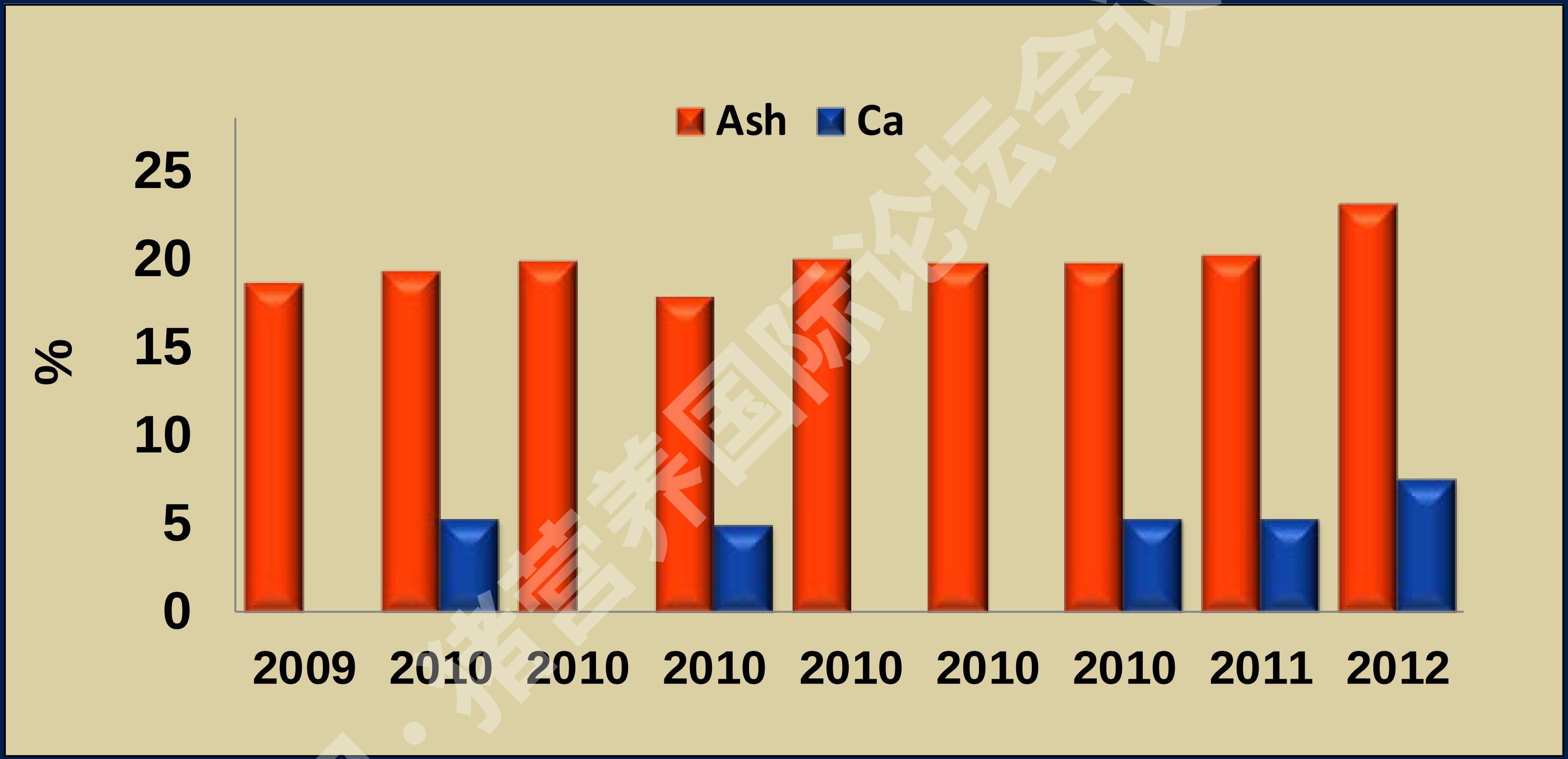
ATTD of Ca (%) = 67.316 + 3.833 × ash – 12.398 × Ca

(R^2 = 0.87)

STTD=标准总肠道消化率
ATTD=表观总肠道消化率
ash：灰分

Sulabo and Stein, 2013

鱼粉中的灰分含量
Ash in Fish Meal



Univ. IL. 2012

鱼粉的能量
Energy in Fish Meal (ME/kg)

关于灰分的结论
Conclusions on Ash

- 灰分是一种重要的组成部分 Ash is an important component
  - 尤其在动物蛋白中 Specifically in animal proteins

⇧ ash灰分增加 ⇨ ⇩ ME代谢能降低

– But also ⇧ Ca and P 但也增加钙和磷

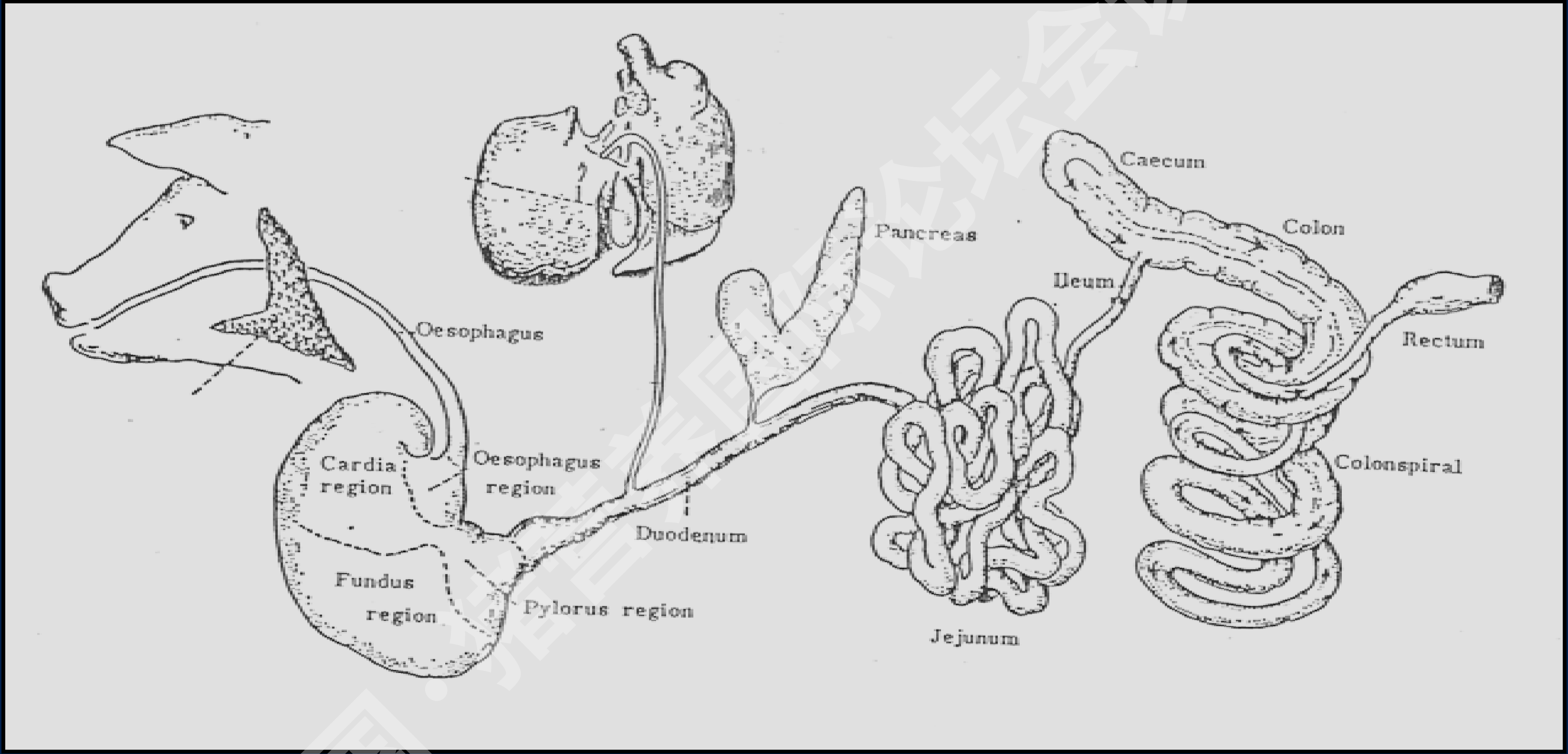
蛋白质和氨基酸
Protein and Amino Acids

H. H. Stein

蛋白质品质 Protein Quality

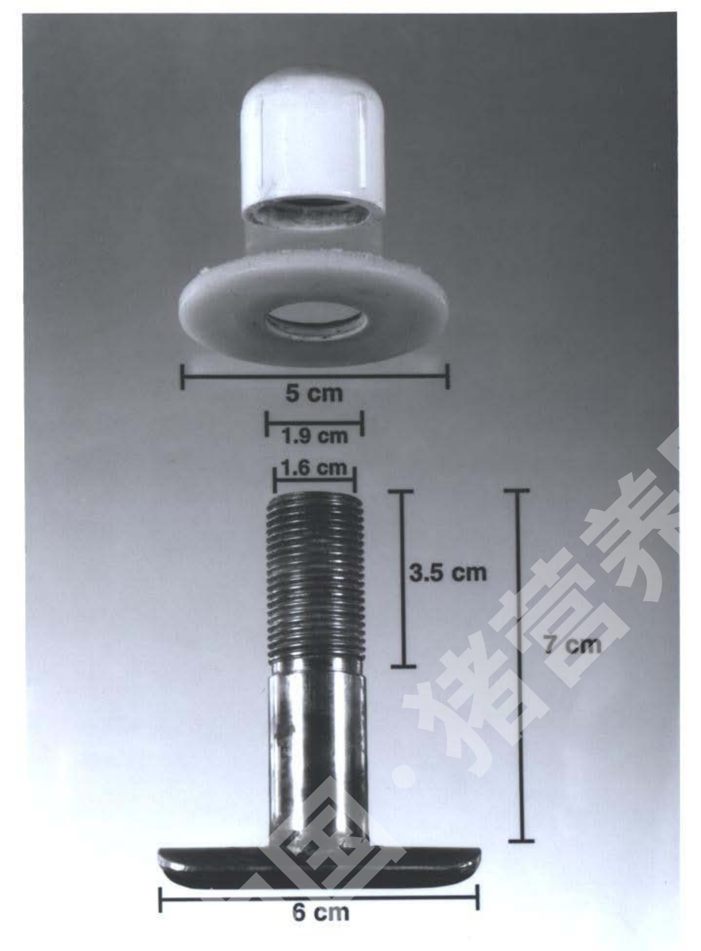
Item	豆粕SBM	玉米蛋白粉 CGM	DDGS
蛋白质 CP, %	47.5	62.9	27.5
赖氨酸 Lys, %	3.02	1.18	0.78
色氨酸 Trp, %	0.65	0.44	0.21
赖氨酸占蛋白质的百分比Lys, % of CP	6.35	1.88	2.84
色氨酸占蛋白质的百分比 Trp, % of CP	1.37	0.70	0.76

回肠氨基酸消化率
Ileal AA Digestibility



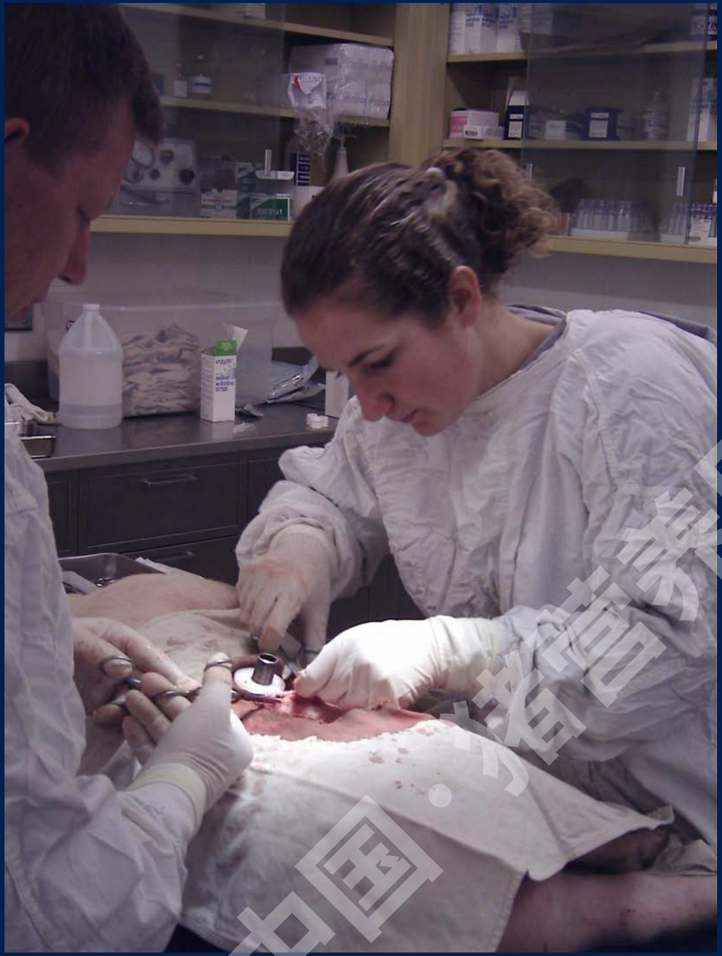
H. H. Stein

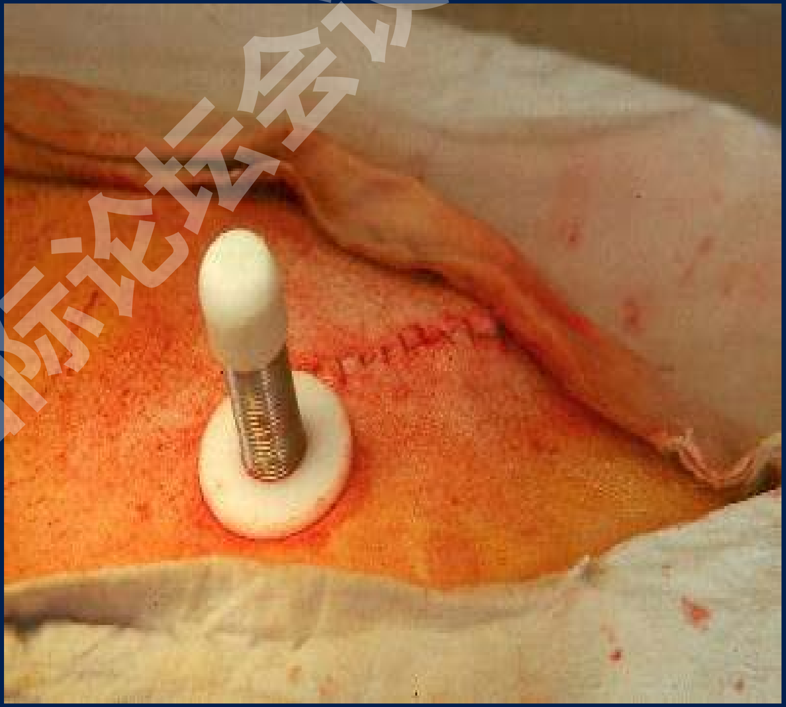
T型瘘管 T-Cannula



H. H. Stein

安装瘘管 Installing a Cannula





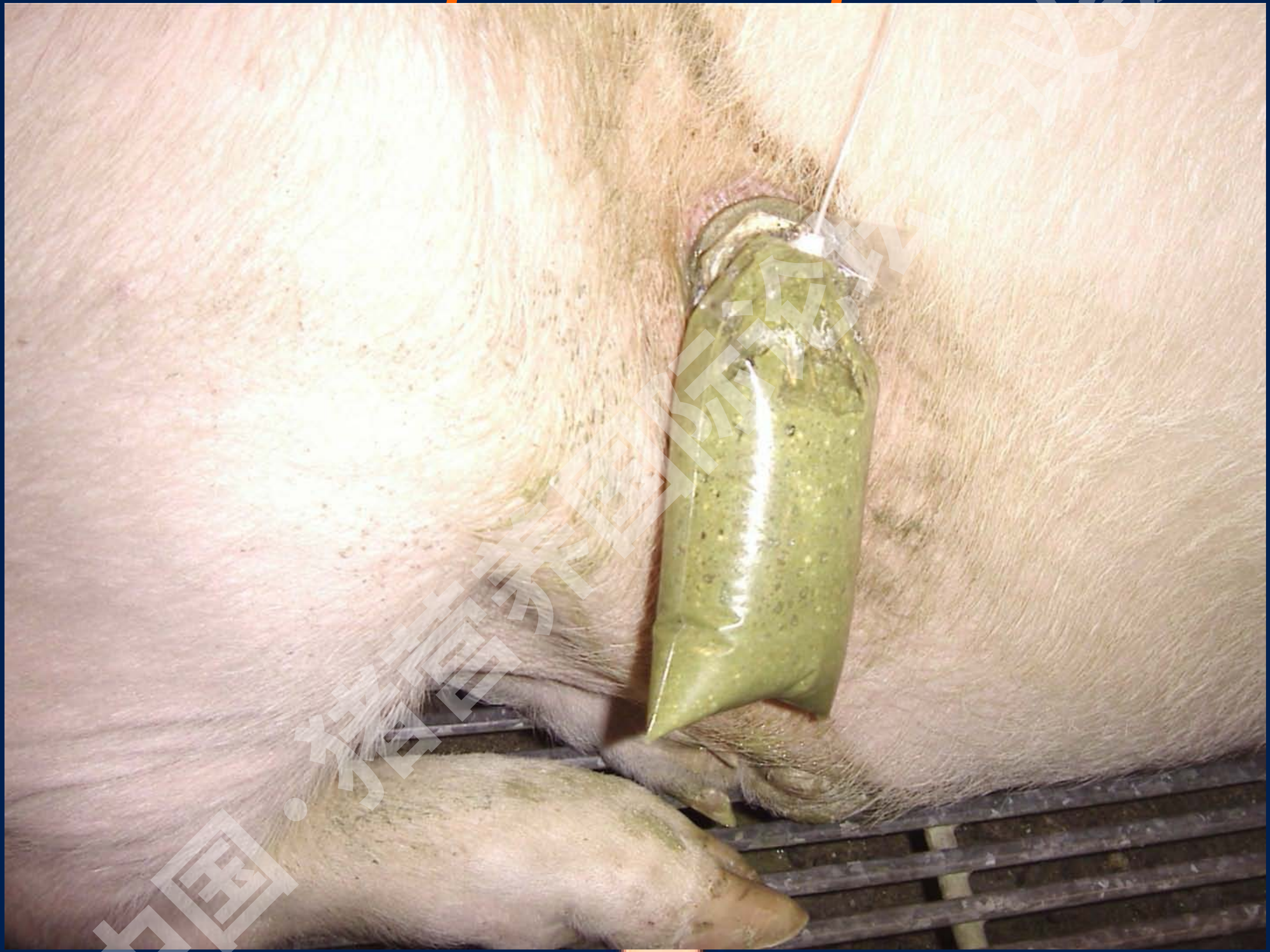
准备收集 Ready for collection

打开瘘管 Open Cannula

将样品袋套进瘘管

Attach Bag to Cannula

收集到的整袋食糜
Bag Full of Digesta



将食糜放入塑料桶中

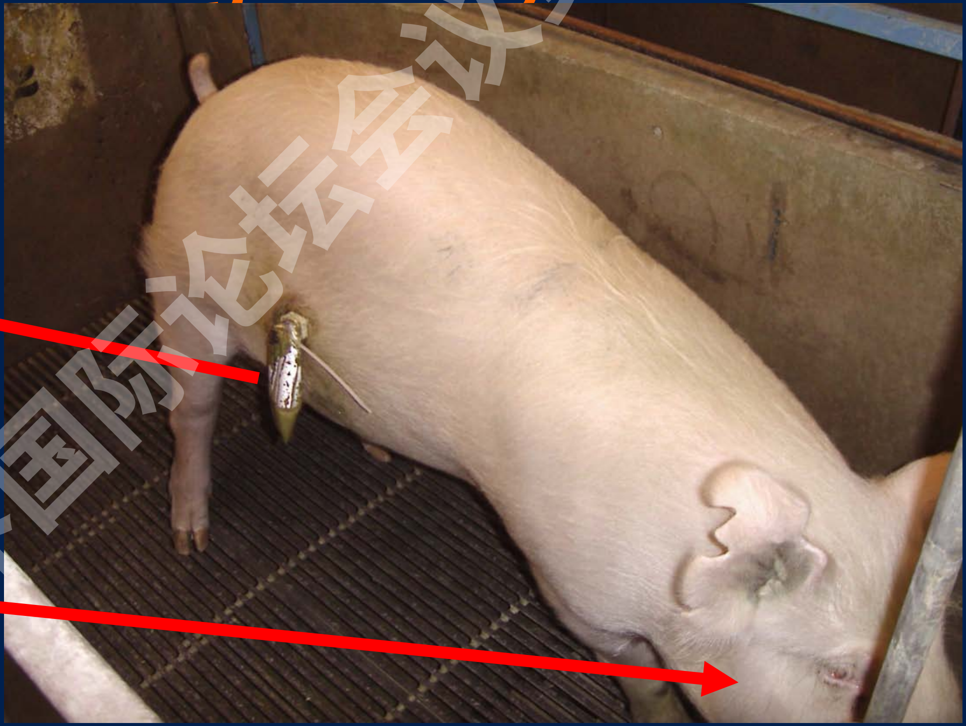
Empty Digesta into Pitcher

表观回肠消化率(AID)

Apparent Ileal Digestibility

3克赖氨酸
3 g Lys

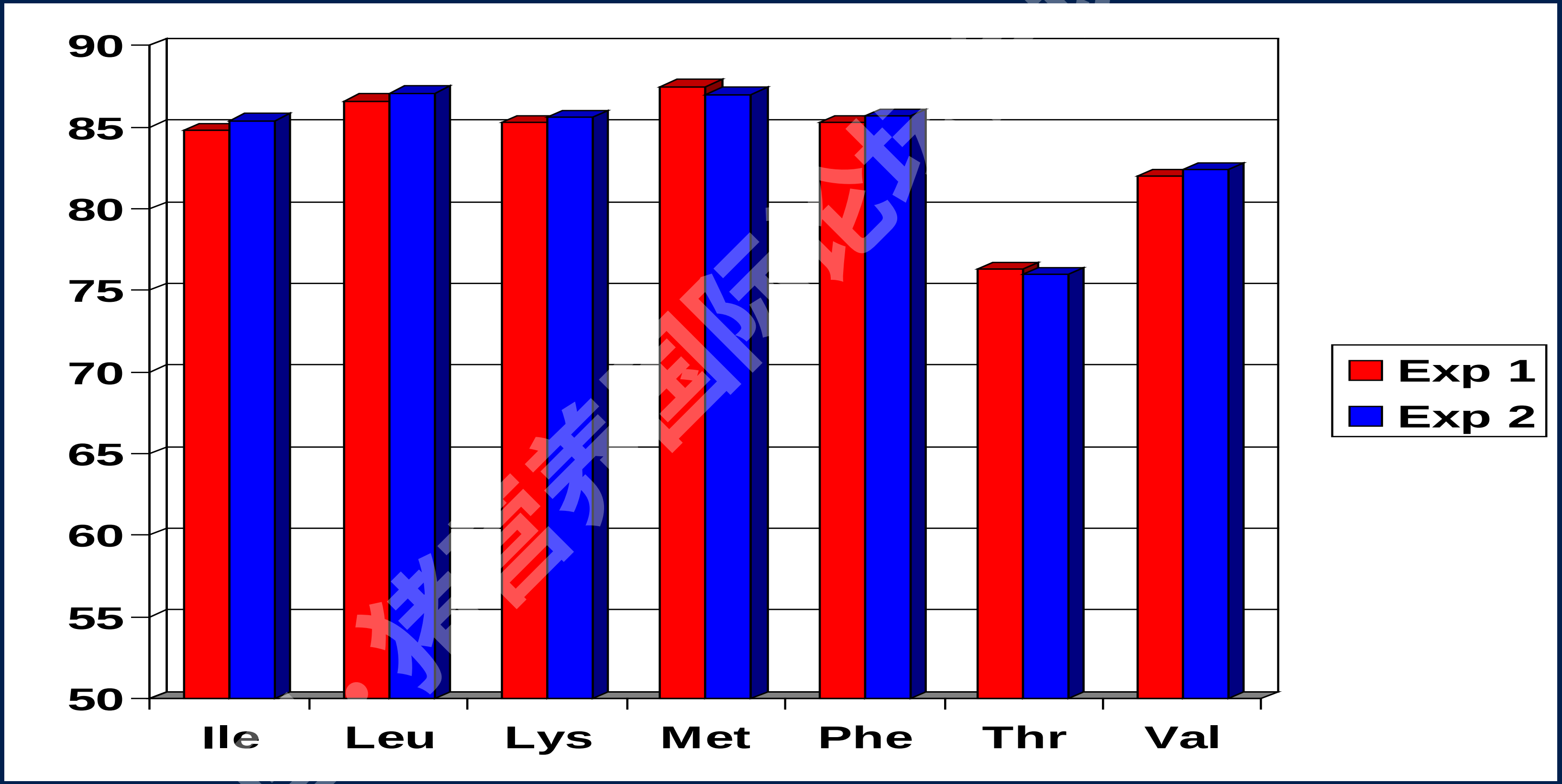
20克赖氨酸
20 g Lys



AID, Lys: (20-3)/20 x 100 = 85%

方法的准确度Accuracy of Procedure

玉米-豆粕型日粮的AID AID in corn – SBM diet

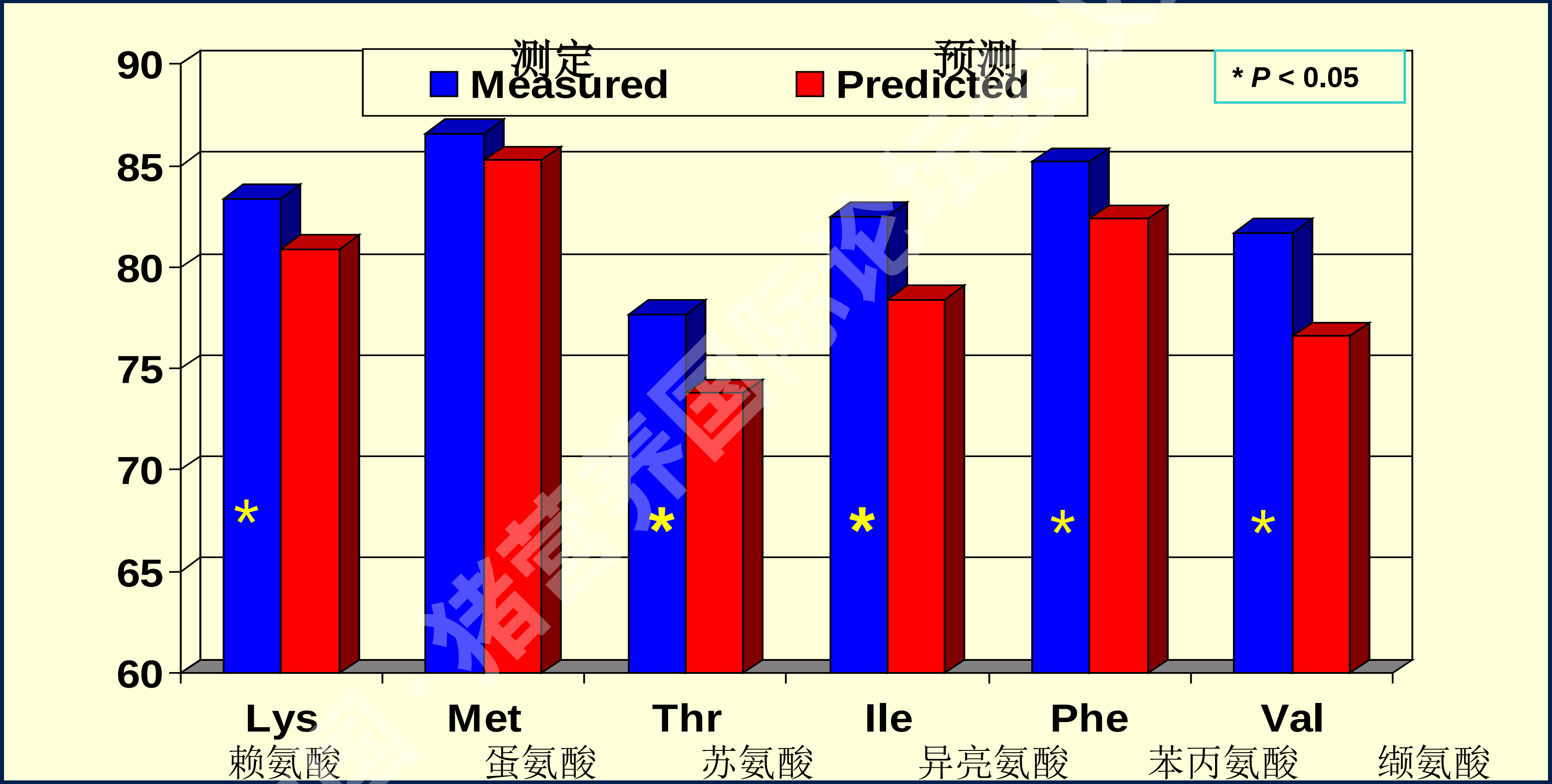


异亮氨酸 亮氨酸 赖氨酸 蛋氨酸 苯丙氨酸 苏氨酸 缬氨酸

Pedersen et al., 2005

玉米-豆粕-棉籽粕日粮的AID

AID in Corn-SBM-CM Diet



Stein et al., 2005

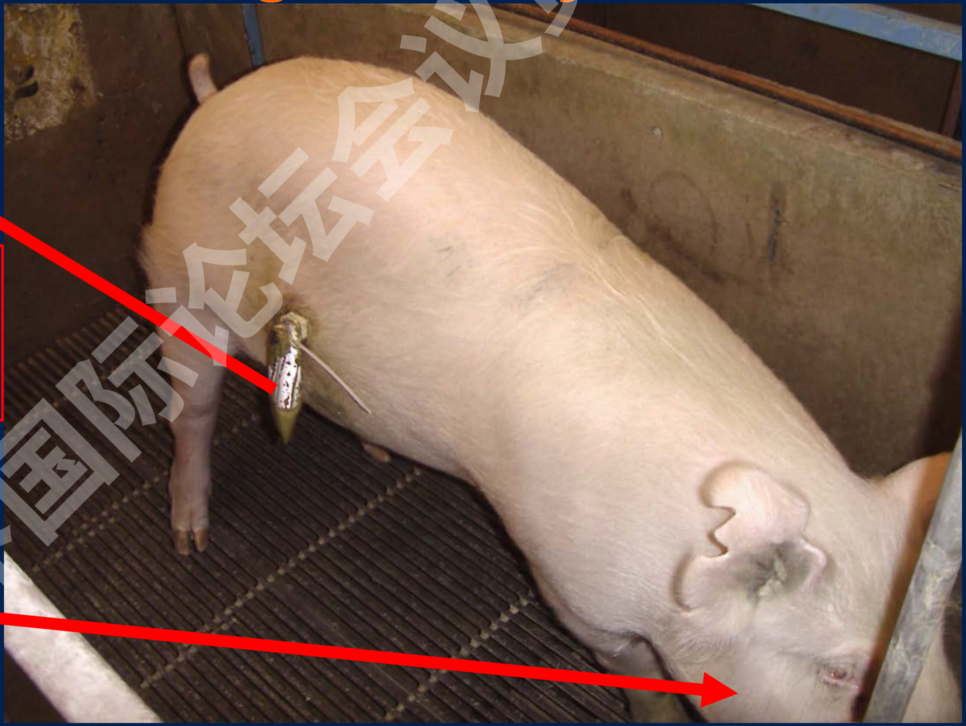
标准回肠消化率(SID)

Standardized Ileal Digestibility

3 g Lys

1g basal end. Lys

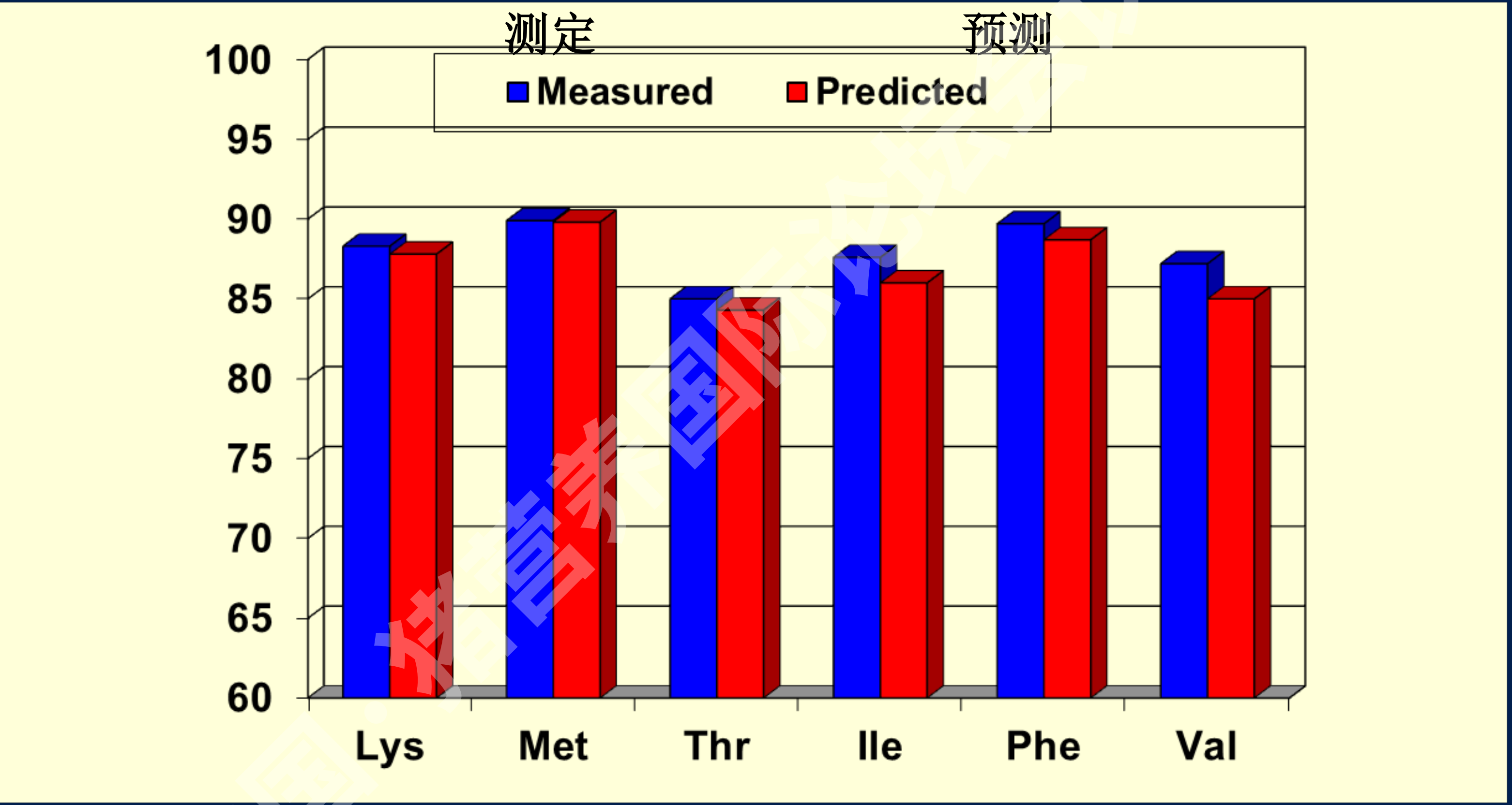
2 g feed Lys + Spec. end Lys



20 g Lys

SID: [20 – (3 - 1)]/20 x 100 = 90%

玉米-豆粕-棉籽粕日粮的SID
SID in Corn-SBM-CM diet



Stein et al., 2005

SID：标准回肠消化率

J. C. Gonzalez-Vega

蛋白源替代物
Alternative Protein Sources

蛋白源替代物
Alternative protein sources

油菜籽Canola seeds

棉籽粕
Cottonseed meal

葵花籽Sunflower seeds

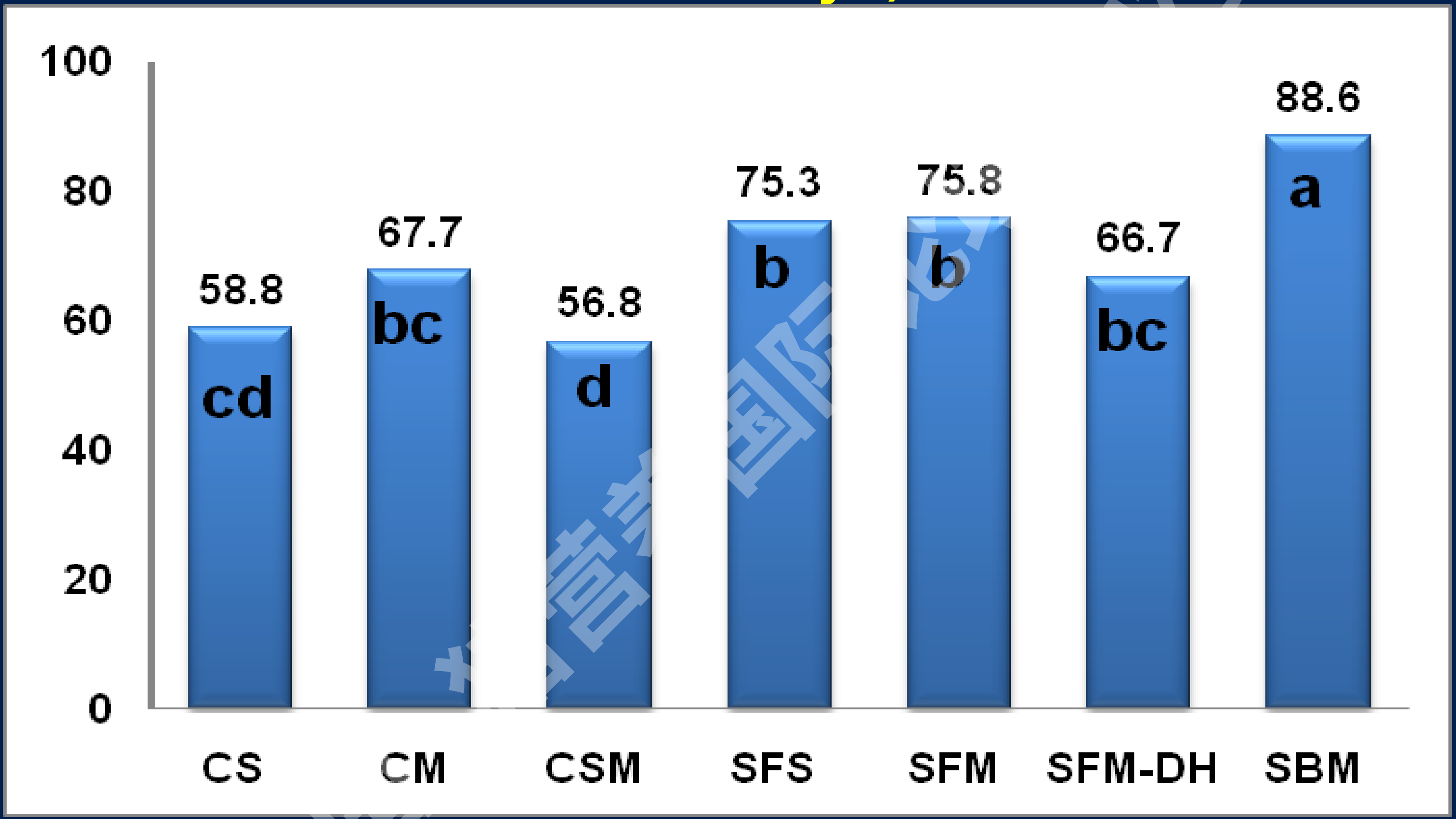
葵花粕Sunflower meal

菜籽粕Canola meal

去皮葵花粕Sunflower meal dehulled

赖氨酸的标准回肠消化率

SID of Lys, %

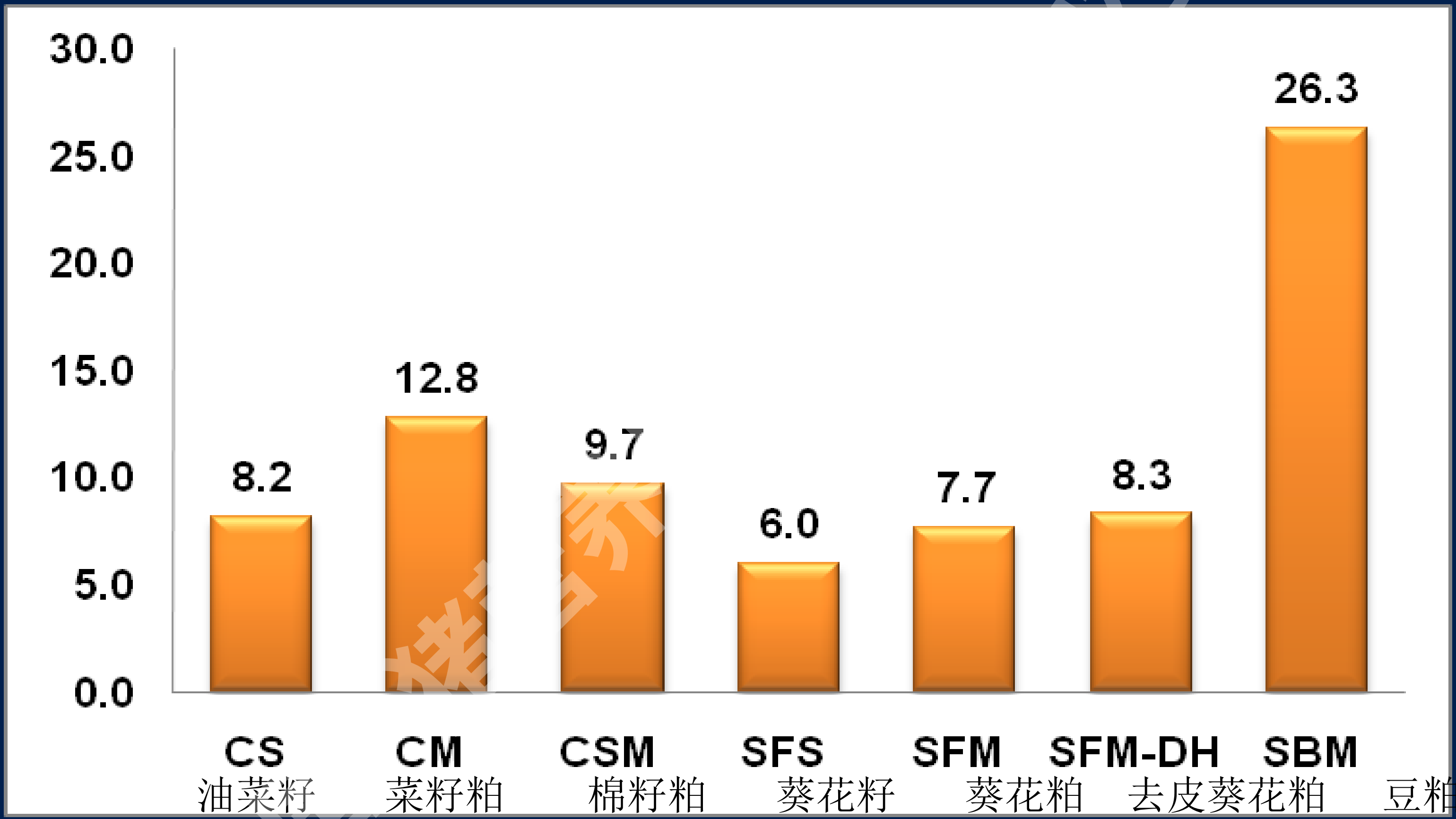


油菜籽 菜籽粕 棉籽粕 葵花籽 葵花粕 去皮葵花粕 豆粕

Gonzalez-Vega et al., 2012

可消化的赖氨酸含量

Digestible Lys, g/kg



Gonzalez-Vega et al., 2012

美拉德反应 Maillard Reaction

赖氨酸Lysine

↑↓

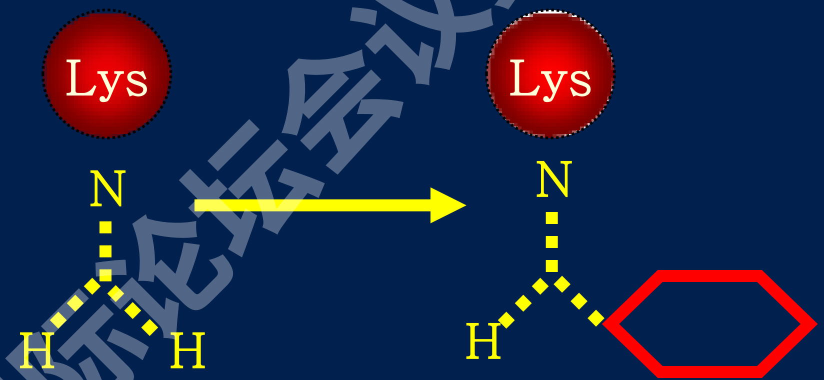
希夫碱Shiff Bases

↓

Amadori

↓

类黑精 Melanoidins



反应的赖氨酸 Reactive Lys

未反应的赖氨酸 Unreactive Lys

Amadori → 降低赖氨酸的消化率 Reduces Lys Digest.

Amadori, 类黑精 Melanoidins → 减少赖氨酸的浓度 Reduces Lys conc.

热处理豆粕

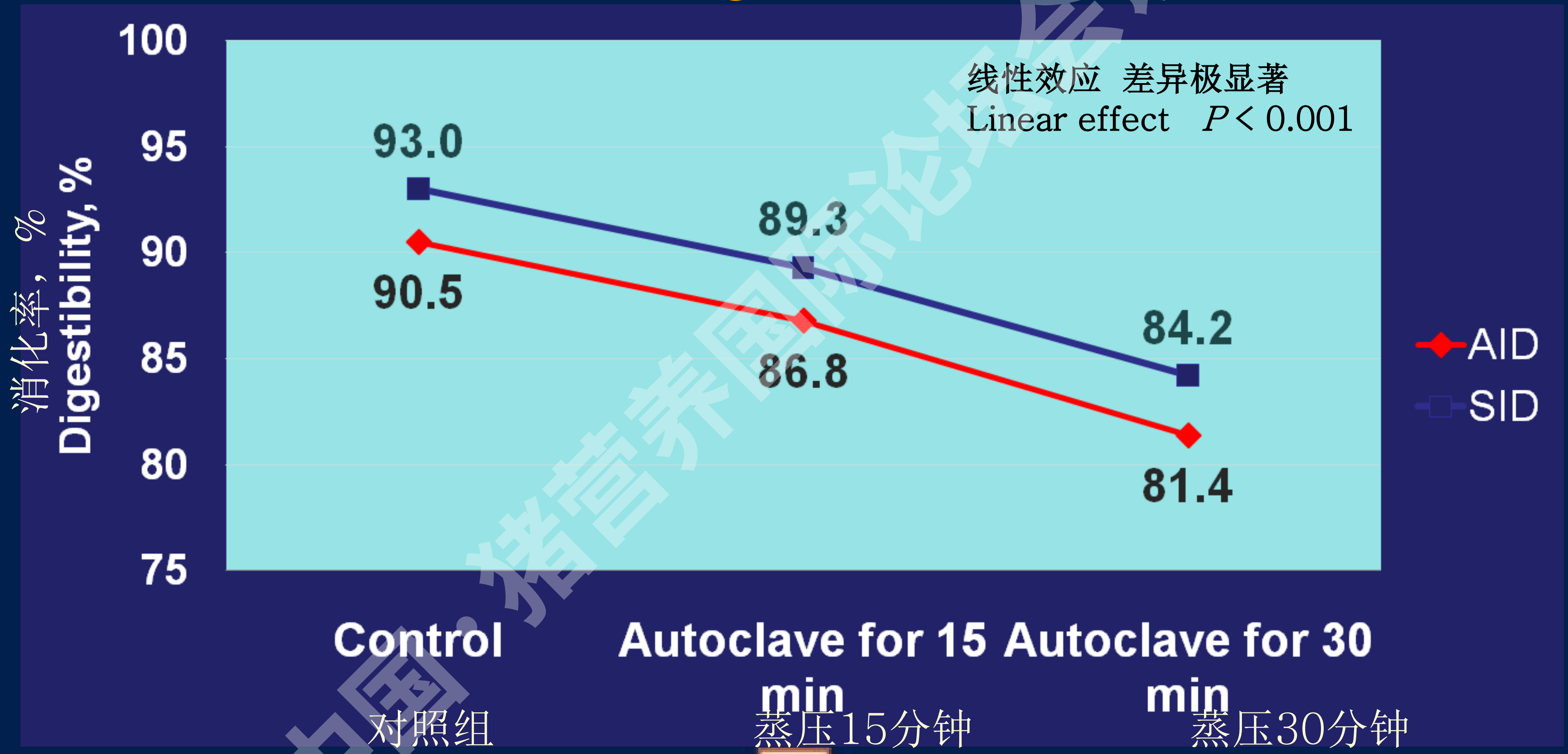
Heat Treatment of Soybean Meal

	对照组 Control	125° C 蒸压豆粕15 分钟 Autoclaved SBM to 125° C for 15 min	125° C 蒸压豆粕30 分钟 Autoclaved SBM to 125° C for 30 min	125° C烘箱干燥豆粕30分钟 Oven dried SBM to 125° C for 30 min
L*	76.7	61.7	52.5	77.4
a*	3.4	10.0	12.5	2.85

Gonzalez-Vega et al., 2011

蒸压时间对赖氨酸的表观回肠消化率和标准回肠消化率的影响

Effect of autoclaving time on AID & SID of Lys



Gonzalez-Vega et al., 2011

热处理对赖氨酸/蛋白质的影响
Effect on Lys/CP

Item	豆粕 Soybean meal			
	对照组 Control	蒸压15分钟 Autoclaved 15 min	蒸压30分钟 Autoclaved 30 min	烘箱干燥30分钟Oven dried 30 min
蛋白质CP, %	48.5	49.2	48.3	49.1
赖氨酸Lys	3.05	2.83	2.69	3.07
Lys/CP, %	6.29	5.75	5.57	6.25

Gonzalez-Vega et al., 2011

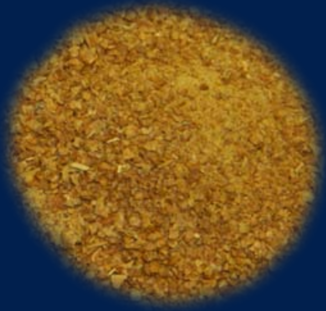
热损伤的实际影响
Practical Impact of Heat Damage

Ferdinando N. de Almeida

豆粕的热损伤
Heat Damage of SBM

2.0 kg

130˚C, 60 min

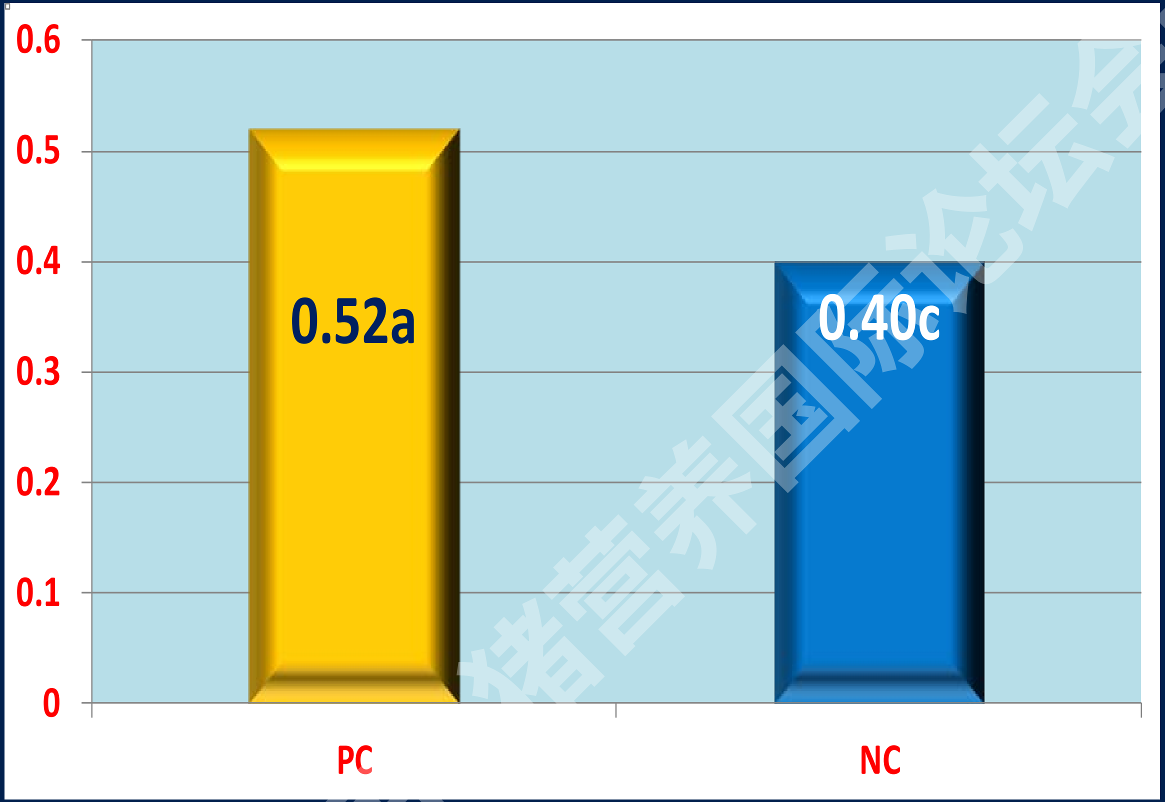


材料和方法
Materials and Methods

颜色Color L*	67.7	53.6
蛋白质CP, %	46.4	46.1
赖氨酸Lys, %	2.85	2.58
赖氨酸:蛋白质 Lys:CP	6.1	5.6

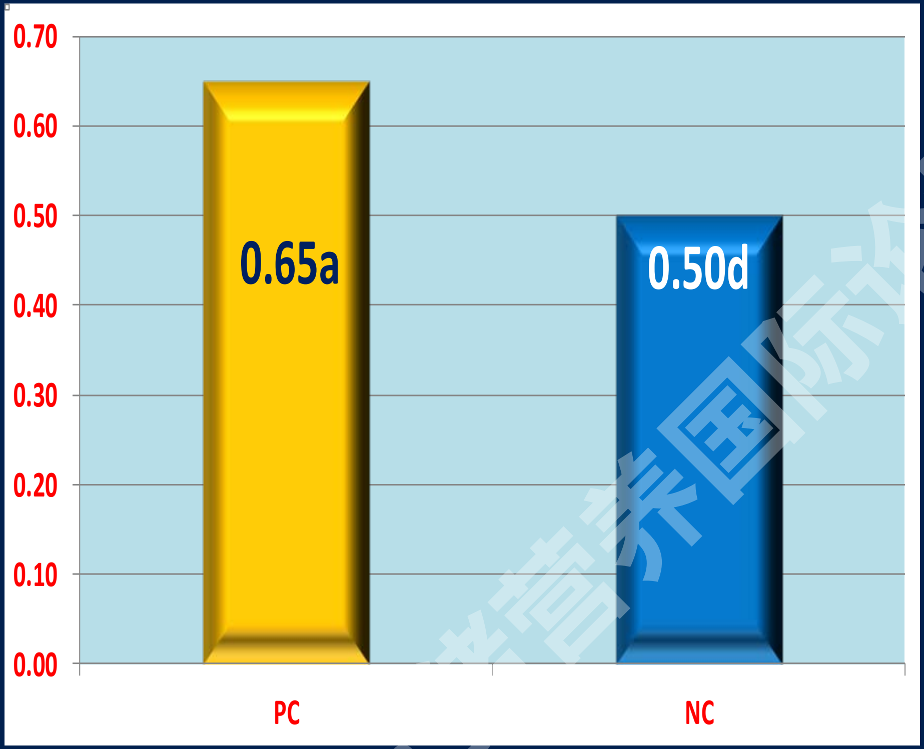
Almeida, 2012, unpublished

平均日增重 Average Daily Gain, g



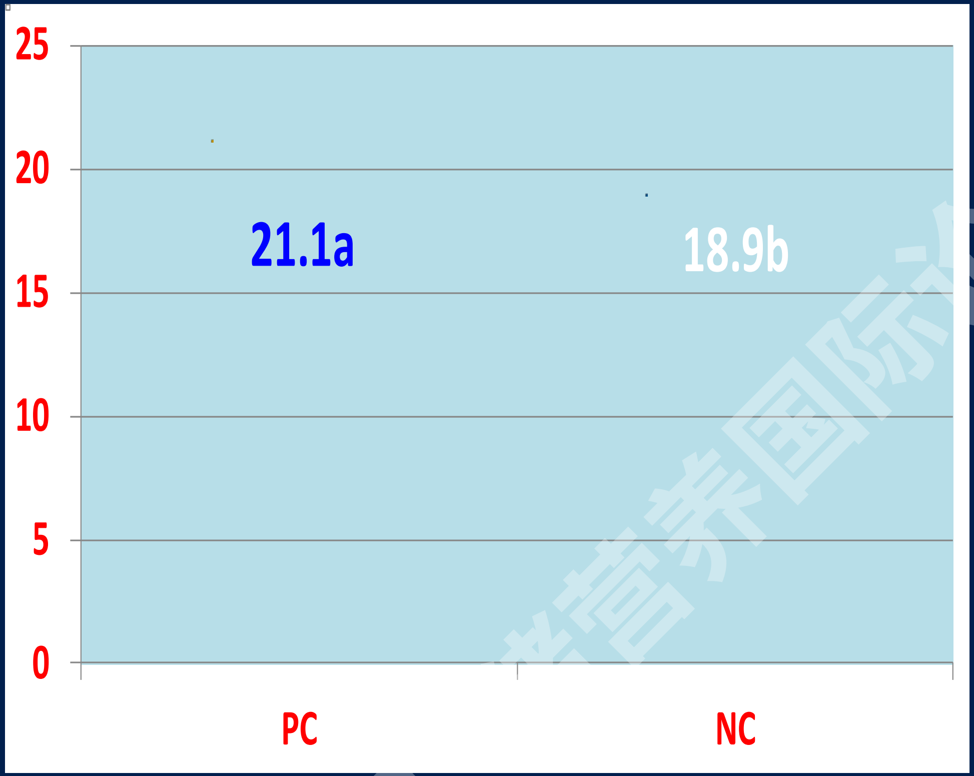
Almeida, 2012, unpublished

肉料比 Gain:Feed Ratio



Almeida, 2012, unpublished

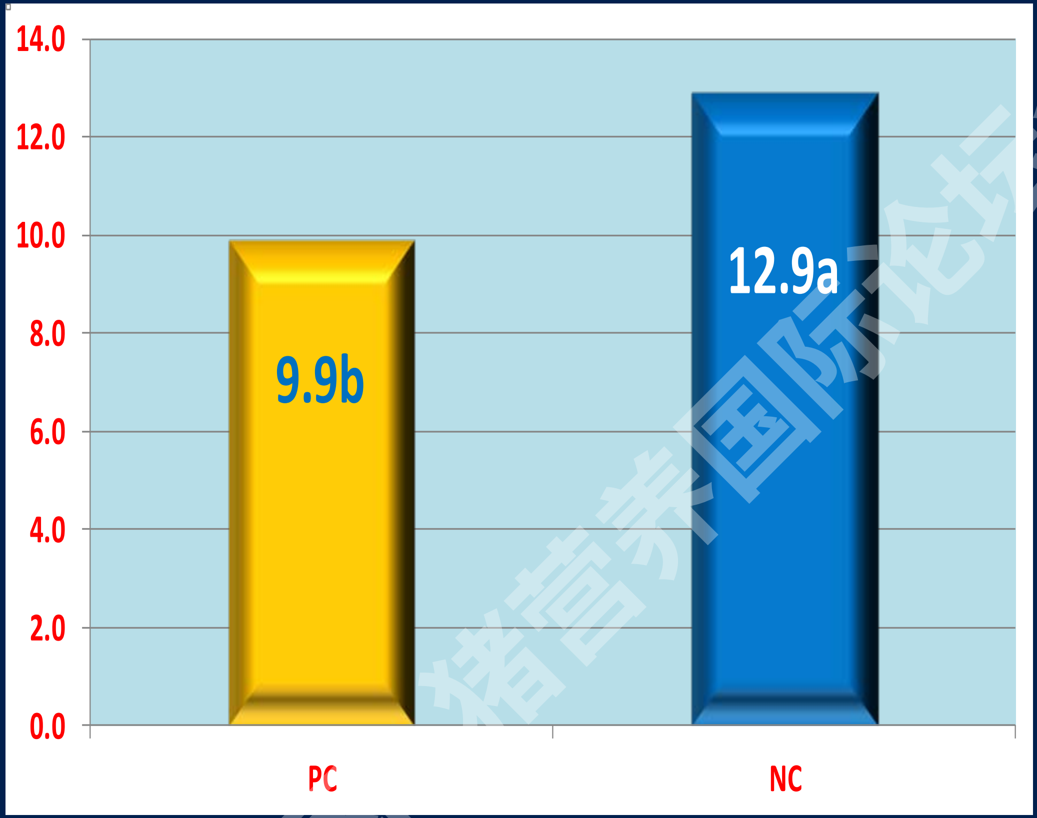
末重 Final BW, kg



Almeida, 2012, unpublished

血浆尿素氮

Plasma Urea Nitrogen, mg/dl



Almeida, 2012, unpublished

测定加工过程原料的热损伤程度
Determining degree of heat damage in processed ingredients

H. H. Stein

反应的赖氨酸 Reactive Lysine

总赖氨酸Total Lys

美拉德反应
Maillard reaction

未反应的赖氨酸Unreactive Lys

反应的赖氨酸Reactive Lys

再生赖氨酸
Regenerated Lys (40%)

糠氨酸Furosine (32%)

Pyridosine (28%)

分析赖氨酸
Analyzed Lys

酸水解
Acid Hydrolysis

色谱法Chromatography

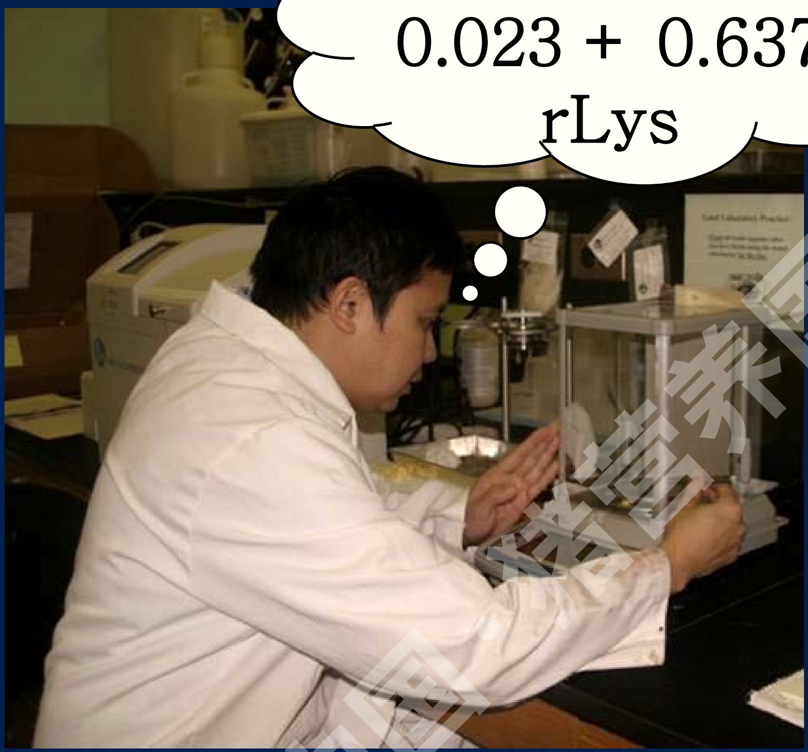
豆粕的热损伤 Heat Damaged SBM

Item	豆粕Soybean meal			
	对照组 Control	蒸压15分钟 Autoclaved for 15 min	蒸压30分钟 Autoclaved for 30 min	烘箱烘30分钟Oven dried for 30 min
CP, %	48.5	49.2	48.3	49.1
Lys	3.05	2.83	2.69	3.07
Lys/CP, %	6.29	5.75	5.57	6.25
糠氨酸 Furosine, %	0.015	0.023	0.026	0.016

Gonzalez-Vega et al., 2011

测定DDGS中反应的赖氨酸的方法
Reactive Lys Procedure, DDGS

SID Lys = 0.023 + 0.637 rLys



Dr. Ameer A. Pahm

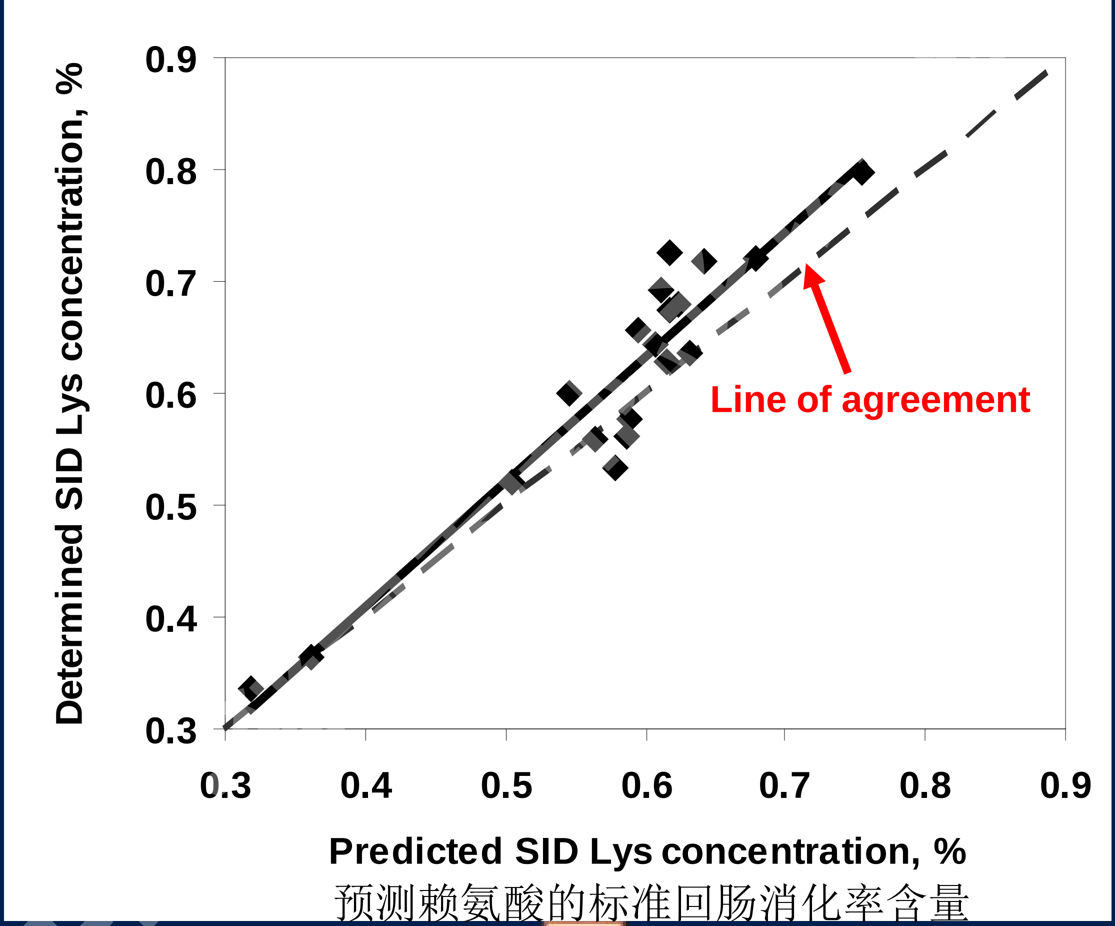
1. 测定糠氨酸浓度 Measure Furosine conc.
2. 计算反应的赖氨酸 Calculate rLys
3. 预测标准回肠赖氨酸 Predict SID Lys

验证方程式
Validation of Equation

- 21个DDGS样品 21 samples of DDGS
- 给猪安装瘘管 Cannulated pigs
- 赖氨酸的标准回肠消化率 SID of Lys
- 测定糠氨酸含量 Determination of furosine

Dr. B. G. Kim

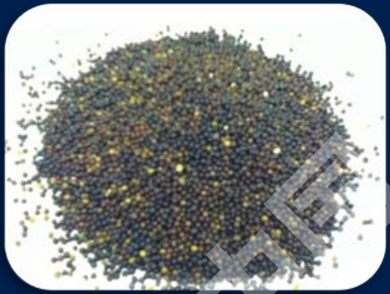
验证方程式
Validation of Equation



Kim et al., 2012

未损伤原料的赖氨酸与蛋白质比例
Lys:CP (%) in undamaged ingredients

- 豆粕 Soybean meal: > 6.0%
- 菜籽粕Canola meal: > 5.2%
- 玉米DDGS Corn DDGS: > 3.1%
- 玉米 Corn: > 3.1%
- 葵花粕 Sunflower meal: >3.4%



蛋白质和氨基酸的结论
Conclusion on CP and AA

- 测定蛋白质和氨基酸的浓度
- Determine concentration of CP and AA
- 以氨基酸标准回肠消化率配制日粮
  Formulate diets based on SID of AA
- 计算热处理原料的赖氨酸:蛋白质的比例
  Calculate Lys as % of CP in heated ingredients
  - 测定原料是否被热损伤

Determine if ingredient is heat damaged

脂质
Lipids

日粮脂肪Dietary Lipids (AEE)

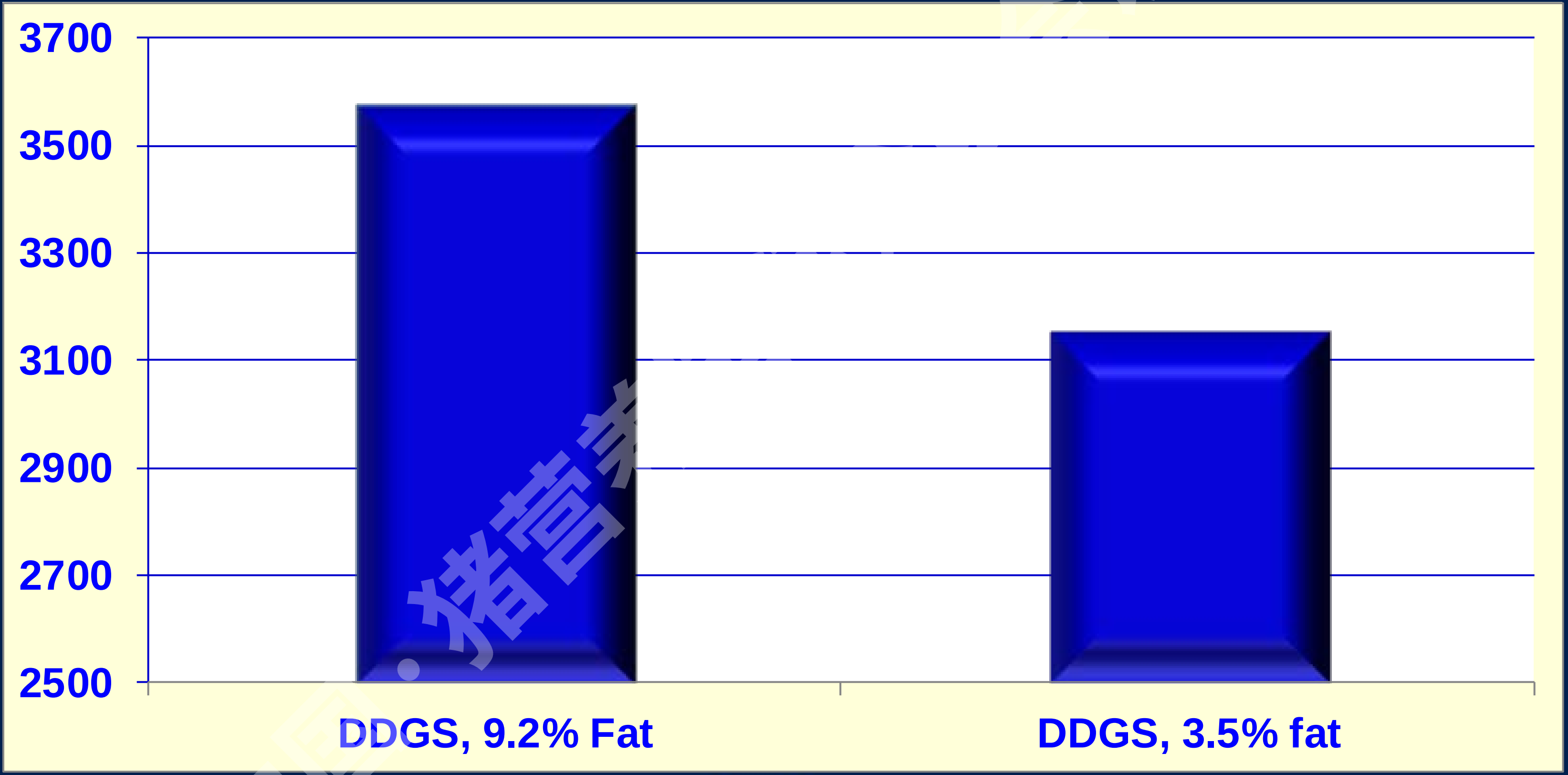
Item	碳水化合物 CHO	蛋白质 Protein	脂肪 Fat
Kcal/g	~4.0	5.6	9.5

- 净能= (0.70 x消化能) + (1.61 x 脂肪) + (0.48 x 淀粉) + (0.91 x 蛋白质) – (0.87 x 酸性洗涤纤维)
- NE = (0.70 x DE) + (1.61 x EE) + (0.48 x starch) + (0.91 x CP) – (0.87 x ADF)

NRC, 2012

不同脂肪含量DDGS的代谢能

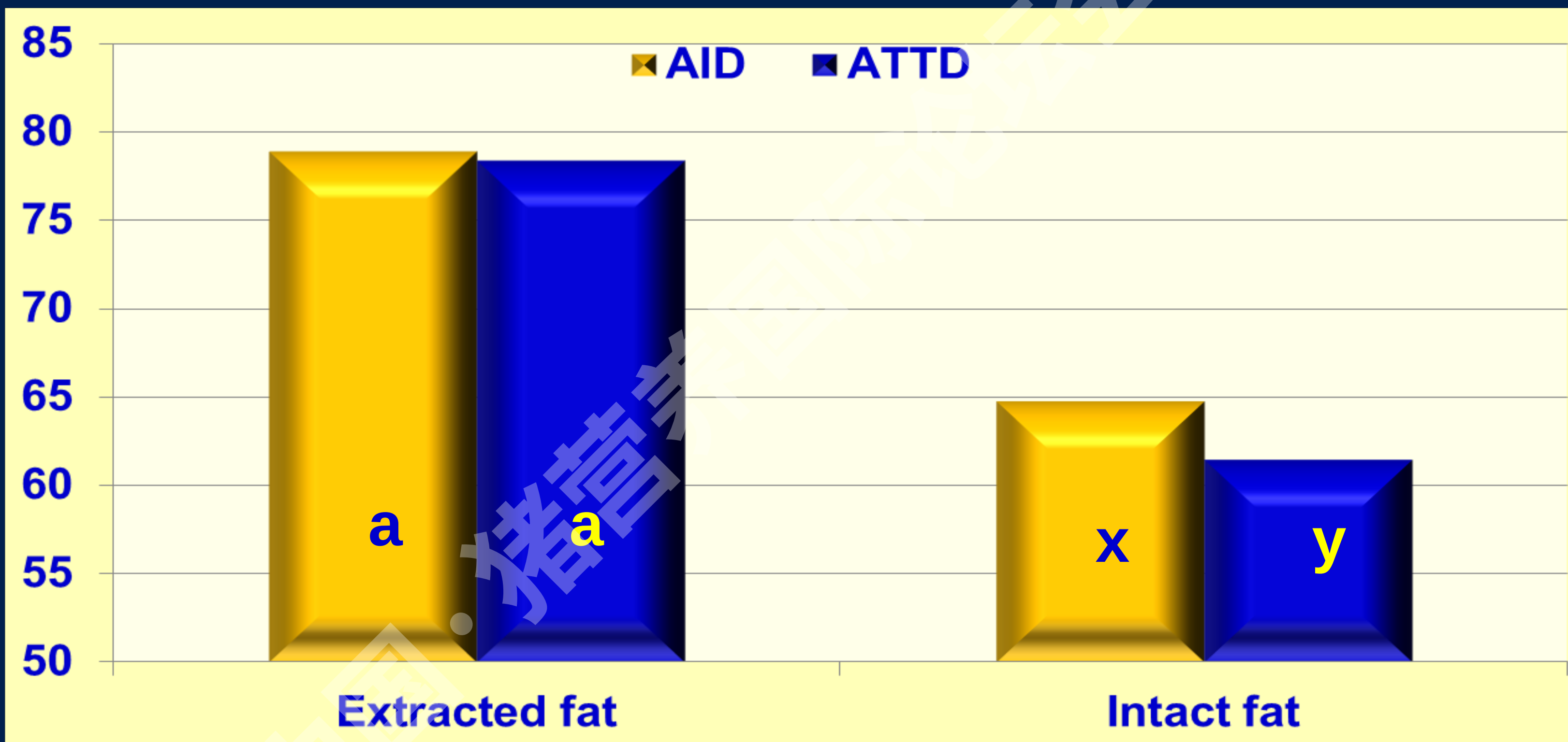
ME in DDGS (kcal/kg DM)



Ren et al., 2011

玉米中脂肪的表观回肠消化率和表观总肠道消化率

AID and ATTD of Fat from Corn



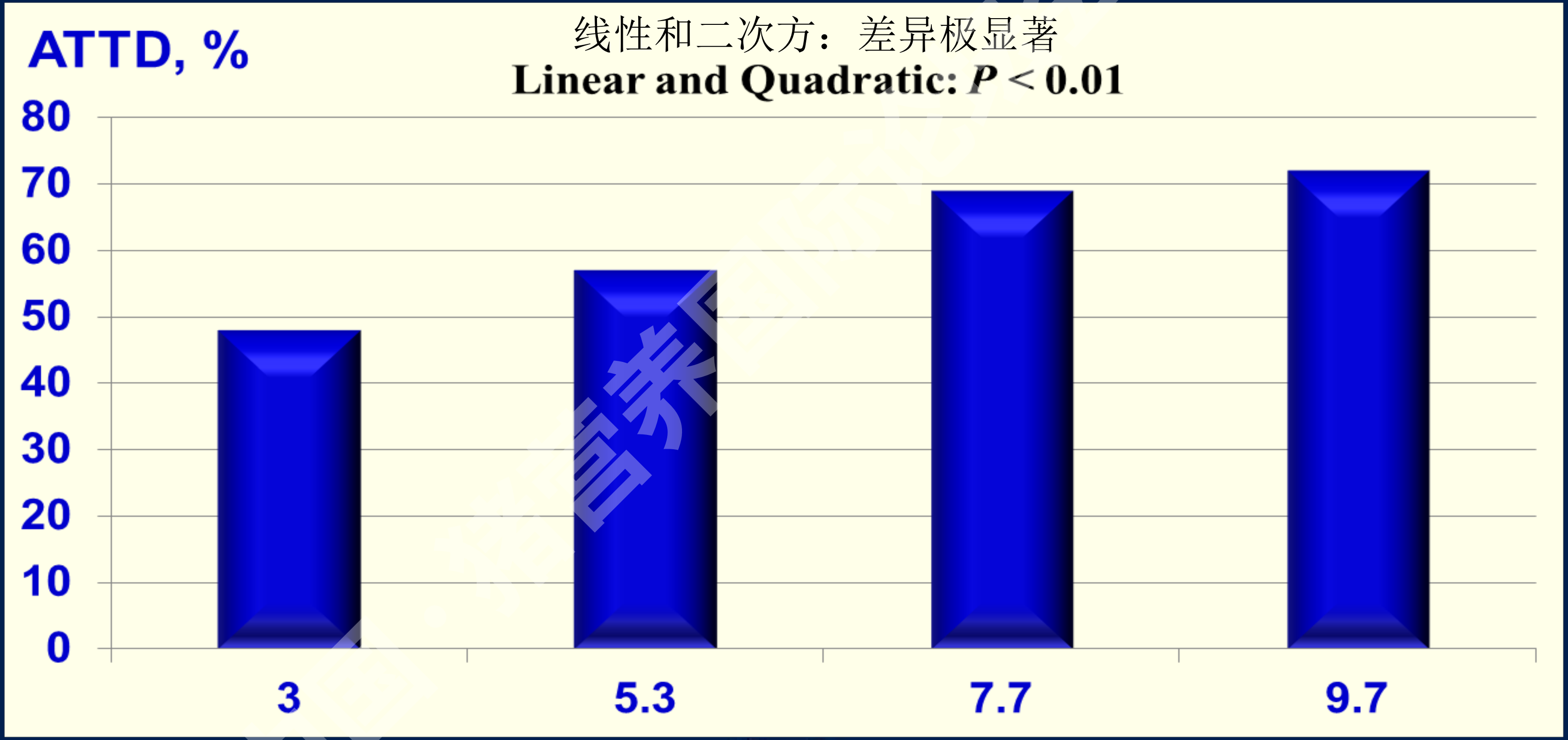
提取脂肪

完整的脂肪

Kil et al., 2010

日粮脂肪浓度对脂肪表观总肠道消化率的影响

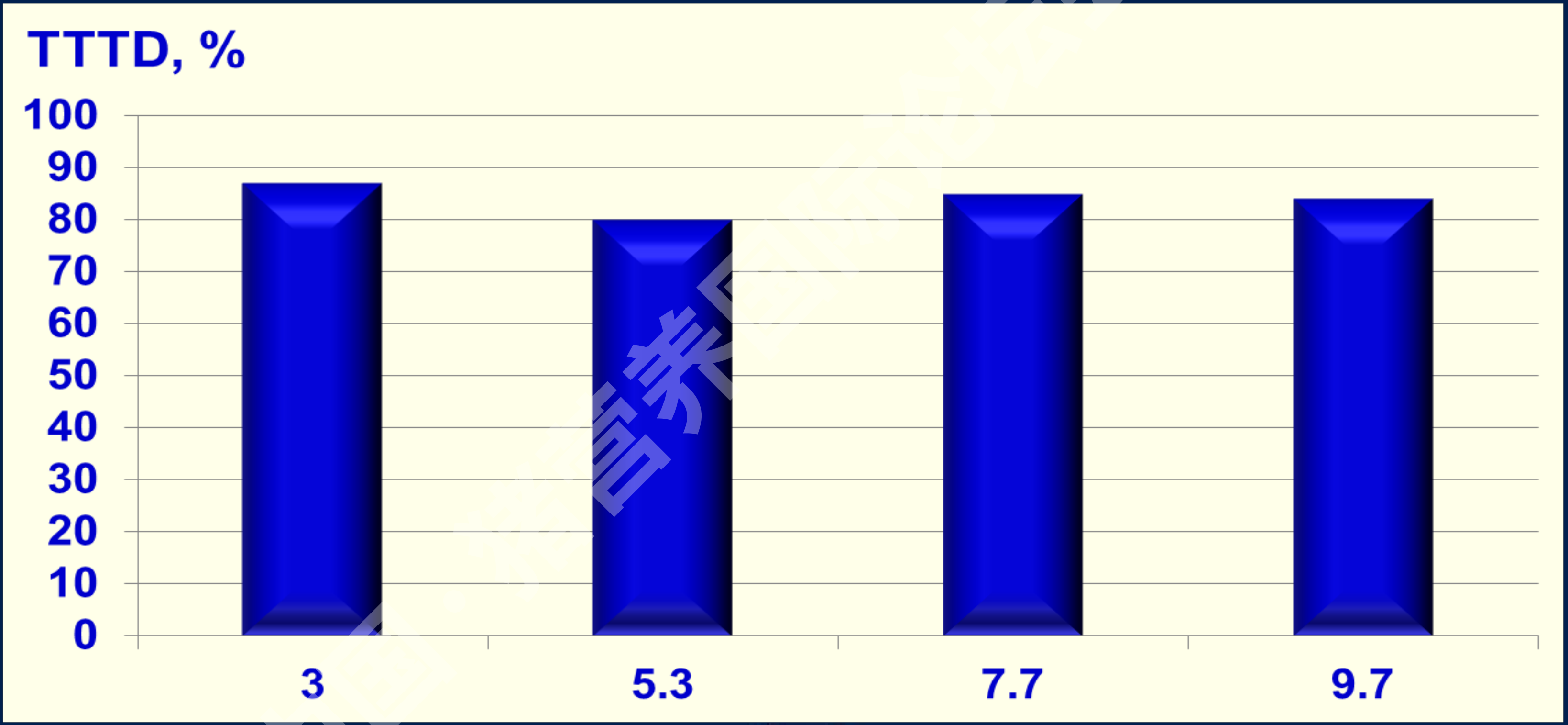
Effect of Dietary Lipid Conc. on ATTD of Lipids



Kil et al., 2010

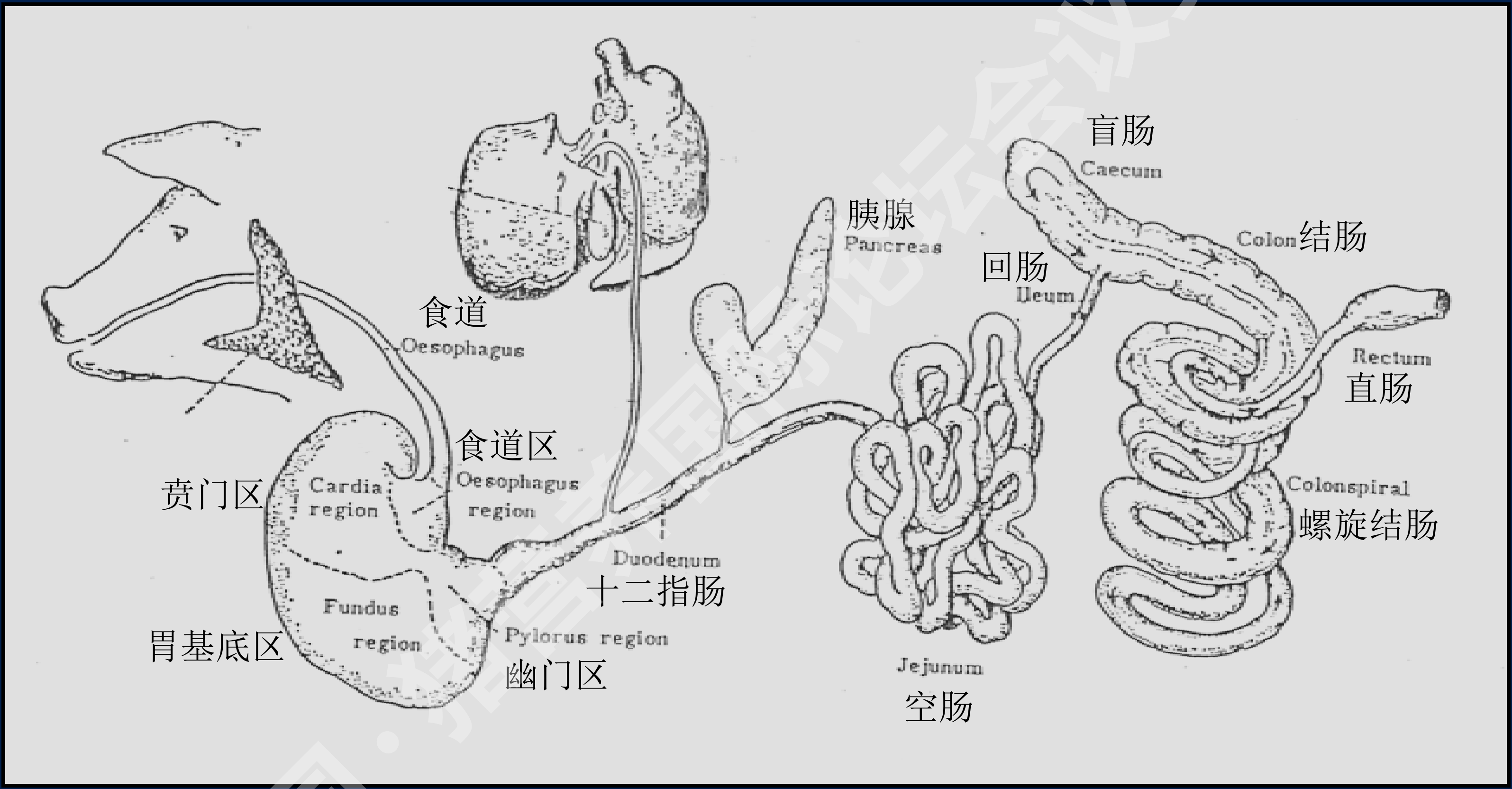
日粮脂肪浓度对脂肪标准总肠道消化率的影响

Effect of Dietary Lipid Conc. on TTTD of Lipids



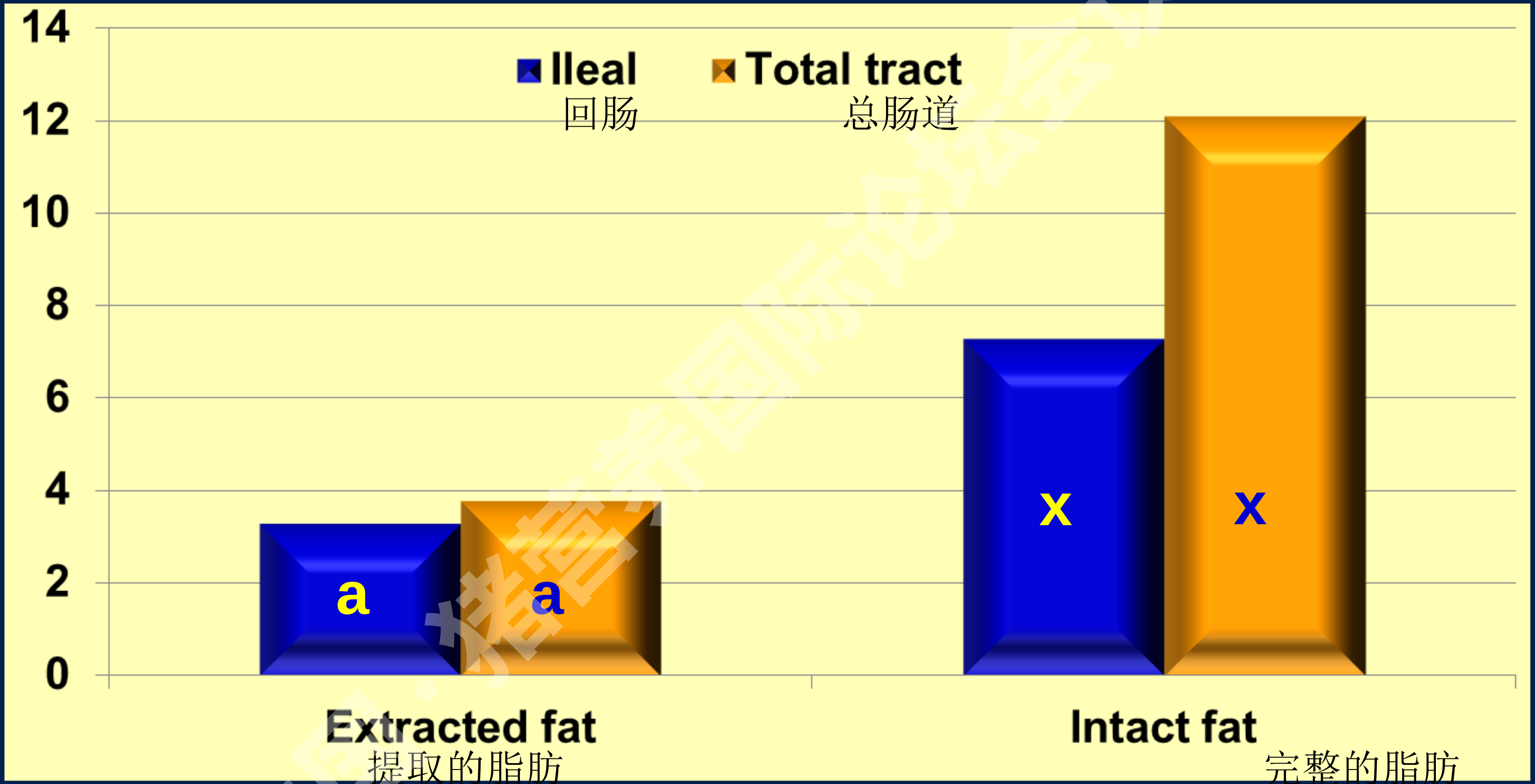
Kil et al., 2010

回肠消化率 Ileal Digestibility



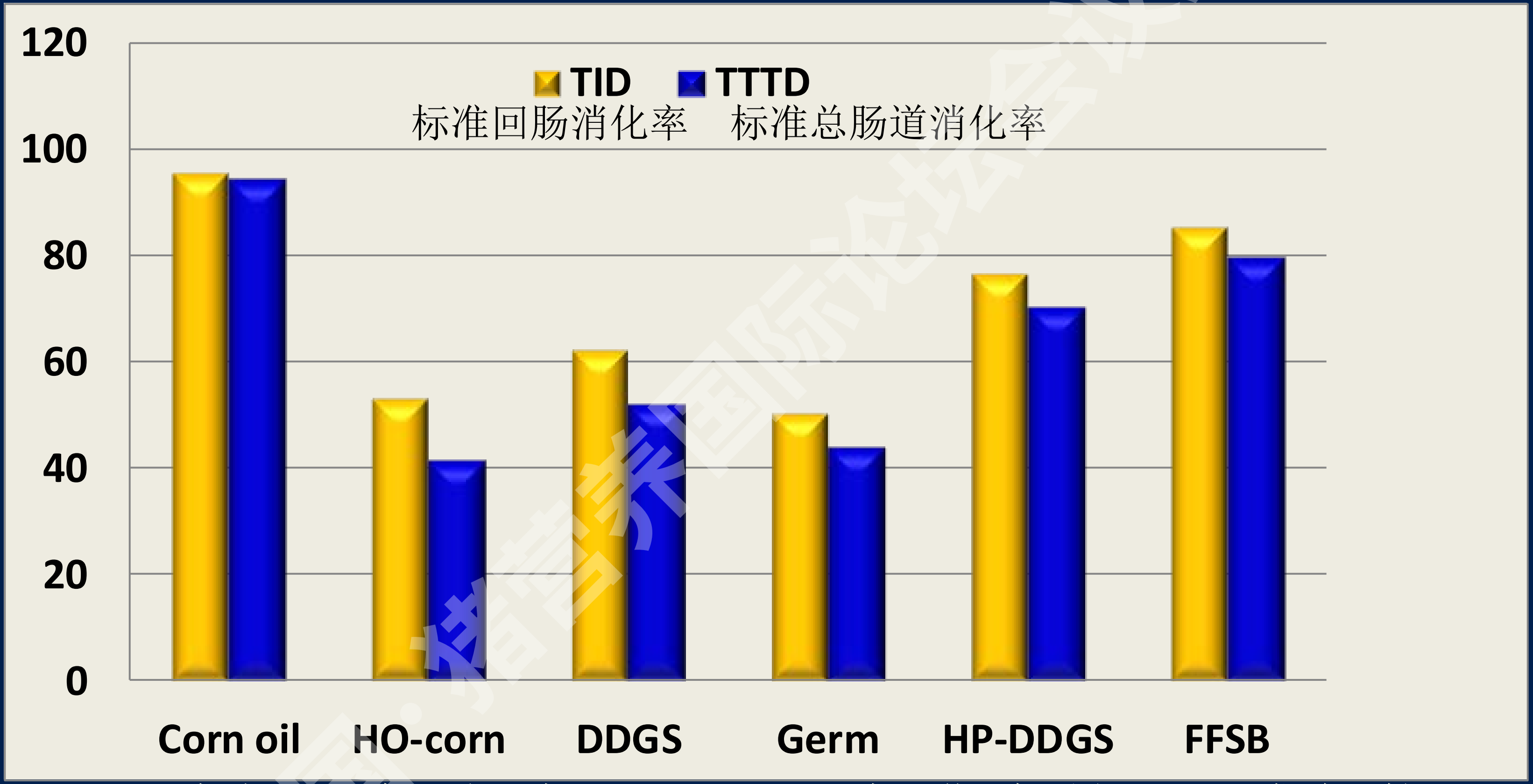
脂肪的内源损失

Endogenous loss of Fat (g/kg DMI)



Kil et al., 2010

微生物脂肪对标准总肠道消化率的影响
Effect of Microbial Fat on TTTD



玉米油 高脂肪玉米 DDGS 玉米胚芽 高蛋白DDGS 发酵豆粕

Kim et al., 2013

猪肉脂肪品质 Pork Fat Quality

日粮 Diet								
	0% DDGS				30% DDGS			
玉米胚芽 Corn germ %	0	10	20	30	0	10	20	30
脂肪 Fat, %	3.0	4.7	6.1	7.3	6.5	7.6	8.7	10.5

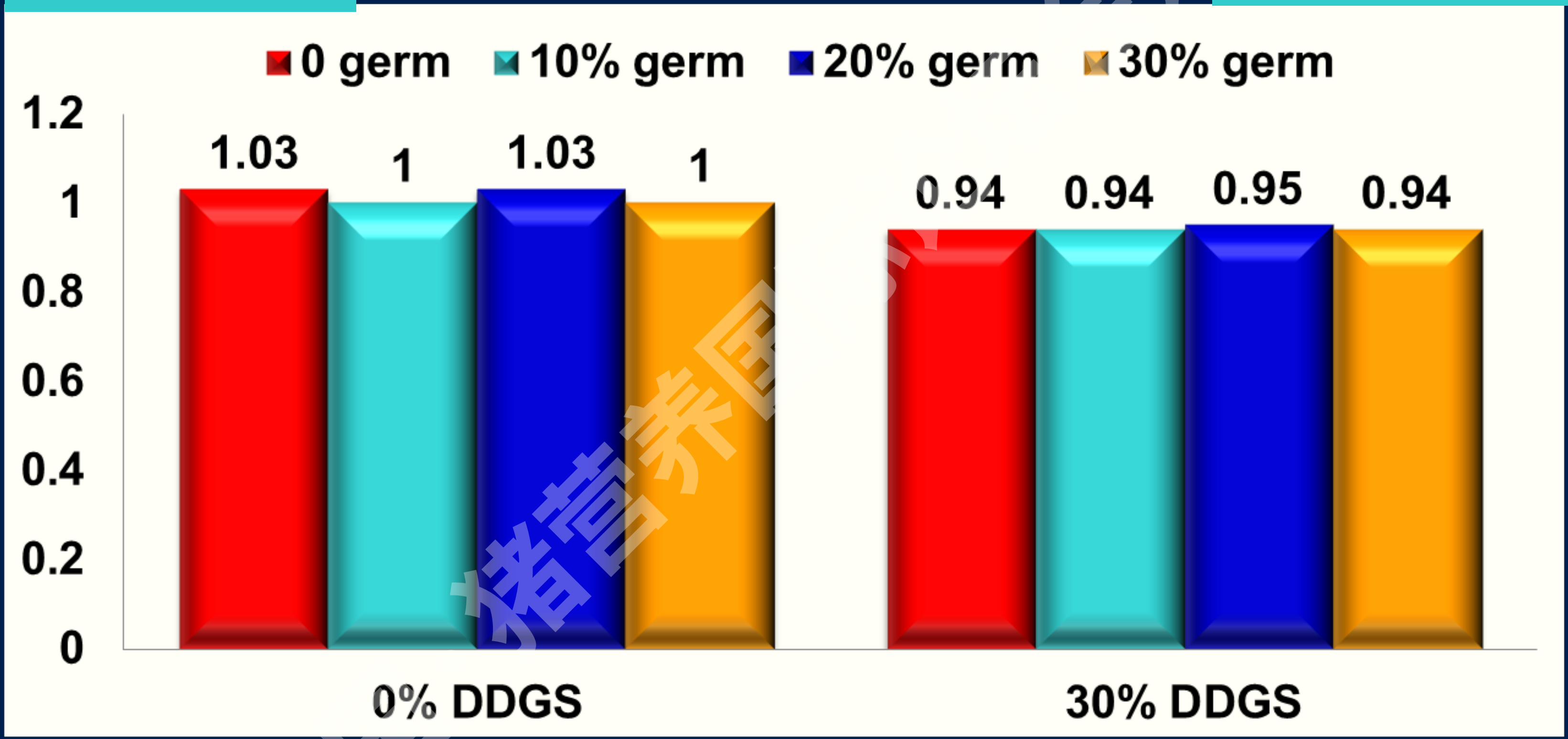
Lee et al., 2012

平均日增重

Average Gain, kg per day

胚芽间无差异
Germ: NS

DDGS间差异显著
DDGS: $P < 0.05$



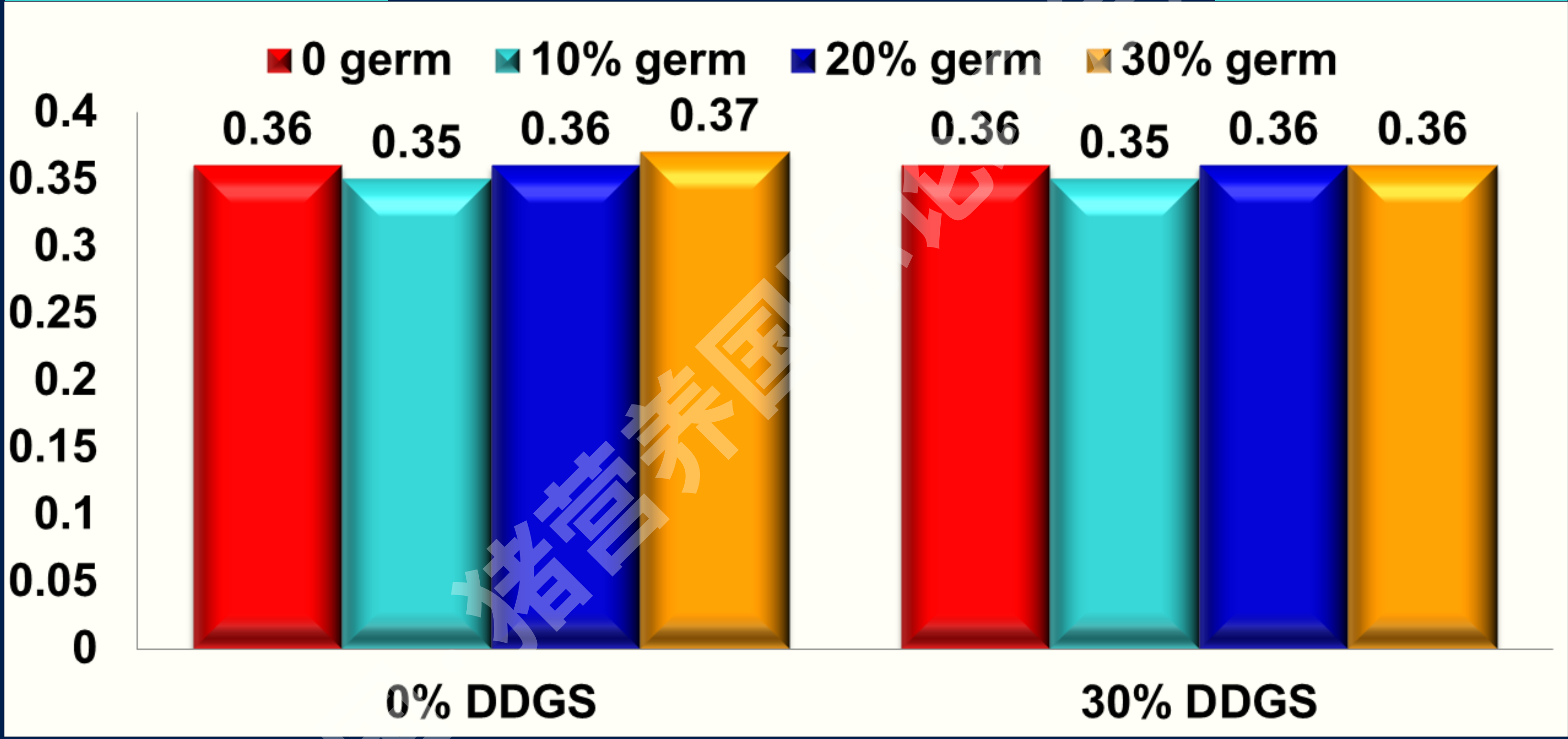
Lee et al., 2012

平均肉料比

Average Gain to Feed Ratio

Germ: NS 无差异

DDGS: NS

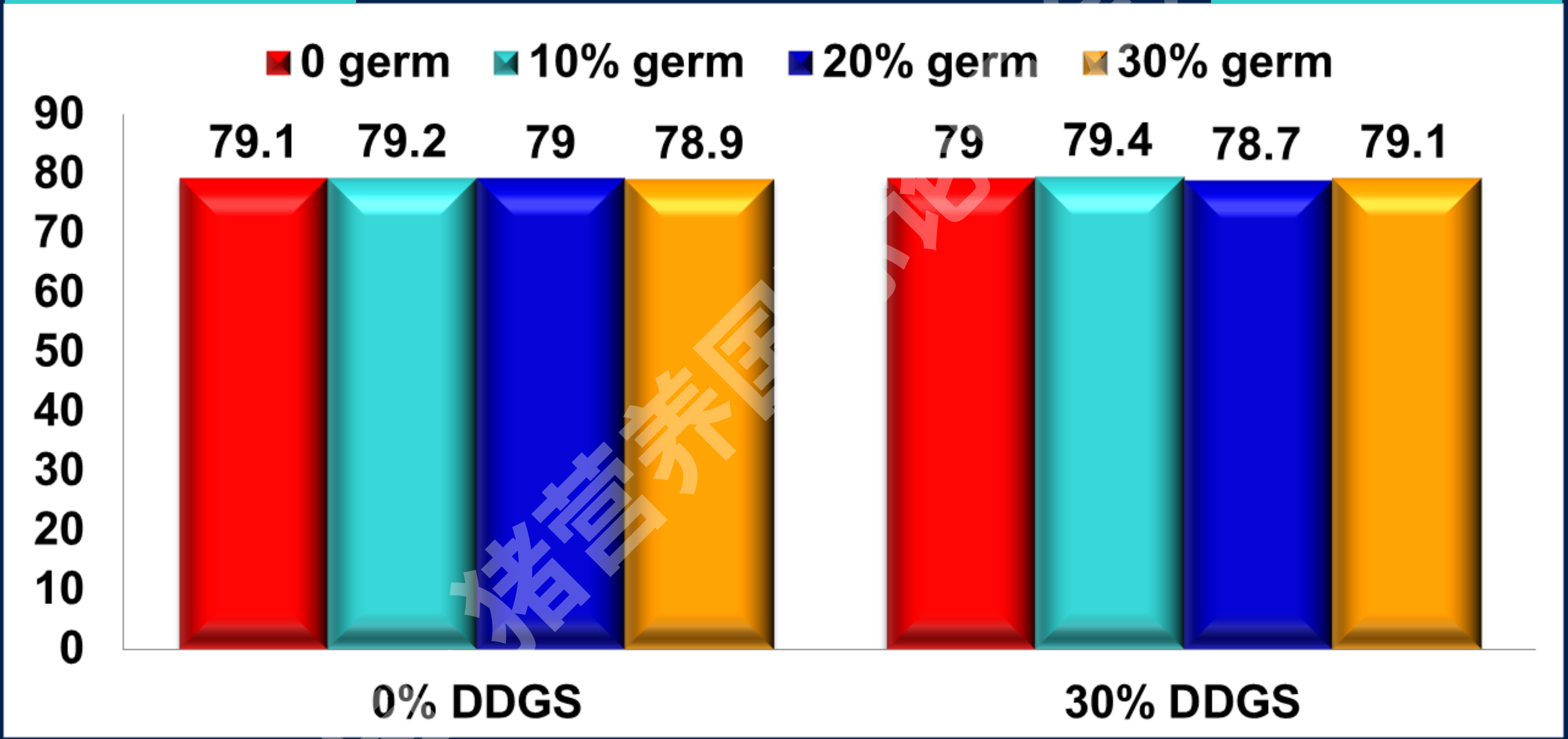


Lee et al., 2012

平均屠宰率
Average Dressing percentage

Germ: NS

DDGS: NS



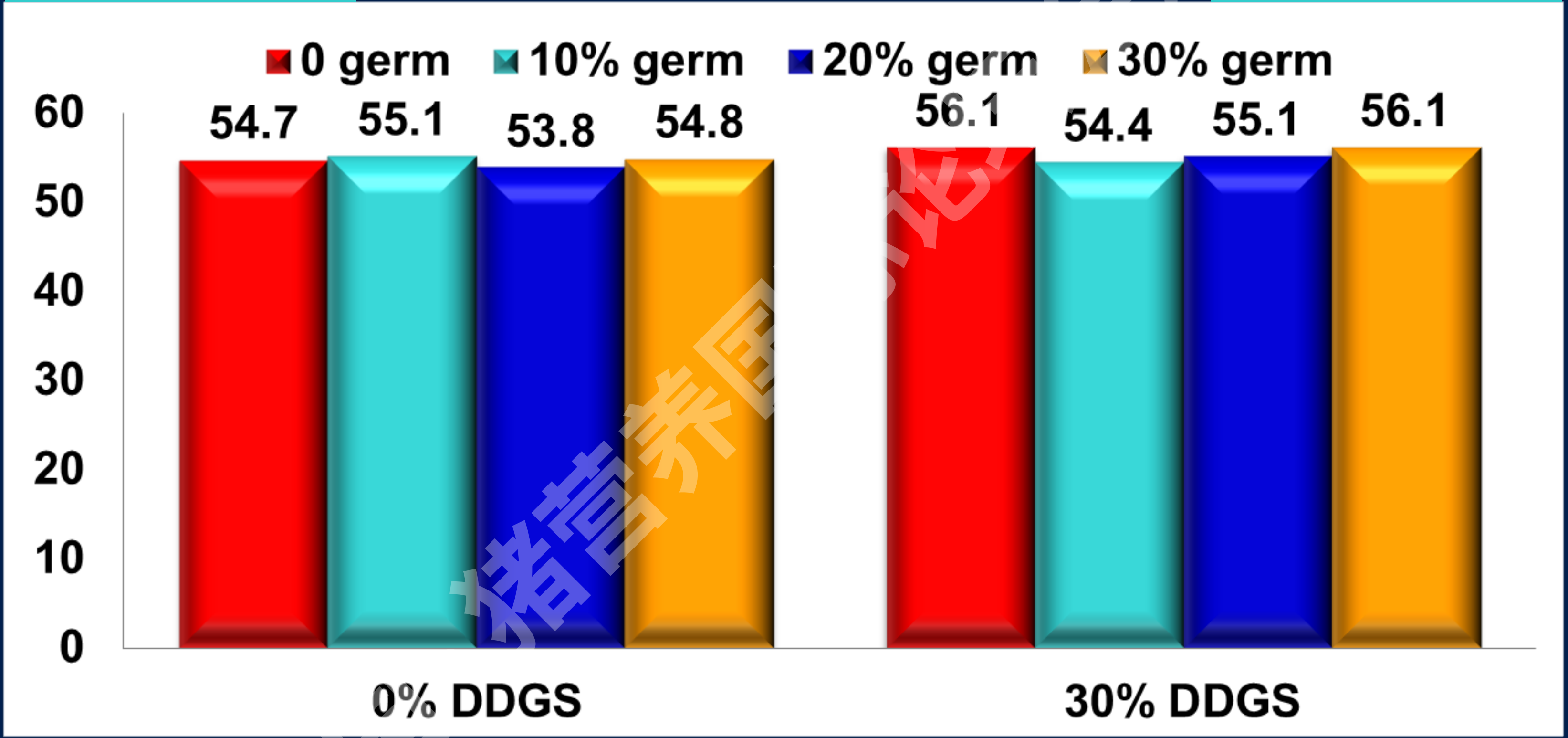
Lee et al., 2012

无脂瘦肉率

Fat Free Lean Percentage

Germ: NS

DDGS: NS



Lee et al., 2012

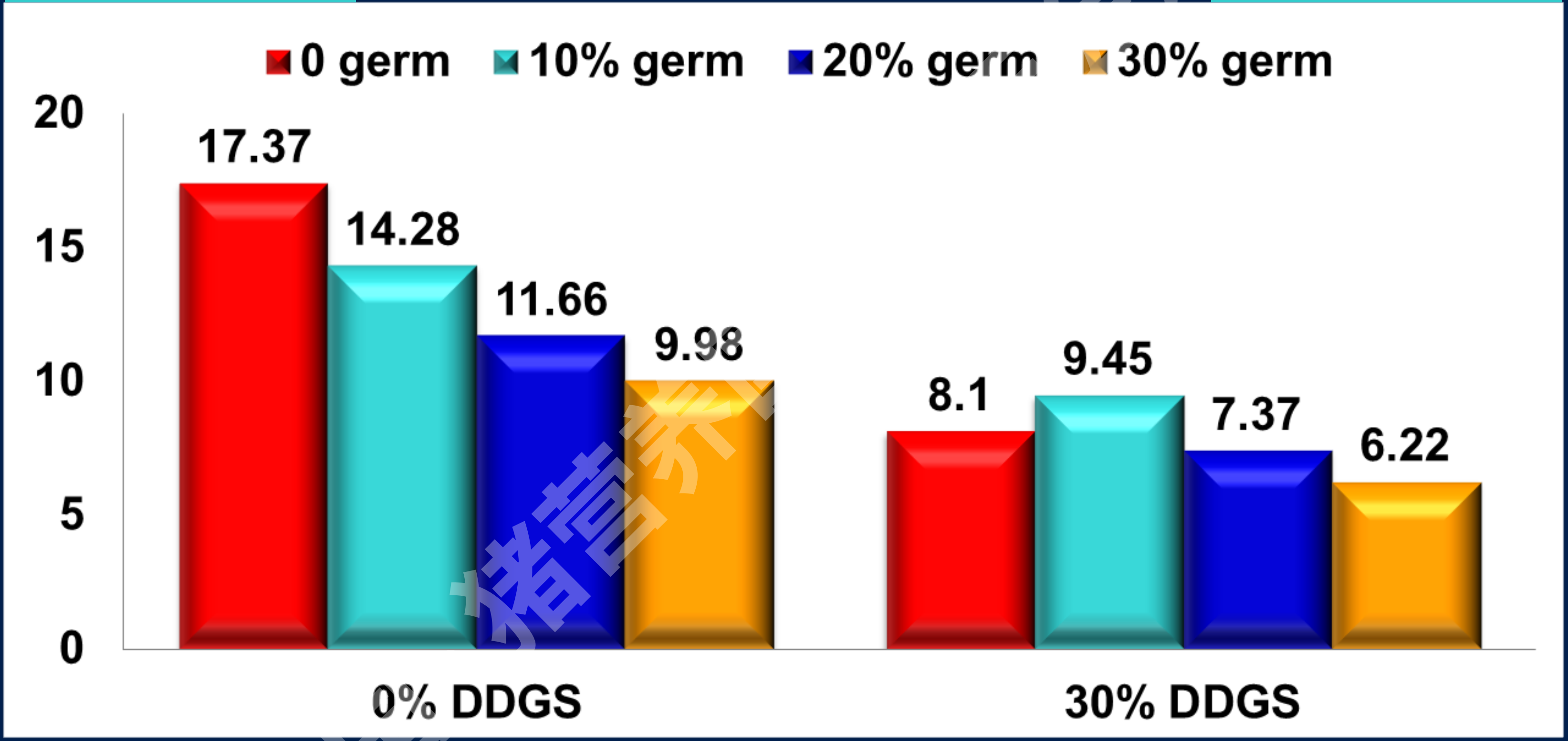
腹脂 Belly Flop

腹脂下垂距离

Belly Flop Distance, cm

Germ: $P < 0.05$

DDGS: $P < 0.05$



Lee et al., 2012

脂肪结论
Conclusions on Lipids

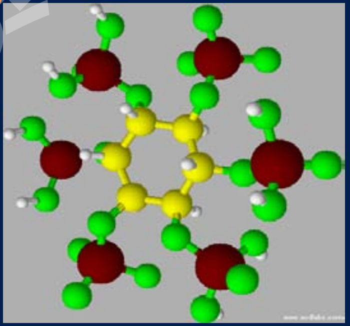
- 消化率应该测定真回肠消化率 (TID)
  Digestibility should be determined as True Ileal Digestibility (TID)
  - 一些原料脂肪的真回肠消化率低 Some ingredients have low TID of fat
- 含大量的不饱和脂肪酸会导致猪肉质变差
  Unsaturated fat in high quantities may result in poor pork fat quality

磷 Phosphorus

H. H. Stein

关于磷消化率的问题

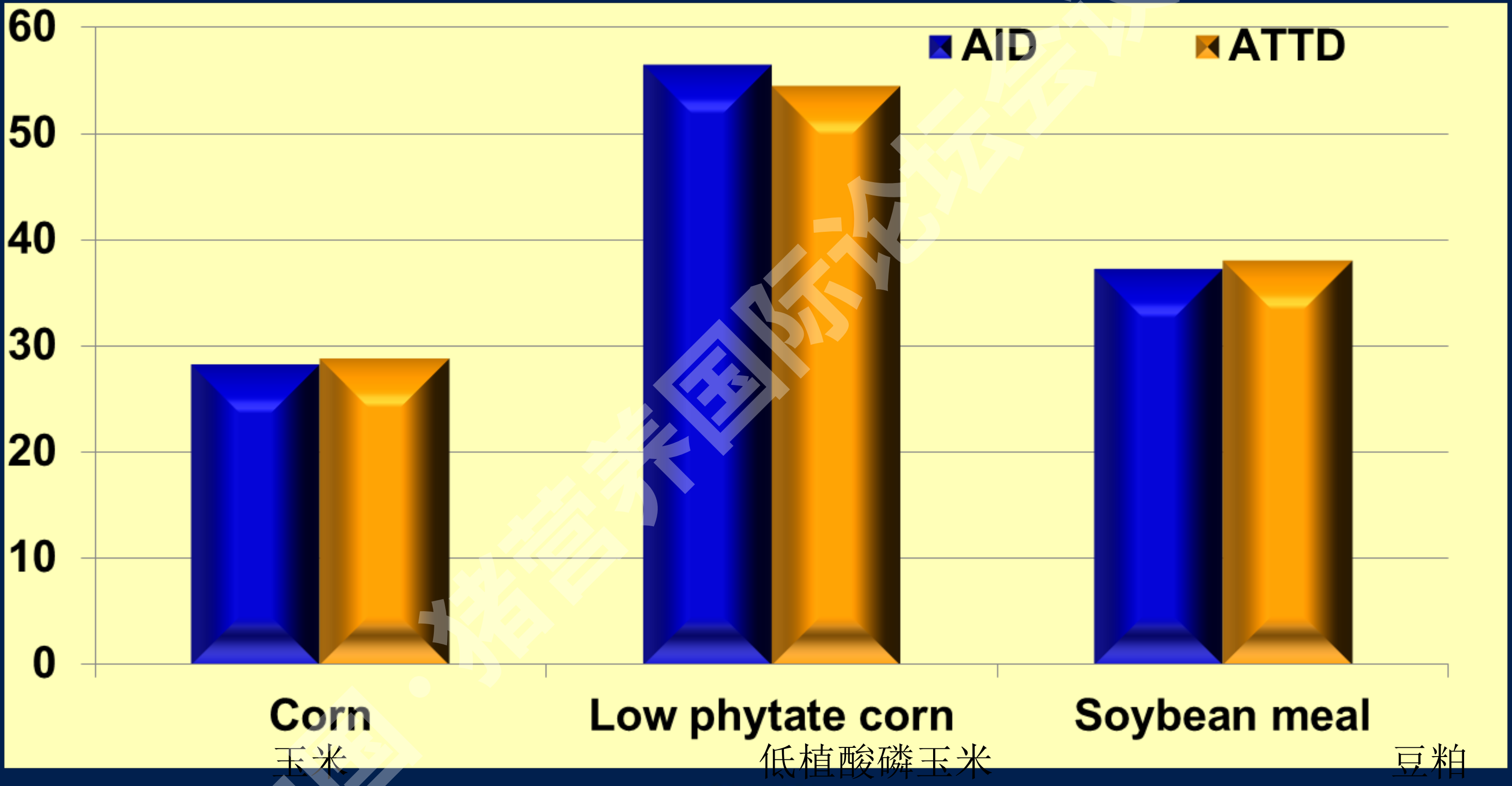
Questions on P-Digestibility



- **Ileal or total tract digestibility**
  回肠或者总肠道消化率
- **Apparent or standardized digestibility**
  表观或者标准消化率

磷的表观回肠消化率 与表观总肠道消化率

AID vs. ATTD for P



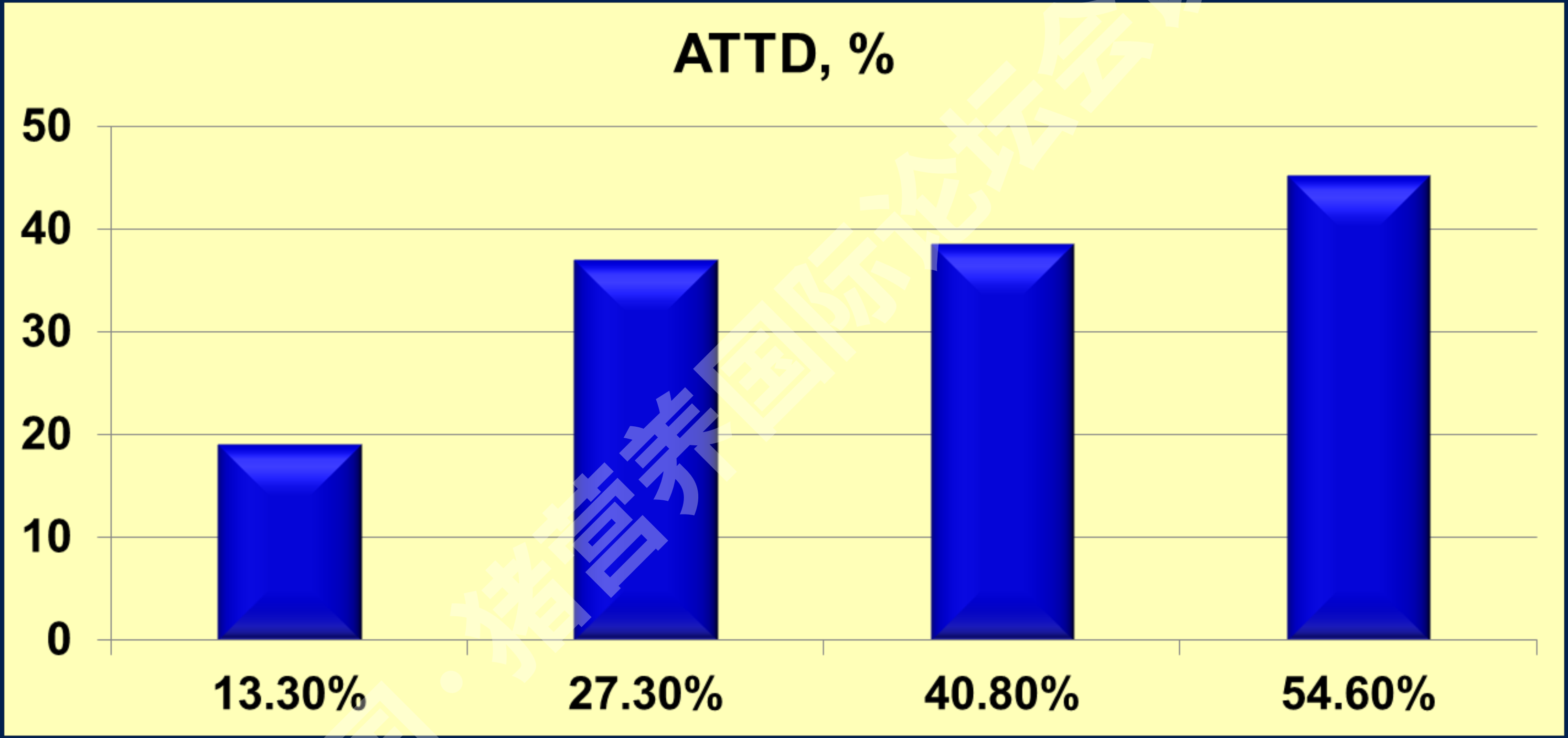
Bohlke et al., 2005

磷的表观、标准或真消化率
Apparent, Standardized, or True Digestibility of P

- **ATTD = Intake – output**
  表观总肠道消化率=摄入-输出

- **STTD = Intake – (output – EPL_{basal})**
  标准总肠道消化率=摄入– (输出–磷基础内源损失)

表观总肠道消化率值的变化
Challenges with ATTD values



Fan et al., 2001

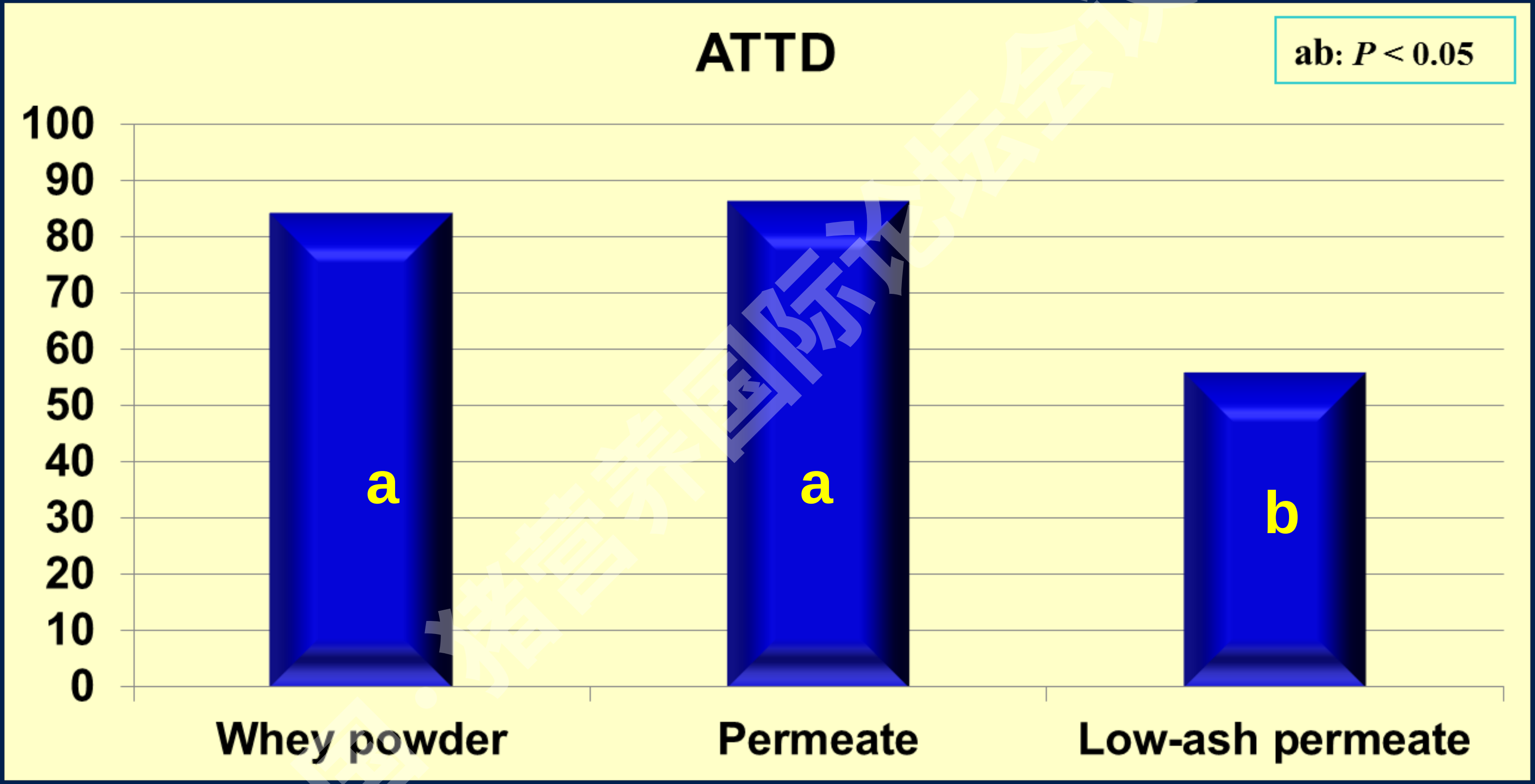
乳清粉和无蛋白乳清
Whey Powder and Permeate

Item	乳清粉 Whey powder	无蛋白乳清 Permeate	低灰分无蛋白乳清 Low-ash permeate
干物质 DM	95.8	97.7	98.4
磷 P, %	0.63	0.57	0.10

Kim et al., 2010

磷的表观总肠道消化率

ATTD of P (%)



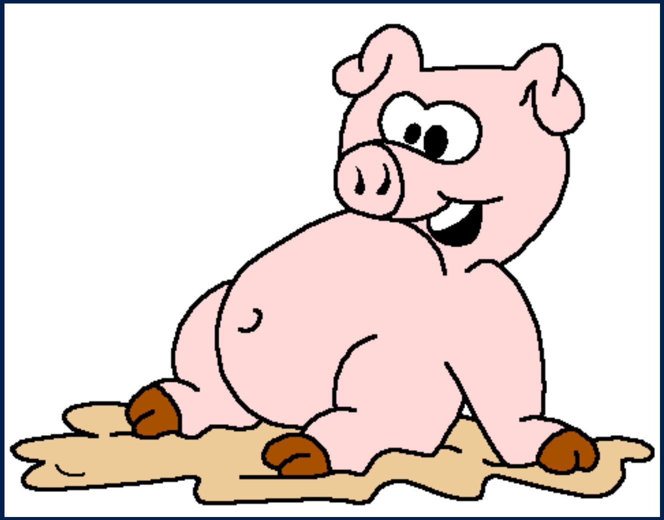
乳清粉清　　无蛋白乳清　　低灰分无蛋白乳

Kim et al., 2012

基础内源损失
Basal Endogenous Losses

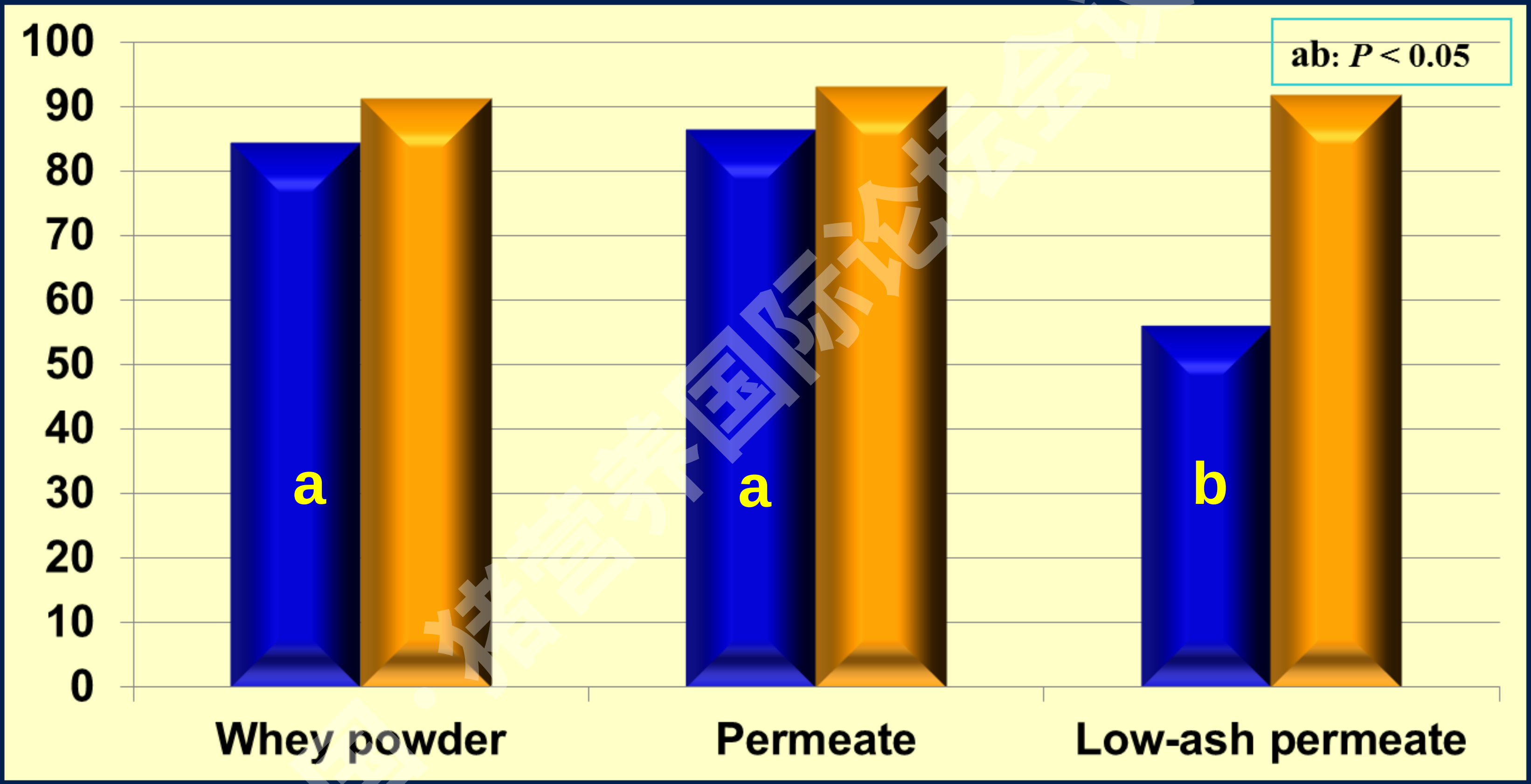
- 表观总肠道消化率校正基础内源损失后的值为标准总肠道消化率

  If ATTD values are corrected for Basal Endogenous losses, values for STTD are calculated



磷的表观总肠道消化率和标准总肠道消化率

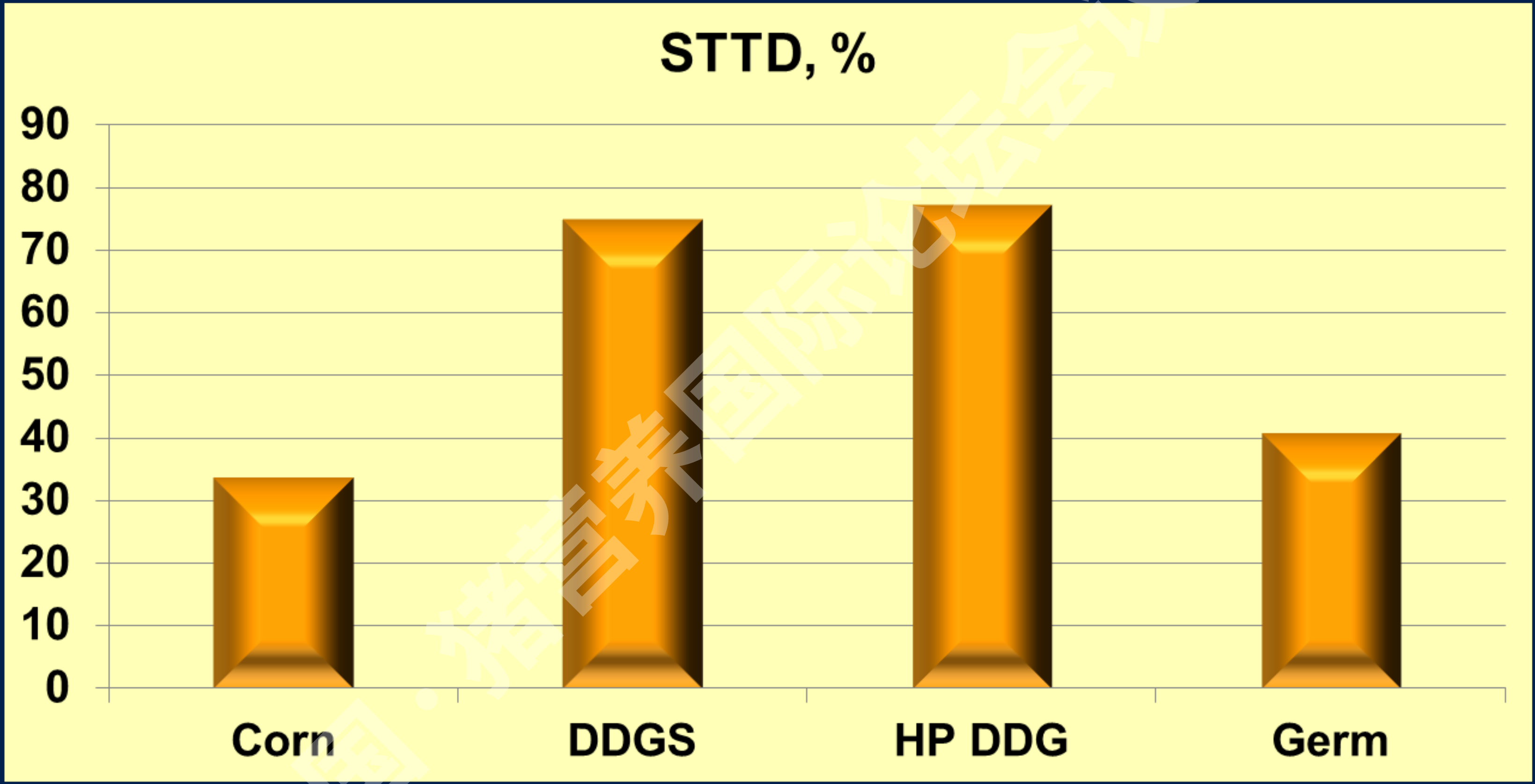
ATTD and STTD of P (%)



乳清粉
无蛋白乳清
低灰分无蛋白
乳清

Kim et al., 2012

玉米副产物中磷的标准总肠道消化率
STTD of P in corn co-products

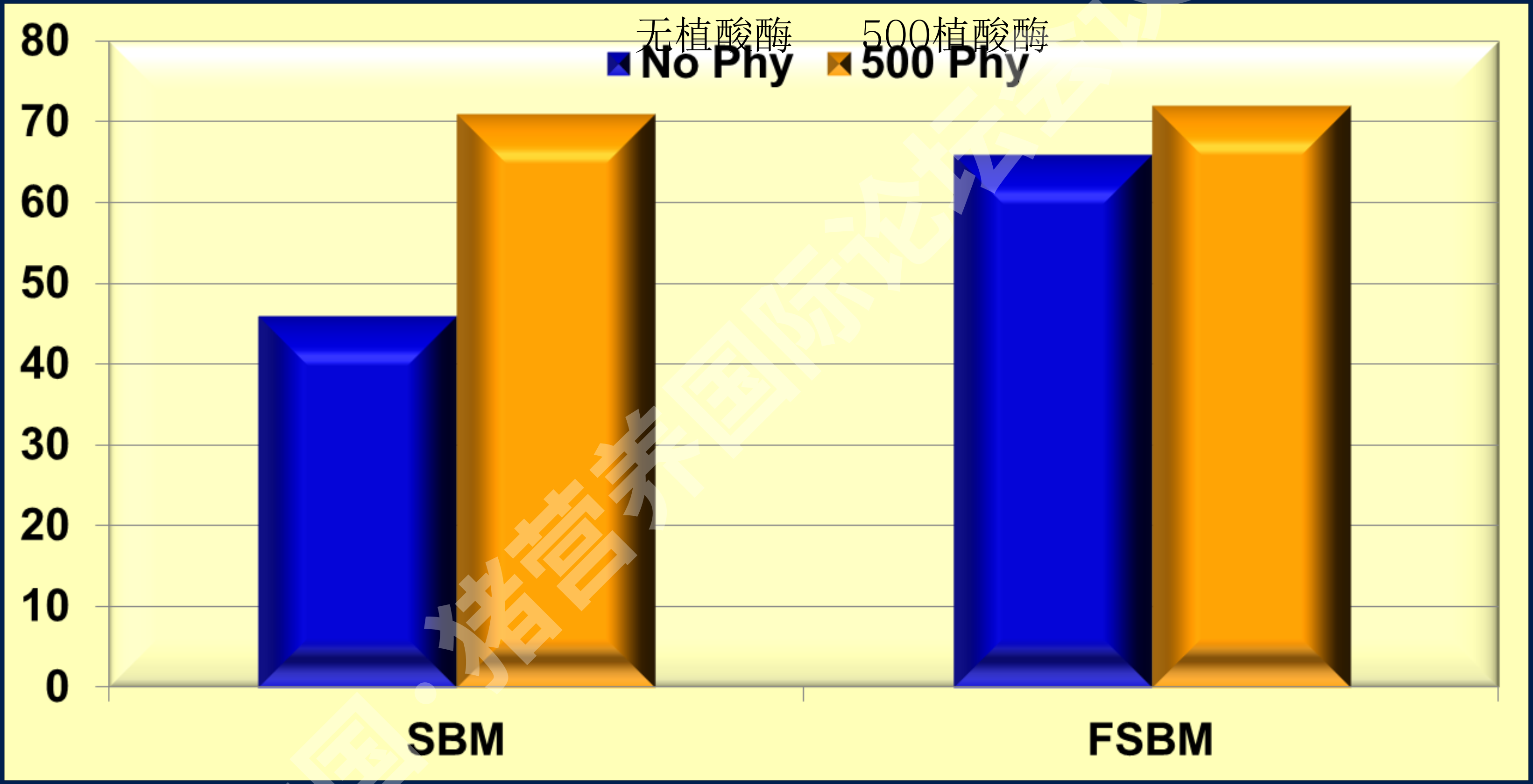


玉米　DDGS　高蛋白DDG　玉米胚芽

Almeida and Stein, 2012

发酵豆粕中磷的标准总肠道消化率

STTD of P in Fermented SBM



豆粕

发酵

豆粕

Rojas and Stein, 2012

关于磷的结论
Conclusions on Phosphorus

- No differences in ileal and total tract digestibility of P

  磷的回肠和总肠道消化率无差异

- Diets should be formulated based on values for STTD of P

  以磷的标准总肠道消化率为基础配制日粮

- Fermentation increases STTD of P

  发酵增加磷的标准总肠道消化率

碳水化合物
Carbohydrates

H. H. Stein

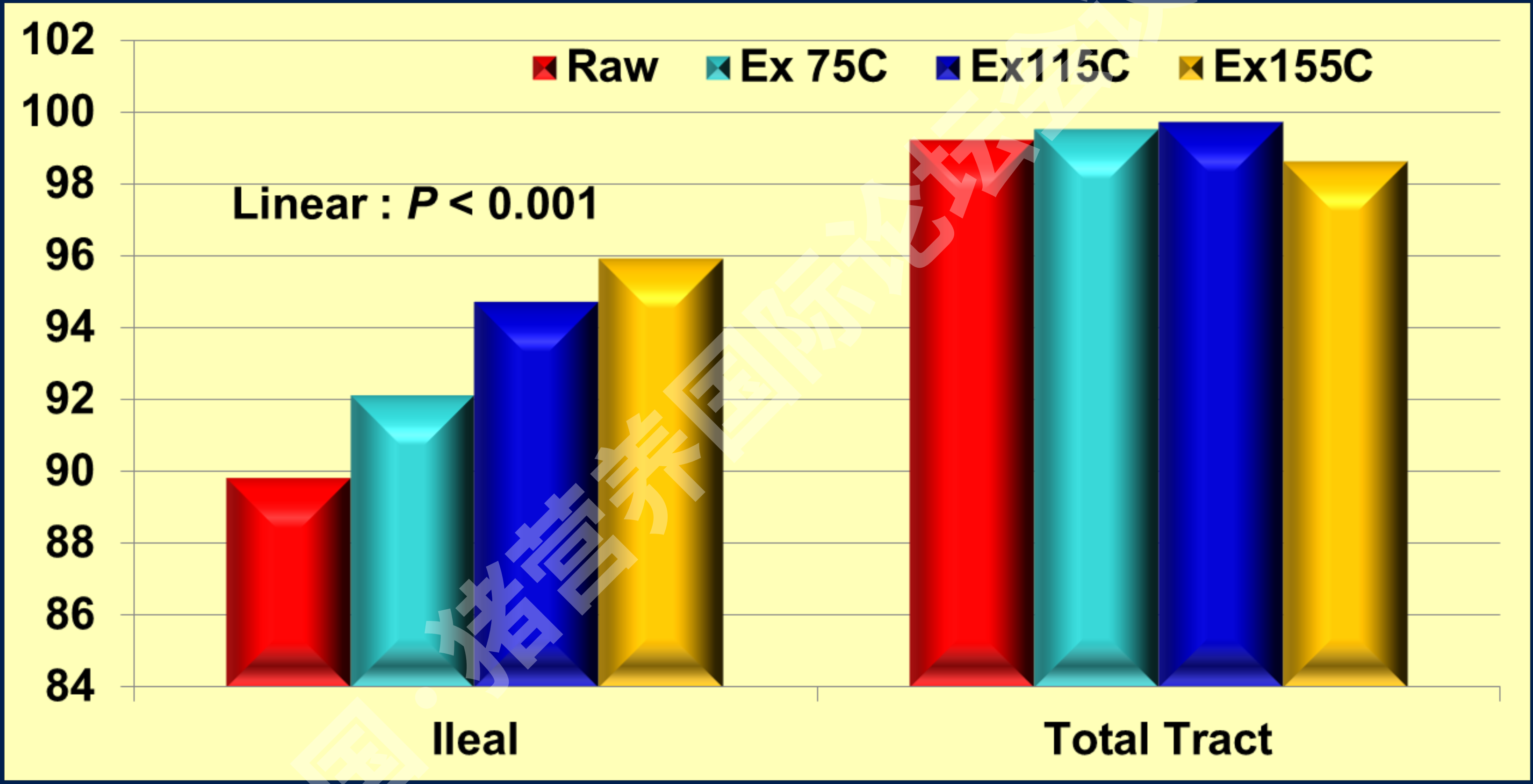
碳水化合物 Carbohydrates

- 单糖 Monosaccharides
- 双糖 Disaccharides
- 寡糖 Oligosaccharides
- 多糖 Polysaccharides
  - 淀粉 Starch
  - 非淀粉多糖+木质素 NSP + lignin

碳水化合物 Carbohydrates

- 单糖 Monosaccharides
- 双糖 Disaccharides
- 寡糖 Oligosaccharides
- 多糖 Polysaccharides
  - 淀粉 Starch
  - 非淀粉多糖+木质素NSP + lignin

野豌豆的淀粉消化率
Starch Digestibility in Field Peas

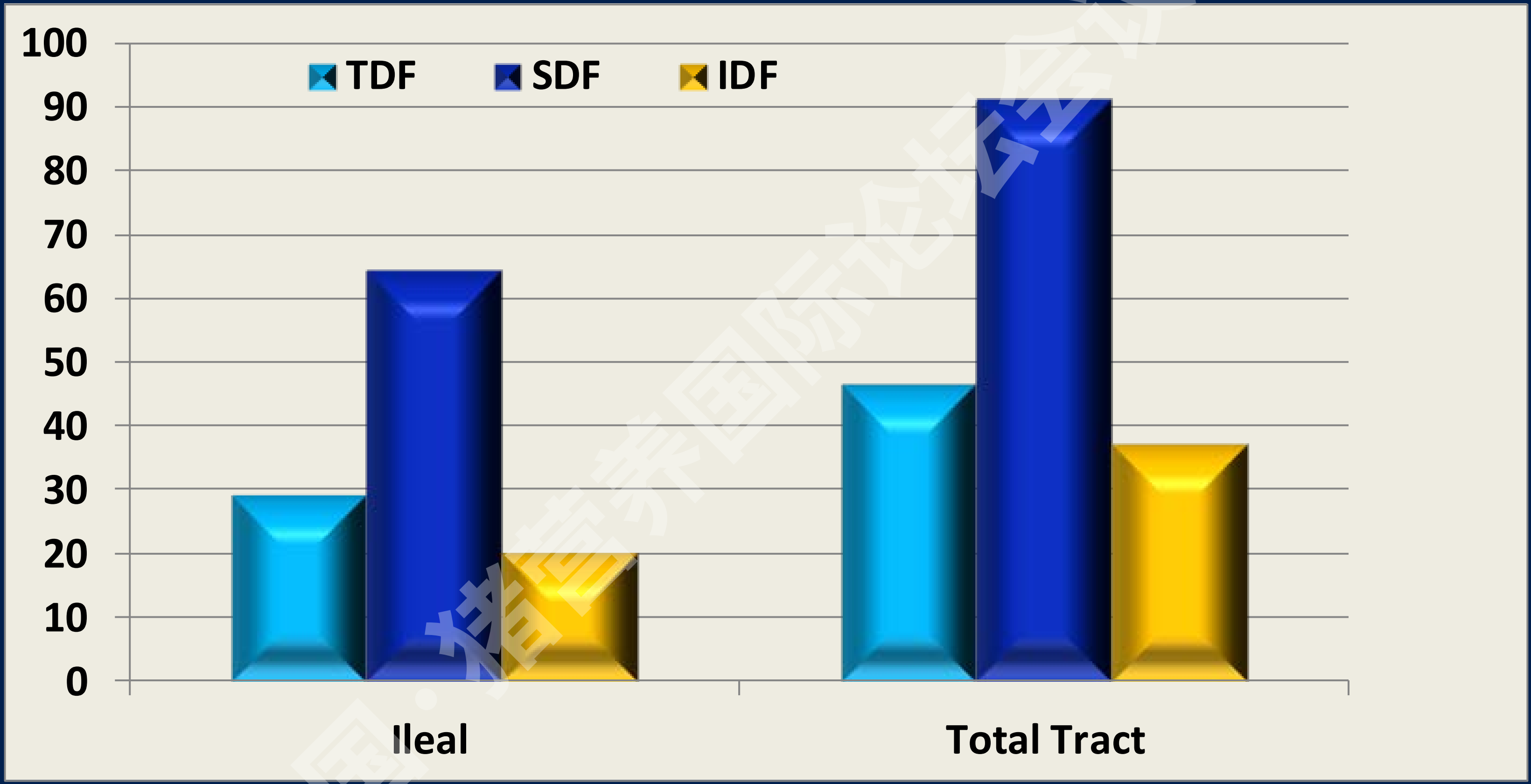


回肠　　总肠道

Stein and Bohlke, 2007

DDGS中纤维发酵

Fermentation of Fiber in DDGS, %



回肠

总肠道

Urriola et al., 2010

碳水化合物小结

Summary on Carbohydrates

- 假设糖可以100%消化
- Sugars assumed to be 100% digestible in small intestine
- 淀粉测定回肠消化率
- Starch measured as ilial digestibility
- 纤维测定表观总肠道消化率
- Fiber measured as ATTD of fiber

总结
Overall Conclusions

回肠或总肠道消化率
Ileal or total tract digestibility

回肠消化率：氨基酸、淀粉、糖和脂肪

Ileal digestibility for AA, starch, sugars, and fat

总肠道消化率：磷、纤维和能量 Total tract digestibility for P, fiber, and energy

表观、真、标准消化率
Apparent, true or standardized

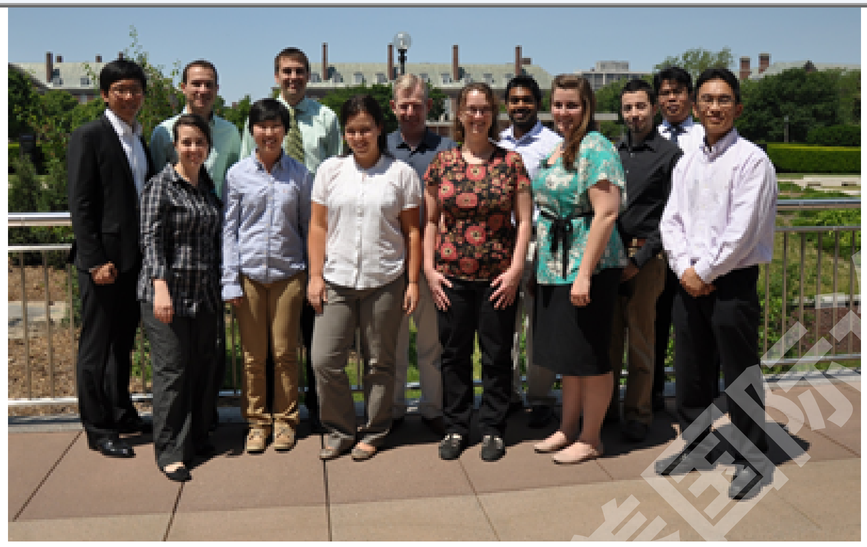
标准消化率： 氨基酸，磷
Standardized digestibility: AA, P

真消化率：脂肪
True digestibility: Fat

表观消化率：淀粉、糖和纤维
Apparent digestibility: starch, sugar, fiber

nutrition.ansci.illinois.edu

nutrition.ansci.illinois.edu



Welcome

Our mission

Our vision

In the Stein Monogastric Nutrition Laboratory, Dr. Hans Stein and his graduate students and employees conduct research with monogastric animals to evaluate feed ingredients, nutrient requirements, and feeding strategies. A number of research techniques are used in the laboratory and in particular, Dr. Stein's group has expertise in the area of measuring ileal and total tract energy and nutrient digestibility, and in measuring energy and nutrient balances.

Social networks

Find us on:

Featured items

Latest podcast: Energy value of low-fat and de-oiled DDGS to pigs

Finding ways to feed pigs for less

New student profile: Jessica Lowell

Stein Nutrition Newsletter

Email: *

Subscribe

Acknowledgement