

Grain Sorghum: Current Considerations for Use in Poultry and Swine Production

高粱：目前在禽料和猪料中的应用探讨

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Grain Sorghum in a Kansas field

堪萨斯田地中种植的高粱



Kansas Grain Sorghum Mountain Before Storage

堪萨斯入仓前的高粱谷堆



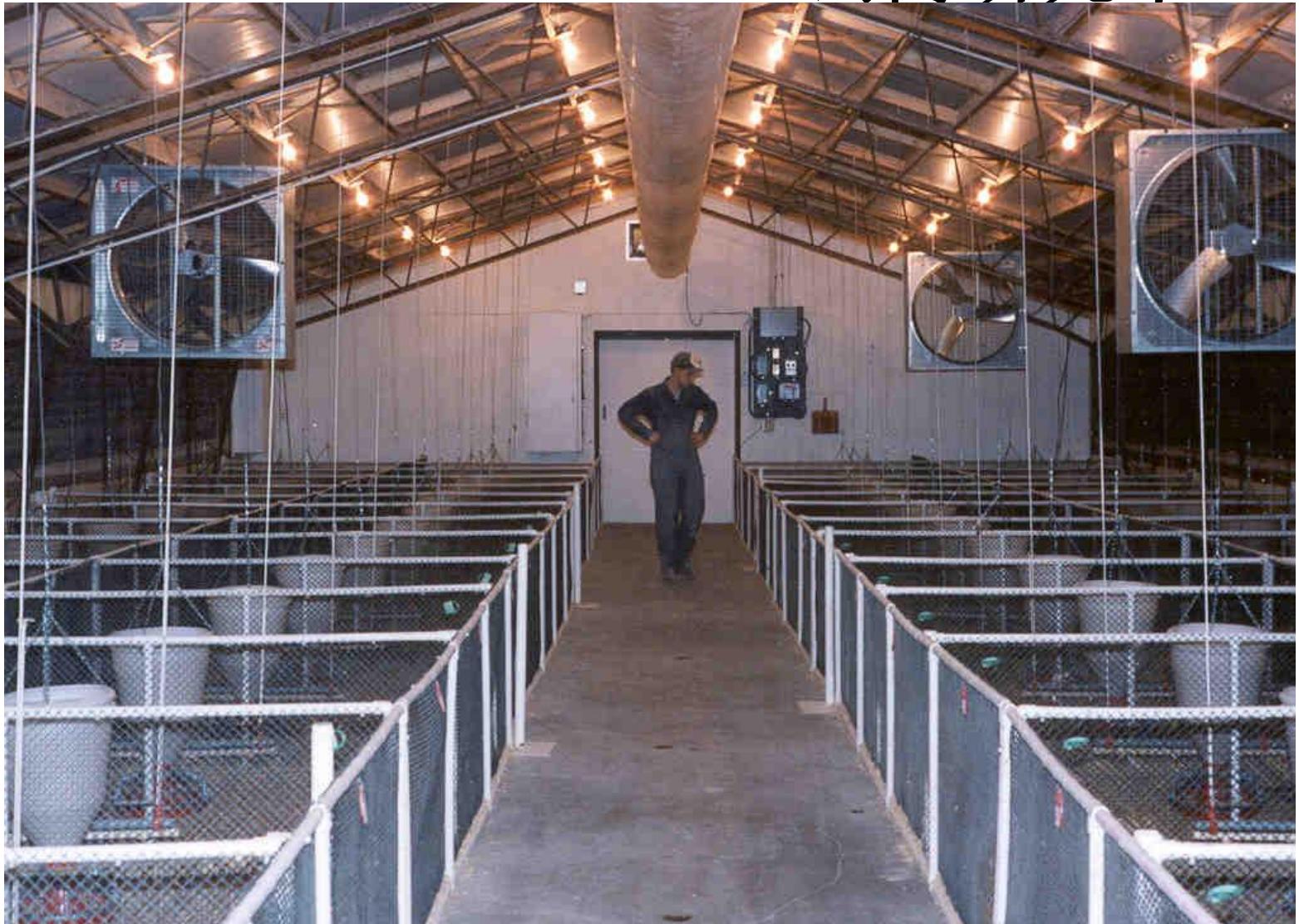
Feed Technology Center

饲料技术中心



Poultry Research Center

饲禽研究中心



Swine Research Center

猪研究中心



Grain Sorghum

高粱

- **Hardy crop with a relatively low requirement for rainfall and/or irrigation**
耐旱作物，对降水量和灌溉水量的需求相对较低
- **Is an important human foodstuff in drought-prone regions**
是偏干旱地区人们的重要食物来源
- **Renewed interest in sorghum grain as a foodstuff for humans and feedstuff for animals and for industrial applications such as ethanol production**
对高粱各种用途的兴趣再度升温，包括作为人类食品、动物饲料，以及燃料乙醇生产等工业用途等

Sorghum in Animal Feeds

高粱作为动物饲料



- **Sorghum can be formulated on a least-cost basis into broiler, layer, duck and swine feed**

高粱可以用于最低成本配方的肉鸡、蛋鸡、鸭和猪饲料

Sorghum can replace up to 100% corn in poultry and swine feed

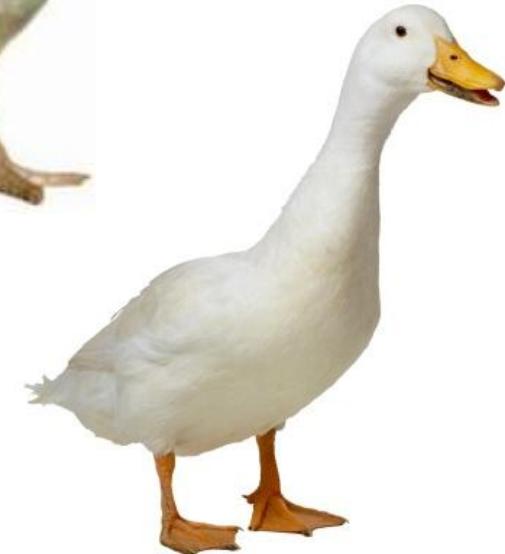
高粱可以在禽料和猪料中
100%替代玉米

- **Non GMO 非转基因**

Some Considerations for Using Sorghum in Feeds

高粱饲料用途的一些考量

- **Nutrients in sorghum**
高粱中的营养成分
- **Processing requirements**
加工要求
- **Formulation strategies**
配方策略



Nutrient Advantages of Sorghum

高粱的营养优势



- Good source of feed energy
好的饲料能量来源
- Up to 10% more protein than corn 比玉米的蛋白质含量高10%
- Up to 50% more available phosphorus compared to corn 比玉米的可用磷含量高50%
 - P can be expensive
磷添加剂成本高
 - Environmental issues
环境问题

Nutrient composition of sorghum 高粱的营养组成

	<u>Sorghum</u> 高粱	<u>Corn</u> 玉米	<u>Nutrient Difference</u> 营养差异
Dry matter, % 干物质	89.0	89.0	0
Energy, kcal/kg 能量			
Digestible 消化能	3,380	3,525	-4%
Metabolizable 代谢能	3,340	3,420	-2% ←
Crude protein, % 粗蛋白	9.2	8.3	+11% ←
Calcium, % 钙	0.03	0.03	0
Phosphorus, % 磷	0.29	0.28	+4%
Available P, % 可用磷	0.058	0.039	+49% ←
Crude fat, % 粗脂肪	2.9	3.9	-26% ←
Linoleic acid, % 亚油酸	1.13	1.92	-41%
Crude fiber, % 粗纤维	2.4	2.2	+9%
NDF, % 中性洗涤纤维	9.4	10.4	-10%
ADF, % 酸性洗涤纤维	3.8	2.6	+46%

Corn vs Sorghum as % of Poultry NRC, 0-3wk^a

玉米和高粱的营养成分与NRC禽类营养需求比较

Nutrient 营养成分	Requirement, % 需求占比	Corn 玉米	Sorghum 高粱
Protein 蛋白	23.0	38	41
Arginine 精氨酸	1.25	31	29
Gly + Ser 甘氨酸+丝氨酸	1.25	57	58
Histidine 组氨酸	0.35	67	65
Isoleucine 异亮氨酸	0.80	37	45
Leucine 亮氨酸	1.20	85	98
Lysine 赖氨酸	1.10	24	20
Met + Cys 蛋氨酸+半胱氨酸	0.90	41	38
Phe + Tyr 苯丙氨酸+酪氨酸	1.34	52	62
Proline 脯氨酸	0.60	?	?
Threonine 苏氨酸	0.80	37	37
Tryptophan 色氨酸	0.20	31	41
Valine 缬氨酸	0.90	46	50

^aAdapted from NRC (1994). All values on a 90% DM basis.

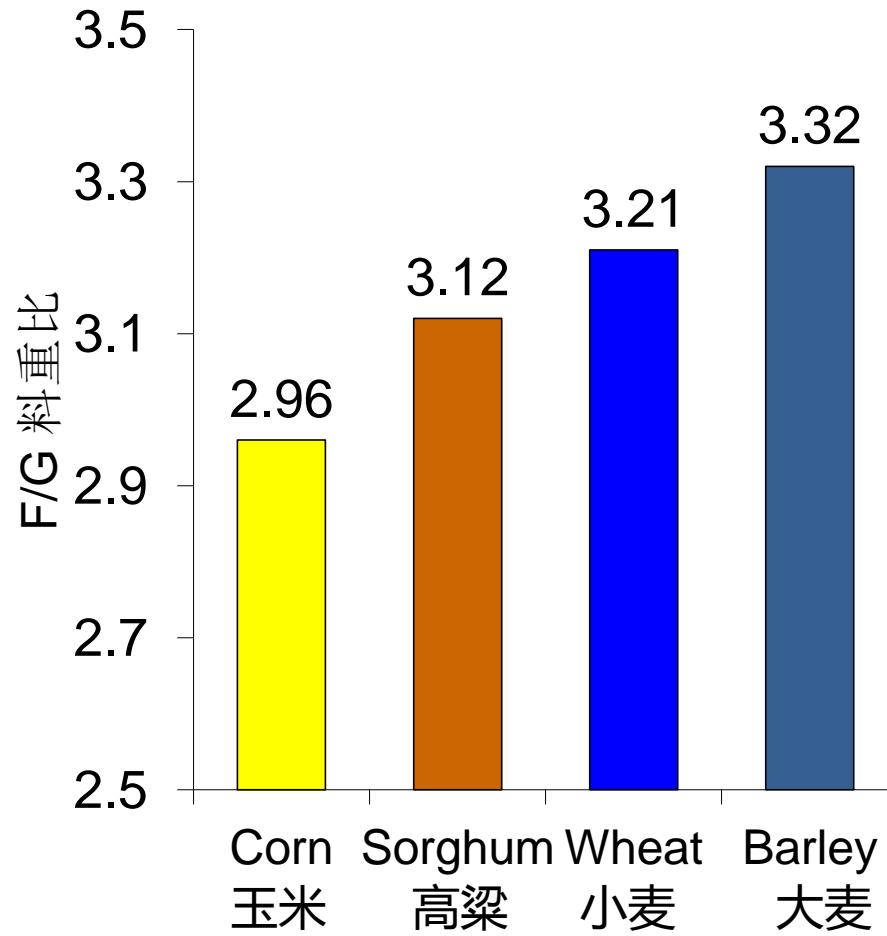
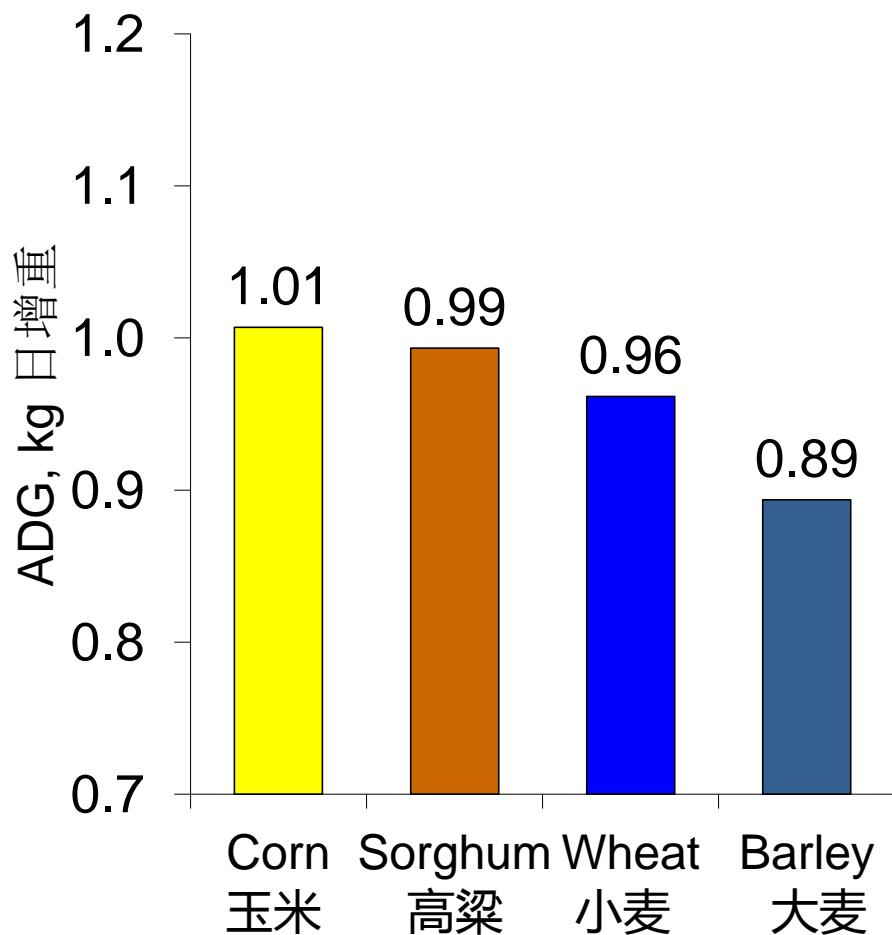
Metabolizable Energy of Sorghum Compared to Corn in White Pekin Ducks

高粱和玉米在北京白鸭日粮中的代谢能比较

	AME 表观代谢能 (kcal/kg)	TME 真代谢能 (kcal/kg)
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Corn 玉米	3,210	3,600
Sorghum 高粱	3,363	3,802

Comparing sorghum versus other grains on Pig Performance 高粱与其它谷物的猪性能比较



Broiler Growth Performance

肉鸡生长性能

Parameter 参数	Corn 玉米	Sorghum,1 高粱1	Sorghum,2 高粱2	Sorghum,3 高粱3
0-21d BWG, g 0-21天增重	796	815	799	802
0-21d Feed:gain, g:g 0-21天料重比	1.40	1.36	1.45	1.30
21-42d BWG, g 21-42天增重	1674	1663	1702	1692
21-42d Feed:gain, g:g 21-42天料重比	1.84 ^a	1.86 ^{ab}	1.87 ^{ab}	1.90 ^b
0-42d BWG, g 0-42天增重	2470	2477	2501	2495
0-42d Feed:gain, g:g 0-42天料重比	1.69	1.69	1.74	1.70

^{a,b} Values with different superscripts are significantly different ($P<0.05$)

Elkin *et al*, 2002

Broiler Growth Performance

肉鸡生长性能

Parameter 参数	Corn 玉米	Sorghum,1 高粱1	Sorghum,2 高粱2	Sorghum,3 高粱3
0-7d BWG增重, g	100	96	98	96
0-7d Gain:feed, g:g 0-7天料重比	0.835	0.827	0.845	0.833
7-14d BWG增重, g	246	251	250	263
7-14d Gain:feed, g:g 7-14天料重比	0.775	0.812	0.796	0.807
14-21d BWG增重, g	365	382	380	376
14-21d Gain:feed, g:g 14-21天料重比	0.720	0.733	0.730	0.703
0-21d BWG增重, g	711	729	728	736
0-21d Gain:feed, g:g 0-21天料重比	0.740	0.770	0.767	0.753

Nyannor *et al*, 2007

No Tannins in US Grown Grain Sorghum

美国种植的高粱不含单宁

Old varieties of sorghum can contain tannin which inhibits animal growth – to prevent wild bird damage in fields.

传统高粱品种含单宁，抑制动物生长 – 以减少野生鸟类对高粱田的损害

US farmers are prohibited from using sorghum seed from varieties of sorghum that contain tannin
美国不允许农民种植含有单宁的高粱品种

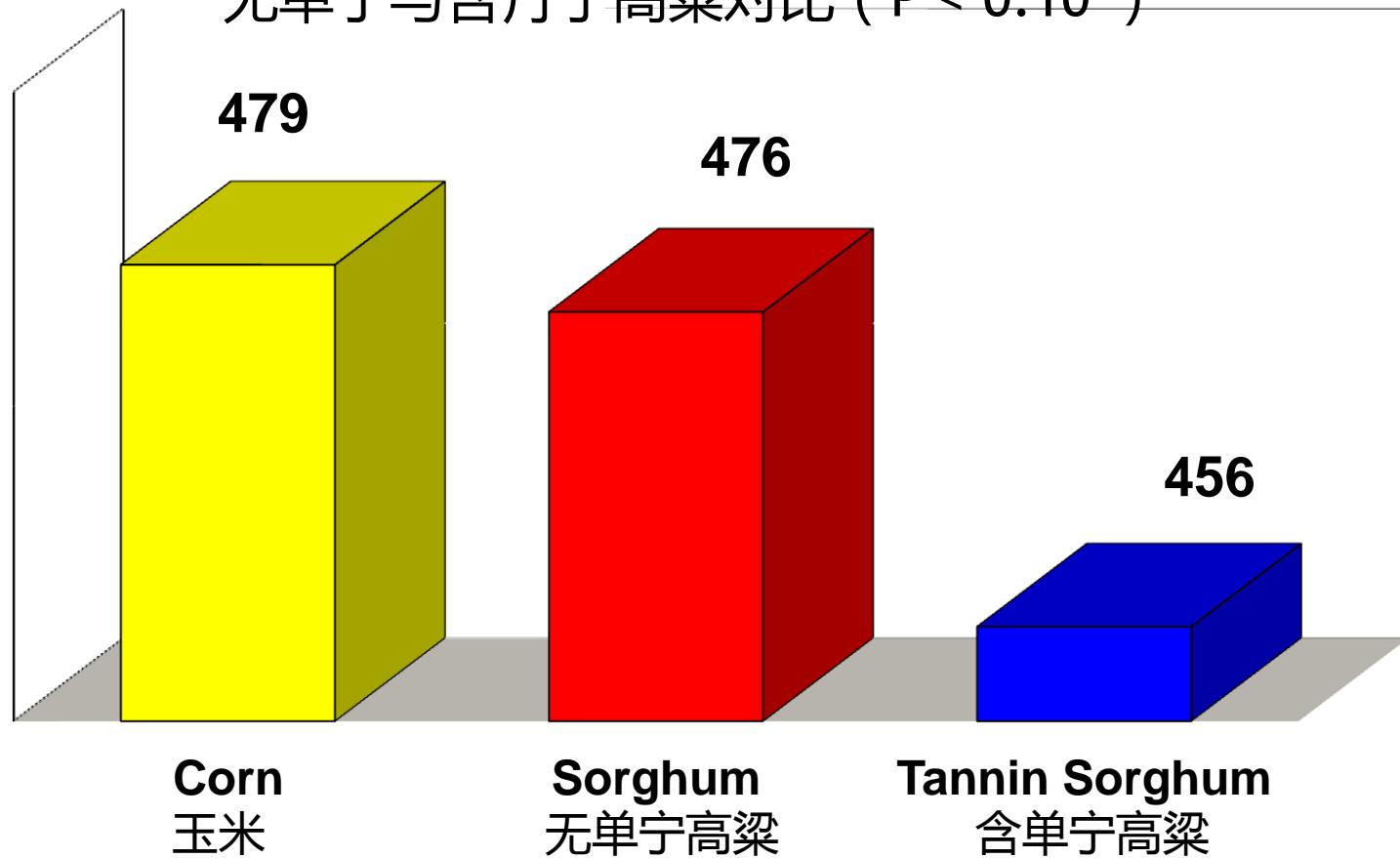
Sorghum is grown in dry regions, has a round seed coat so that it will not break
高粱种植在干旱地区，种皮为球形，保证种子不被破坏

Tannins & BW Gain in Broiler Chicks

单宁对肉鸡增重的影响

Sorg vs Tannin Sorg ($P < 0.10$)

无单宁与含丹宁高粱对比 ($P < 0.10$)

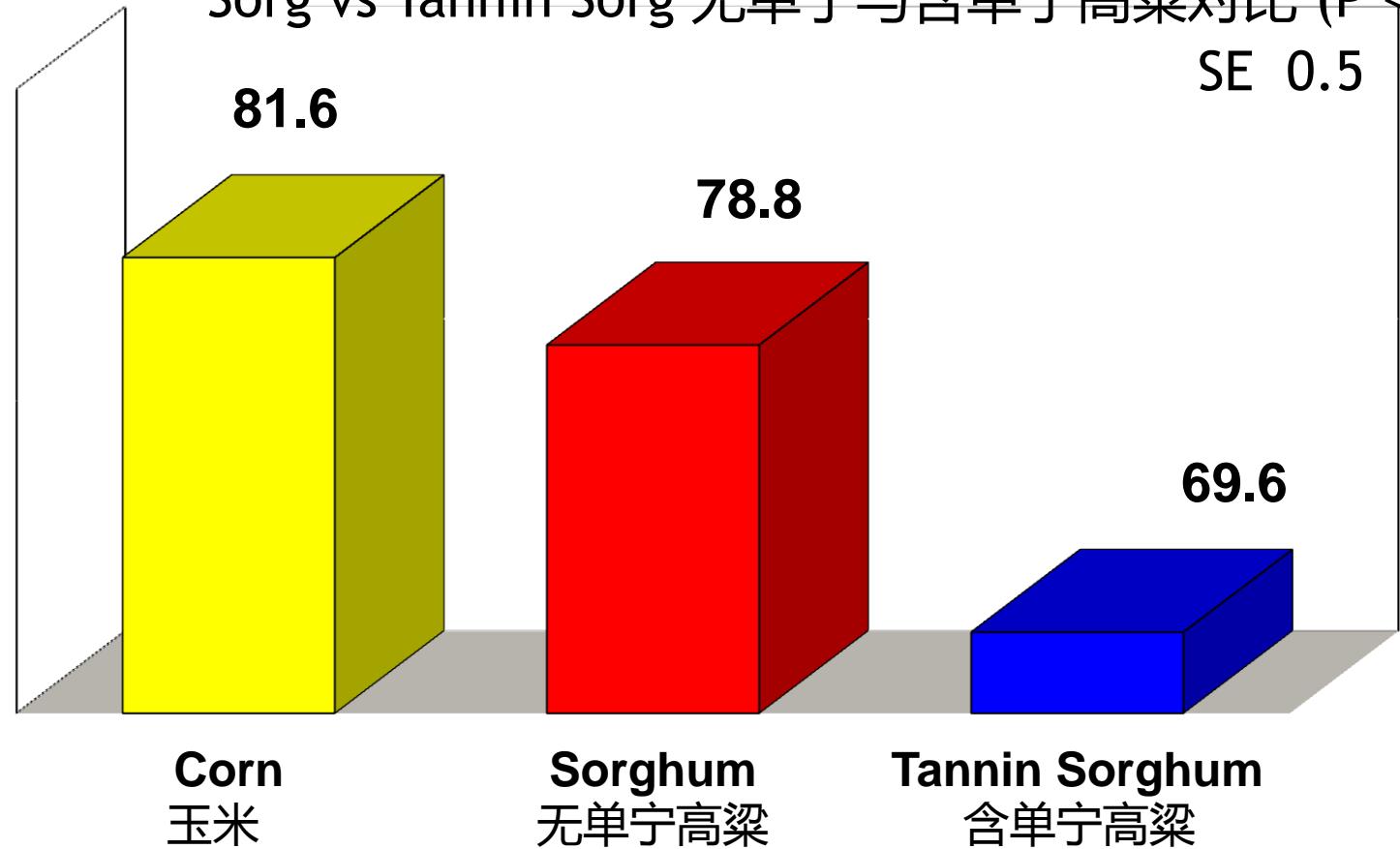


Tannins & Ileal Digestibility of N in Growing Pigs

单宁和生长猪的氮回肠消化率

Corn vs Sorgs 玉米与高粱对比 ($P < 0.01$)

Sorg vs Tannin Sorg 无单宁与含单宁高粱对比 ($P < .01$)



Nutrient Variability in Grain Sorghum

高粱的营养成分变动



The nutrients in grain sorghum vary to a degree, but no more than other grains
高粱的营养成分有一定变动，但程度与其它谷物相同

Sorghum Nutrient Profile 高粱的营养成分

Grain 谷物	ME (kcal/kg) 代谢能 (千卡/公斤)	CP (% dry matter) 粗蛋白 (%干物质)	EE (% dry matter) 粗脂肪 (%干物质)	NFE (% dry matter) 无氮浸出物 (%干物质)	Lysine (% dry matter) 赖氨酸(% 干物质)	Methionine + Cystine (% dry matter) 蛋氨酸+胱氨酸(% 干物质)
Sorghum, Variety 1 高粱样品1	3,590	13.5	3.6	70.8	0.26	0.46
Sorghum, Variety 2 高粱样品2	3,370	12.9	3.8	71.5	0.26	0.44
Sorghum, Variety 3 高粱样品3	3,290	14.1	3.4	70.9	0.26	0.47
Sorghum, Variety 4 高粱样品4	3,340	13.3	3.5	71.4	0.25	0.45
Sorghum, Variety 5 高粱样品5	3,360	13.2	3.4	71.9	0.25	0.47
Sorghum, Variety 6 高粱样品6	3,320	12.1	3.1	73.3	0.26	0.43
Sorghum, Variety 7 高粱样品7	3,460	12.7	3.4	72.1	0.26	0.43
Sorghum, Variety 8 高粱样品8	3,320	12.3	3.4	72.6	0.26	0.45

Corn Nutrient Profile 玉米的营养成分

Grain 谷物	ME (kcal/kg) 代谢能 (千卡 / 公斤)	CP (% dry matter) 粗蛋白 (%干物质)	EE (% dry matter) 粗脂肪 (%干物质)	NFE (% dry matter) 无氮浸出物 (%干物质)	Lysine (% dry matter) 赖氨酸 (%干物质)	Methionine & Cystine (% dry matter) 蛋氨酸+胱氨酸 (%干物质)
Corn, Variety 1 玉米样品1	3311	7.8	3.2	72.1	0.27	0.34
Corn, Variety 2 玉米样品2	3332	8.5	3.0	73.5	0.26	0.39
Corn, Variety 3 玉米样品3	3270	9.0	3.2	73.4	0.28	0.39
Corn, Variety 4 玉米样品4	3163	7.5	2.5	74.9	0.24	0.36
Corn, Variety 5 玉米样品5	3350	7.5	2.4	73.2	0.25	0.36
Corn, Variety 6 玉米样品6	3259	8.8	2.3	72.7	0.26	0.42
Corn, Variety 7 玉米样品7	3306	8.9	2.7	73.9	0.25	0.39
Corn, Variety 8 玉米样品8	3034	7.8	3.0	73.8	0.24	0.35

Seed Coat Color of Grain Sorghum

高粱的种皮颜色

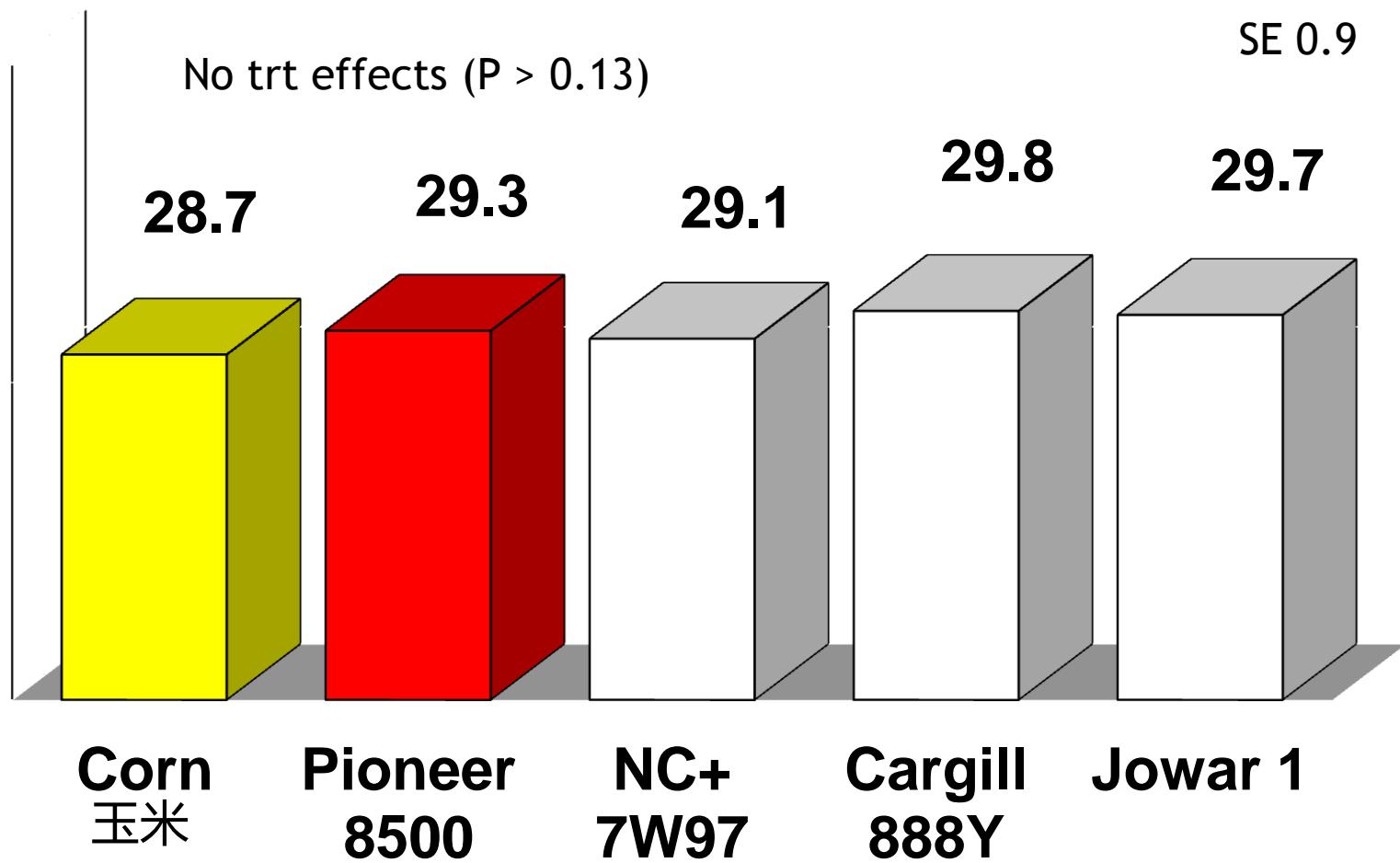
The seat coat color gives no indication of nutritional value of sorghum for feed

种皮颜色与高粱的饲料营养价值没有关系



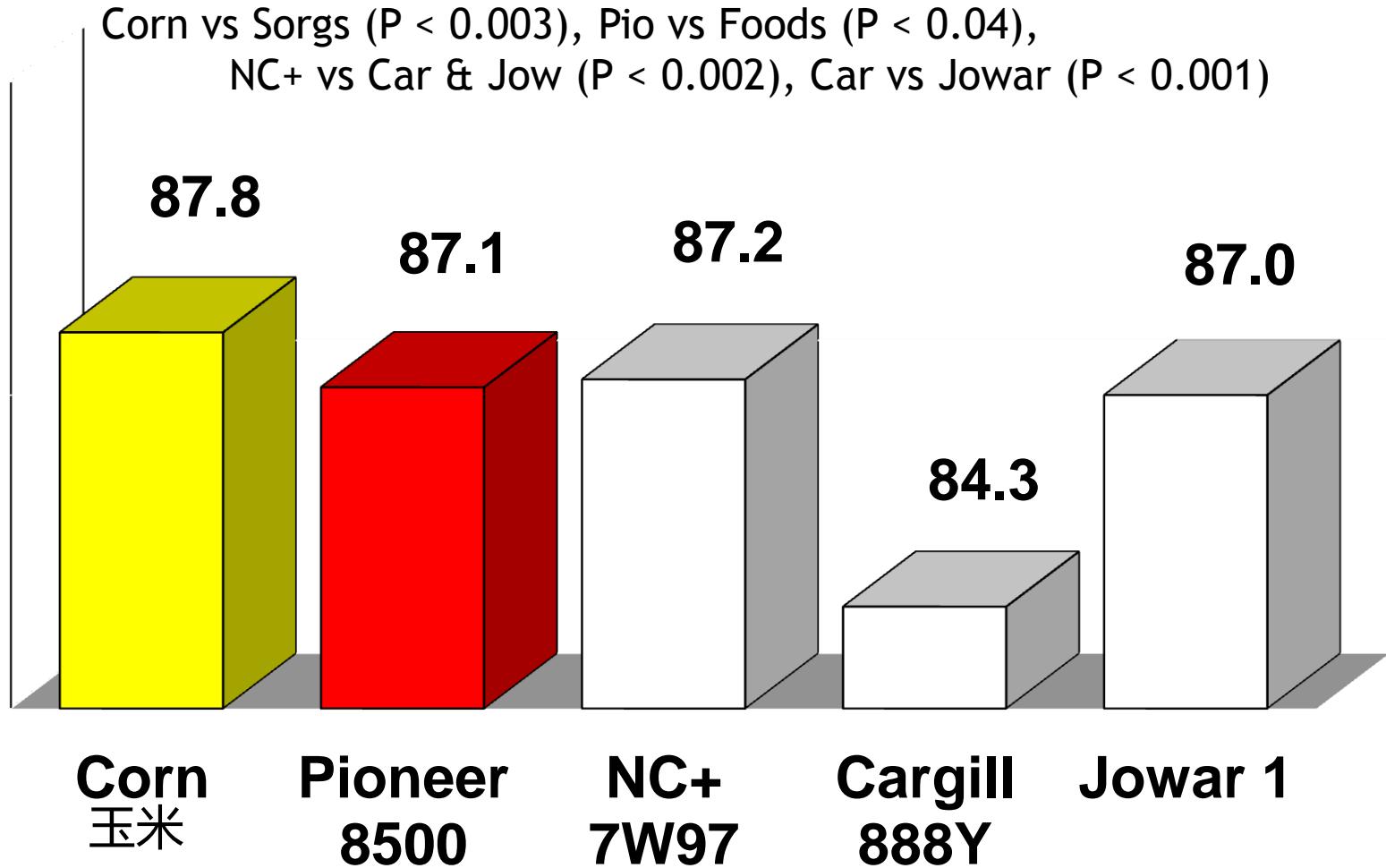
Food Quality Sorghums & ADG in Broiler Chicks

肉禽料中的食品级高粱及平均日增重



Food Quality Sorghums & DM Dig in Finishing Pigs

育成猪料中的食品级高粱及其干物质消化率



Sorghum Seed Coat Color

高粱种皮的颜色

- When planting modern varieties, pericarp and endosperm color do not seem to be nutritionally significant
种植新品种高粱时，种皮和胚乳的颜色与营养价值关系不大
- Starch type/texture and protein quality/quantity are nutritionally significant 淀粉类型/质地和蛋白质的质量/含量对衡量营养价值非常重要
- Seed color may be important in marketing and perception of sorghum but have no nutritional advantages
种子颜色或许对高粱的销售和视觉效果有影响，但与其营养价值没有关系

Sorghum Nutrient Digestibility in Poultry

高粱在禽料中的营养消化率

Item 项目	Corn 玉米	Sorghum, Variety 1 高粱, 样品1	Sorghum, Variety 2 高粱, 样品2	Sorghum, Variety 3 高粱, 样品3
Dry matter, % 干物质	72.45 ^a	72.35 ^a	71.47 ^{ab}	69.86 ^b
Energy, % 能量	77.18 ^a	77.11 ^a	76.72 ^{ab}	75.28 ^b
Nitrogen, % 氮	67.83 ^a	64.69 ^b	63.19 ^{bc}	60.68 ^c
Phosphorus, % 磷	40.39	40.20	40.53	43.27
Calcium, % 钙	58.10	60.78	56.53	55.65
ME, kcal/kg 代谢能	3,898 ^a	3,807 ^b	3,827 ^{ab}	3,806 ^b

^{a,b,c}Values with different superscripts were statistically significant ($P<0.05$)

Nyannor *et al*, 2007

Energy Digestibility

能量消化率

- True metabolizable energy (TME) 真代谢能
 - Measures the available energy for poultry of a feed ingredient 禽料原料中可利用能量的衡量
 - Usually conducted with mature Leghorn roosters 通常用成年的Leghorn公鸡做实验

Grain 谷物	TME _n 1 d (kcal/kg) 真代谢能，第1天	TME _n 3 d (kcal/kg) 真代谢能，第3天	TME _n 10 d (kcal/kg) 真代谢能，第10天
Sorghum 高粱	3,150 ^b	3,260 ^b	3,320 ^b
Corn 玉米	3,520 ^a	3,550 ^a	3,700 ^a

^{a,b} Values with different superscripts in same column differ significantly
Sulistiyanto *et al*, 1999

Amino Acid Profile and Digestibility

氨基酸类型和消化率

Amino Acid 氨基酸	Sorghum A.A. concentration (g/kg) 高粱的氨基酸含量	Sorghum A.A. digestibility 高粱的氨基酸消 化率	Corn A.A. concentration (g/kg) 玉米的氨基酸含量	Corn A.A. digestibility 玉米的氨基酸消 化率
Arginine 精氨酸	9.9	0.80	4.1	0.85
Cystine 胱氨酸	1.6	0.80	1.9	0.71
Histidine 组氨酸	2.5	0.73	2.5	0.83
Isoleucine 异亮氨酸	4.5	0.80	3.1	0.82
Leucine 亮氨酸	14.5	0.84	10.8	0.90
Lysine 赖氨酸	2.4	0.76	2.6	0.79
Methionine 蛋氨酸	1.6	0.87	1.9	0.87
Phenylalanine 苯基丙氨酸	5.8	0.81	4.3	0.86
Threonine 苏氨酸	3.4	0.66	3.5	0.68
Valine 缬氨酸	5.6	0.78	4.4	0.81

Comparison of Corn and Sorghum the Quality of Muscle and Foie Gras in Overfed Geese

玉米和高粱饲喂肥鹅的肉质和鹅肝品质对比

Item 项目	Corn 玉米	Sorghum 高粱
Number of Samples 样品数	65	61
Magret (right) 鹅胸肉		
Magret weight, g 鹅胸肉重	458	547
Breast Muscle weight, g 鹅胸瘦肉重	249	249
Skin of magret weight, g 鹅胸皮重	210^b	207^b
Pectoral muscle color 鹅胸瘦肉颜色		
L* 浅色	36.8^a	37.5^a
a* 红色	17.4	17.2
b* 黄色	2.6^b	2.4^b
Foie gras 鹅肝		
Foie gras weight, g 鹅肝重	910b^c	1,026^a
Foie gras color 鹅肝颜色		
L* 浅色	68.4	69.2
a* 红色	12.4	12.7
b* 黄色	23.8	18.1

^{a-c} Within a row, means with no common superscript differ significantly ($P < 0.05$)

Broiler Carcass Characteristics

肉鸡胴体特性

Characteristic 特性	Sorghum 高粱	Corn 玉米
Carcass weight, g 胴体重	1,614	1,657
Fillet weight, g 鸡胸肉重	135	137
L*, lightness 浅色	45.39	45.57
a*, redness 红色	4.34	4.10
b*, yellowness 黄色	1.93 ^b	4.31 ^a

^{a,b} Values with different superscripts are statistically significantly different ($P<0.05$) Smith *et al*, 2002

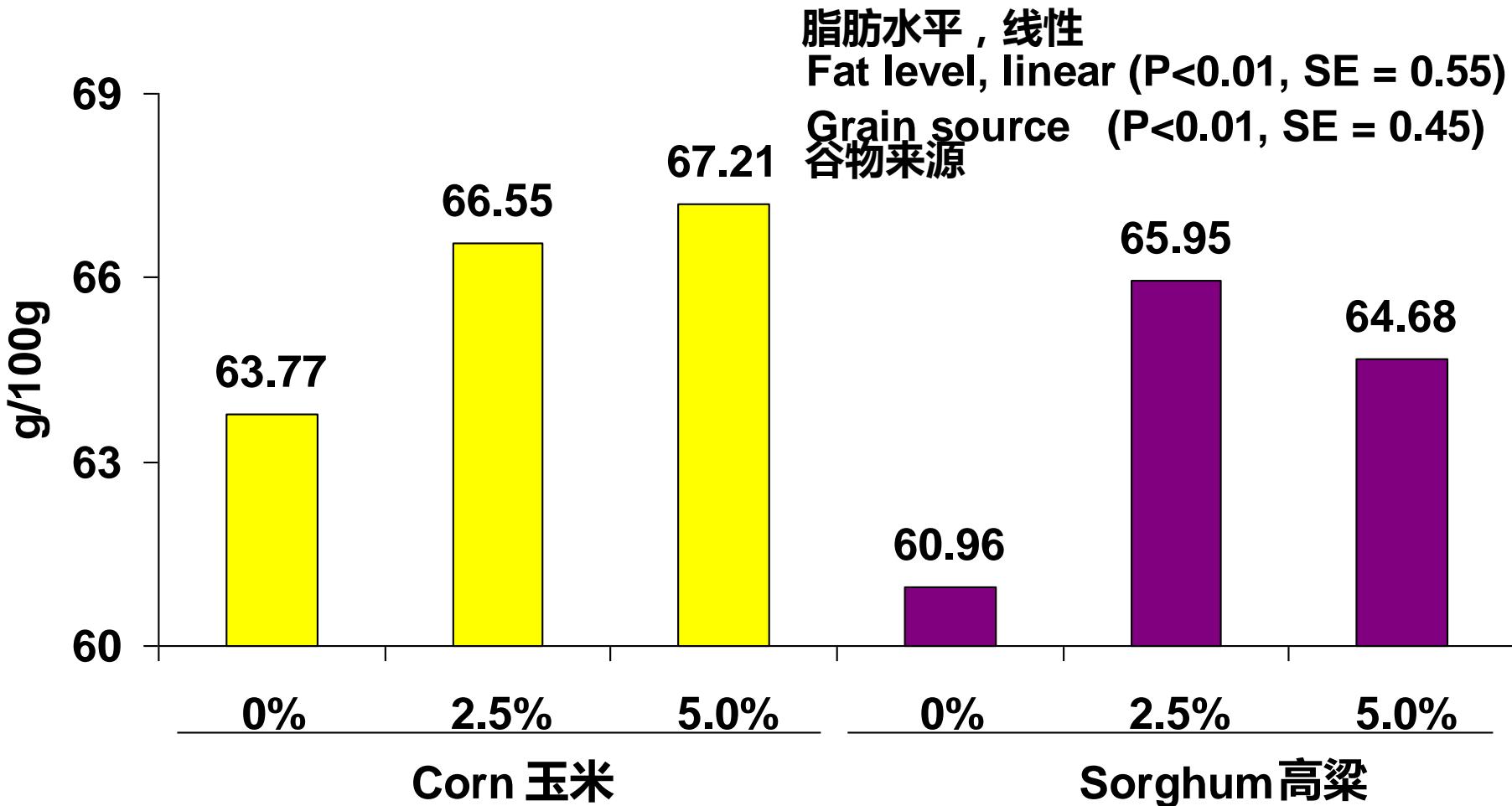
Color Sources – xanthophyll

颜色来源——叶黄素

- 50/50 of corn/sorghum
玉米高粱各一半
- DDGS
- Marigold oil 万寿菊油
- Marigold leaf meal
万寿菊叶粉
- Gold yeast 金酵母

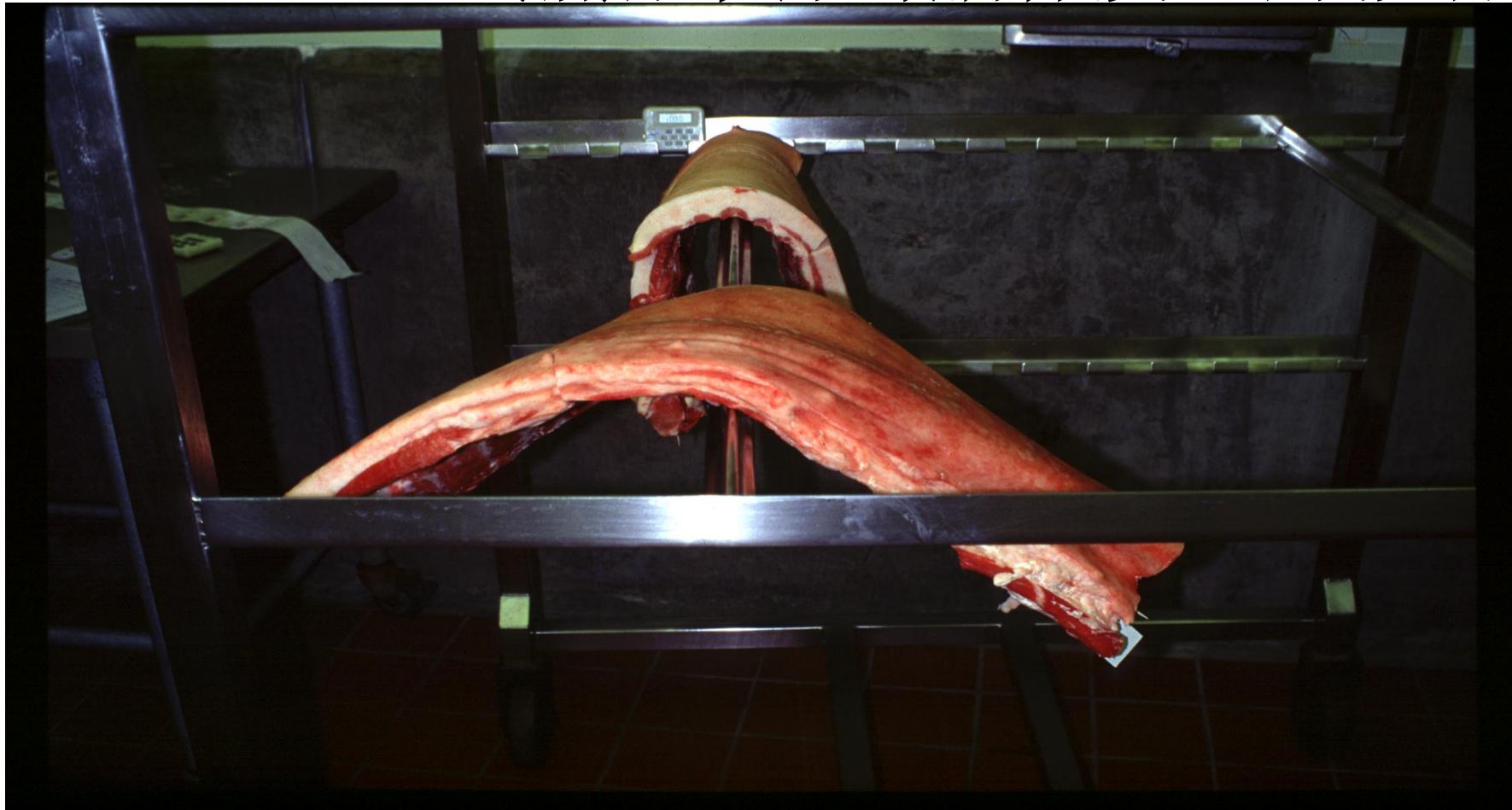


Effect of grain source and fat level on backfat iodine value 谷物来源对脂肪水平和背膘碘值的影响



Effect of Fat Source on Carcass Quality

脂肪来源对胴体质量的影响



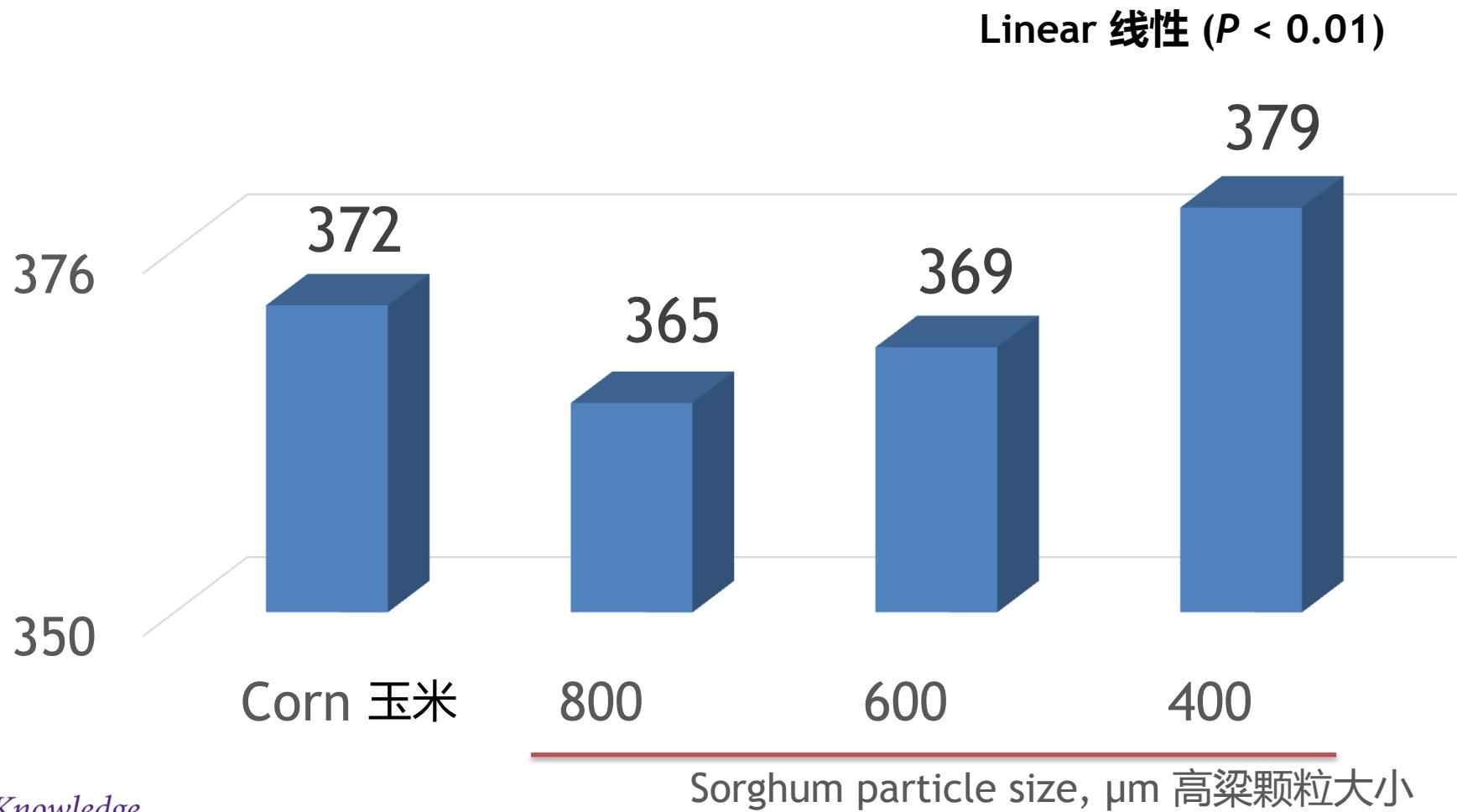
Grinding and Conditioning Grain Sorghum

谷物高粱的研磨和加工



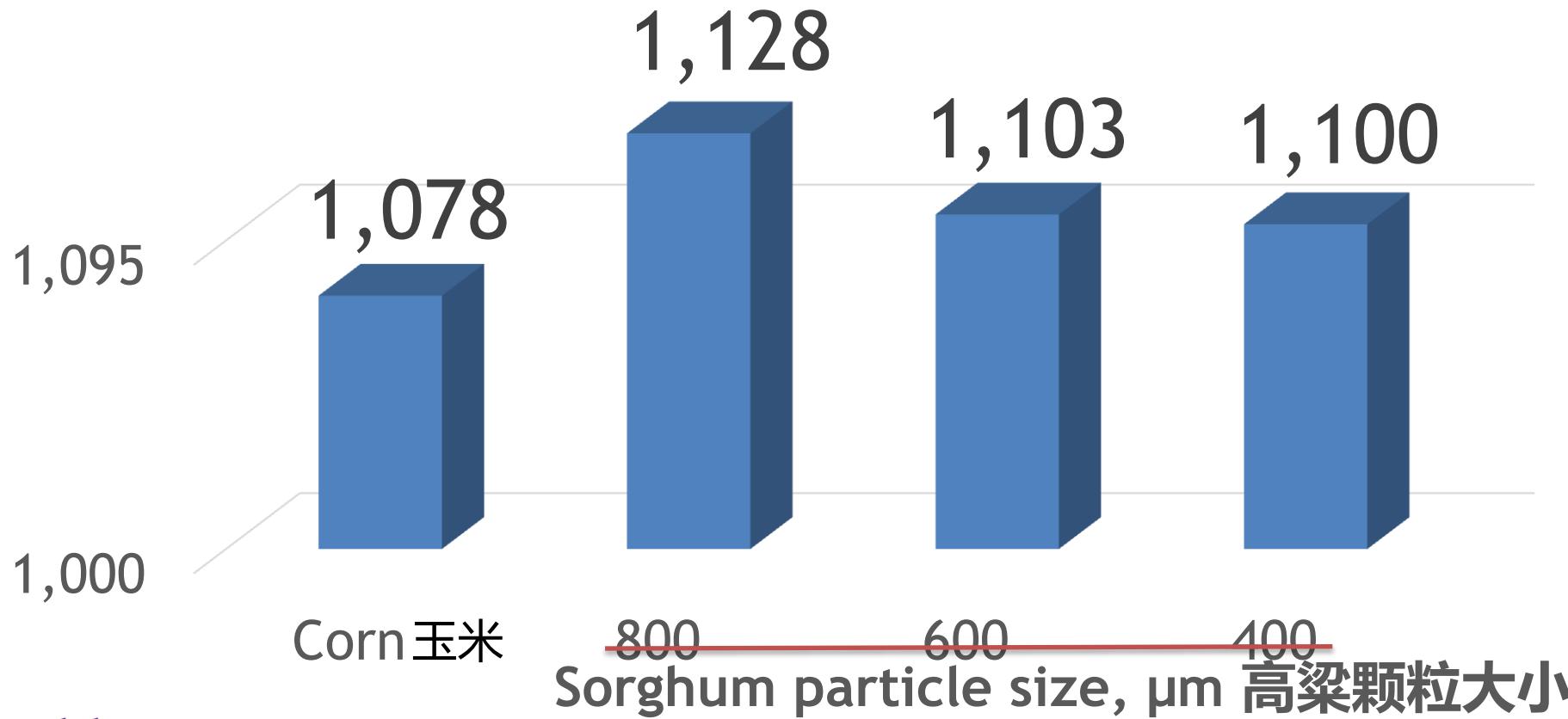
Particle Size of Sorghum and G:F in Finishing Pigs

高粱颗粒大小与育成猪料重比的关系



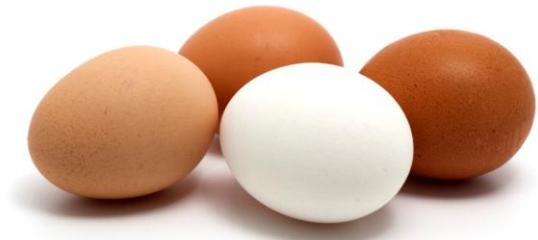
Particle Size of Sorghum and ADG in Finishing Pigs 高粱颗粒大小与育成猪日增重的关系

No trt effect ($P > 0.15$)



Laying Hens 产蛋母鸡

- Fed mash diets in the US
在美国饲喂粉料
 - No pelleting 不制粒
 - No grinding improvement for pelleting
在研磨制粒方面没有改进
- Little grinding 很少研磨
 - Large sieve sizes 筛孔尺寸大
- No need for small grinds 没有必要精细研磨
 - Can handle whole or coarsely ground grains
可以消化全粒或粗颗粒谷物



Recommended Particle Sizes

建议颗粒尺寸

- Broilers – screen size of 4-6 mm and particle size of 600 – 900um
肉鸡 – 篮孔尺寸4-6mm， 颗粒大小600-900um
- Layers – 900um 蛋鸡 – 900um
- Test YOUR shipment – berry size variation will dictate choice of screen size
您的原料 – 原料颗粒大小决定篮孔尺寸

Can Whole Sorghum be Fed to Broilers?

全粒高粱可以用来饲喂肉鸡吗？

	Control 对照组	10% Whole Sorghum 10%全粒高粱	20% Whole Sorghum 20%全粒高粱
Gain, 0 to 21 days 增重 0-21天	763	831	820
FE, g/kg 0 to 21 days 粪能，克/公斤 0-21天	717	700	701

Best Particle Size for Grain Sorghum for Poultry

禽料中高粱的最佳颗粒大小



What are the Conditioning Effects on Sorghum for Poultry? 禽料中高粱加工工艺的影响

- Increasing conditioning temperatures from 65C to 95 was found to depress FCR and gain in a linear manner (Selle, et al, 2013)
将加工温度从65摄氏度提高到95度会线性降低饲料转化率和增重
- Increasing temps also quadratically affected N utilization with higher temps causing a reduction
温度提高以几何级数影响氮利用率，温度越高利用率越低
- Are sulphydryl groups getting tied up?
巯基不发挥作用吗？

The Effect of Processing Method on Sorghum TME for Poultry

加工方法对禽料中高粱真代谢能的影响

Grain 谷物	TME 1 d (kcal/kg) 真代谢能，1天
Ground Sorghum 细磨高粱	3,360 ^a
Extruded Sorghum, 46% gelatinized starch 膨化高粱，46%糊化淀粉	3,318 ^a
Extruded Sorghum, 94% gelatinized starch 膨化高粱，94%糊化淀粉	3,078 ^b

^{a,b} Values with different superscripts in same column differ significantly
Beyer, *et al*, 2013, unpublished lab data

Addition of Enzymes to Sorghum Based Diets

在高粱日粮中添加酶

- Phytase supplementation in sorghum based diets numerically improved (not statistically different) apparent metabolisable energy by 1.9%. (Wu et al. 2004)
高粱日粮中添加植酸酶可以将表观代谢能量提高1.9%
(没有统计上的差别)
- Supplementation of microbial phytase improved ($P < 0.05$) the digestibilities of protein and amino acids in sorghum. (Ravindran et al. 1998)
添加微生物植酸酶会提高高粱中蛋白质和氨基酸的消化率 ($P < 0.05$)
 - Amino acid digestibility increased from 74.7 to 79.4%
氨基酸消化率从74.7%提高到79.4%

Protease may be most Effective Enzyme for Sorghum

蛋白酶也许是高粱最有效的酶

- When processed at 80C, the addition of protease enzyme increased N digestibility in broilers.
在80摄氏度加工时，蛋白酶的添加会提高肉鸡料的氮消化率
- When processed at any temperature, protease improved starch digestion on broilers
在任何温度加工，蛋白酶的添加都会提高肉鸡料的淀粉消化率

Selle, et all, 2013, *Animal Production Science*

Limits for Sorghum in Poultry Rations

高粱用于禽日粮的限制

- Broilers 肉鸡
 - Up to 100% of the cereal grain ration provided the diet is balanced
只要将配方平衡好，高粱可以作为日粮100%的谷物来源
 - 25/75 or 50/50 rations may help if you encounter a **poor batch** of other cereal grain
如果其它谷物某批次质量较差，可以按25/75或50/50的比例替代
- Layers 蛋鸡
 - Up to 50% of the corn fraction if the diet is balanced and no adjustments for color are made, otherwise, many use far more if you add xanthophylls
只要将配方平衡好，可以替代50%的玉米，且无需调整颜色，如果添加叶黄素，则可以更大比例替代

Sorghum Processing Requirements for Poultry

禽料中高粱的加工要求

- Do not over condition 不要过度加工
- PDI range should be closer to 80 PDI, not higher
颗粒耐久性指数组控制在接近80PDI，但不要更高
- Feed course ground grain sorghum to poultry
给禽类饲喂粗颗粒谷物高粱

Limits for Sorghum in Feed Rations

高粱用于饲料日粮的限制

- Broilers 肉鸡
 - Up to 100% of the cereal grain ration provided the diet is balanced
只要将配方平衡好，高粱可以作为日粮100%的谷物来源
 - 25/75 or 50/50 rations may help if you encounter a **poor batch** of other cereal grain
如果其它谷物某批次质量较差，可以按25/75或50/50的比例替代
- Layers 蛋鸡
 - Up to 50% of the corn fraction if the diet is balanced and no adjustments for color are made, otherwise, many use far more if you add xanthophylls
只要将配方平衡做好，可以替代50%的玉米，且无需调整颜色，如果添加叶黄素，则可以更大比例替代

Limits for Sorghum in Feed Rations

高粱用于饲料日粮的限制

- Ducks 鸭
 - Up to 100% of the cereal grain ration provided the diet is balanced
只要将配方平衡好，高粱可以作为日粮100%的谷物来源
 - Must account for color in foie gras products
生产鸭肝产品必须考虑颜色
- Swine 猪
 - Up to 100% of the corn fraction if the diet is balanced.
Must grind to smaller particle sizes
只要将配方平衡好，可以100%替代玉米，必须加工到更小的颗粒尺寸

Conclusions 结论

- The supplies of feedstuffs that have traditionally been used to manufacture animal feeds are likely to change due to energy and global food concerns
出于能量和全球对食品问题方面的考虑，传统用于动物饲料加工的谷物种类将发生变化
- Those producers who can learn to look at other feed ingredients differently and learn how to use them will profit in the end 那些学会重新审视饲料原料种类及其使用方法的生产商将从中获益
- Grain Sorghum will be competitive with corn at times for use in poultry feed rations
高粱将成为禽料日粮中玉米的竞争者