# NUTRITIONAL GUIDE TO FEEDING SORGHUM



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## **OVERVIEW**

- Why feed U.S. Sorghum?
- Feeding sorghum to non-ruminants
  - Swine
  - Broilers
  - Ducks
  - Processing considerations
- Feeding sorghum to ruminants
  - Beef cattle
  - Dairy cattle
  - Processing considerations
- Forage sorghum
  - Take Home Messages





## WHY US SORGHUM?

- Fits well in least cost formulation of feed rations
- Feed acceptance
- Non-GMO
  - No current GMO traits are present in sorghum
- Mycotoxins
  - Low incidence of occurrance, but is possible
- Tannin levels
  - U.S. Sorghum is considered to have low/no tannins
  - 99% of all sorghums in the U.S. <u>do not</u> contain tannin
- Ancient Grain / Gluten Free / antioxidents
  - Potential consumer preference in food items

**Continued research and end-use development** 



Sorghum can replace corn (or other grains) in rations

- Know the differences in nutritional value
- Species specific (non-ruminant / ruminant)

Key differences:

- Amino acid profile / Crude protein values
- Fatty acid profile / Fat content
- Phosphorus

Advantages to processing

Grinding / Heat + Pressure



### FEEDING SORGHUM TO SWINE

- Sorghum is an excellent energy source
- Can completely replace corn or other grains in swine diets
  - Nursery and Finishing Pigs
  - Gestating and Lactating Sows
- Enhanced nutritional value:
  - Favorable digestible amino acid profile, available phosphorus content, and fatty acid profile
- Keys to utilization:
  - Slightly lower energy value
  - Need for proper grinding





#### Advantages and Disadvantages of Feeding Sorghum to Swine

- Advantages:
  - Often a cheaper source of energy than corn
  - Sorghum has approximately 96% the energy of corn
  - Due to the slightly lower energy, feed efficiency is often poorer, but gain is similar
  - Should price at ~96% the cost of corn on an equal weight basis
  - Swine deposit a firmer carcass fat when fed sorghum
- Disadvantages:
  - Can be more variable in nutrient content than corn because of growing conditions
  - Fine grinding (3 to 4 mm) or rolling is needed for best utilization



#### **NUTRIENT COMPOSITION OF SORGHUM**

	Sorghum	Corn	Sorghum:Corn
Dry matter, %	89.0	89.0	100%
Energy, kcal/kg			
Digestible	3,380	3,525	96%
Metabolizable	3,340	3,420	98%
NE INRA	2,629	2,653	99%
NE NRC	2,255	2,395	94%
Crude protein, %	9.2	8.3	111%
Calcium, %	0.03	0.03	100%
Phosphorus, %	0.29	0.28	104%
Available P, %	0.058	0.039	149%
Crude fat, %	2.9	3.9	74%
Linoleic acid, %	1.13	1.92	59%
Crude fiber, %	2.4	2.2	109%
NDF, %	9.4	10.4	90%
ADF, %	3.8	2.6	146%



NRC, 1998; INRA, 2004

#### **NUTRIENT COMPOSITION OF SORGHUM**

Total amino acids, %	Sorghum	Corn	Sorghum:orn
Lysine	0.22	0.26	85%
Isoleucine	0.37	0.28	132%
Leucine	1.21	0.99	122%
Methionine	0.17	0.17	100%
Cysteine	0.17	0.19	89%
Threonine	0.31	0.29	107%
Tryptophan	0.10	0.06	166%
Valine	0.46	0.39	118%



NRC, 1998; INRA, 2004

# SORGHUM FOR FINISHING PIGS





### **SORGHUM VS CORN IN FINISHING PIGS**

Relative value (%) of sorghum versus corn in finishing pigs					
Study	ADG	ADFI	G:F	Reference	
1	104	109	96	Brand et al. (1990) variety 1	
2	102	108	95	Brand et al. (1990) variety 2	
3	98	104	95	Hancock et al. (1992)	
4	106	106	100	Johnston et al. (1998)	
5	104	109	95	Shelton (2004) waxy	
6	106	114	93	Shelton (2004) Non-waxy	
7	104	100	104	Issa (2009)	
8	99	100	100	Seaboard Farms (2010)	
9	106	105	101	Benz et al. (2010)	
Average	103	106	98		

Recent studies report improved feeding value of sorghum, likely due to:

- Improved cultivars
- Better knowledge of processing sorghum-based diets



#### INFLUENCE OF GRAIN SOURCE ON PIG PERFORMANCE



Hancock et al., 1992

#### **PROCESSING OPTIONS**





#### **PARTICLE SIZE REDUCTION**

- Reducing particle size increases surface area, allowing greater interaction of digestive enzymes
- Advantages of reducing particle size:
  - Simple process
  - Improves feed efficiency
  - Improves energy digestibility
  - Improves DM and N digestibility
  - Decreases DM and N excretion



- Disadvantages as particle size decreases:
  - Cost increases
  - Mill throughput decreases
  - Bridging may occur



**Richert and DeRouchey** 

#### EFFECT OF SORGHUM PARTICLE SIZE IN FINISHING PIG DIETS



#### EFFECT OF SORGHUM PARTICLE SIZE IN FINISHING PIG DIETS



### PARTICLE SIZE REDUCTION: OPTIMUM PARTICLE SIZE FOR SWINE

- <u>BALANCE:</u> feed efficiency, processing cost, incidence of gastric ulcers & potential for bridging
- <u>GOAL</u>: Optimize both pig performance and milling efficiency
- Large swine operations in the U.S. grind to 650 μm
- Ideal range is 450-650 μm
- 300 µm may result in ulcers
- Either hammer or roller mill will work with sorghum
  - Hammer mill = small screen size (1/8 inch; 3.2mm)
  - Roller mill = 14 to 16 corrugations per inch to aid in slicing



### PARTICLE SIZE REDUCTION: HAMMER MILL

- Advantages:
  - Can grind a wide range of feedstuffs
  - Capable of a wide range of particle sizes
- Disadvantages:
  - Noisy and dusty
  - Can generate heat during grinding
  - Less energy efficient than roller mills (> 700µm)



## PARTICLE SIZE REDUCTION: ROLLER MILL

- Advantages:
  - Less noise and dust than hammer mill
  - More uniform particle size; thus, may improve digestibility (less large particles)
  - Better feed flow (less fines)
  - More efficient than hammer mill at larger particle sizes
- Disadvantages:
  - Overall require more monitoring than hammer mills
  - Maintain roller gap width to produce targeted particle sizes
  - Width will change with roller wear and grain quality
  - More costly maintenance than a hammer mill



#### PARTICLE SIZE REDUCTION: HAMMER MILL VS ROLLER MILL



#### **IMPROVED PORK FAT PROFILE**



- Fatty acid profiles of pig diets influences carcass fat composition (measured as 'fat iodine value')
- Sorghum also has a lower iodine level
- Fat quality is important:
  - Soft fat can result from higher unsaturated fatty acids
  - Soft fat becomes rancid faster, may 'smear', and is more difficult to slice
- Sorghum has a favorable fatty acid profile
  - Contains less unsaturated fatty acids than corn



# SORGHUM FOR NURSERY PIGS





#### **SORGHUM VS CORN IN NURSERY PIGS**

Relative value (%) of sorghum versus corn in nursery pigs					
Study	ADG	ADFI	G:F	Reference	
1	90	91	99	Richert et al. (1992) Exp 1	
2	113	112	101	Richert et al. (1992) Exp 2	
3	80	84	95	Healy et al. (1994) Hard	
4	84	88	95	Healy et al. (1994) Soft	
5	111	104	108	Hongtrakul et al. (1998)	
6	103	105	99	Jones et al. (2000) Mill-run	
7	105	105	100	Jones et al. (2000) Red	
8	103	101	102	Jones et al. (2000) White	
9	96	103	93	Fialho et al. (2004)	
Average	98	99	99		

Overall, feeding sorghum to weanling pigs had no effect on feed efficiency

- More variation in gain and feed intake compared to finishing pigs



NRC, 1998; INRA, 2004

#### INFLUENCE OF GRAIN TYPE AND PARTICLE SIZE IN STARTER PIG RATIONS



Healy et al., 1991

# SORGHUM FOR Sows





### **RELATIVE VALUE OF SORGHUM VS CORN FOR LACTATING SOWS (% DIFFERENCE)**

	Louis	Johnston	Sotak	
Item	et al., 1991	et al., 1998	et al., 2012	Average
Sow performance				
Lactation ADFI	90	102	104	99
Lactation weight change	90	62	74	75
Wean to estrous interval	94	111	NA	103
Litter performance				
Litter size born alive	108	102	99	103
Litter size at weaning	103	99	99	100
Litter BW at birth	99	101	99	100
Litter BW at weaning	93	98	98	96
Litter BW gain	92	97	94	94

Feeding sorghum to sows can generally support a level of reproductive performance that is equal to feeding corn.



# SORGHUM FOR POULTRY



#### FEEDING SORGHUM TO POULTRY

- Sorghum can replace corn in poultry rations
  - Sorghum can comprise 70% of broiler and layer rations
  - Sorghum can be included up to 55% in turkey rations
- Amino acid digestibility compares favorably to corn
  - Sorghum AA digestibility averages 95-97% of corn AA
  - Methionine and Lysine values are lower for sorghum compared to corn
  - Synthetic AA or byproducts can compliment sorghum diets
  - Sorghum contains more protein than corn, which means the actual AA available for growth would be higher for sorghum compared to corn
- Fat is slightly lower, but balances with meals/oils



## NUTRIENT COMPOSITION OF SORGHUM FOR POULTRY

	Sorghum,	Sorghum,	
	8-10% Protein	> 10% protein	Corn
Dry matter, %	87	88	89
ME, kcal/kg	3,288	3,212	3,350
TME, kcal/kg	3,376		3,470
Protein, %	8.8	11.0	8.5
Ether Extract, %	2.9	2.6	3.8
Linoleic Acid, %	1.13	0.82	2.20
Crude fiber, %	2.3	2.3	2.2
Total Calcium, %	0.04	0.04	0.02
Non-phytate P, %	0.30	0.32	0.28
Phosphorus, %			0.08

Proximate analysis indicates similarities between corn and sorghum

- Sorghum has reduced oil resulting in slightly less energy value
- Sorghum has more protein
- Sorghum has slightly more non-phytate phosphorus than corn



NRC, 1994

#### FEEDING SORGHUM TO POULTRY

- Sorghum planted in the U.S. <u>does not</u> contain high tannin levels
  - Data from 15 years ago undervalues sorghum
  - Reported sorghum to be 85-90% feeding value of corn due to high tannin content
- Reduced tannins in current varieties greatly improves nutrient digestibility for poultry
  - Low tannin varieties are grown in the U.S. to maximize the value of sorghum in animal rations



#### **TANNIN AND GAIN IN BROILER CHICKS**



#### FEEDING SORGHUM TO POULTRY

Other considerations:

- Enzyme additives can increase amino acid digestibility and ME of sorghum diets
- Pelleted rations are common in the U.S.
  - Sorghum can be difficult to pellet
- Unprocessed sorghum can be included in rations
- Grinding can increase feeding value



## **FEEDING SORGHUM TO DUCKS**

- Differences in nutrient metabolism do exist between ducks and chickens
- Consequently, nutrient utilization and bioavailability from one species cannot be confidently applied to another
- Studies feeding ducks have compared corn to other grain sources, including sorghum
- Most have used a high-tannin sorghum
- (Bagliacca et al., 1997; Ragland et al., 1997; Elkin and Rogler, 1991)
- Creates a challenge for poultry nutritionists based on the sparse amount of information available specifically for ducks



# SORGHUM FOR Cattle





#### **NUTRIENT COMPOSITION FOR RUMINANTS**

	Grain	Beef NRC	Dairy NRC	Dairy One
CP, %	Sorghum	12.60	11.60	10.53
	Corn	9.80	9.40	9.20
ADF, %	Sorghum	6.38	5.90	7.90
	Corn	3.30	3.40	3.63
NE <sub>m</sub> , Mcal/kg	Sorghum	2.01	1.94	2.11
	Corn	2.25	2.05	2.20
NE <sub>a</sub> , Mcal/kg	Sorghum	1.34	1.30	1.43
	Corn	1.54	1.39	1.52
NE <sub>I</sub> , Mcal/kg	Sorghum		1.80	2.00
	Corn		1.92	2.07
Ash, %	Sorghum	1.87	2.00	1.92
	Corn	1.46	1.50	1.55

Beef NRC, 1996; Dairy NRC, 2001; Dairy One, 2010



#### SORGHUM IN THE U.S. FEEDLOT INDUSTRY

Cereal grains are the most common energy source

• Comprise up to 95% of total diet

ltem	Corn	Milo	Barley	Oats	Wheat
ADG, kg	1.43	1.39	1.42	1.50	1.38
DMI, kg	8.93 <sup>b</sup>	9.43 <sup>a</sup>	8.77 <sup>b</sup>	9.15 <sup>ab</sup>	8.65 <sup>b</sup>
Feed:Gain	6.32 <sup>b</sup>	6.88 <sup>a</sup>	6.24 <sup>b</sup>	6.12 <sup>ab</sup>	6.34 <sup>b</sup>

Owens et al., 1997; <sup>a,b</sup> (P < 0.05)

#### Compared to corn, milo

- Had similar ADG
- Processing ↓ DMI





Milo <u>must</u> be processed for ruminant diets Options include:

- Dry rolling
- Steam flaking
- Roasting



Primary reason to steam or roast:

- 1. Disrupt the protein matrix encapsulating starch
- **2.** Damage starch granules that are compacted



#### **PROCESSING SORGHUM**

**Mechanics of flaking:** 

- Hydrate starch with moist heat to create irreversible swelling (gelatinization) of granules
- Compress starch between rolls to rupture granules and shear the protein matrix

Heat + Moisture + Pressure = 1 Starch Availability Implemented alone = less impact on starch





#### **PROCESSING SORGHUM BY METHOD**

Compared to dry rolling sorghum, steam flaking:

- ADG is similar
- DMI is reduced
- Resulting in a 15% increase in feeding efficiency

Process	ADG, kg	DMI, kg/d	F:G	ME, Mcal/kg
Dry Rolled	1.43	10.47 <sup>a</sup>	7.43 <sup>a</sup>	2.94 <sup>a</sup>
Steam Flaked	1.40	8.68 <sup>b</sup>	6.33 <sup>b</sup>	3.56 <sup>b</sup>

Owens et al., 1997; <sup>a,b</sup> (P < 0.05)





# The added growth performance and feeding efficiency is due to the increase in starch digestion

Process	Rumen, % Intake	Post-rumen, % Entering	Total Tract, % Digestibility
Dry Rolled	60 +/- 12	62 +/- 11	87 +/- 5
Steam Flaked	78	90	98

Huntington, 1997

 The added rumen availability of starch increases microbial synthesis resulting in more bacterial protein available to the small intestine



Flake density is an important metric:

- Medium thickness is ideal = 23 to 26 lb
- Thinner flakes cause acidosis (< 23 lb)
- Thicker flakes reduce starch availability (> 26 lb)

Monitor starch availability by fecal starch content.

- 2 4% = maximized digestibility
- $4 6\% = \uparrow$  bypass and  $\downarrow$  digestibility

**Positive 'associative effects'** 

• Can be paired with highly fermentable grains



#### **PROCESSING OPTIONS**





#### **Milo Roasting Process**



## **ROASTING THE MILO**

#### **Design includes:**

- Roasting drum at a decline
- Milo free falls through spinning drum
- Milo goes through a gas flame
- Temperature is 330-360°F

Moisture + heat = milo to swell Goal is to swell, not pop







### **ROLLING THE MILO**

#### **Design includes:**

- 2 rollers 2-3 mm apart
- Spring action in the rolls
- Flattens milo, but expands after rolling

#### Goal is a 24 lb/bu

- Flake check
- Adjust to maintain 24 lb/bu
- Must maintain 23 to 26 lb/bu
- Moisture is 9-10%





## **ROASTING VS FLAKING MILO**

	Roasting	Flaking
Flake consistency	Can be variable	More consistent
Temperature	330-360°F	212°F
Cook time	0.5 – 1.0 minutes	1 – 1.5 hours
Rate	8-9 tons/hr	4-5 tons/hr
Cost	\$2/processed ton	\$7/processed ton
Starch availability	78 - 84%	72 - 78%
Feed conversion	5.2 – 5.6	5.5 – 5.8

#### Why not roast?

- 1 Liability due to temperature & open flame
- 2 Its not as 'pretty' for custom feeders



#### SORGHUM IN THE U.S. DAIRY INDUSTRY

Starch is the primary energy source when feeding dairy cows for high levels of milk production

- Ruminal fermentation profiles vary based on grain
- Sorghum ferments slower than other grains
- A mixture of grains may be ideal

Numerous studies report that sorghum can replace corn in dairy rations with no difference in: DMI, milk yield, milk fat %, and BW





Normal processing methods include:

 Dry rolling, grinding, steam rolling, steam flaking and pelleting

#### **GOAL**: increase ruminal starch digestion

- Heat + Moisture + Pressure = 1 Starch Availability
- † starch digestion
- = 1 microbial protein production
- = ↑ available protein for milk production



Steam-flaking of either corn or sorghum resulted in a 20% increase in NE<sub>I</sub> as compared to dry rolled

 A review of 24 studies found steam-flaked corn and sorghum were similar in intake and lactation performance

	SF-Sorghum	SF-Corn	P value
Dry Matter Intake, kg/d	25.9	26.1	0.82
Milk, kg/d	36.5	36.9	0.84
Protein, %	2.96	3.00	0.58
Fat, %	3.19	3.11	0.45
Total track starch digestion, %	98.6	97.9	0.86
		The	irer et al 1999



#### **FORAGE SORGHUM**

#### **Different types and traits:**

- Yield vs Quality
- **Different uses:**
- Graze, Hay, or Silage



- Different segments of the cattle industry
- Stocker cattle
- Feedlot cattle
- Dairy cattle





## **NUTRITIONAL CHARACTERISTICS**

Type to consider:

- Target use will dictate type
- Traits to consider:



- Brown midrib (BMR) high in nutritional value
- Photoperiod Sensitive (PS) high yielding



Characteristic	Non- BMR		
		BMR	PS
Yield, tons DM/ac	<b>8.5</b> <sup>a</sup>	7.5 <sup>b</sup>	10.7°
CP, % DM	<b>7.3</b> <sup>a</sup>	7.9 <sup>b</sup>	6.0 <sup>c</sup>
NDF, % DM	<b>46.6</b> <sup>a</sup>	<b>45.5</b> <sup>a</sup>	<b>64.4</b> <sup>b</sup>
ADF, % DM	<b>28.0</b> <sup>a</sup>	<b>27.0</b> ª	<b>39.4</b> <sup>b</sup>
IVTD, % DM	<b>76.2</b> <sup>a</sup>	<b>80.7</b> <sup>b</sup>	68.5°

Sorghum can replace corn (or other grains) in rations

- Know the differences in nutritional value
- Species specific (non-ruminant / ruminant)

Key differences:

- Amino acid profile / Crude protein values
- Fatty acid profile / Fat content
- Phosphorus

Advantages to processing

Grinding / Heat + Pressure



## TAKE HOME MESSAGES

- Sorghum can replace other grains in rations
- Nutritionists have numerous ways to use sorghum due to processing options
- Process sorghum to optimize animal performance and milling efficiency
- Use U.S. sorghum with confidence that low tannin varieties will not affect animal performance
- Use current nutrient composition data





## **THANK YOU!**







Link to the livestock feeding guides: http://sorghumcheckoff.com/sorghum-markets/animal-nutrition/

