Nutritional Characteristics and Feeding Recommendations for Corn Distiller's By-Products

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What is DDGS?

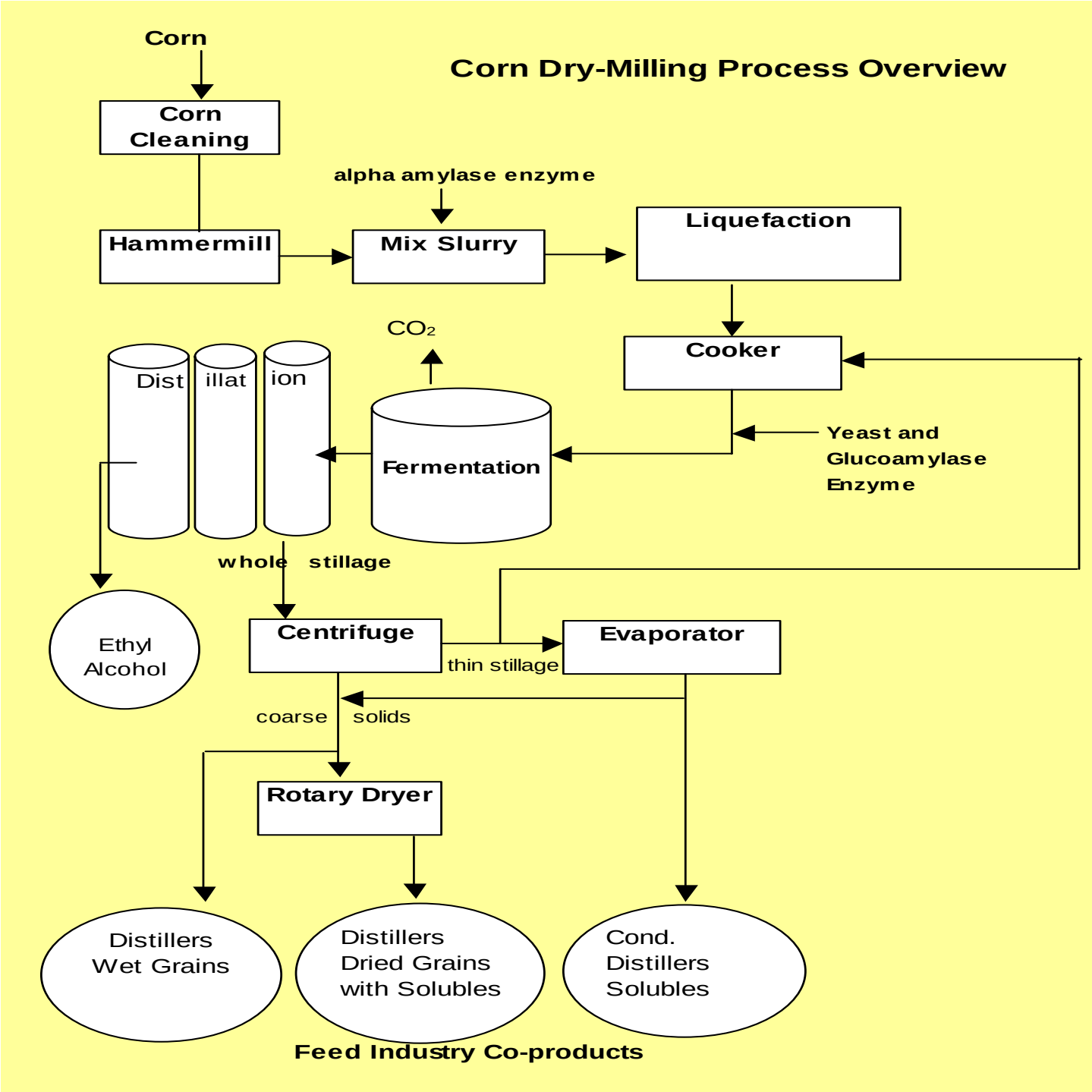
- By-product of the dry-milling ethanol industry
- Nutrient composition is **different** between dry-mill, wet-mill and beverage alcohol by-products
  - DDGS – fuel ethanol
  - DDGS - whiskey distilleries
  - Corn gluten feed – wet mill
  - Corn gluten meal – wet mill
  - Brewer's dried grains – beer manufacturing
- Nutrient content depends on the grain source used
  - **Corn DDGS - Midwestern US**
  - Wheat DDGS - Canada
  - Sorghum (milo) DDGS - Great Plains US
  - Barley DDGS

Comparison of Nutrient Composition (Dry Matter Basis) of "New Generation" DDGS to Corn Gluten Feed, Corn Gluten Meal, Corn Germ Meal, and Brewer's Dried Grains

	"New Generation" Corn DDGS (UM)	Corn Gluten Feed (NRC)	Corn Gluten Meal (NRC)	Corn Germ Meal (Feedstuffs)	Brewer's Dried Grains (NRC)
Protein, %	30.6	23.9	66.9	22.2	28.8
Fat, %	*10.7*	3.3	3.2	1.1	7.9
NDF, %	43.6	37.0	9.7	No data	52.9
DE, kcal/kg	*4011*	3322	4694	No data	2283
ME, kcal/kg	*3827*	2894	4256	3222	2130
Lys, %	0.83	0.70	1.13	1.00	1.17
Met, %	0.55	0.39	1.59	0.67	0.49
Thr, %	1.13	0.82	2.31	1.22	1.03
Trp, %	0.24	0.08	0.34	0.22	0.28
Ca, %	0.06	0.24	0.06	0.33	0.35
Available P, %	*0.80*	0.54	0.08	0.17	0.21

By-Products from Dry-Mill Ethanol Plants

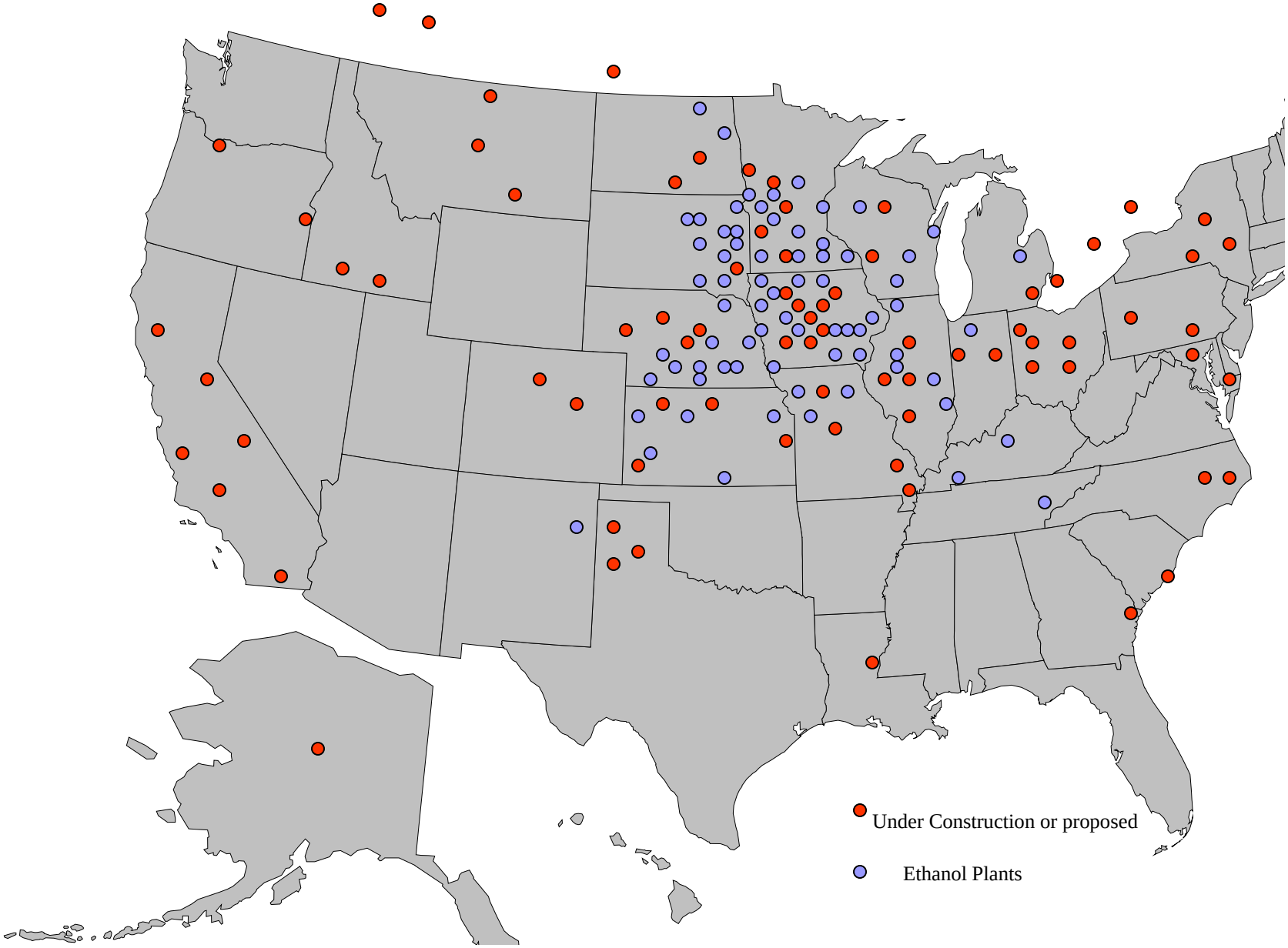
- Distiller's grains
  - Wet – 30 to 35% DM
  - Dry – 90 to 92% DM
- Condensed distiller's solubles
  - Wet – 30 to 32% DM (variable)
  - Dry – 99% DM (new spray drying process developed at U of M)
- Distiller's dried grains with solubles
  - Wet – 30 to 35% DM
  - Dried – 88 to 90% DM (most common by-product)


Corn Dry-Milling Process Overview
Corn
Corn Cleaning
Hammermill
alpha amylase enzyme
Mix Slurry
Liquefaction
Cooker
Yeast and Glucoamylase Enzyme
Fermentation
CO2
Dist
illat
ion
whole stillage
Ethyl Alcohol
Centrifuge
thin stillage
Evaporator
coarse solids
Rotary Dryer
Distillers Wet Grains
Distillers Dried Grains with Solubles
Cond. Distillers Solubles
Feed Industry Co-products

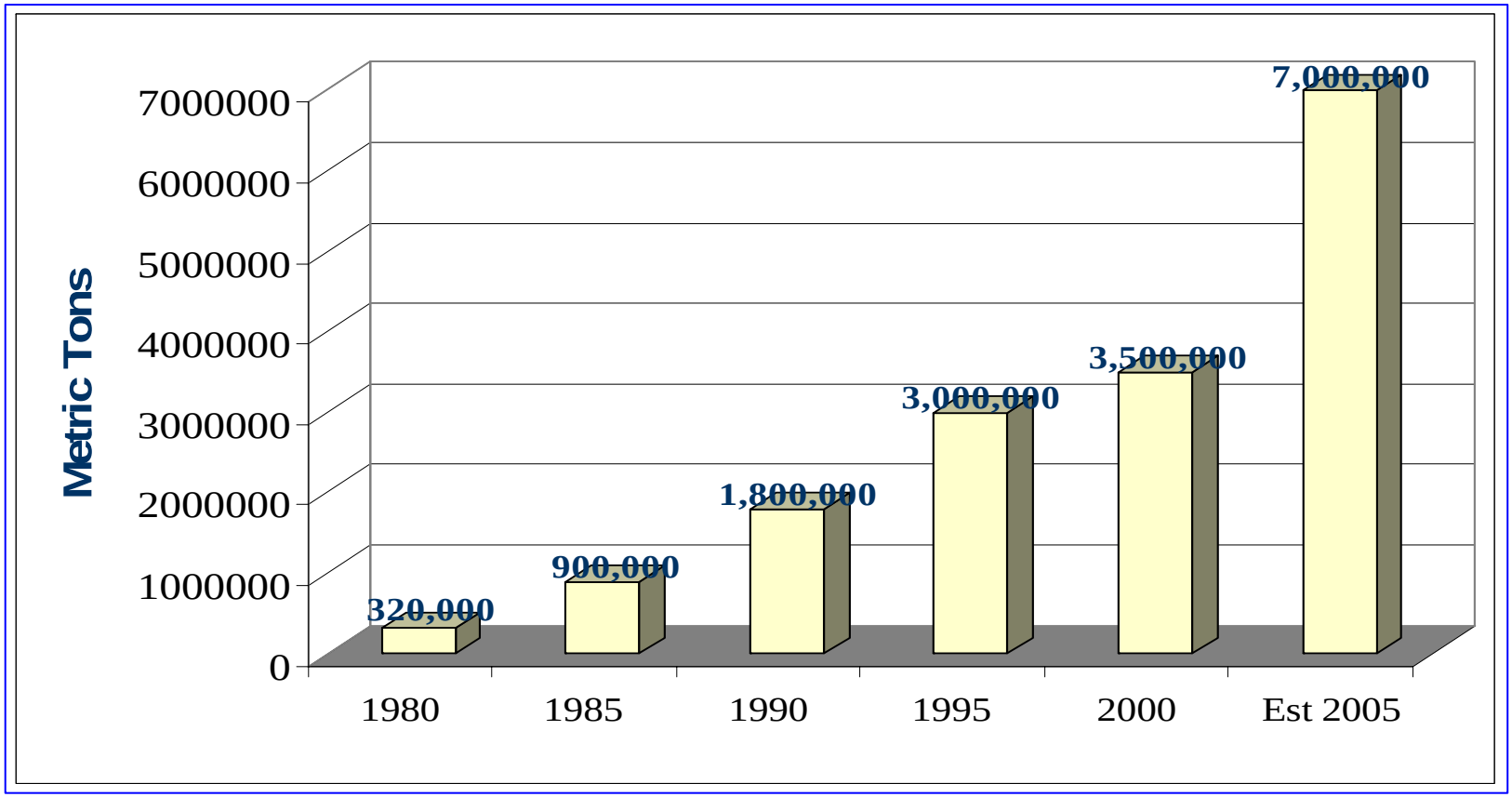
Dry-Milling Average Ethanol Yield Per Bushel of Corn

- Ethanol 2.7 gal.
- DDGS 18 lbs.
- CO_2 18 lbs.

Ethanol Plants in North America - June 16, 2004



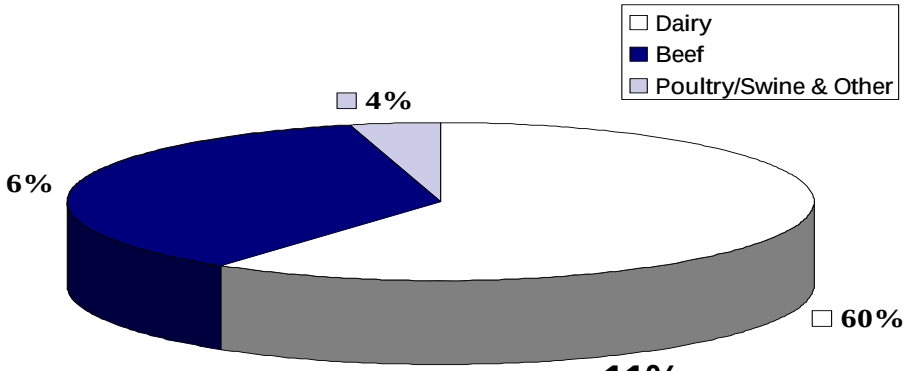
U.S. DDGS Production



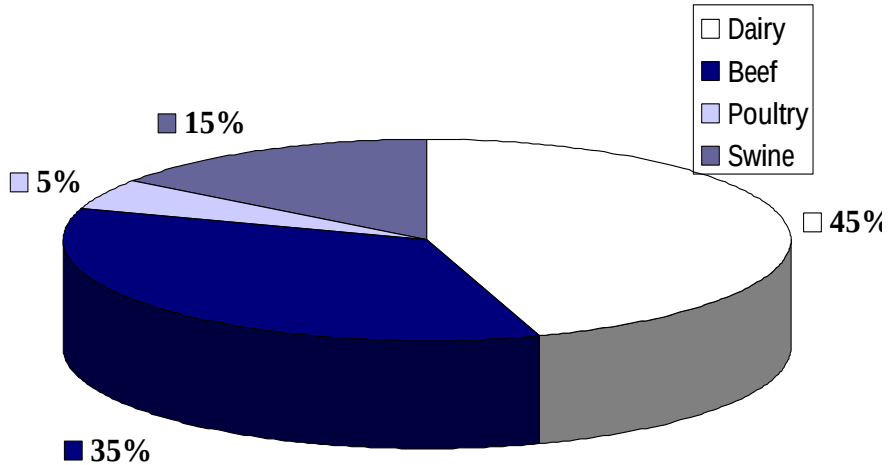
Source: Steve Markham – Commodity Specialists Company

U.S. DDGS Consumption

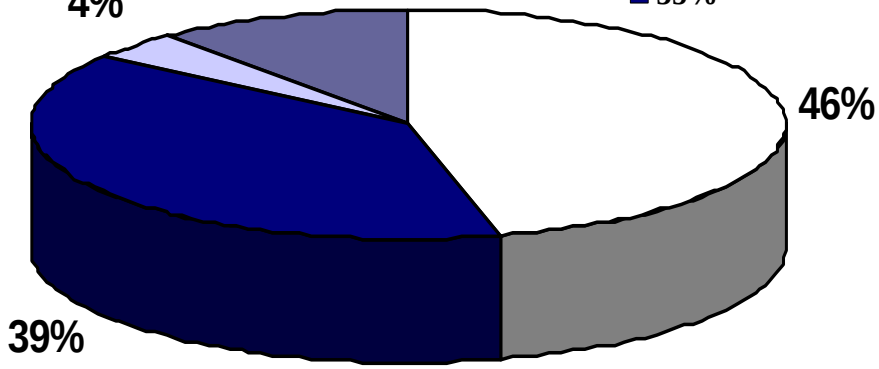
Estimate 2001



Estimate 2002



Estimate 2003



Dairy
Beef
Poultry
Swine

CSC 2004

What Are the Challenges?

1. **No grading system** to differentiate quality and price
2. **Inconsistent quality**
   - nutrient content
   - color
   - particle size
3. System to directly **connect customers to suppliers**
4. **Misrepresenting** quality and nutrient specifications and **blending DDGS** with other ingredients
5. **Flowability**

DDGS Varies Nutrient Content and Digestibility, Color, and Particle Size Among U.S. Sources

Samples of Golden Corn DDGS from Various Midwestern U.S. Ethanol Plants

VeraSun - Aurora, SD

CVEC - Benson, MN

Al-Corn - Claremont, MN

MGP – Lakota, IA

CMEC - Little Falls, MN

Agri-Energy - Luverne, MN

LSCP - Marcus, IA

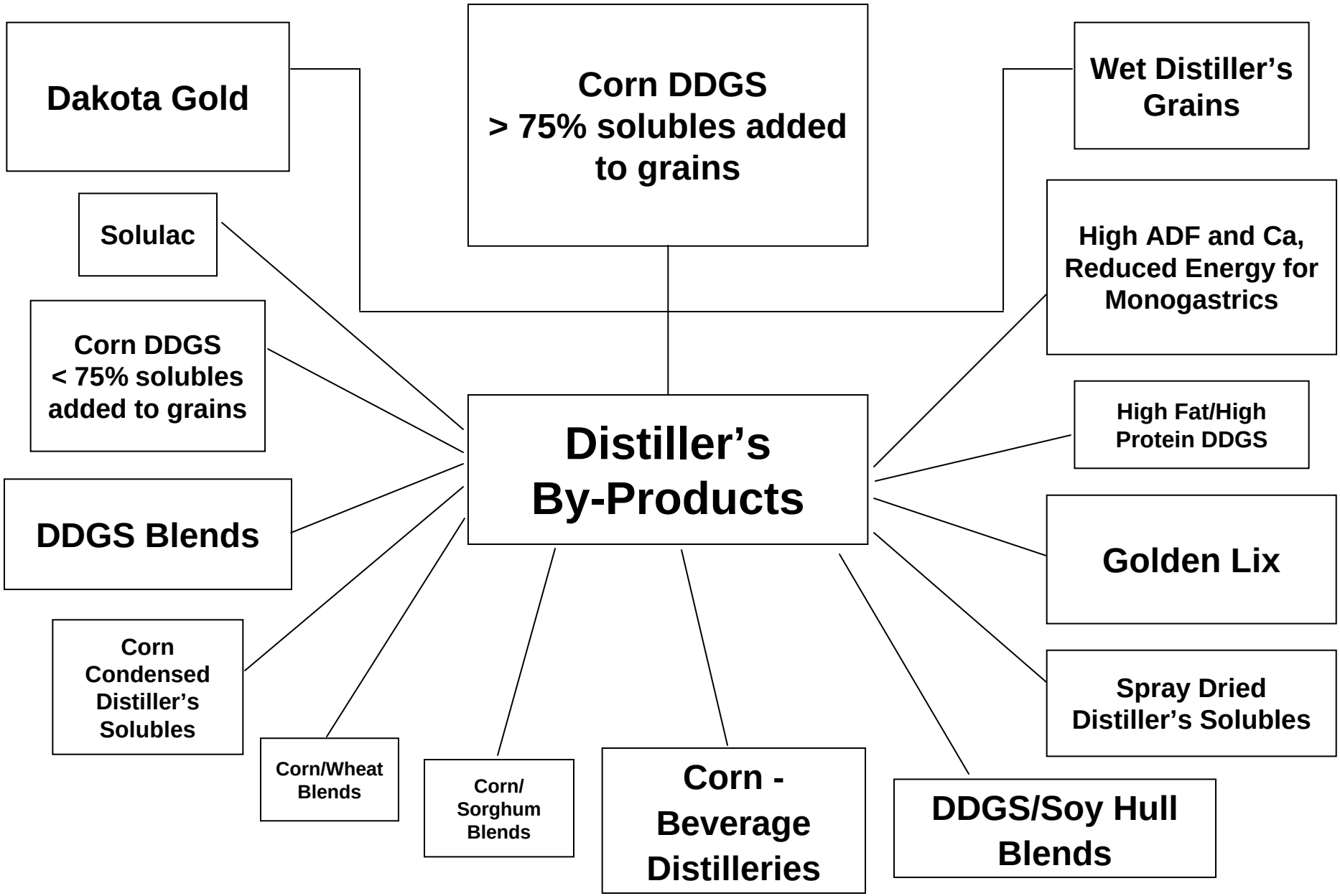
DENCO – Morris, MN

Comparison of Nutrient Composition (Dry Matter Basis) of "New Generation" DDGS to Other "DDGS Sources"

	"New Generation" Corn DDGS	Solulac	Badger State Ethanol	ADM - Peoria	Extruded DDGS/Soy (XDS Plus)	AGP Pelleted
Protein, %	31.82	29.32	31.62	30.12	34.44	27.0
Fat, %	11.32	3.52	15.25	8.96	13.33	9.00
Crude fiber, %	6.25	7.90	No data	7.77	7.78	15.10
ADF, %	12.37	11.80	17.91	20.95	14.44	No data
Ash, %	6.93	5.29	4.58	7.30	5.56	4.28
DE, kcal/kg*	4053	3808	No data	3796	No data	No data
ME, kcal/kg*	3781	3577	No data	3560	3749	No data
Lys, %	0.92	0.61	0.90	0.83	1.67	No data
Met, %	0.62	0.54	0.54	0.66	0.61	No data
Thr, %	1.17	1.01	1.04	1.13	2.50	No data
Trp, %	0.25	0.18	0.23	0.25	0.39	No data
Ca, %	0.07	0.12	0.06	0.51	0.22	0.17
P, %	0.77	0.78	0.89	0.68	0.72	0.62

*Calculated energy values for swine

Potential Categories of Distiller's By-Products



Proximate Analysis of “New Generation”DDGS (100% Dry Matter Basis)

Nutrient	“New Generation” DDGS
Dry matter, %	89.2
Crude protein, %	31.6
Fat, %	11.5
Crude fiber, %	6.2
Ash, %	7.8
NFE, %	42.8
ADF, %	11.2

Comparison of Amino Acid Composition of DDGS (88% dry matter basis)

	"New" DDGS	"Old" DDGS	DDGS (NRC, 1998)
Lysine, %	0.75 (17.3)	0.47 (26.5)	0.59
Methionine, %	0.63 (13.6)	0.44 (4.5)	0.48
Threonine, %	0.99 (6.4)	0.86 (7.3)	0.89
Tryptophan, %	0.22 (6.7)	0.17 (19.8)	0.24
Valine, %	1.32 (7.2)	1.22 (2.3)	1.23
Arginine, %	1.06 (9.1)	0.81 (18.7)	1.07
Histidine, %	0.67 (7.8)	0.54 (15.2)	0.65
Leucine, %	3.12 (6.4)	2.61 (12.4)	2.43
Isoleucine, %	0.99 (8.7)	0.88 (9.1)	0.98
Phenylalanine, %	1.29 (6.6)	1.12 (8.1)	1.27

Values in ( ) are CV's among plants

Composition of Distiller's Grains for Cattle

Nutrient	% of DM
Crude Protein	30-36
RUP, % of CP	47-57
NE_L, Mcal/lb	1.00
Fat, %	9.8
ADF, %	19.0
NDF, %	38.0
Ca, %	0.15
P, %	0.83

Energy Value of DDGS for Ruminants

Good Quality DDGS contains:

7-11% more energy than “book values”

10-20% more energy than corn

NE_L= 1.00 Mcal/lb

NE_M = 1.06 Mcal/lb

NE_G = 0.73 Mcal/lb

TDN = 94%

DE = 1.84 Mcal/lb

ME = 1.64 Mcal/lb

Protein in Distiller's Grains

> 30% of DM and more than old "book values"

- Similar for DDG & DDGS

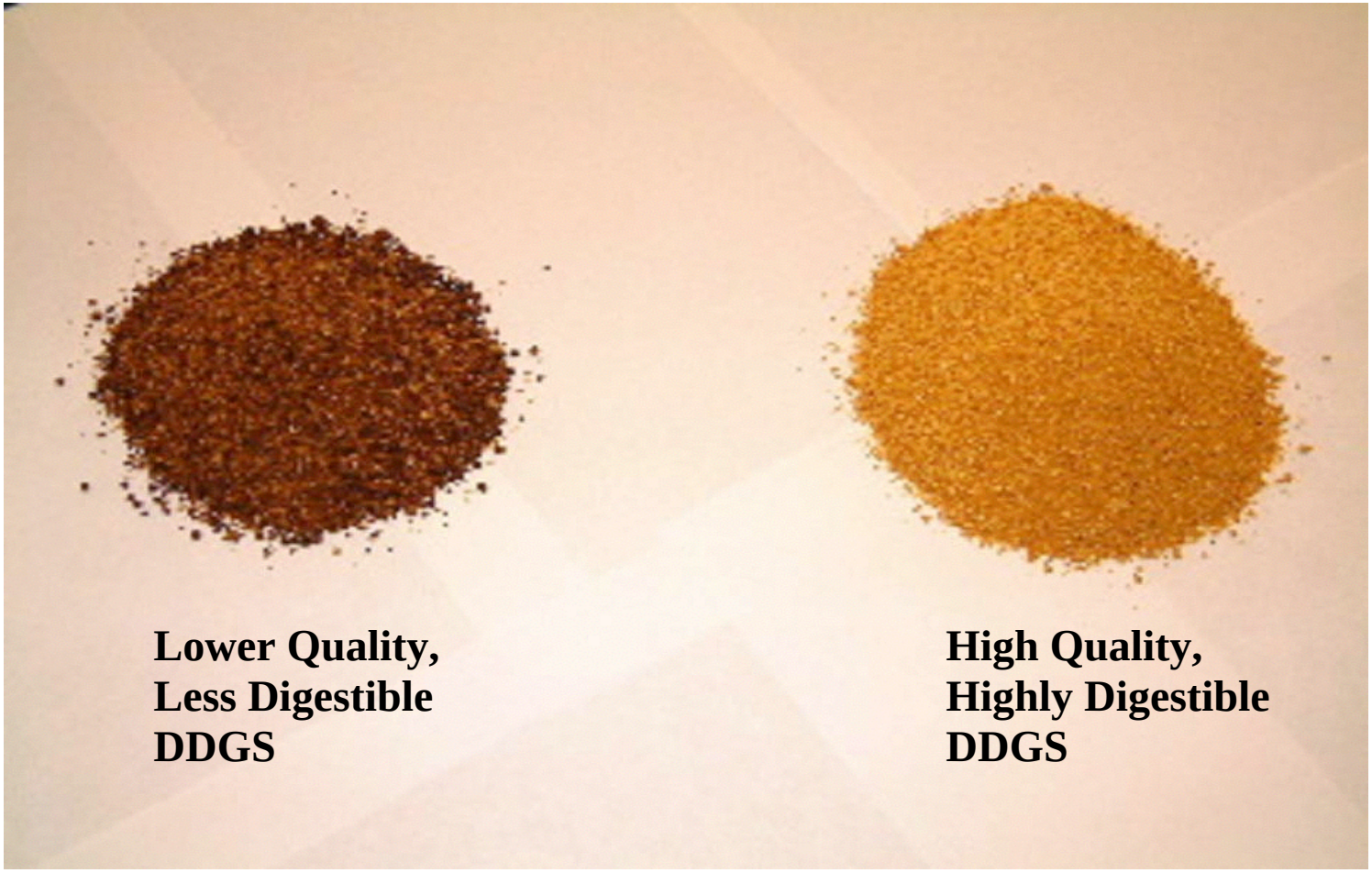
Good source of Ruminally Undegradable Protein (~55% RUP)

- RUP is slightly less for wet vs. dried DDG

Protein quality

- Fairly good quality
- Lysine is the first limiting amino acid

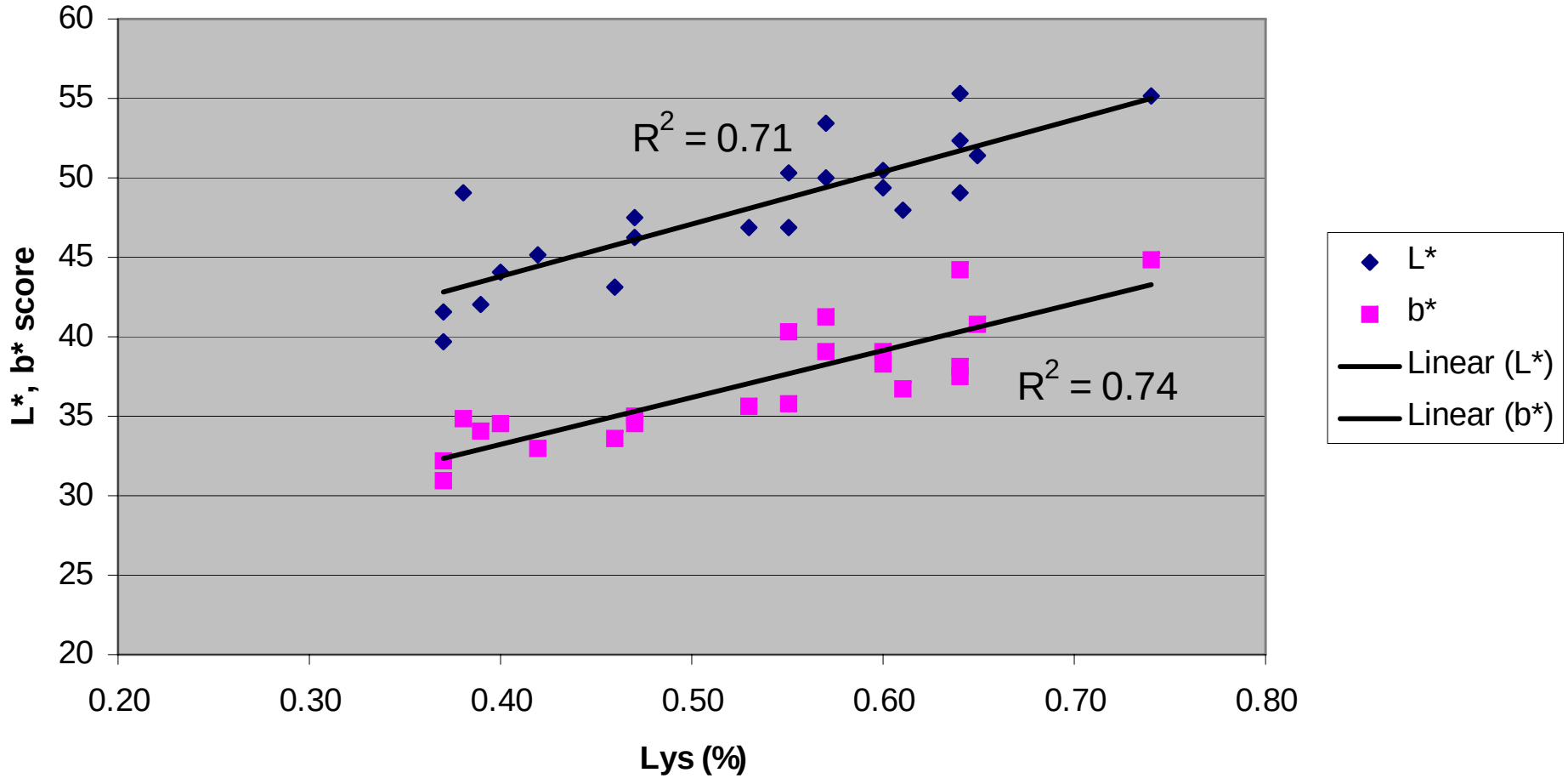
“Old Generation” vs. “New Generation” DDGS



Corn DDGS Color and Smell are Indicators of Digestibility for Monogastrics

- **Color varies among sources**
  - ranges from dark to golden **(Cromwell et al., 1993)**
  - golden color of corn DDGS is correlated with higher amino acid digestibility in swine and poultry
- **Smell varies among sources**
  - ranges from burnt or smoky to sweet and fermented **(Cromwell et al., 1993)**
  - golden DDGS has a sweet, fermented smell
  - smell may affect palatability

Fig. 1. Regression of digestible lys (%) and color (L*, b*)



The Use of DDGS in Swine Diets

DDGS Feeding Value for Swine

- Energy value of golden sources comparable to corn
- High available P – reduces manure P
- Adding 10% DDGS to finishing diets reduces the length, severity, and prevalence of ileitis lesions in a moderate disease challenge
- Feeding a 50% DDGS diet in gestation and 20% DDGS diet in lactation may increase litter size

Maximum Inclusion Rates of "New Generation" DDGS in Swine Diets

(Based Upon University of Minnesota Performance Trials)

- Nursery pigs (> 7 kg)
  - Up to 25 %
- Grow-finish pigs
  - Up to 20% (higher levels may reduce pork fat quality)
- Gestating sows
  - Up to 50%
- Lactating sows
  - Up to 20%

Assumptions: no mycotoxins
formulate on a digestible amino acid and available phosphorus basis

Comparison of DE and ME Estimates of DDGS (88% DM)

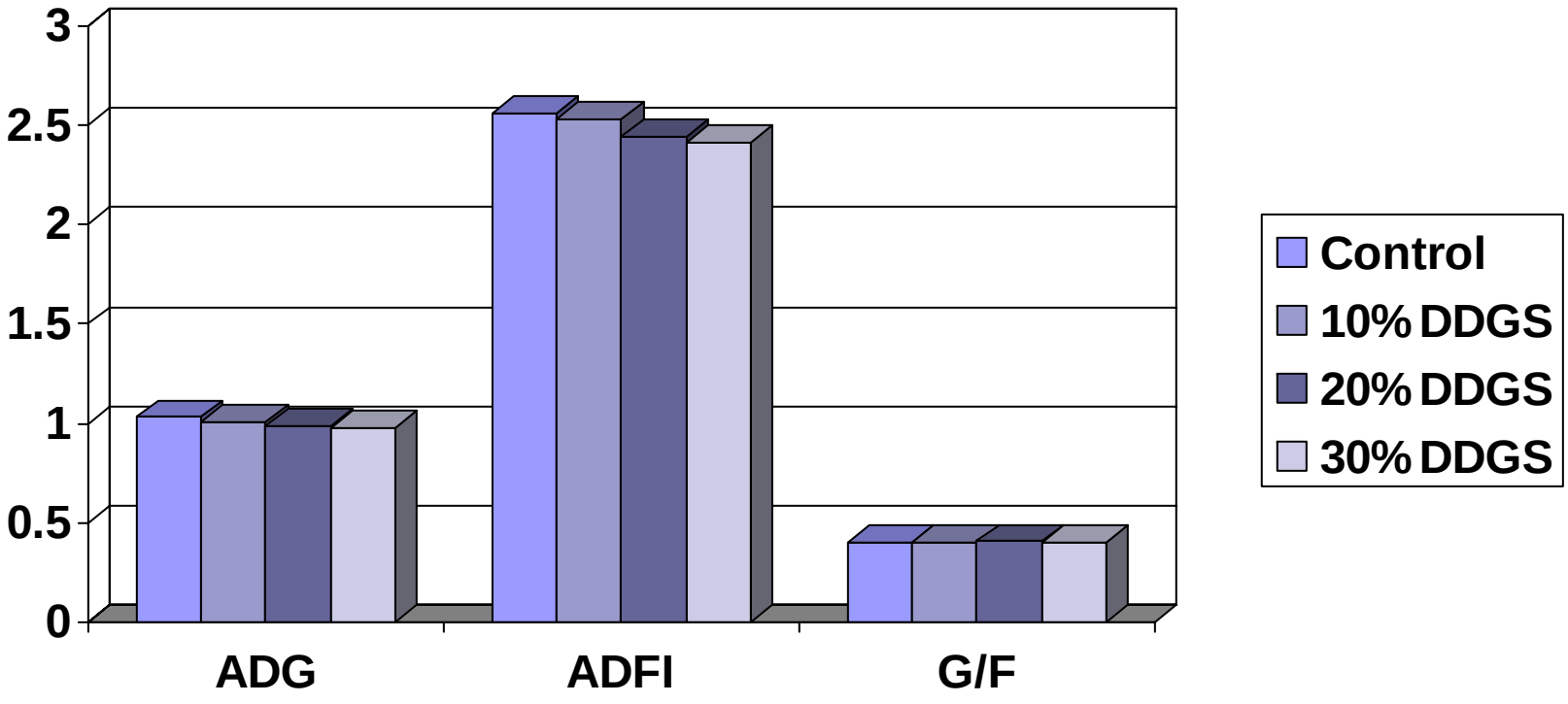
	DE, Mcal/kg	ME, Mcal/kg	NE, Mcal/kg
U of M – New Generation (1999)	3.49	3.37	No data
U of M – Old Generation (1999)[1]	3.41	3.10	No data
KSU – New Generation (2004)[2]	3.87	3.49 – 3.70	2.61
KSU – "Old Generation" (2004)[3]	3.73	3.13 – 3.59	2.45
Hanor-Hubbard-Ajinomoto (2004)[4]	No data	3.25	2.42
NRC (1998)	3.45	2.67	No data

[1] Calculated values
[2] Determined by growth and metabolism trials (source Dakota Gold)
[3] **Not DDGS** but corn gluten from a NE ethanol plant
[4] Determined by growth trials (source Dakota Gold)

G-F Trial Procedures (Fu et al. 2004)

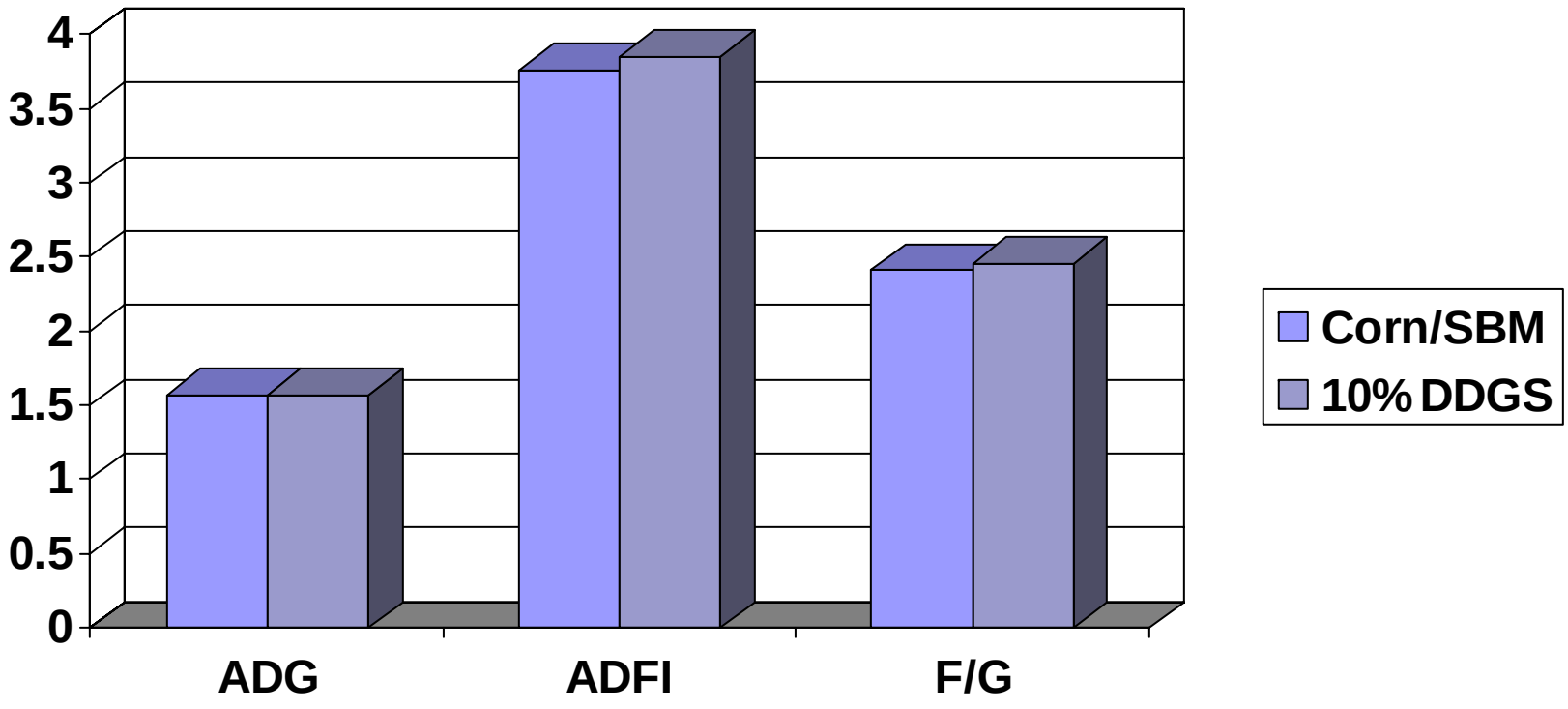
- DDGS source – Dakota Gold
- Used 256 barrows (initial wt.= 28.5 kg)
- 92 d feeding period
- 5 phase feeding program
- Diets contained 0, 10, 20, or 30% DDGS
  - Formulated on a equivalent ileal digestible lysine and isocaloric basis
  - Contained 0.15% (phase 1-4) or 0.10% (phase 5) L-lysine HCl to keep digestible threonine, tryptophan, and sulfur amino acids $\geq$ the control diets

Effect of DDGS Inclusion Rate on ADG, ADFI, and G/F for 92-d Grow-Finish Period



Fu et al. (2004)

Effect of Adding 10% DDGS to Grow-Finish Diets on ADG, ADFI, and F/G for a 64 d Grow-Finish Period



Lawrence (2003) – Hubbard Milling Commercial Feeding Trial

Effect of DDGS Inclusion Rate on Carcass Characteristics (Fu et al. 2004)

- Increasing dietary DDGS level:
  - Linearly decreased carcass weight
  - No effect on backfat
  - No effect on loin depth
  - No effect on % carcass lean
  - No effect on carcass yield

Typical Grow-Finish Pig Performance in a 1000 Head Commercial Finishing Barn

Grow-Finish Pigs Fed Diets Containing DDGS

	No DDGS	10% DDGS
Pigs in	993	988
Pigs Out	979	971
Daily Gain, lb	1.63	1.62
Feed:Gain	2.75	2.74
Feed cost, $/hd	$32.69	$32.53

Source: Land O'Lakes Farmland Feed

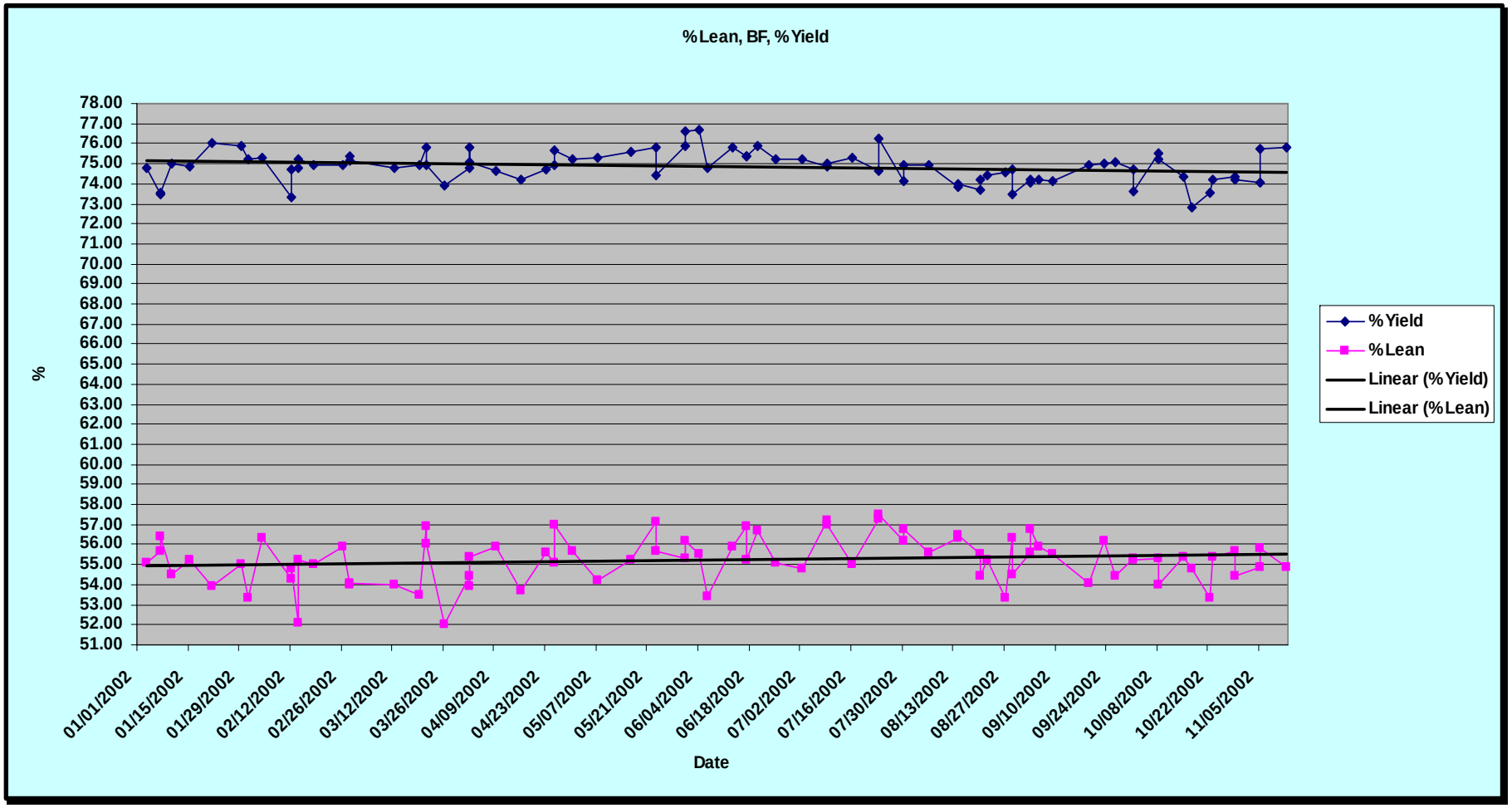
Actual Close-Outs on Commercial Swine Finishing Operations

	# in	# out	Wt in	Wt out	DL	ADG	F/G	ADC	Days
Farm 1:									
Averages			58.7	253.0	3.35	1.71	2.79	4.79	113
Total head	24,676	23,852							
Farm 2:									
Averages			47.2	265.2	2.88	1.75	2.86	5.00	124
Total head	8,798	8,545							
Farm 3:									
Averages			51.5	259.2	2.33	1.74	2.76	4.82	119
Total head	13,887	13,563							

Source: Land O'Lakes Farmland Feed

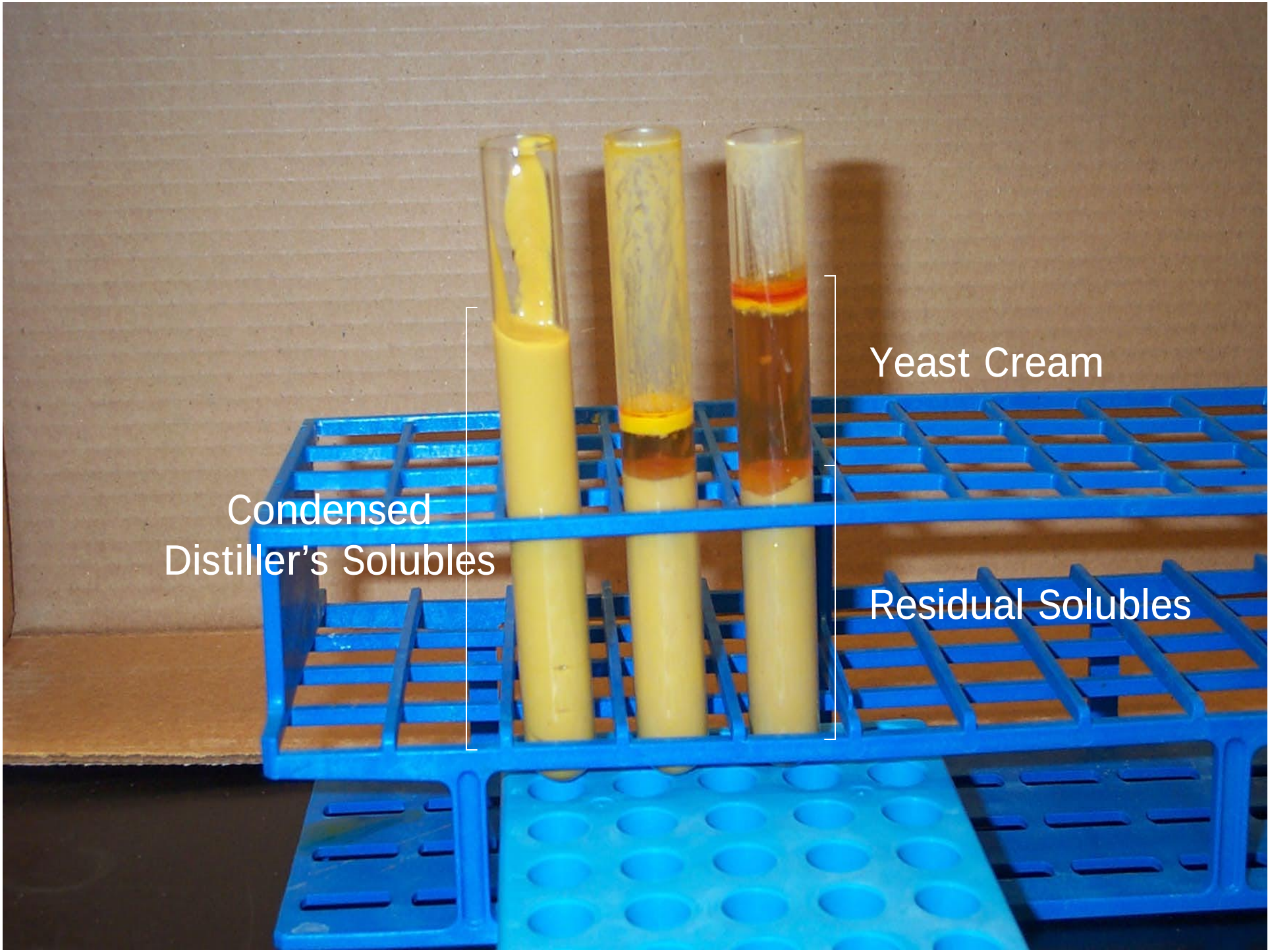
Carcass Yield and % Lean of Pigs Fed 10% DDGS Diets on a Commercial Swine Operation in 2002

(10% DDGS was added to diets mid-year)



Source: Land O' Lakes

Are There Components of Corn Distiller's Solubles that Are Responsible for Enteric Health Benefits?

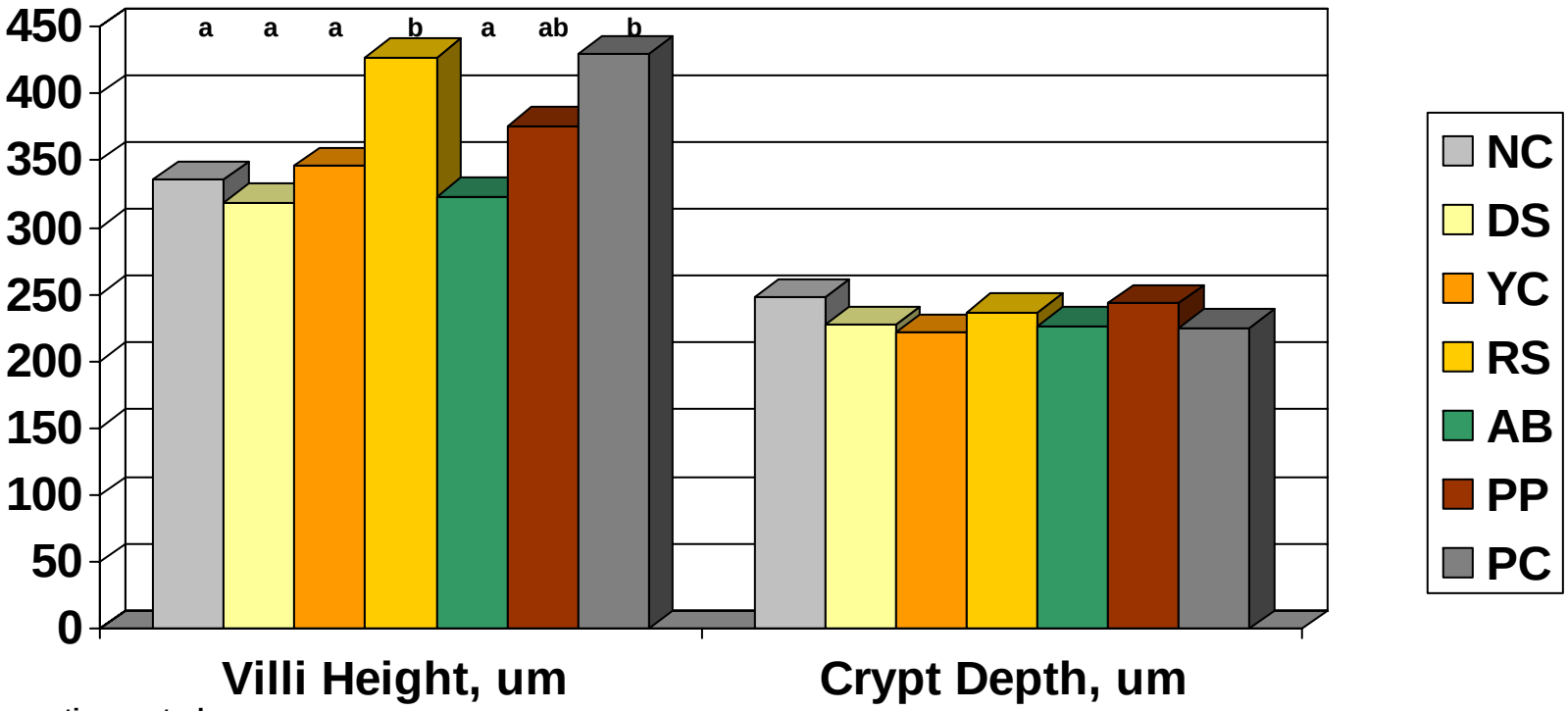

Yeast Cream
Condensed
Distiller's Solubles
Residual Solubles


Spray Dried Distiller's Solubles
(DS)
Spray Dried Yeast Cream
(YC)
Spray Dried Residual Solubles
(RS)

Materials and Methods

- 7 dietary treatments fed from day 0 to 10 post-weaning
  - **NC = negative control**
  - **DS = spray dried distiller's solubles**
    - **15% of the diet**
  - **YC = spray dried yeast cream**
    - **7.5% of the diet**
    - **replaced animal fat**
  - **RS = spray dried residual solubles**
    - **15% of the diet**
  - **AB = carbadox**
    - **50 g/ton**
  - **PP = spray dried porcine plasma**
    - **6% of the diet**
  - **PC = spray dried porcine plasma + carbadox**
    - **6% PP + 50 g/ton AB**

Villi Height and Crypt Depth in the Upper 25% of the Small Intestine



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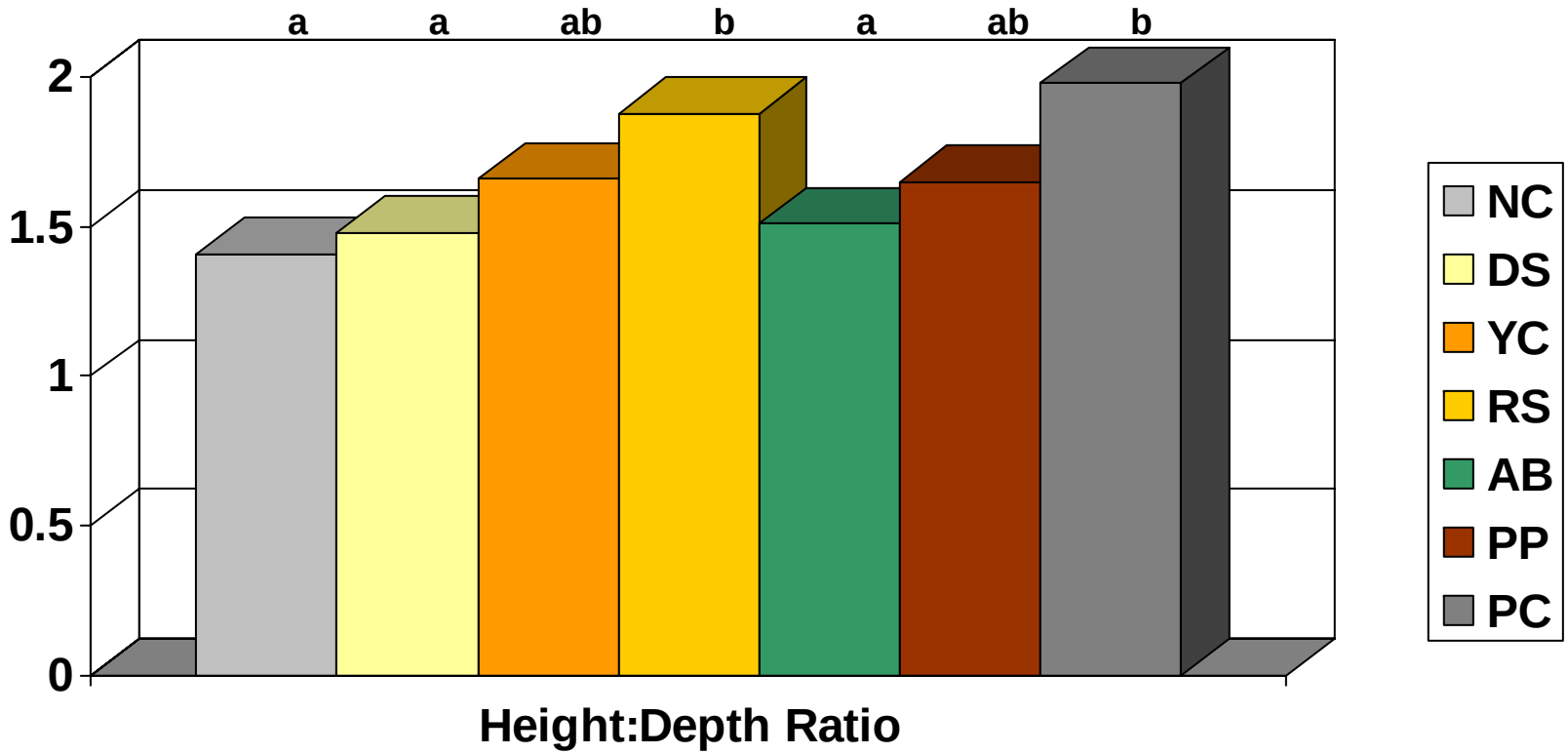
a, b = Least squares means with different superscripts are different ($P < .05$)

Villi Height:Crypt Depth Ratio in the Upper 25% of the Small Intestine



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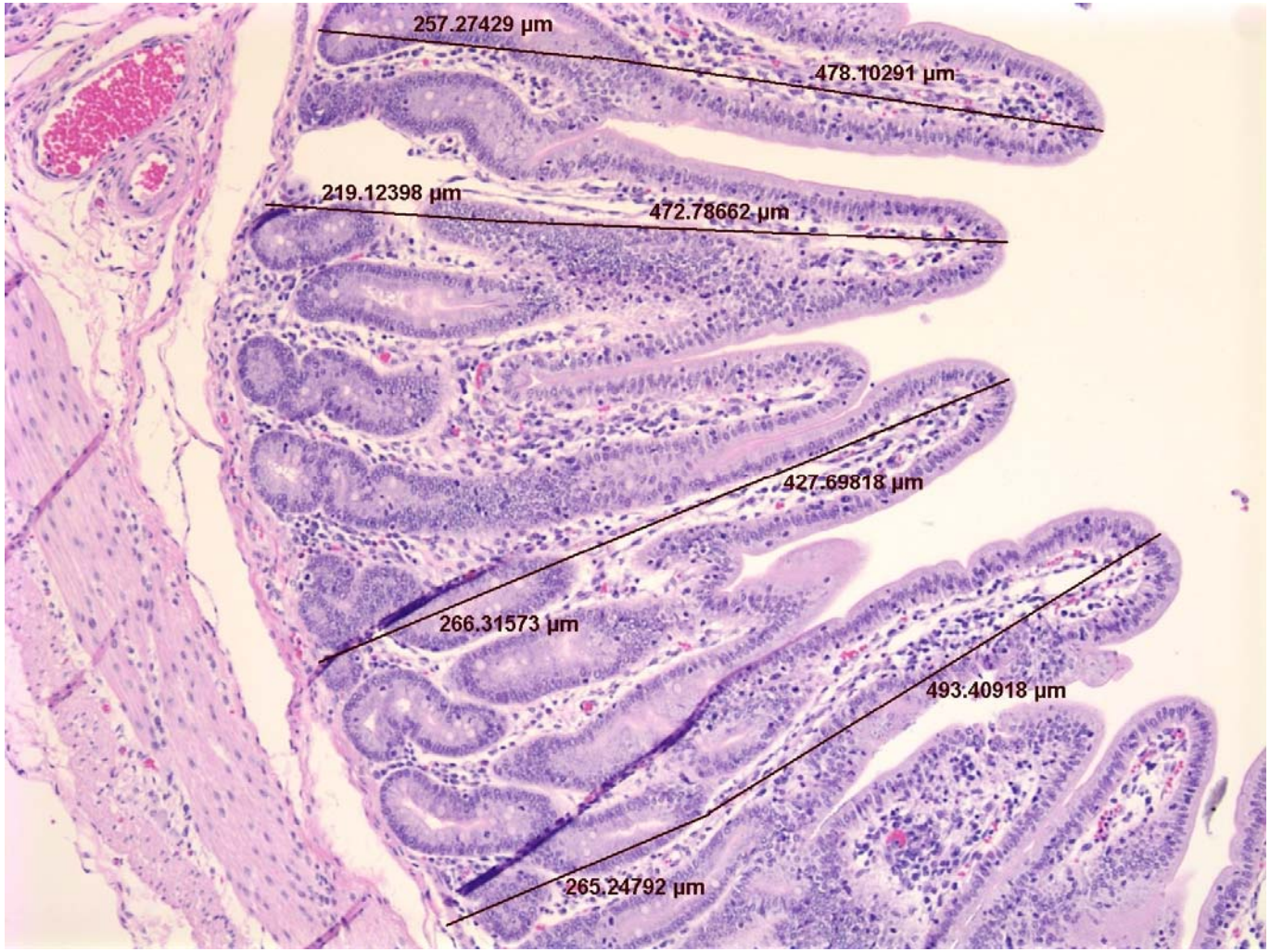
Villi Measurements from the Upper 25% of the Small Intestine from a Pig Fed the Residual Solubles Diet (10X)



Villi Measurements from the Upper 25% of the Small Intestine from a Pig Fed the Carbadox Diet (10X)

The Use of DDGS in Dairy Rations

Is There a Difference When Feeding Whiskey or Fuel Ethanol Distillers Grains?

When milk production was compared between feeding DDGS from whiskey or fuel ethanol plants:

* Similar milk production
* Higher production than when fed SBM
* If DDGS was dark (heat damaged?):
  - production was the same as when fed SBM

Florida Research (1995)

Wet vs. Dried Distiller's Grains

Nutrient content of DM is the same for both

Considerations for Wet Distiller's Grains:

- Can usually store only 5-7 days
- May need preservatives (e.g. propionic acid or other organic acids, etc.)
- Limited economical hauling distances
- Rations may be too wet
    - limit total DM intake, especially if ensiled forages are also fed

Production Response of Dairy Cows When Fed Distiller's Grains

The same as, or greater than when fed SBM

Increased or no change when supplemented with protected lysine & methionine

Similar to when fed a blend of protein supplements (SBM, FM, DG)

How Much Distiller's Grains Can be Fed to Dairy Cows?

Recommend max. of ~ 20% of ration DM

- 10-13 lb/d of dried
- 30-40 lb/d of wet

Usually no palatability problems

At 30% of DM:

- May decrease DMI, especially if Wet CDG
- May feed excess protein

Example Ration Considerations for Dairy Cattle

Diets containing 50:50 forage:concentrate

- If equal proportions of alfalfa & corn silage

  *** DG can replace most or all protein supplement**

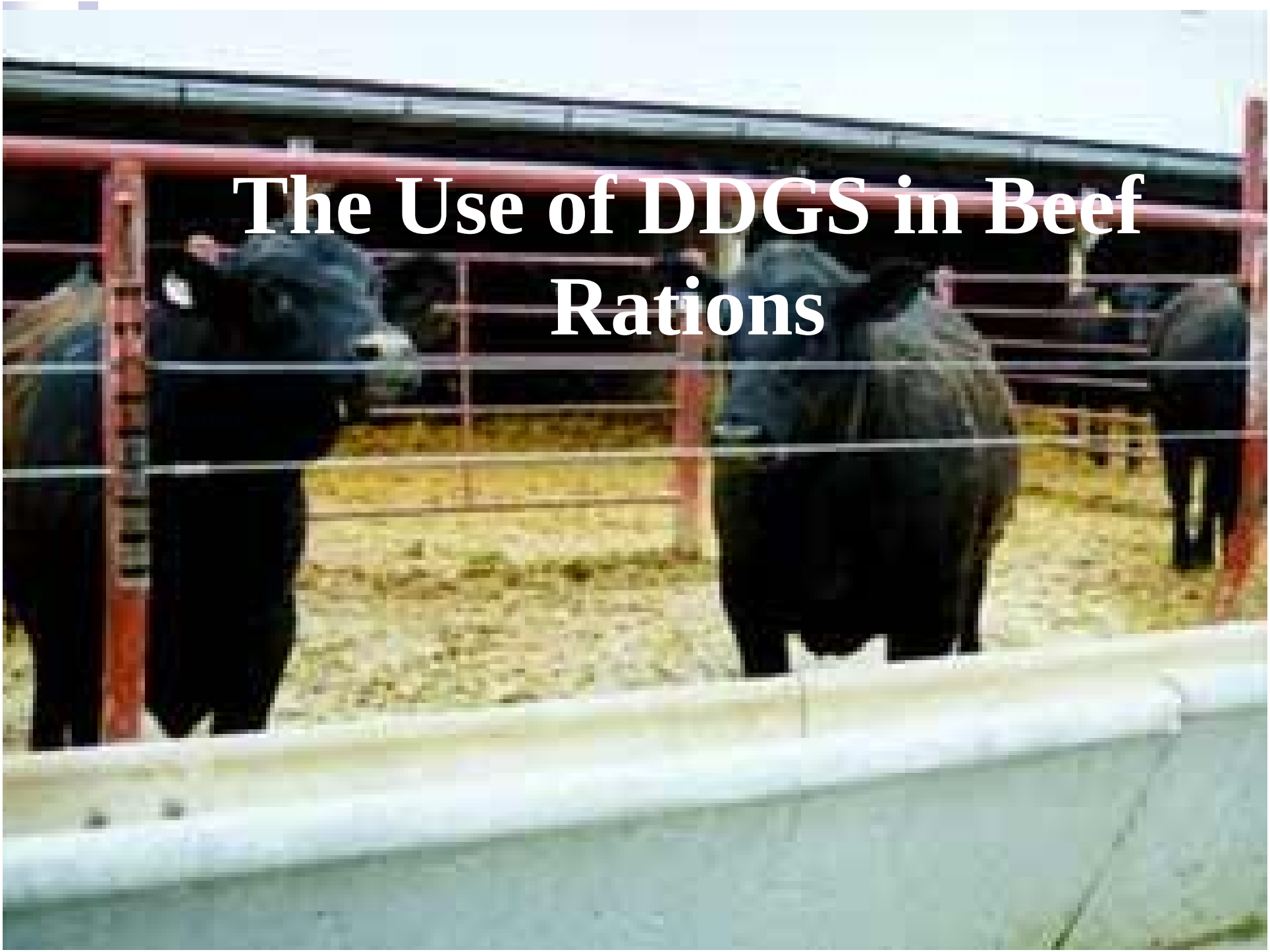
- If mostly corn silage

  * **More DG can be fed but may need some other protein supplement (check Lysine and P levels)**

- If mostly alfalfa

  *** Less DG likely needed to supply diet CP**

The Use of DDGS in Beef Rations



Nutritional Value of DDGS for Beef Cattle

- Excellent protein source (28% crude protein)
- High by-pass protein
- Excellent source of essential minerals (P and K)
- Improves rumen health
- Very palatable
- 1.8 times more value compared to soybean meal

Distiller's Grains for Beef Cattle

- As protein source
  - 6-15% of ration DM
- As an energy source
  - when fed at >15% of DM
  - may reduce acidosis because highly digestible fiber in place of starch
- ADG and F/G usually better than with corn

Klopfenstein et al., University of Nebraska

Value of Nutrients in DDGS for Finishing Cattle

- Energy
  - Wet distiller's grains – 110 to 125% energy of corn (DM basis)
  - DDGS – 100% of corn (DM basis)
- Protein
  - By-pass > soybean meal
  - Wet = Dry is properly dried
- Fiber
  - High fiber and low starch reduces fermentation rate
    - Safe ingredient to start cattle on finishing diets
    - Reduces subacute acidosis
- Fat
  - Oil content limits the quantity fed (<40%)
- Phosphorus
  - No value in corn-based finishing diets
  - Value as a supplement to low P forages

How Much Distiller's By-Products Can Be Fed to Beef Cattle?

- DDGS (90% DM)
  - Feed to supply protein to meet requirement
    - < 20 % ration dry matter
- Wet DGS (30% DM)
  - Feed to supply protein and energy
    - Commonly fed at < 25% of ration dry matter
    - Greatest value at 15 to 20% of ration dry matter
  - Can feed up to 40% of ration dry matter
    - Overfeed protein and phosphorus
- Wet Condensed Distiller's Solubles (30% DM)
  - Feed to supply protein and energy
    - Limit to < 10% of ration dry matter

Value of By-Products for Beef

	Cost	DM%	NEg	CP%	Ratio
Corn per bushel	**$3.05**	**88.0**	**66**	**9.5**	
Hi Pro Soybean Meal per ton	**$320**	**89.0**	**65**	**53.4**	**25%**
Feed Grade Urea per ton	**$490**	**99.0**	**0**	**286**	**75%**

		100% DM		Maximum Value per Ton, delivered		
Commodity	DM %	NEg Mcal/cwt	CP %	Energy Value/ton	Protein Value/ton	**Total Value/ton**
Corn Screenings	86	52	9.5	$67	$21	**$88**
Corn Gluten Feed, Dry	90	63	20	$85	$47	**$132**
Corn Gluten Feed, Wet	40	63	20	$38	$21	**$59**
Cottonseed, Whole	91	72	23	$98	$54	**$153**
Distillers Grains, Dry	88	66	28	$87	$64	**$151**
Distillers Grains, Wet	30	66	30	$30	$23	**$53**
Distillers Syrup	30	80	30	$36	$23	**$59**

DDGS Relative Value Differs Depending on Species

Assumptions:

- **Corn** **$2.00 / bu**
- **SBM** **$175.00 / ton**
- **Urea** **$360.00 / ton**
- **Non-ruminant diets corn/SBM**
- **Ruminant diets typical diets with competing by-products.**

Feed	Dollars/ ton
Dairy Lactation	$114.24
Poultry Finisher	$100.09
Layer Diet	$104.66
Swine G-F Diet	$96.34
Beef Feedlot	$108.00

Source: Tilstra, Land O' Lakes

U of M DDGS Web Site
www.ddgs.umn.edu

We have developed a DDGS web site featuring:

* research summaries
    - swine, poultry, dairy, & beef
    - DDGS quality
* presentations given
* links to other DDGS related web sites
* international audiences