New Technologies to Aid in Evaluation of Alternative Feedstuffs

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Our challenge

- Cost of feed energy and amino acids are at record highs
- Availability of corn supply?
- Must use higher fiber, by-product ingredients to minimize cost
  - Higher variability in nutrient content and value than corn and soybean meal

Feed ingredient price vs. value

- We purchase on price but formulate on value
  - Price determined by:
    - Moisture
    - Fat
    - Fiber
    - Protein

  - Value determined by:
    - ME or NE content
    - Digestible amino acid content
    - Available P content

Are we asking too much?

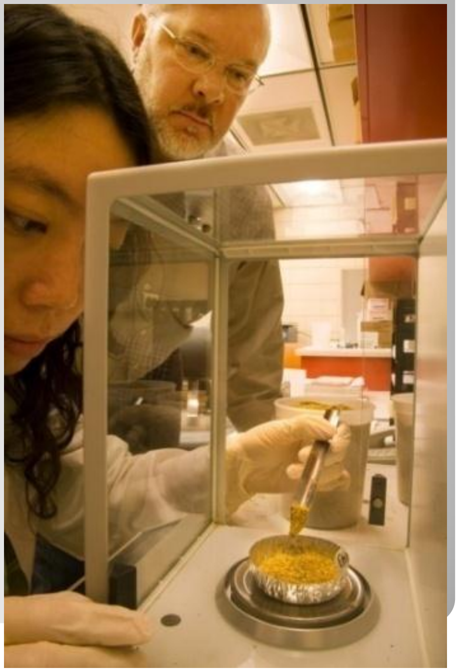
- We want:
  - **Consistent** and **predictable** feed ingredient quality and nutrient content
  - **Rapid**, **easy**, and **inexpensive** nutritional value assessment "tools"

The "cost" of uncertainty for nutritional value of feed ingredients

- Pay too much for what it contributes to the diet
- Use "inflated" safety margins to avoid underfeeding nutrients
  - don't capture full value
- Overestimate nutritional value
  - performance suffers
  - cost of production increases

Chemical determination of quality

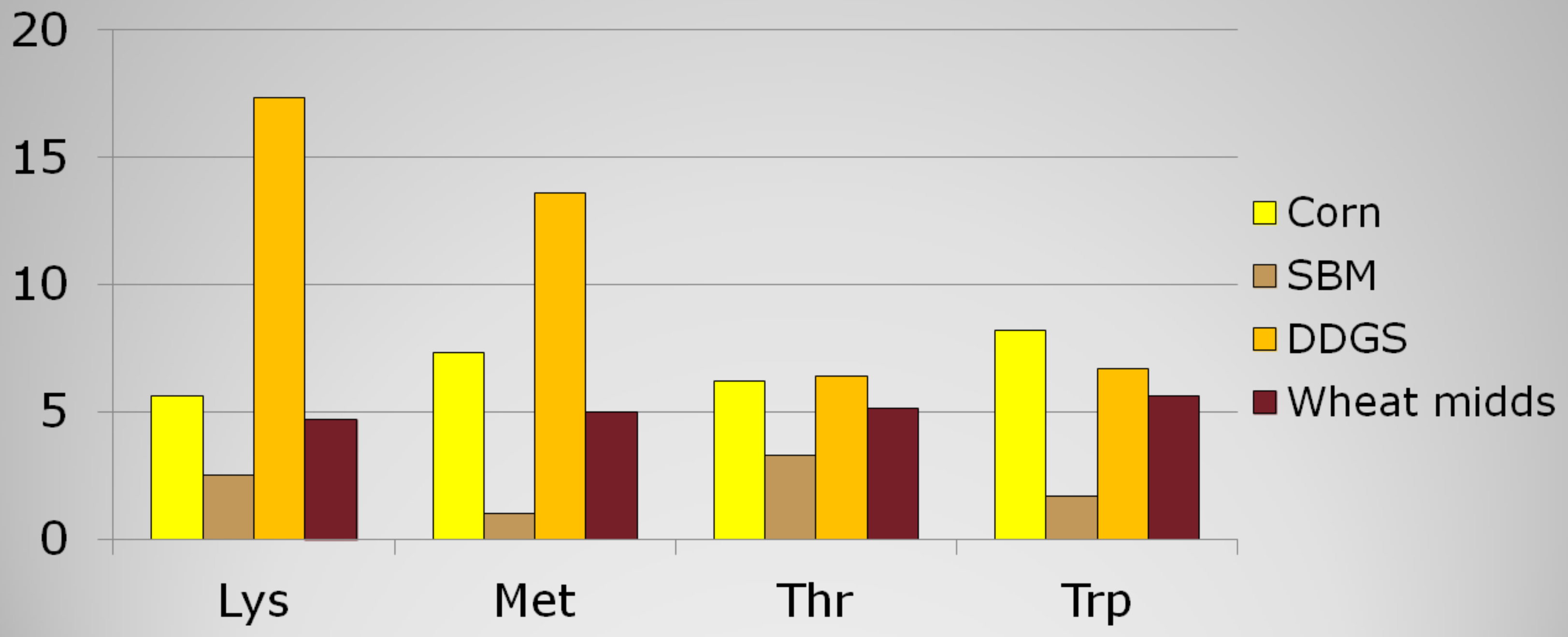
- Quantitatively estimates nutrient content and possible contaminants
  - e.g. moisture, protein, fiber, fat, mycotoxins
- Challenges
  - Cost
  - Time
  - Variation in analytical methods and labs
  - Minimal value in diet formulation



Biological determination of quality

- Quantitative
- Most precise of all quality assessments
- Measure animal responses to specific feeds
  - Very expensive
  - Time consuming
  - Requires specialized knowledge, equipment, and procedures
  - Not practical for routine quality assurance programs at feed mills

Coefficients of variation (CV,%) for selected amino acids among samples of corn, soybean meal, DDGS, and wheat midds



Nutrient composition and variability of DDGS

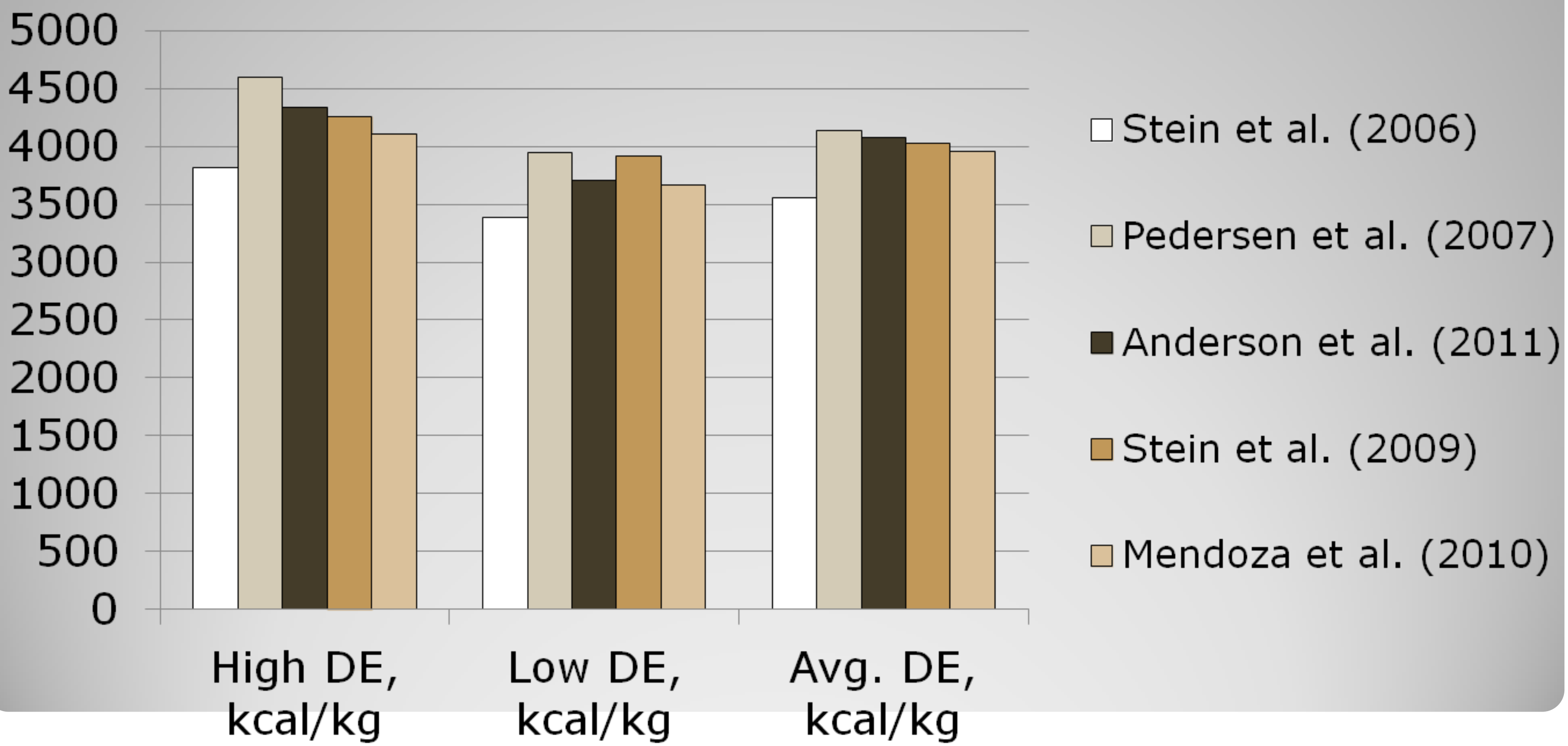
Nutrient composition among 32 DDGS sources (DM basis)

Nutrient	Average (CV, %)	Range
Dry matter, %	89.3	87.3 – 92.4
Crude protein, %	30.9 (4.7)	28.7 – 32.9
Crude fat, %	10.7 (16.4)	8.8 – 12.4
Crude fiber, %	7.2 (18.0)	5.4 – 10.4
Ash, %	6.0 (26.6)	3.0 – 9.8
Swine ME, kcal/kg (calculated)	3810 (3.5)	3504 – 4048
Lysine, %	0.90 (11.4)	0.61 – 1.06
Phosphorus, %	0.75 (19.4)	0.42 – 0.99

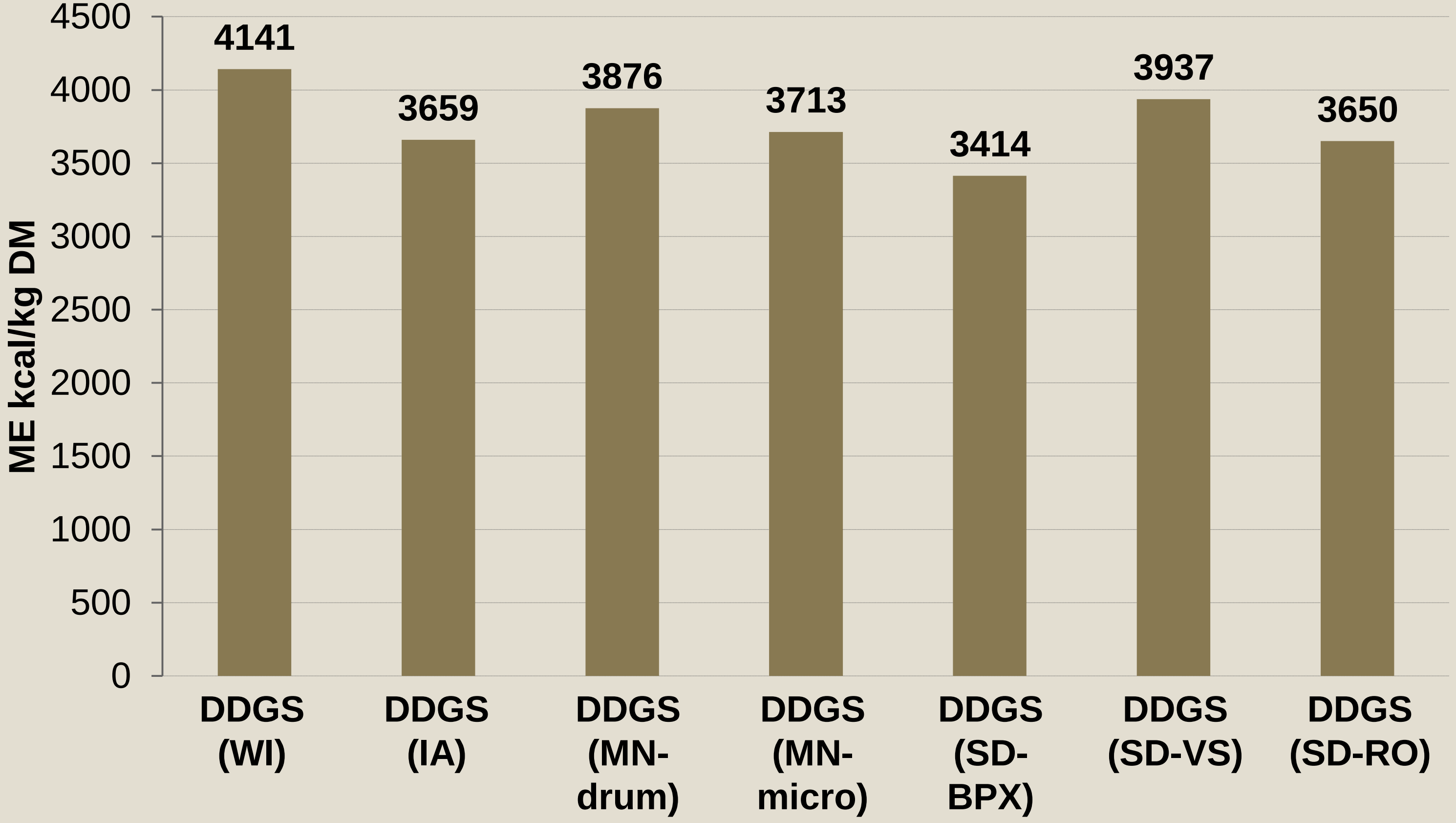
Source: University of Minnesota

ME content and prediction in DDGS sources for swine

Comparison of DE estimates among DDGS sources from 5 studies



ME content of corn DDGS from 7 different process technologies



Anderson et al. (2011)

Why does DE and ME content of DDGS vary so much?

- Variable fat levels among sources
  - Variation is increasing due to "back-end" oil extraction
- Variable carbohydrate composition and digestibility

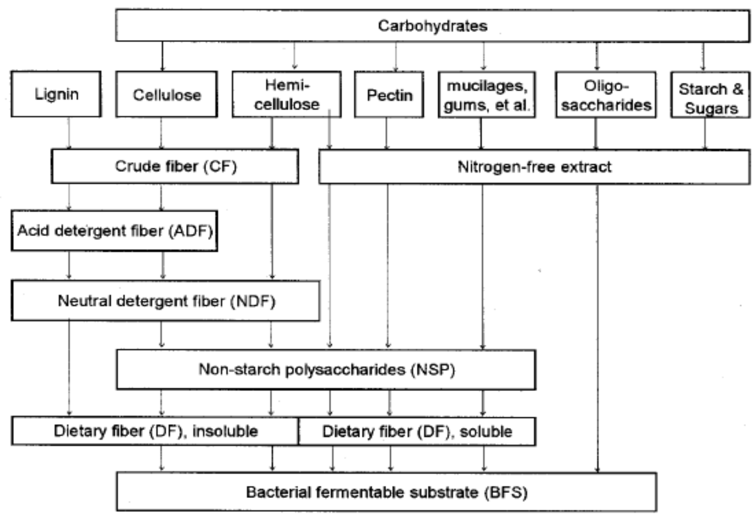


Figure 1.2. Classification of the carbohydrates (adapted from Bakker et al. (1998))

Concentration of carbohydrates and apparent total tract digestibility (ATTD) of dietary fiber in corn DDGS

Carbohydrate fraction	Average	Range	SD
Total starch, %	7.3	3.8 – 11.4	1.4
Soluble starch, %	2.6	0.5 – 5.0	1.2
Insoluble starch, %	4.7	2.0 – 7.6	1.5
ADF, %	9.9	7.2 – 17.3	1.2
NDF, %	25.3	20.1 – 32.9	4.8
Insoluble total dietary fiber, %	35.3	26.4 – 38.8	4.0
Soluble dietary fiber, %	6.0	2.4 – 8.5	2.1
Total dietary fiber, %	42.1	31.2 – 46.3	4.9
ATTD, total dietary fiber, %	43.7	23.4 – 55.0	10.2

Stein and Shurson (2009)

Why does DE and ME content of DDGS vary so much?

- Variability in procedures and labs

Commonly Referenced Prediction Equations for Energy (Noblet and Perez, 1993)

- ME (kcal/kg DM) = 4167 – 9.1 x Ash + 1.1 x CP + 4.2 x EE – 2.6 x Hemi – 4.0 x Cell – 6.8 x ADL
  - R^2 = .93
- ME (kcal/kg DM) = 872 + .782 x GE – 4.6 x Ash – 3.4 x NDF – 5.7 x ADL
  - R^2 = .92
- ME (kcal/kg DM) = 4369 – 10.9 x Ash + 4.01 x EE – 6.5 x CF
  - R^2 = .87

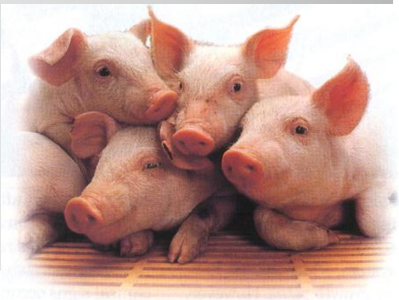
ME prediction equations for DDGS in swine diets

ME kcal/kg DM = (0.949 × kcal **GE**/kg DM) – (32.238 × % **TDF**) – (40.175 × % **ash**)

Anderson et al. (2011) $r^2 = 0.95$ SE = 306

ME kcal/kg DM = 2,815 + (94.5 × % **crude fat**) + (96.2 × % **crude fiber**) – (33.2 × % **NDF**) – (66.2 × % **ash**) + (25.9 × % **starch**)

Mendoza et al. (2010) $r^2 = 0.90$ SE = 49



ME prediction equations for DDGS in swine diets (Pedersen et al., 2007)

ME kcal/kg DM = −10,866 − (108.12 × % **ash**) + (37.55 × % **CP**) − (8.04 × % **starch**) − (71.78 × % **EE**) − (164.99 × % **ADF**) + (15.91 × % **NDF**) + (3.007 × **GE**, kcal/kg)
$r^2 = 0.99$

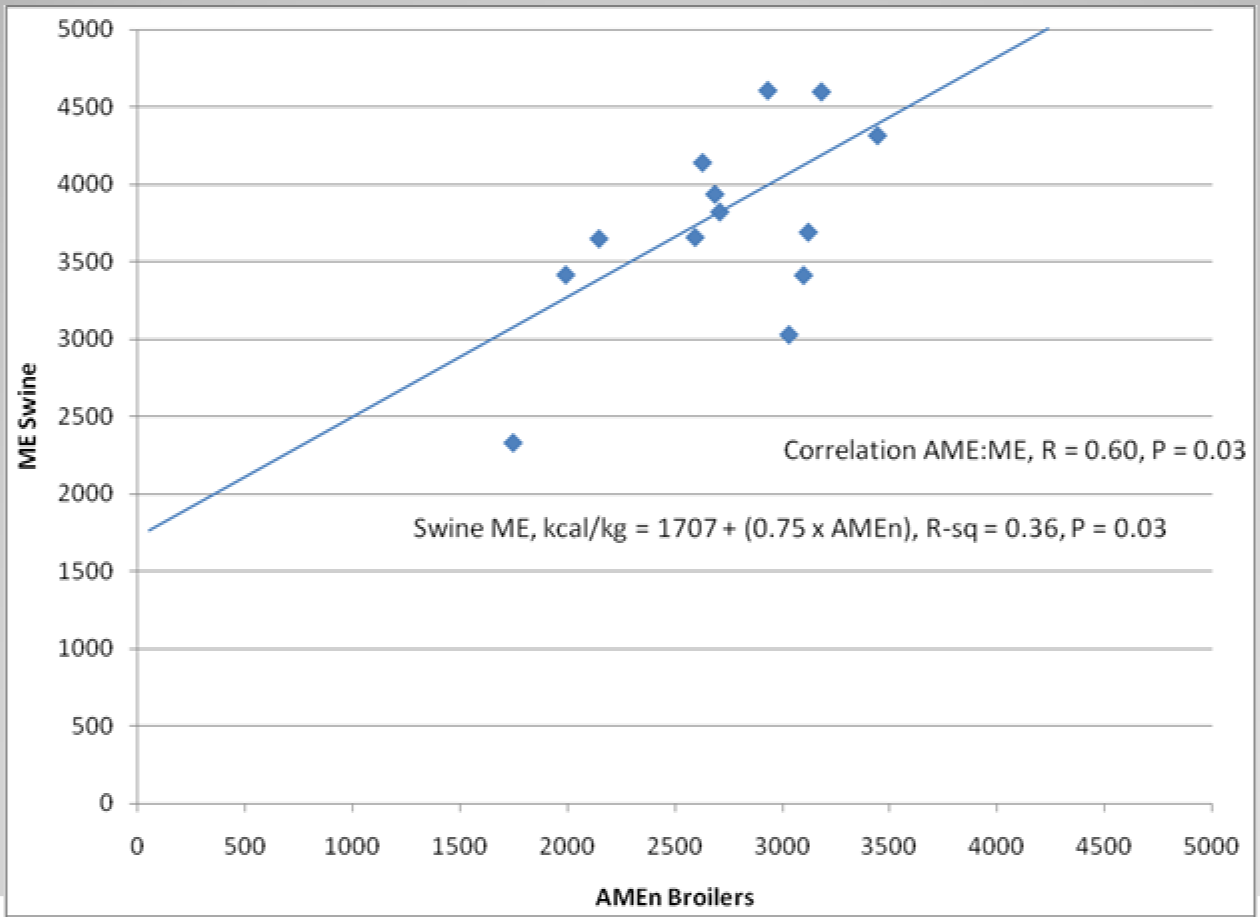
ME kcal/kg DM = −11,128 − (124.99 × % **ash**) + (35.76 × % **CP**) − (63.40 × % **EE**) − (150.92 × % **ADF**) + (14.85 × % **NDF**) + (3.023 × **GE**, kcal/kg)
$r^2 = 0.99$

ME kcal/kg DM = −10,267 − (175.78 × % **ash**) + (23.09 × % **CP**) − (71.22 × % **EE**) − (137.93 × % **ADF**) + (3.036 × **GE**, kcal/kg)
$r^2 = 0.99$

ME kcal/kg DM = −7,803 − (223.19 × % **ash**) − (61.30 × % **EE**) − (121.94 × % **ADF**) + (2.702 × **GE**, kcal/kg)
$r^2 = 0.97$

ME kcal/kg DM = −4,212 − (266.38 × % **ash**) − (108.35 × % **ADF**) + (1.911 × **GE**, kcal/kg)
$r^2 = 0.94$

Correlation between swine ME and poultry AME for corn co-products



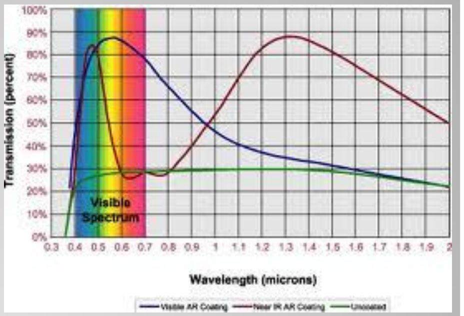
Dozier and Kerr, 2011 (unpublished)

Challenges of using ME equations

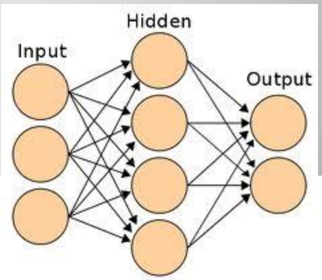
- Accuracy has not been validated
- Are they representative of nutrient variability among sources?
- Some analytes required by equations (e.g. GE, TDF) are not:
  - routinely measured
  - expensive
- Analytical variability among labs and procedures affects accuracy (e.g. NDF).
- Adjustments for fat and fiber in some equations seem counterintuitive.
- Methods used to determine DE and ME values vary
- Methods used to develop regression equations
- Effect of particle size?

Other possible *in vitro* methods to predict ME of feed ingredients

- 3-step *in vitro* enzymatic procedure (Wang et al., 2010)
  - Accurate prediction of ATTD of grain samples
  - Poor prediction of corn DDGS or canola meal



- NIR
  - Need 200+ *in vivo* ME estimates and samples
  - Calibrations must be updated regularly
  - Calibrations cannot be universally applied to different types of NIR equipment (e.g. FOSS vs. Perten)
  - Use of data from multiple labs can often result in "clustering" of data in the spectrum



- Neural networks?

Prediction of Amino Acid Content and Digestibility of DDGS

Variation in SID crude protein and amino acid content among 34 sources of corn DDGS

Nutrient	Maximum	Minimum	CV, %
Crude protein, %	28.3	18.8	12.2
Lysine, %	0.77	0.33	18.4
Methionine, %	0.66	0.40	12.6
Threonine, %	0.96	0.68	10.2
Tryptophan, %	0.21	0.10	15.8

Urriola et al. (2007)

Variation in lysine content and digestibility in DDGS

DDGS

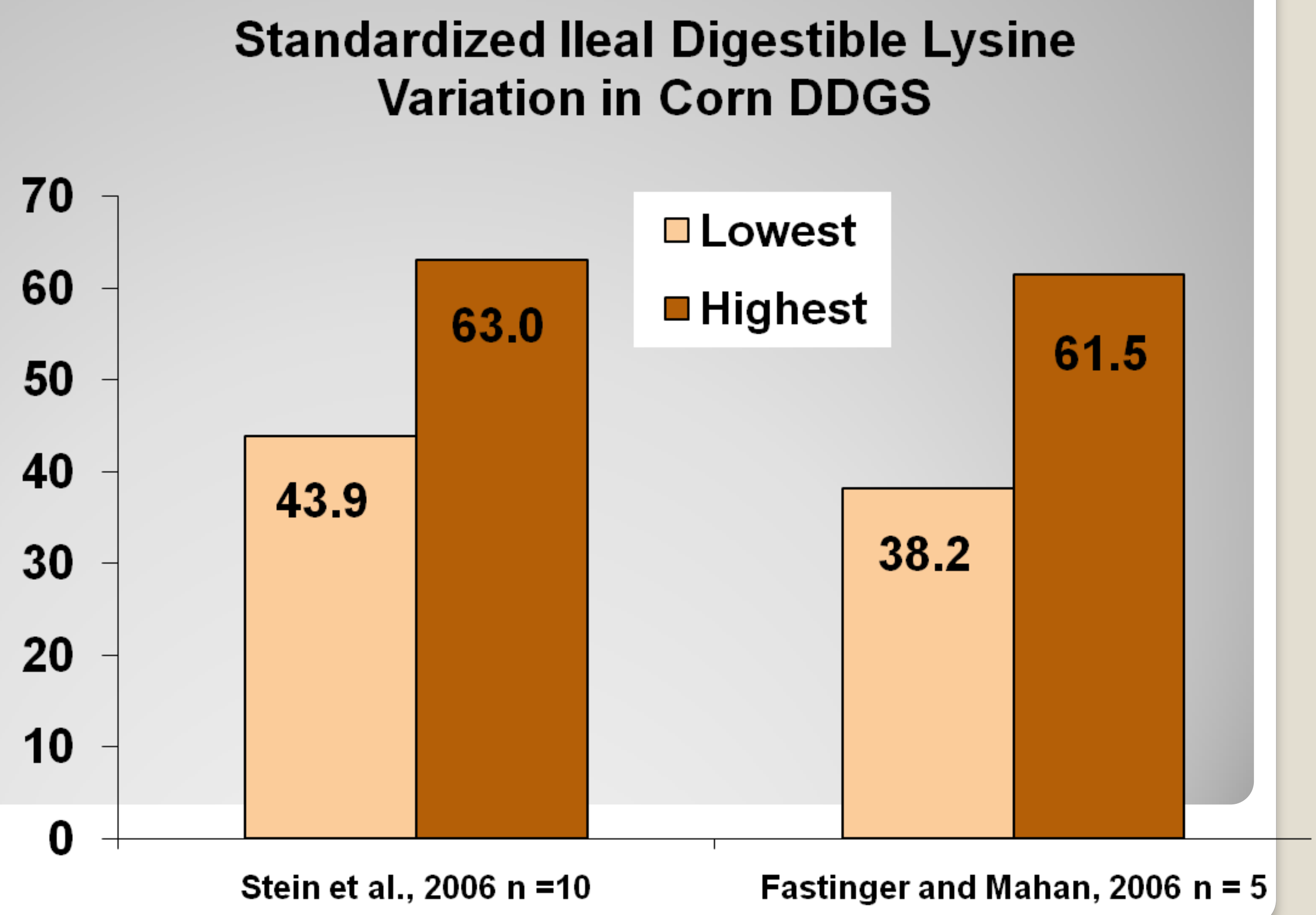
CV = 17%

Corn

CV = 5.6%

SBM

CV = 2.5%



Equations to predict amino acid content of DDGS from crude protein (CP), fat, and fiber

Amino acid	Equation	R^2
Arg	Y = 0.07926 + 0.0398 x CP	0.48
Ile	Y = -0.23961 + 0.04084 x CP + 0.01227 x fat	0.86
Leu	Y = -1.15573 + 0.13082 x CP + 0.06983 x fat	0.86
Lys	Y = -0.41534 + 0.04177 x CP + 0.00913 x fiber	0.45
Met	Y = -0.17997 + 0.02167 x CP + 0.01299 x fat	0.78
Cys	Y = 0.11159 + 0.01610 x CP + 9.00244 x fat	0.52
TSAA	Y = -0.12987 + 0.03499 x CP + 0.05344 x fat – 0.00229 x fat^2	0.76
Thr	Y = -0.05630 + 0.03343 x CP + 0.02989 x fat – 0.00141 x fat^2	0.87
Trp	Y = 0.01676 + 0.0073 x CP	0.31
Val	Y = 0.01237 + 0.04731 x CP + 0.00054185 x fat^2	0.81

Fiene et al. (2006)

Relationship between crude protein and amino acid content in wheat midds

Amino acid	a	b	r^2
Arg	-.376	.0929	.84
His	.023	.0249	.86
Ile	.079	.0261	.94
Leu	.262	.0466	.90
Lys	.281	.0235	.61
Met	.069	.0108	.80
Cys	.043	.0183	.81
Met+cys	.112	.0291	.85
Thr	.123	.0254	.88
Trp	.074	.0071	.39
Val	.082	.0397	.90

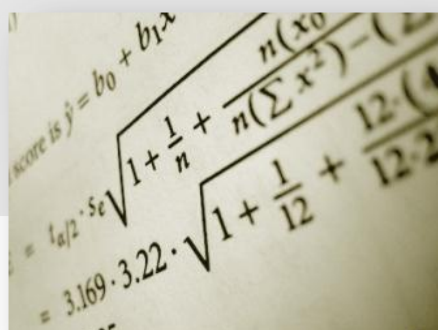
[a]Y = a + bX; Y = predicted amino acid (%); X = crude protein (%); based on 14 samples of wheat middlings analyzed by 20 labs for crude protein and 7 to 9 labs for amino acids.

Cromwell et al. (2000)

Prediction of amino acid digestibility in DDGS

- Crude protein
  - **Poor prediction** of SID Lys ($r^2 = 0.02$)
    - Kim et al. (2010)

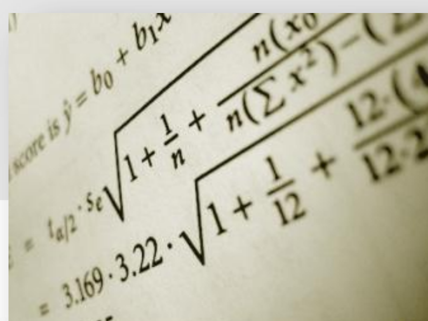
- Total lysine
  - **Good predictor** of SID Lys ($r^2 = 0.85$)
  - SID Lys% = - 0.482 + (1.148 × analyzed Lys, %)
    - Kim et al. (2010)



Prediction of amino acid digestibility in DDGS

- Reactive lysine
  - **Good predictor** of SID Lys (r^2 = 0.90)
  - SID Lys% = - 0.016 + (0.716 × reactive Lys, %)
    - Kim et al. (2010)

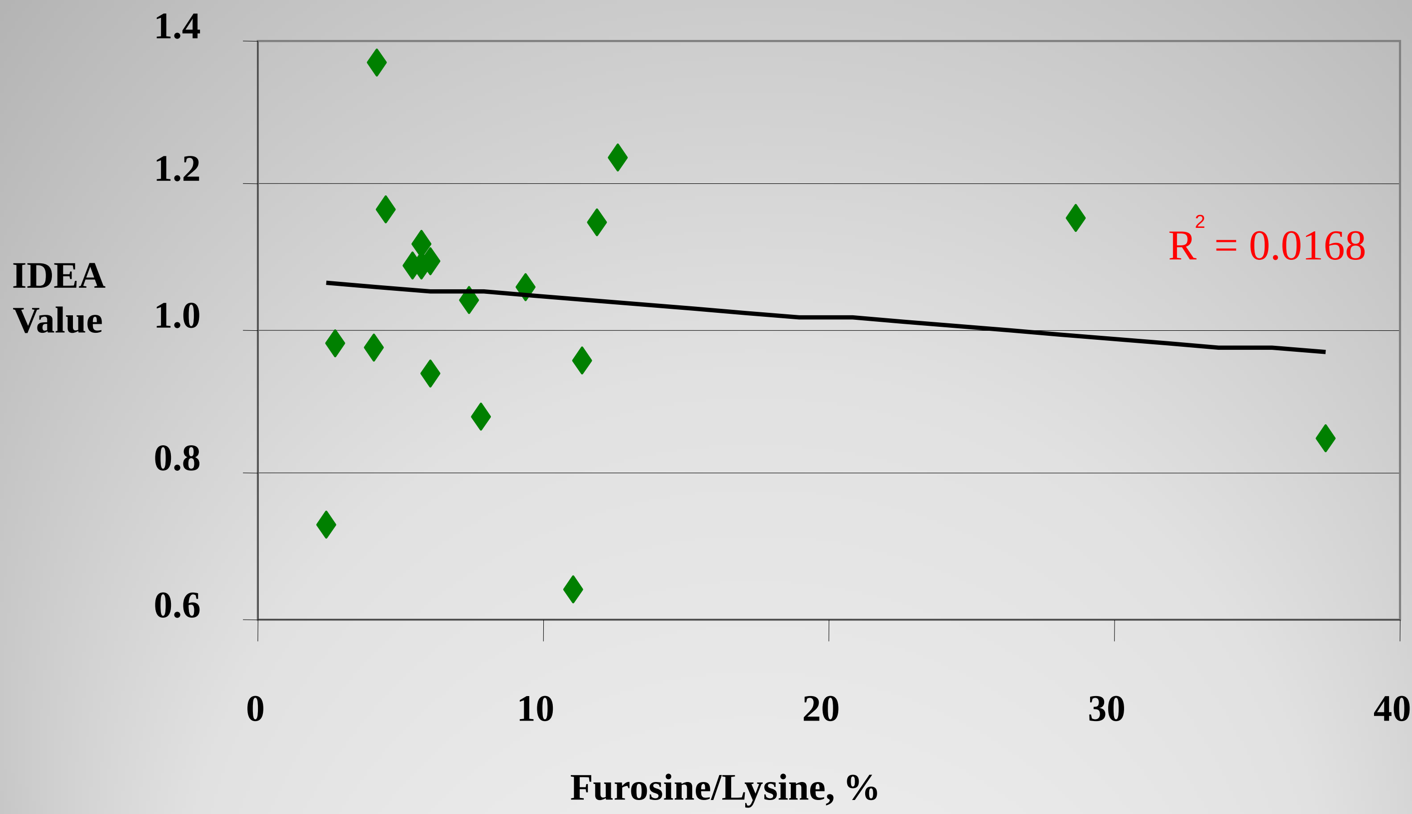
- Lysine:CP ratio
  - **General indicator** of relative lysine digestibility
    - > 2.8 lys:CP for use in swine and poultry diets
    - Stein (2007)



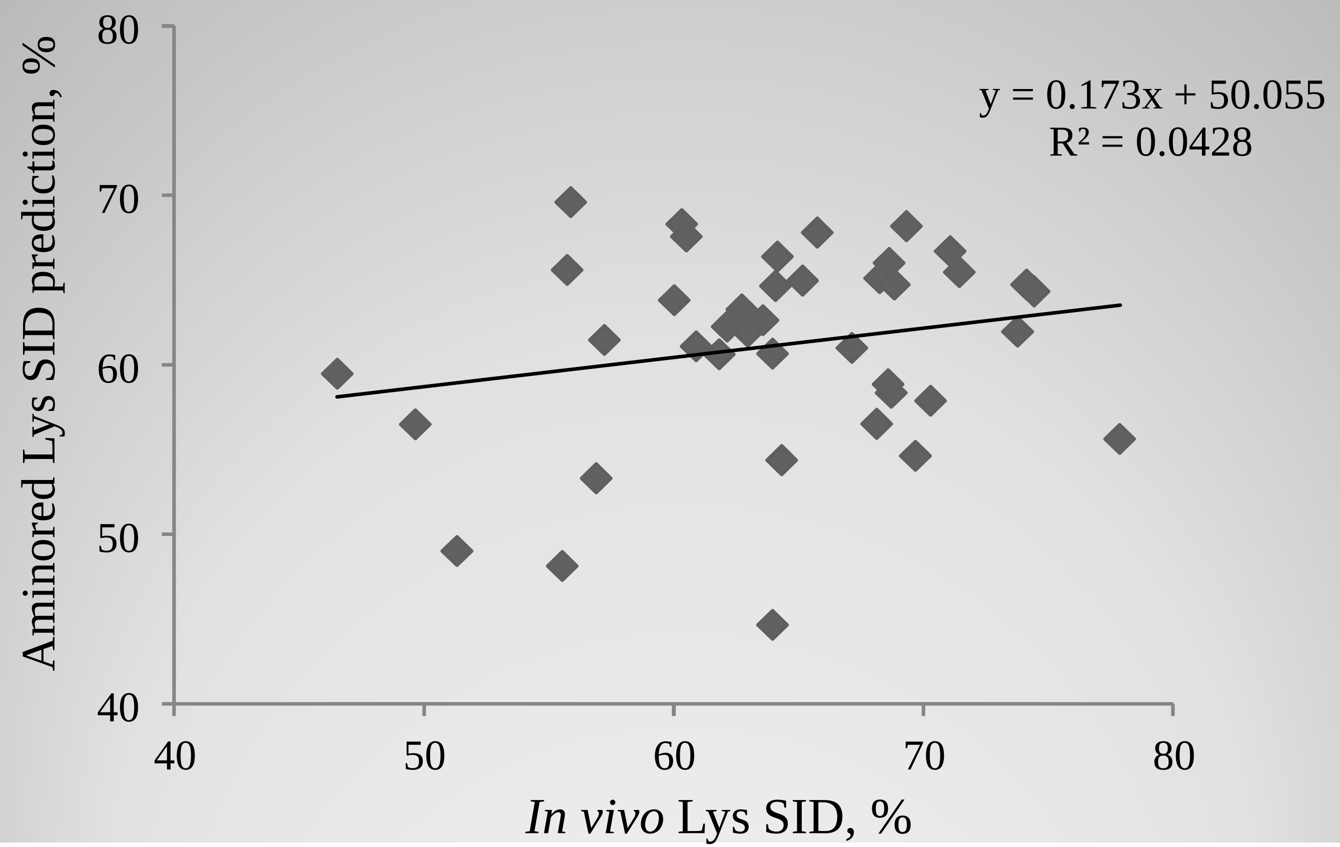
Prediction of amino acid digestibility in DDGS

- IDEA™ - Novus
  - **Good predictor** of Dig Lys for poultry ($r^2 = 0.88$) but not for swine or other amino acids
    - (Schasteen et al., 2005)
- Pepsin-pancreatin
  - **Poor predictor** of CP digestibility ($r^2 = 0.55$)
    - Pedersen et al. (2005)
- ADIN
  - **Moderate correlation** with DDGS color ($r^2 = 0.62$)
  - **Higher correlation** with broiler ADG ($r^2 = 0.86$) and F/G ($r^2 = 0.72$)
    - Cromwell et al. (1991)

Relationship between IDEA® values and furosine:lysine in 20 DDGS samples (Zhang et al., 2010)



Correlation between SID lysine (*in vivo*) and predicted SID lysine by Aminored® among 40 DDGS sources



Prediction of amino acid digestibility in DDGS

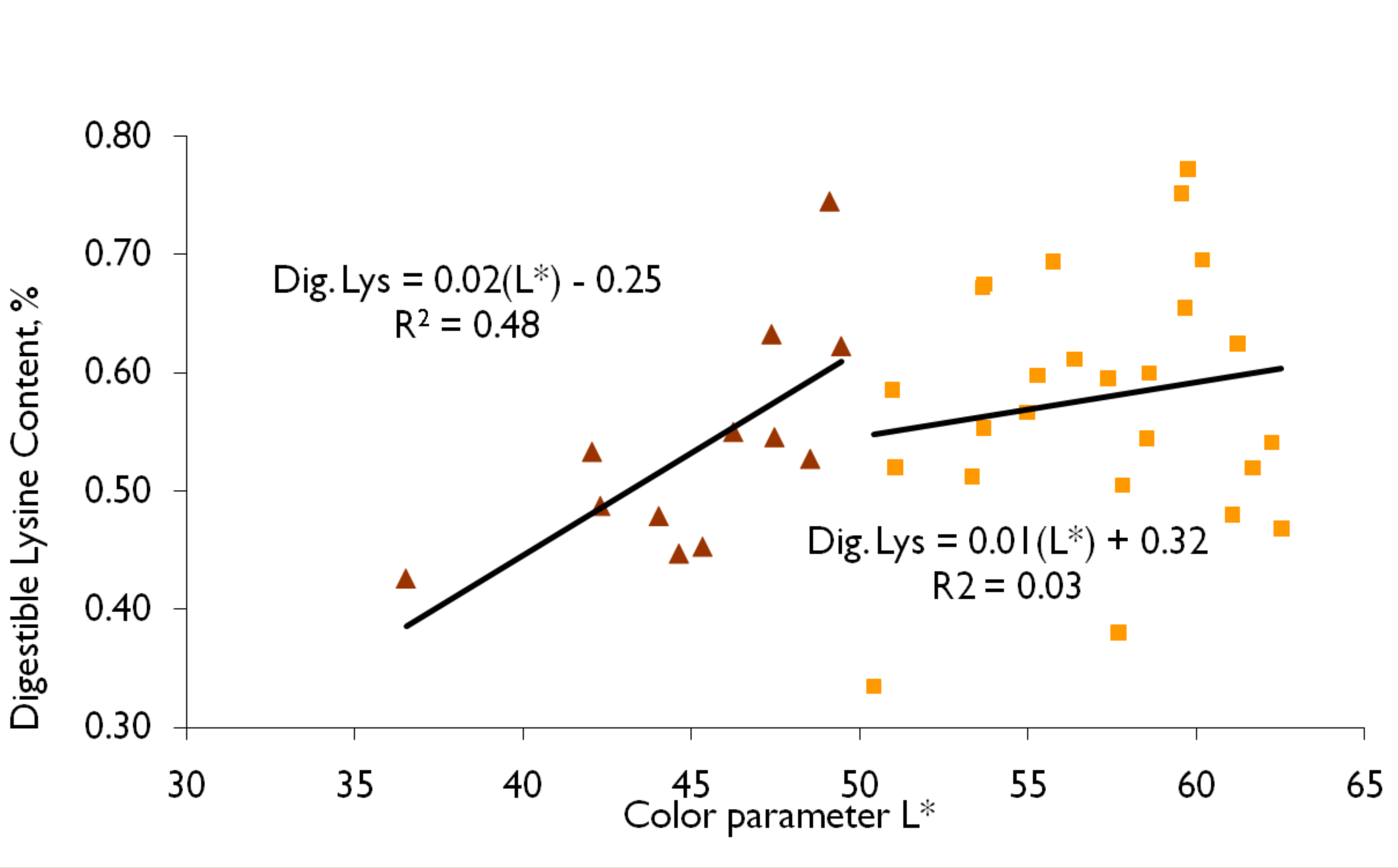
- Color (L*, a*, b*)
- Optical density
- Front face fluorescence

Prediction of SID lysine in DDGS using color, optical density or front face fluorescence with principle components analysis

Method	SID Crude Protein	SID Lysine
	R^2	
Minolta color	.85	.53
Optical density		
without Crude Protein	.90	.97
with Crude Protein	.99	.93
Front Face Fluorescence	1.00	.99

Urriola et al., 2007

Relationship between color (L*) and digestible lysine content in 36 sources of DDGS for swine



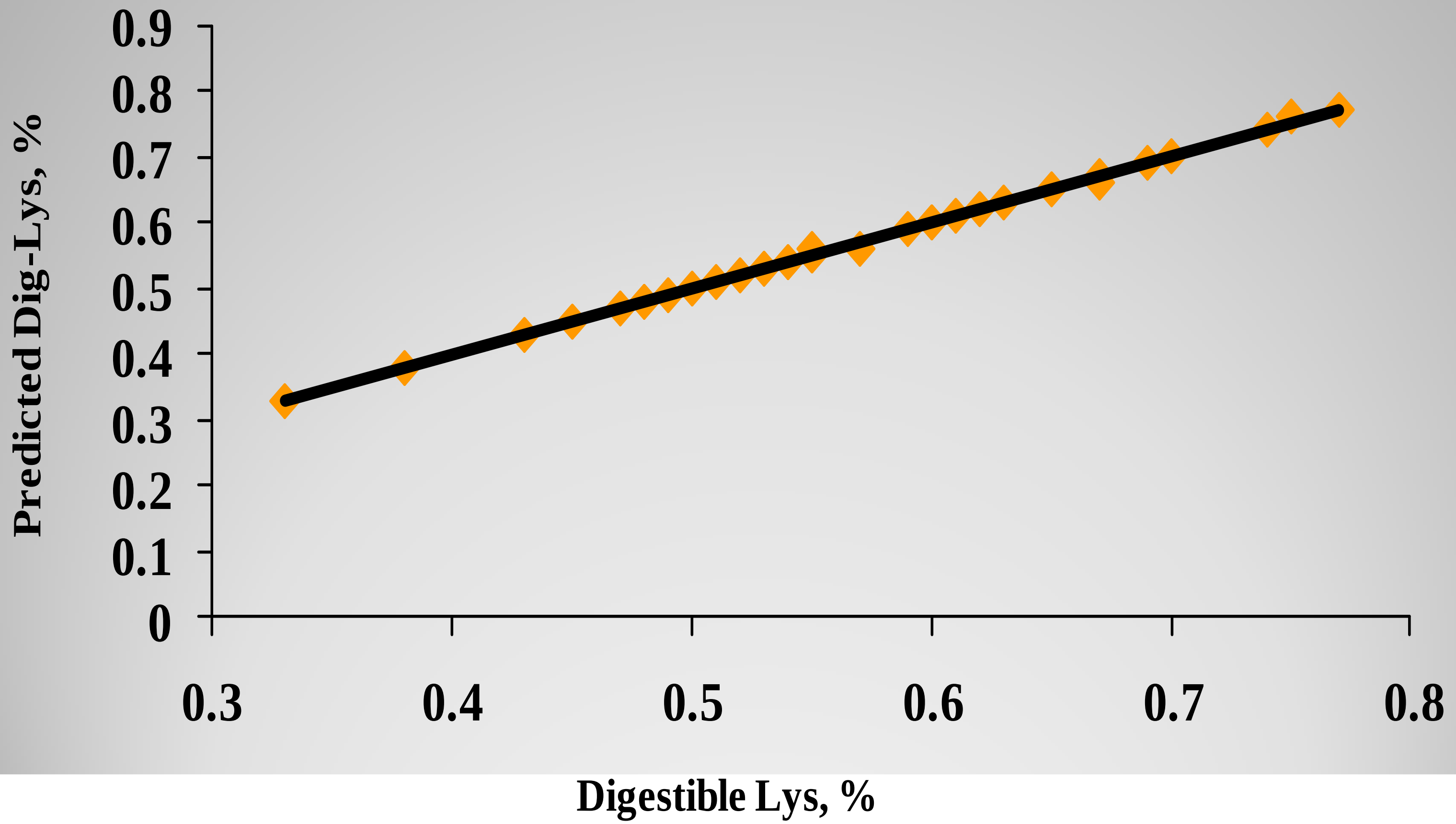
Models to predict digestible amino acids from optical density in DDGS

Amino Acid	Model	Adjusted R^2	RMSE
Lys	$y \sim PC_1 \ldots PC_{14}$	78.0	0.05
Met	$y \sim PC_1 \ldots PC_{11}$	56.6	0.04
Thr	$y \sim PC_1 \ldots PC_7$	66.5	0.05
Trp	$y \sim PC_1 \ldots PC_{17}$	79.2	0.01

n = 37

Urriola et al. (2007)

Prediction of SID lysine from front face fluorescence in DDGS (Urriola et al., 2007)

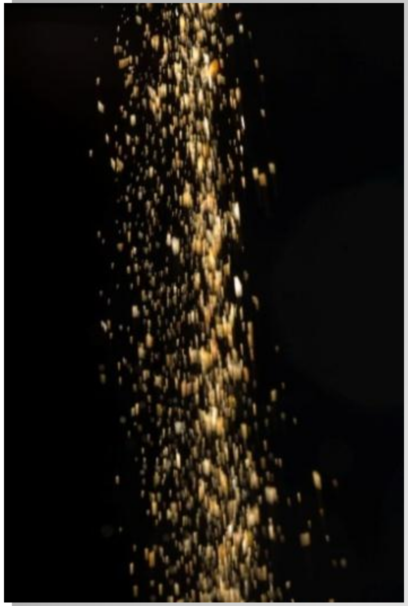


Comparison of nutrient content and SID amino acid content in corn and bakery meal

	Corn	Bakery meal
CP, %	6.68	11.30
CP digestibility, %	89.1	72.5
DM, %	84.11	86.99
ADF, %	2.00	6.28
NDF, %	8.53	17.52
Starch, %	67.29	40.50
Ca, %	0.02	0.14
P, %	0.22	0.34
Arg, %	0.33 (100.1)	0.46 (91.5)
His, %	0.19 (83.7)	0.27 (72.5)
Ile, %	0.23 (80.9)	0.39 (71.0)
Leu, %	0.76 (88.0)	1.10 (78.2)
Lys, %	0.22 (69.2)	0.27 (48.4)
Met, %	0.14 (86.2)	0.18 (76.5)
Phe, %	0.31 (85.9)	0.52 (77.7)
Thr, %	0.24 (74.9)	0.36 (62.1)
Trp, %	0.04 (83.9)	0.10 (83.1)
Val, %	0.32 (80.1)	0.52 (69.8)

Numbers in parentheses indicate standardized ileal digestibility of amino acids
Almeida and Stein (2011)

Commercial nutritional "tools" are available to manage nutrient variability among DDGS sources



- Assess relative value among sources
- Provide accurate nutrient loading values for diet formulation

- Examples:
  - Illuminate® - VAST
  - Optimum Value Supplier® database - Cargill
  - Aminored ® - Evonik
  - IDEA® - NOVUS
  - Adisseo

Illuminate® Laboratory Results

	A	B	C	D	E
DM, %	89.8	90.2	89.3	88.6	89.0
Crude protein, %	26.5	26.1	25.3	25.5	30.4
Fat, %	8.4	10.8	10.3	9.3	8.1
Starch, %	7.3	4.3	7.0	8.3	4.2
ADF, %	11.5	8.3	10.0	10.2	17.0
Ash, %	3.7	4.0	4.4	4.5	2.9
Phosphorus, %	0.70	0.90	0.80	0.80	0.76
Lysine, %	0.90	0.95	0.86	0.89	0.50

Illuminate® Nutrient Loadings and Relative Value Comparison of 5 DDGS Sources for Swine

	A	B	C	D	E
ME, kcal/kg	3190	3540	3310	3200	2860
Dig. Lys, %	0.60	0.65	0.52	0.52	0.49
Dig. Met, %	0.45	0.48	0.46	0.44	0.49
Dig. Thr, %	0.76	0.80	0.69	0.67	0.74
Dig. Trp, %	0.16	0.16	0.15	0.14	0.15
Avail. Phos, %	0.50	0.70	0.60	0.60	0.30
Relative Value, $/ton	$290	$355	$307	$289	$229

DDGS market price (9/11) was $185 to $200/ton

Evaluating Purchase Price

- Purdue Univ. – Substitution Value Calculator
  - www.ansc.purdue.edu/compute/subvalue.htm
- Michigan State University
  - equations for specific ingredients
- Univ. of Missouri – byproduct price list
  - http://agebb.missouri.edu/dairy/byprod/bpmenu.asp

DDGS Value Calculators

- Calculator spreadsheets are available from:
  - University of Illinois
  - South Dakota State University
  - Kansas State University
  - Iowa State University

  - Spreadsheets (IL and SD) can be found at: www.ddgs.umn.edu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