Characterizing Starch Digestion Potential in Corn and Corn Silage.

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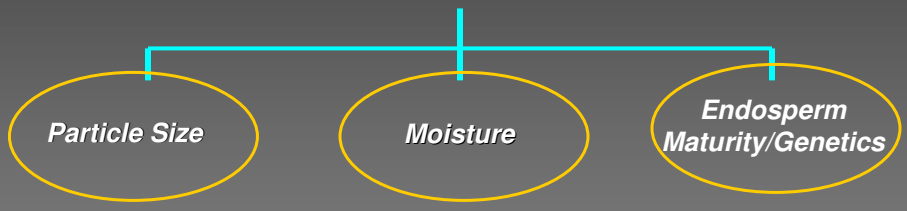
Starch Digestibility

1- Principal Components of Starch Digestion



Easy to Measure in Grain
Challenging to Measure in Corn Silage

Routinely Measured Marker of Maturity

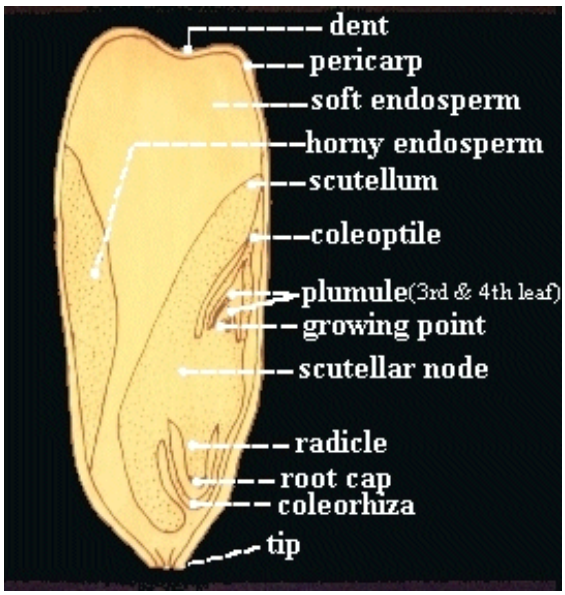
?

•Trick Questions

•**Chemically-What makes forage indigestible?**
•***NDF, ADF, Lignin, Cellulose***

•**Chemically-What makes corn starch indigestible?**

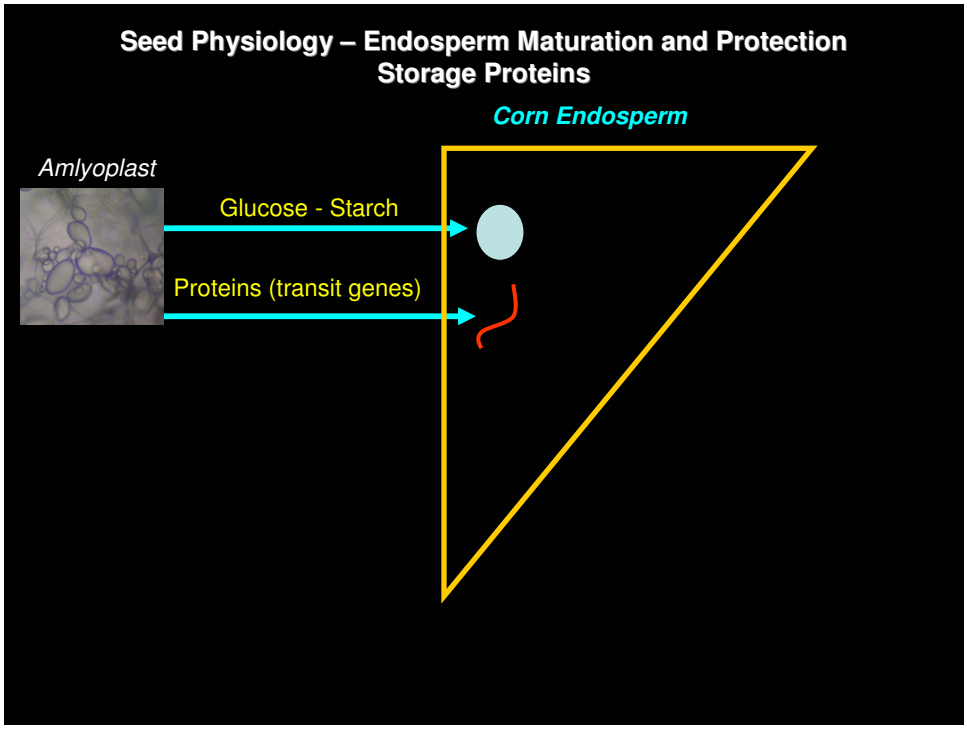
Corn Seed Anatomy - 101

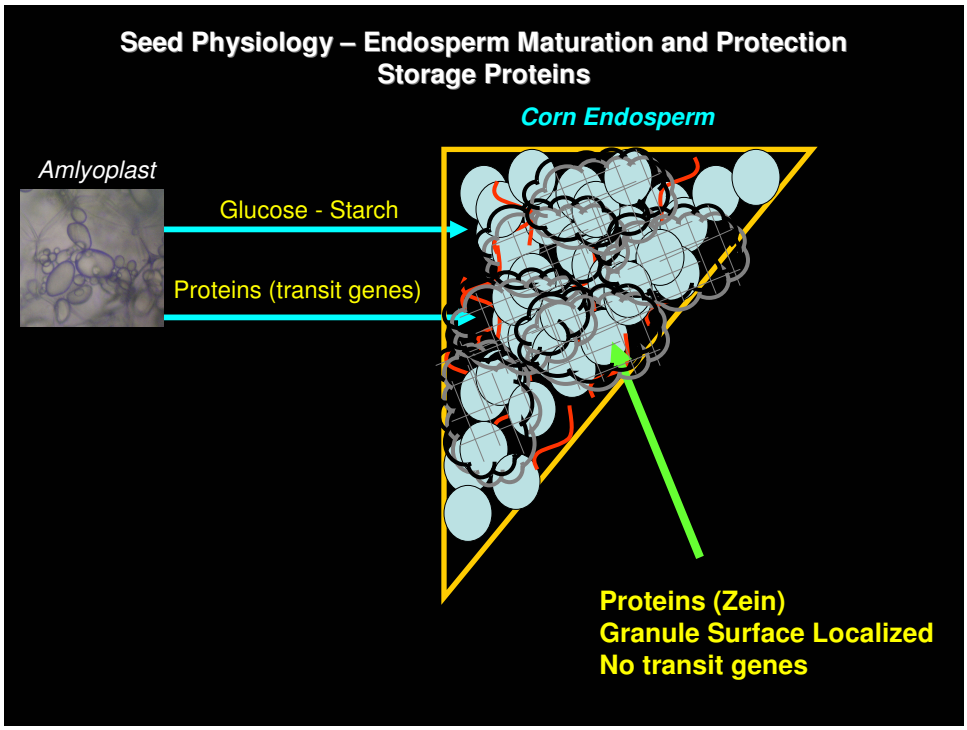


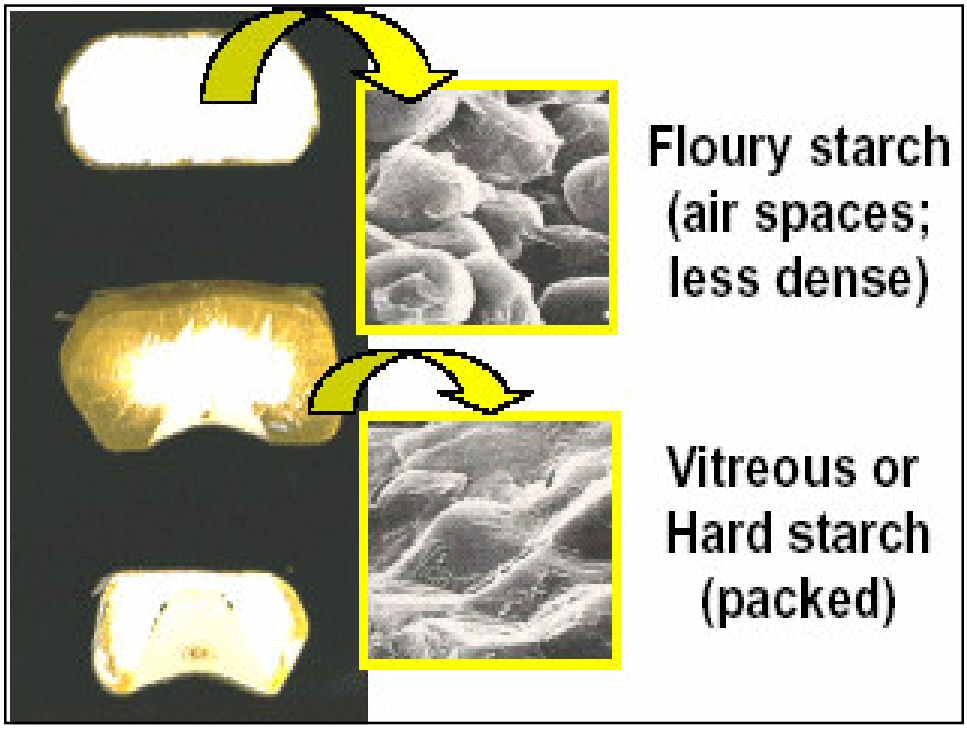
Corn Endosperm Nicknames

- Flint
- Translucent
- Vitreous
- Horny
- Glassy
- Dense
- Floury
- Opaque
- Not-vitreous
- Soft textured
- Mushy
- Porous

Corn endosperm nicknames can not be quantified by routine laboratory methods and do not represent actual chemical properties of the endosperm.


Seed Physiology – Endosperm Maturation and Protection
Storage Proteins
Corn Endosperm
Amlyoplast
Glucose - Starch
Proteins (transit genes)


Seed Physiology – Endosperm Maturation and Protection
Storage Proteins
Corn Endosperm
Amlyoplast
Glucose - Starch
Proteins (transit genes)
Proteins (Zein)
Granule Surface Localized
No transit genes



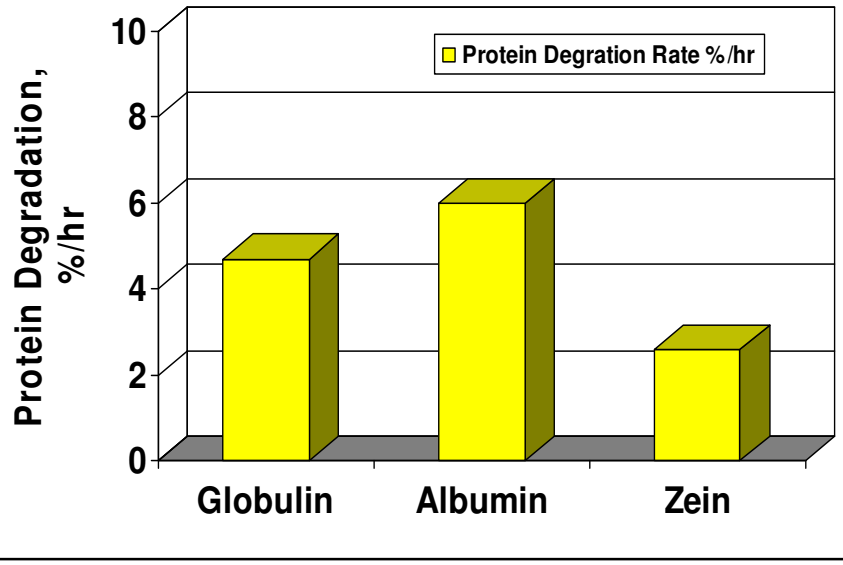
Corn Endosperm Storage Proteins

- Globulin-Albumin
  - Saline, H_20 Soluble
  - High in Lysine
  - Free Amino Acids, NPN
- Zein
  - Soluble in Aqueous Alcohol Solutions
  - Low in Lysine
- Glutelins
  - Alkali Soluble
  - Similar in Flint and Floury Corns

The Corn Endosperm Protein of Interest - Zein

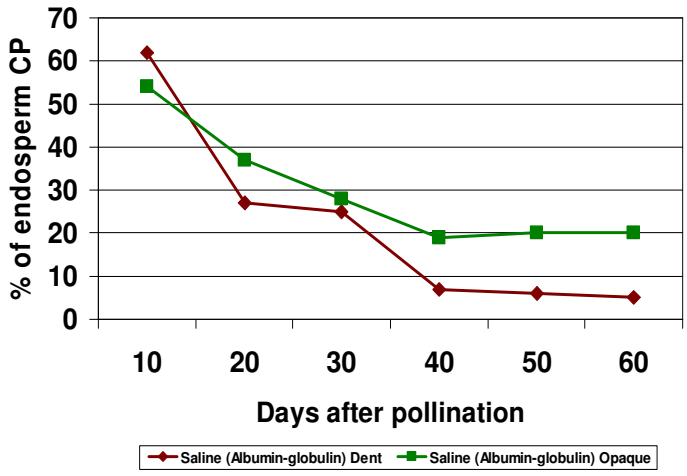
- Zein (4 Types) – άβγδ
- 10-27 kD
- Granule surface
- Cross-linked
- 50-60 % of CP in some corn endosperms
- Insoluble in the rumen environment
- Encapsulates the starch matrix
- *Advances with maturity – (like NDF in forages)*
- *Genetic differences in corn (flint vs floury)*

The Corn Endosperm Protein of Interest – Zein
Romagnolo et al., 1994



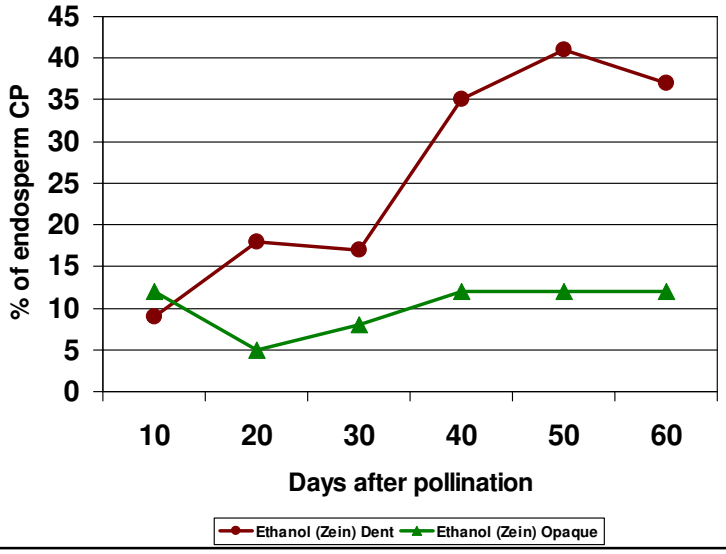
Corn endosperm storage protein x maturity

Murphy and Dalby, 1971: Cereal Chemist



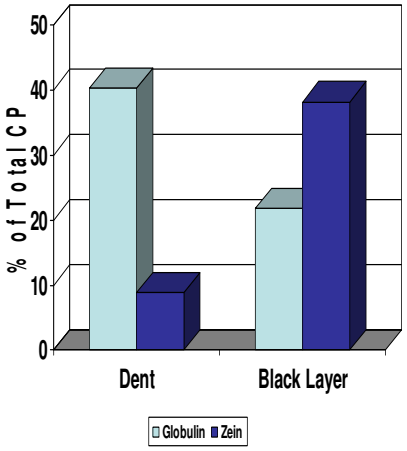
Corn Prolamin-Zein Advances With Maturity

Murphy and Dalby, 1971: Cereal Chemistry

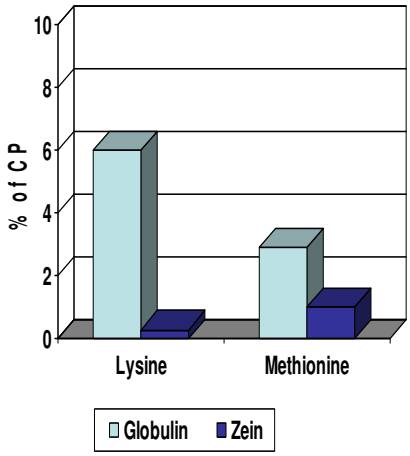


Influence of Zein:Globulin Ratio on Lysine and Methionine Supply

Dorshorst et al., (Unpublished)



Murphy and Dalby, 1971

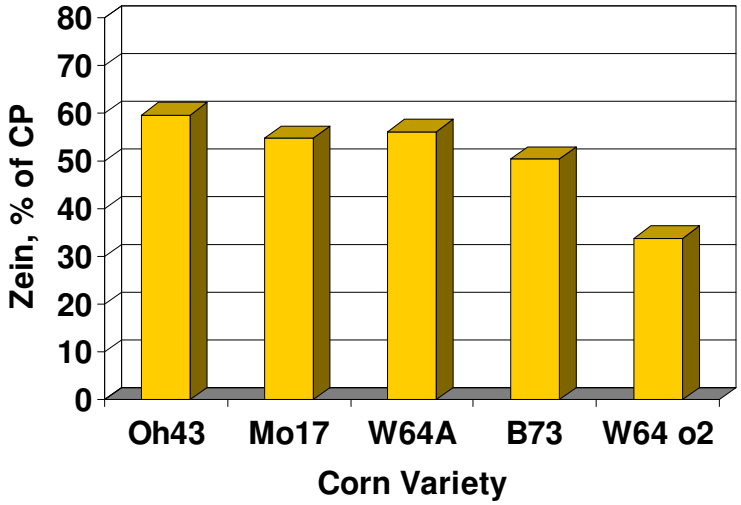


Corn Prolamin-Zein is Not New

- **Differentiation of Corn Protein Types by Solubility T.R. Osborne 1897**
- **Foundation of Present Corn Research (Proteins, DNA, Plastics, Ethanol).**
- **Feed Testing = Goering, H. K., and P. J. Van Soest. 1970 Methods.**
- **Testing Corns for Storage Proteins got Lost in Ruminant Nutrition.**

Prolamin-Zein: Corn Varieties are Different

Hamaker et al., 1995 – Cereal Chemistry

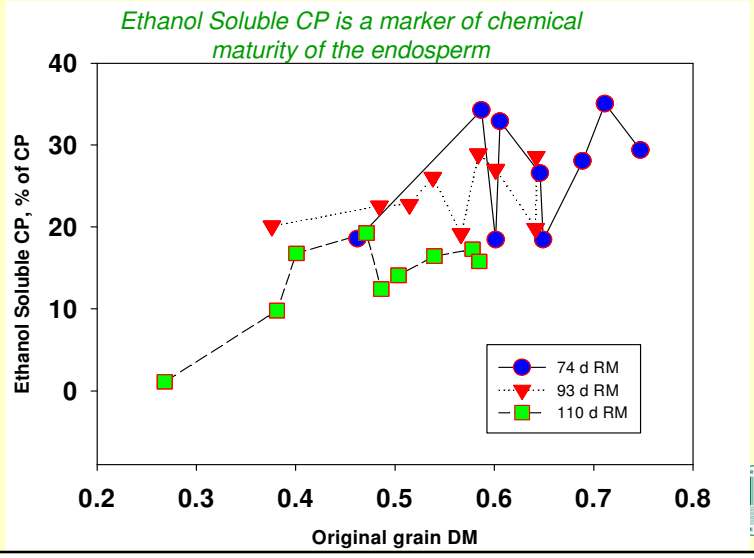


Prolamin-Zein: Why Doesn't my Lab Test It?

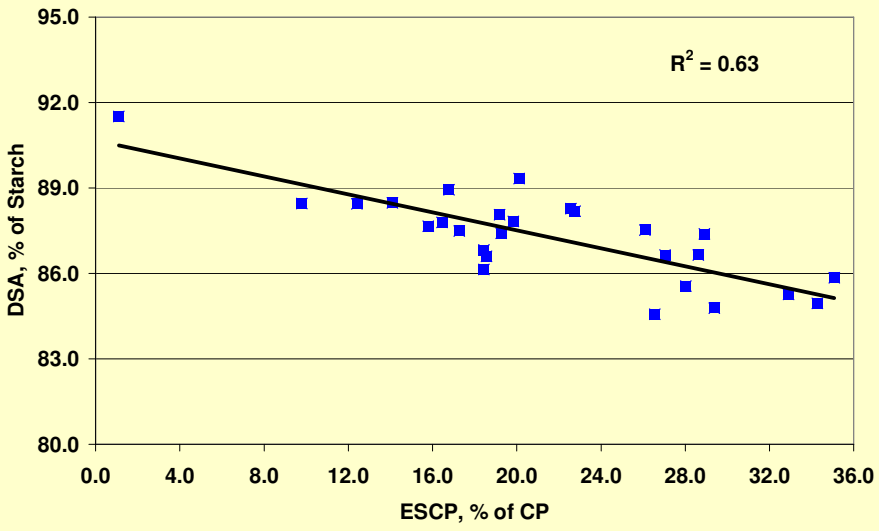
Hamaker et al., 1995 – Cereal Chemistry

- *Grind Corn 1 mm*
- *Rinse with 0.5M NaCl – Centrifuge*
- *Rinse with 0.5M NaCl – Centrifuge*
- *Rinse with 0.5M NaCl – Centrifuge*
- *Rinse with H20 – Centrifuge*
- *Rinse with H20 – Centrifuge*
- *Rinse with SDS solution – Centrifuge*
- *Rinse with SDS solution – Centrifuge*
- *Solubilize Zein with 70 % Ethanol Save Supernatant*
- *Dry Supernatant*
- *Run Kjehdahl Protein*

Pilot Plebian Lab Test- Dorshorst and Hoffman 2007
Prolamin-Zein Advances with Maturity in Corn Silage
Prolamin-Zein Advances Differently X Variety X Maturity ?



Pilot Plebian Lab Test vs Blazel et al., 2005 DSA Procedure



Factors Effecting the Hydrolysis Potential of Starch in Corn Silage

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Relationships Between Principal Components of Starch Digestion and Laboratory Derived Starch Digestion Coefficients

Correlations between potential starch digestion markers in corn silage and starch hydrolysis potential (Degree of starch access: Blazel et al., 2006)

Item	Unit	Correlation: Degree of starch access		
		r	P <	Rank
Adjusted mean particle size (starch)	mm	-0.70	0.0001	1
Kernel processing score	% < 4.75 mm	0.67	0.0001	2
Mean particle size (starch)	mm	-0.64	0.0001	3
Whole plant DM	% of as fed	-0.53	0.0001	4
Grain DM	% of as fed	-0.50	0.0001	5
Stover DM	% of as fed	-0.47	0.0001	6
Ethanol soluble protein (grain)	% of total CP	-0.46	0.0001	7
Ethanol:Saline soluble protein ratio	…	-0.46	0.0001	8
Saline soluble protein (grain)	% of total CP	0.35	0.002	9
CP	% of DM	-0.24	ns	10
Starch	% of DM	-0.22	ns	11
NDF digestibility (48 h)	% of NDF	0.15	ns	12
Picnometer	g/cc	-0.12	ns	13
Grain phosphorus	% of DM	-0.11	ns	14
Yield	DM tons	0.11	ns	15
NDF	% of DM	0.08	ns	16

ns = P > 0.01

Conclusions

- **Starch hydrolysis potential of corn silage starch is best related to particle size, moisture, and prolamin-zein protein.**

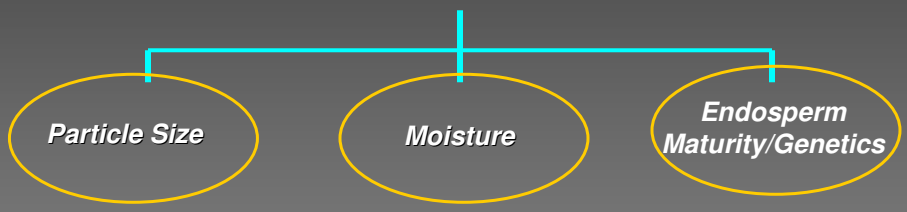
- **Prolamin-zein varies x maturity x variety and has very slow degradation rate.**

- **Measuring chemical factors that make starch indigestible (i.e. prolamin-zein, dehydrins?) would increase our understanding of genetic or genetic x maturity effects on starch digestion. Like forage……**

- **If principal components of starch digestion were routinely (particle size, zein, moisture) measured would could ruminal starch digestion, TT-starch digestion or starch kd be predicted?**

Starch Digestibility

1- Principal Components of Starch Digestion



Challenging to Measure in Corn Silage

Routinely Measured Marker of Maturity

?

Principal Component Measuring Grain Particle Size

Baker, S., and T. Herrman. 2002. MF-2051. Evaluating particle size. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Manhattan, KS.

Principal Component
Measuring Grain Particle Size (Corn Silage)

Kernels and Large Fragments Were Retained on > 4.75-mm Sieves

USDA-ARS US Dairy Forage Research Center

Corn Silage Processing Score

- Index for Corn Silage Processing
- Special Test $20-30
- Does Not Measure Particle Size (Units = %)
- Not Well Suited for High Volume Routine Application

Principal Components – Particle Size

Utility of Near Infrared Reflectance Spectroscopy to Predict Starch Particle Size in Corn Silage

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Methods

- 81 Corn Silages
- Separated using a Vertical Shaker (ASAE, 2001)
  - 10 Screens + Pan
  - Modifications by Ferriera and Mertens (2005)
- DM Retained Evaluated for Starch
  - NIRS Marshfield Soil and Forage Analysis Laboratory
  - $R^2 = 0.97$
- Starch Particle Size Calculated (ASAE, 2001)
  - Mean Particle Size
  - Adjusted Mean Particle Size (Latent Starch- Blasel et al., 2006)

Methods

- 81 Corn Silages
- 3 NIRS Spectra Obtained
  - 1 mm Udy (Spinning Cup Holder) *Negative Control*
  - Un-dried Un-ground (Natural Product Cell)
  - Un-dried Un-ground < 19.0 mm (Natural Product Cell)
- NIRS Calibrations
  - Partial Least Squares
  - 8 Terms Maximum
  - 27 Math Treatment Matrix
  - 6 Cross Validations
- NIRS Calibrations
  - Max R^2 Cross Validation
  - Low SECV

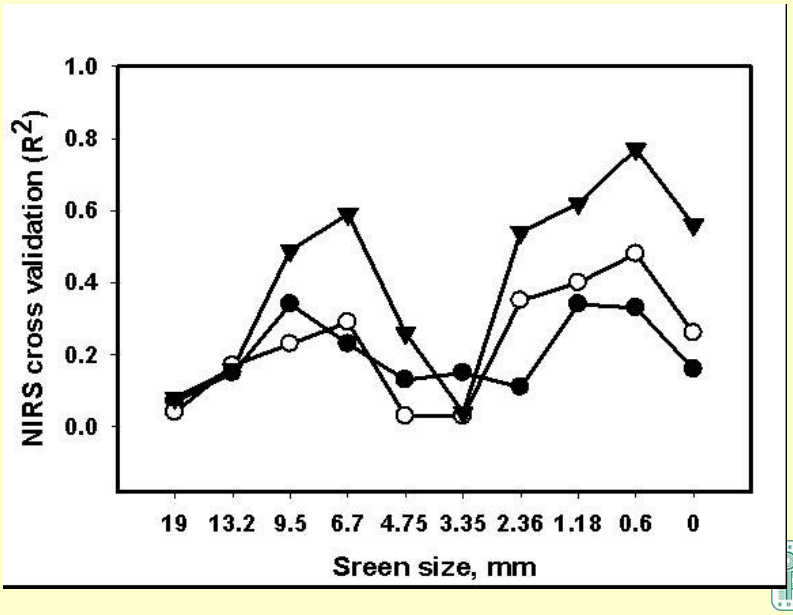
Results

	Mean	n = 81 SD	Minimum	Maximum
Nutrient				
DM, %	35.4	6.2	22.5	48.6
Starch, % of DM	31.5	7.0	10.8	45.6
Starch retained (screen size), % of starch				
19.0 mm	0.6	1.6	0.0	13.0
13.2 mm	0.8	0.9	0.1	6.5
9.5 mm	1.8	1.1	0.6	5.9
6.7 mm	15.9	12.2	2.0	54.0
4.75 mm	22.0	7.0	5.0	38.5
3.35 mm	14.4	3.5	6.4	25.6
2.36 mm	13.9	4.7	4.9	28.3
1.18 mm	17.2	7.7	3.9	33.2
0.6 mm	8.5	3.3	2.0	15.0
Pan	5.0	1.8	1.5	11.5
Starch particle size				
Mean particle size, mm	4.38	0.91	2.51	6.36
Adjusted mean particle size[1], mm	4.14	0.91	2.41	6.27
KPS[2], % of starch < 4.75 mm	58.9	15.8	24.5	89.7

Results

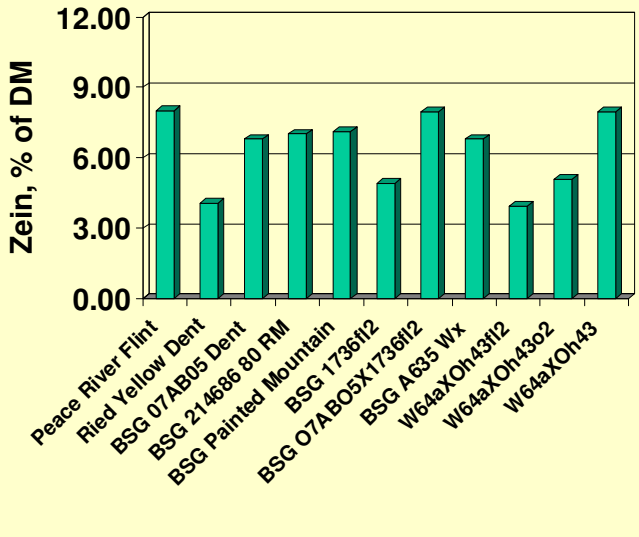
Nutrient[1,2]	Calibration SEC	Calibration R^2	Cross validation[4] R^2	Cross validation[4] SECV	SD:SECV[5]
	1 mm Udy				
Starch, % of DM	0.83	0.99	0.98	1.05	6.7
Mean particle size, mm	0.64	0.42	0.27	0.72	1.3
Adjusted mean particle size, mm	0.66	0.34	0.30	0.68	1.3
KPS, % of starch < 4.75 mm	12.60	0.29	0.21	13.40	1.2
	Un-dried Un-ground				
Starch, % of DM	4.17	0.65	0.51	4.97	1.4
Mean particle size, mm	0.70	0.35	0.23	0.76	1.2
Adjusted mean particle size, mm	0.61	0.48	0.36	0.69	1.3
KPS, % of starch < 4.75 mm	11.95	0.38	0.22	13.48	1.2
	Un-dried Un-ground < 19 mm				
Starch, % of DM	3.21	0.79	0.64	4.19	1.7
Mean particle size, mm	0.32	0.87	0.74	0.41	2.2
Adjusted mean particle size, mm	0.36	0.84	0.75	0.40	2.3
KPS, % of starch < 4.75 mm	6.98	0.81	0.68	9.00	1.8

Results- NIRS Evaluation By Starch Particle Size and Spectral Origin



Principal Component
Measuring Genetic x Maturity Interactions
Prolamin-Zein

Larson and Hoffman – 2008 (3 Step Method)
Example Concept - Research in Progress



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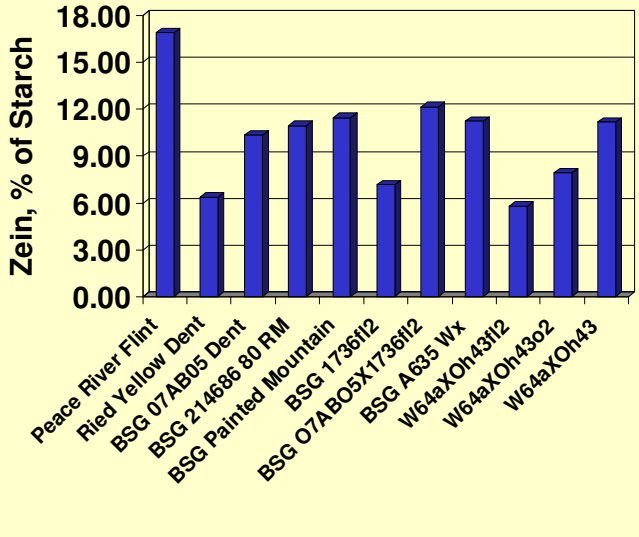

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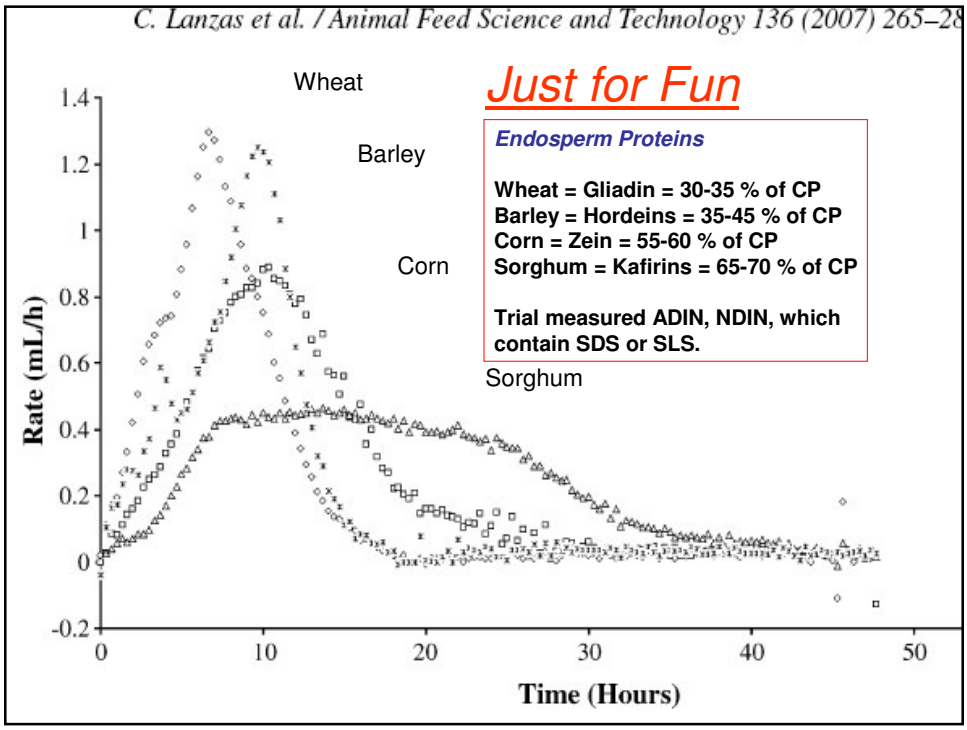

Just for Fun

Endosperm Proteins

Wheat = Gliadin = 30-35 % of CP
Barley = Hordeins = 35-45 % of CP
Corn = Zein = 55-60 % of CP
Sorghum = Kafirins = 65-70 % of CP

Trial measured ADIN, NDIN, which contain SDS or SLS.

•Just for Fun – *McAllister et al., 1992*