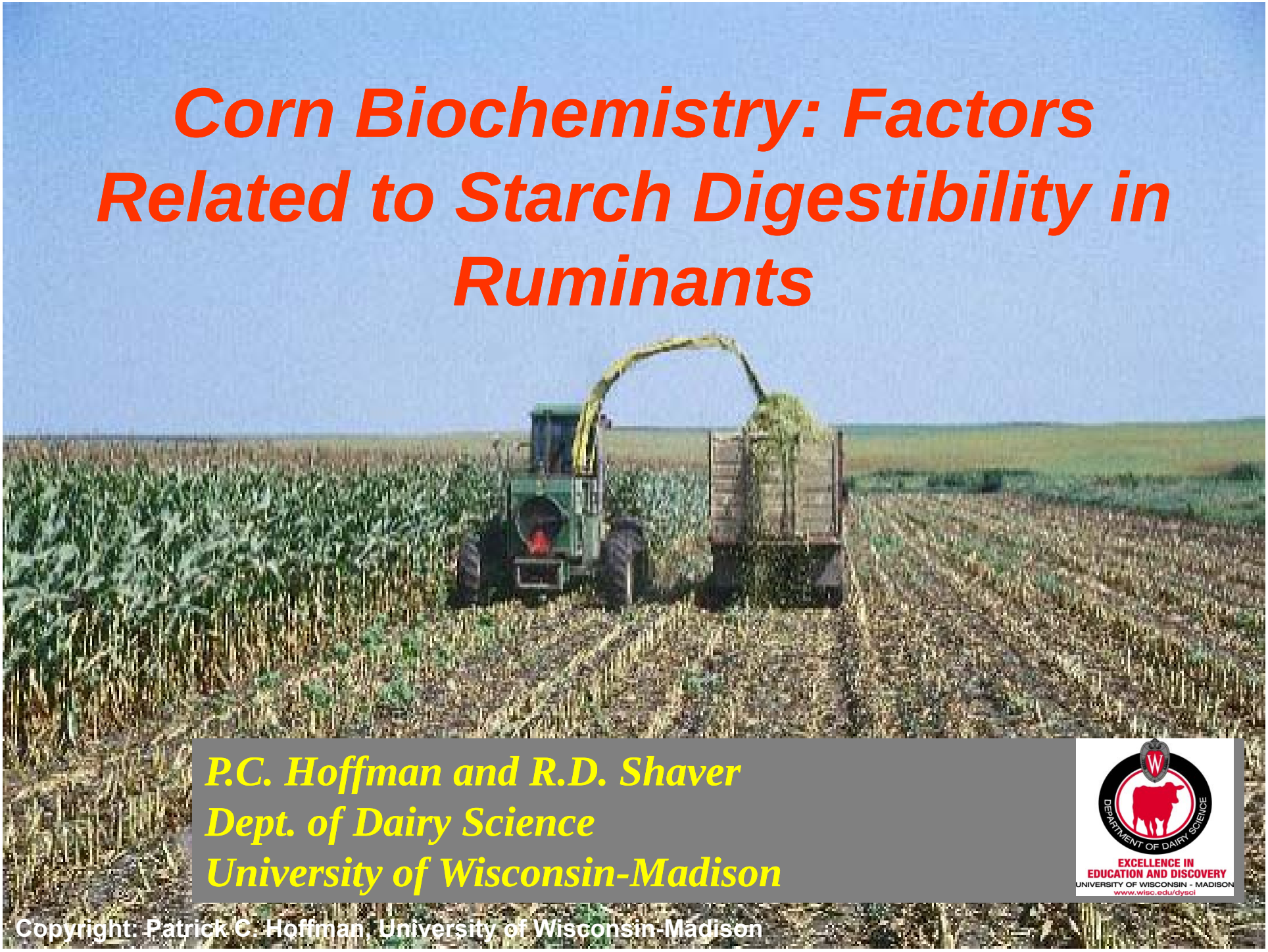
Corn Biochemistry: Factors Related to Starch Digestibility in Ruminants



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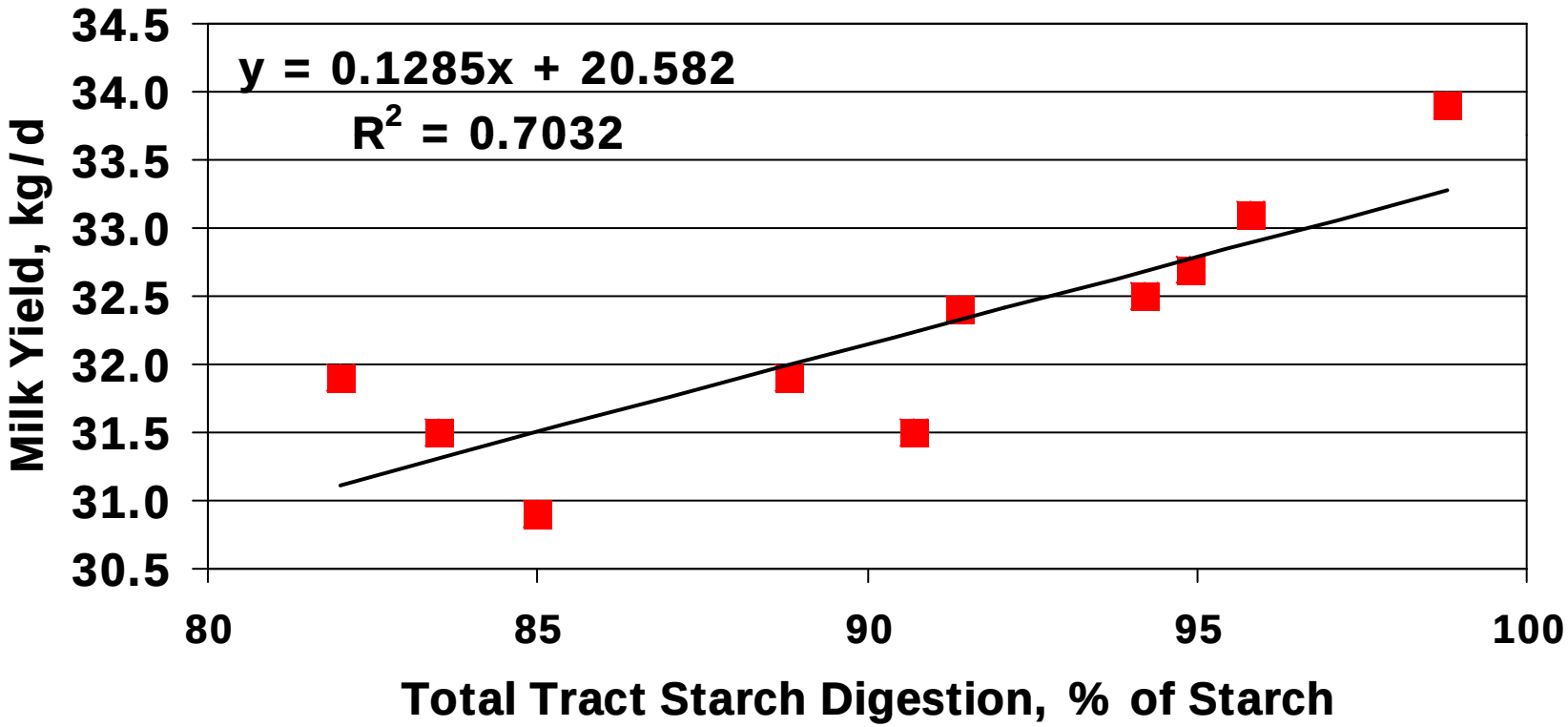
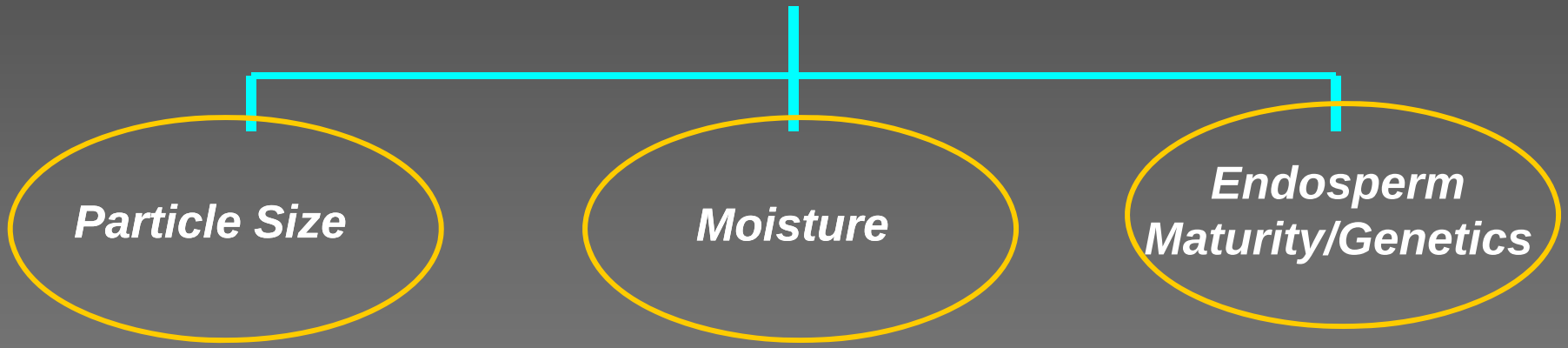
Effect of Starch Digestibility on Milk Yield, **Firkins et al., 2001**



Starch Digestibility

Principal Components of Starch Digestion



Easy to Measure in Grain Challenging to Measure in Corn Silage

Routinely Measured Marker of Maturity

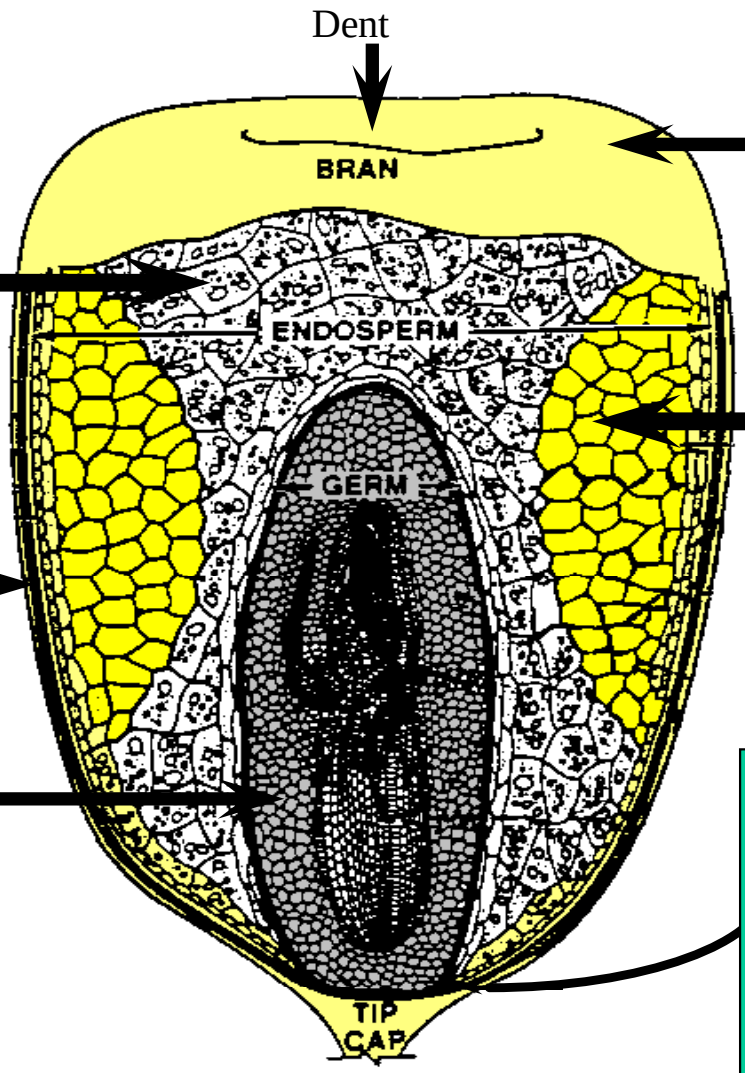
?

•Trick Questions

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

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

Basic Corn Morphology



Floury endosperm. More "open" in structure. Dent corn has about equal proportions of vitreous to floury starch (compared to popcorn w/ mostly vitreous starch.

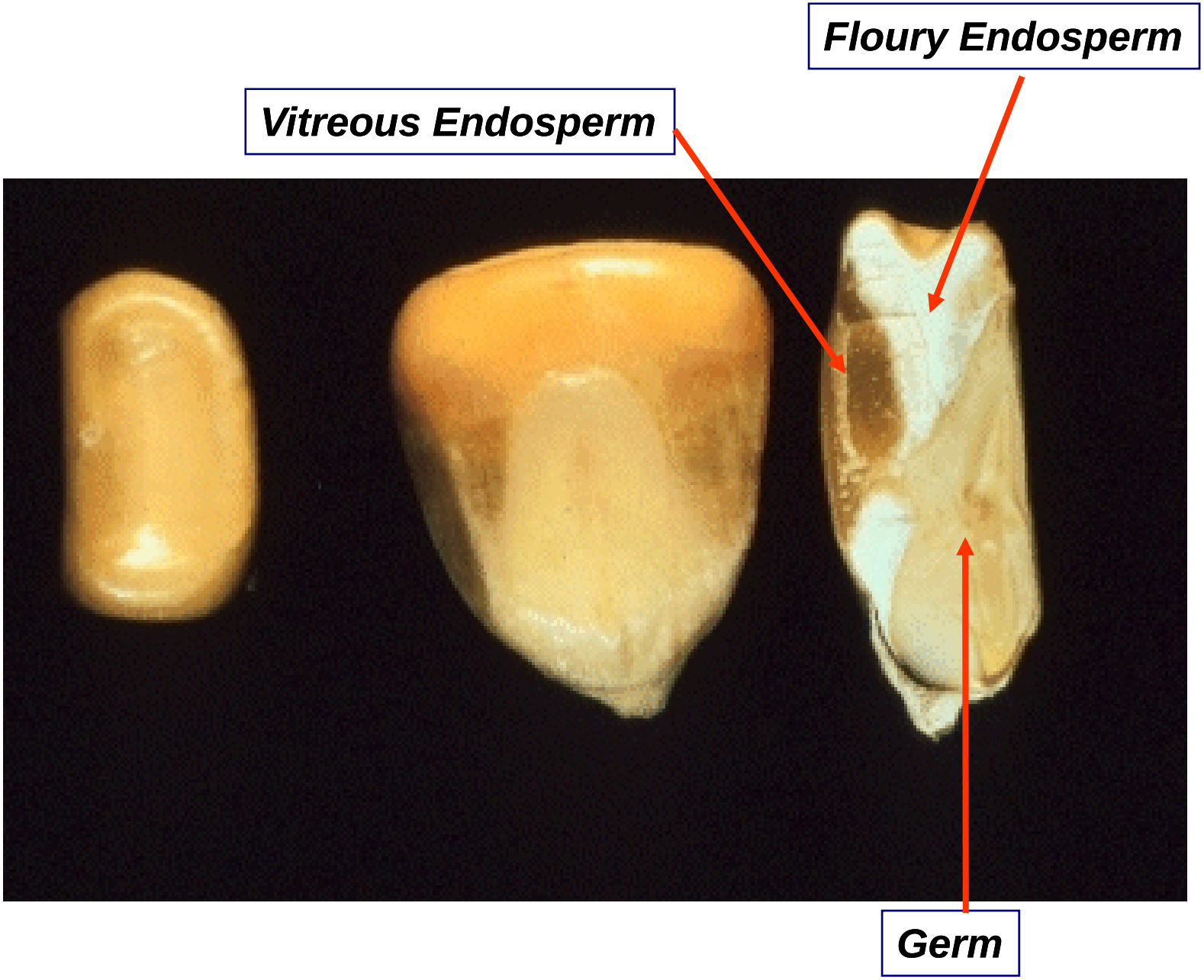
Crown

Vitreous endosperm. Also called horneous, corneous or hard endosperm. Produces grits in dry milling. Tightly compacted and translucent. More of this starch in mature, high test weight kernels.

Pericarp(bran)

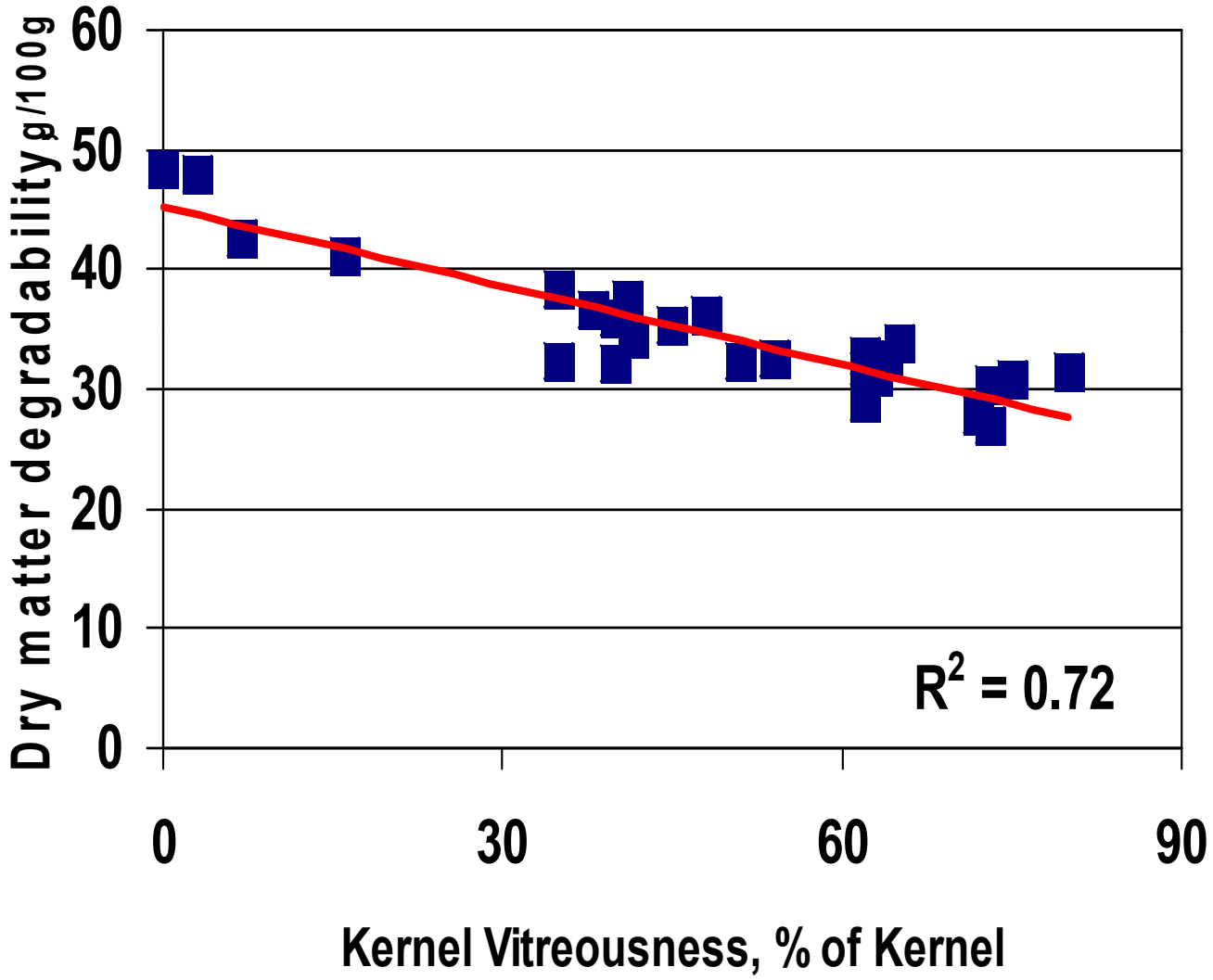
Germ scutellum and embryonic axis. Germ will be bigger in high oil corn at the expense of starch. Each 1% increase in oil, expect 1.3% decrease in starch.

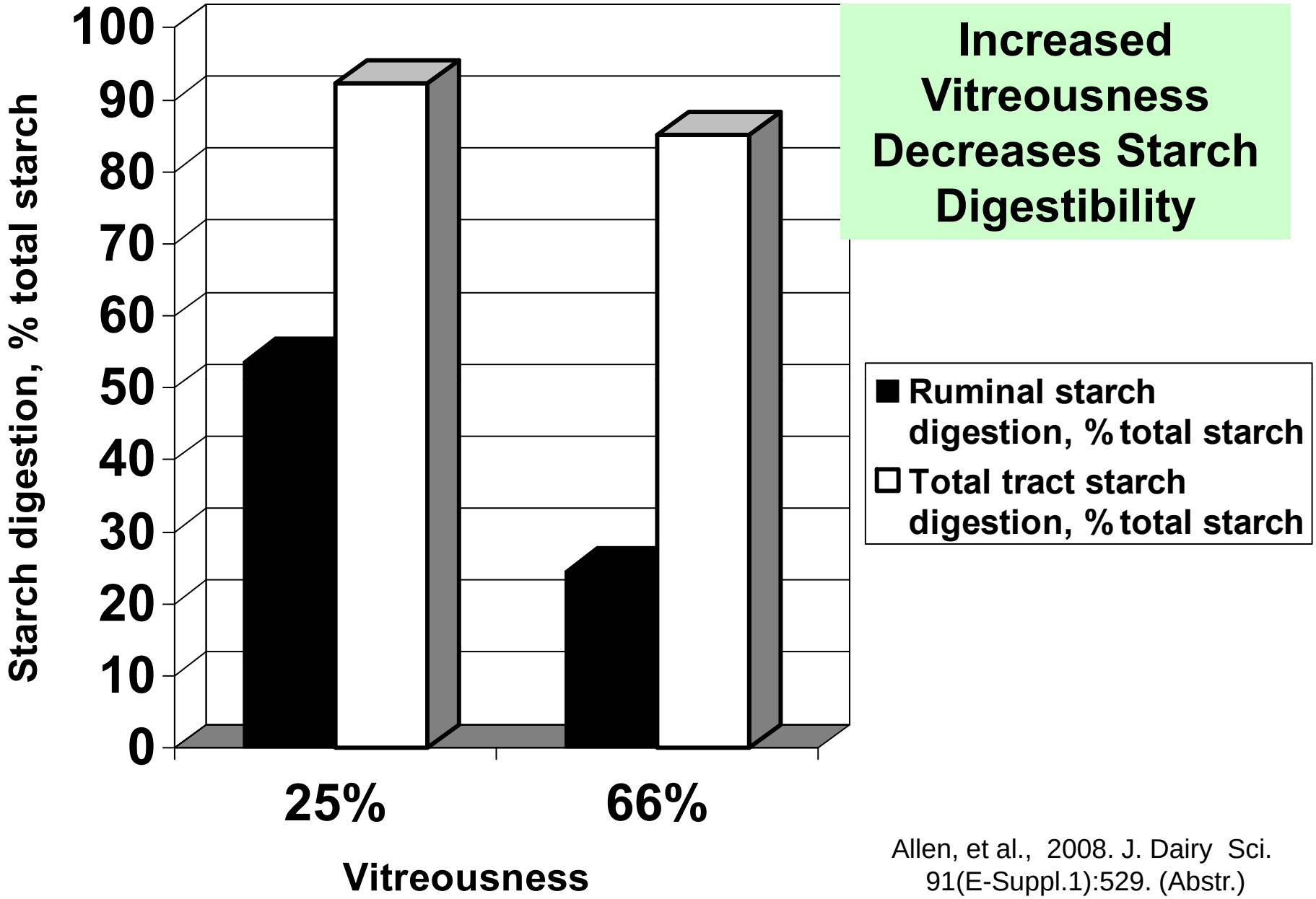
Hilum or abscission layer. Also called blacklayer. Caused by collapse and compression of several layers of cells at physiological maturity. Cool weather can cause premature BL.


Floury Endosperm
Vitreous Endosperm
Germ

Increased Vitreousness Decreases Starch Degradability

Ngonyamo-Majee, et al., Anim. Feed Sci. Technol. 142:259-274.





Allen, et al., 2008. J. Dairy Sci. 91(E-Suppl.1):529. (Abstr.)

- Another Question

- **Chemically-What makes starch vitreous?**

The Starch Protein Matrix

- The endosperm is a starch protein matrix
  - 4 types of Protein in Corn Endosperm
  - Albumins, Globulins, Glutelins, **Prolamins**
- Prolamins
  - Named (Zein) in Corn
  - 50-60 % of the Protein in Corn
  - Major Amino Acid = Proline (Hydrophobic)
  - Prolamins are not Soluble in H_2O or Rumen Fluid
  - Industrial Use (Edible-Biodegradable Plastic)

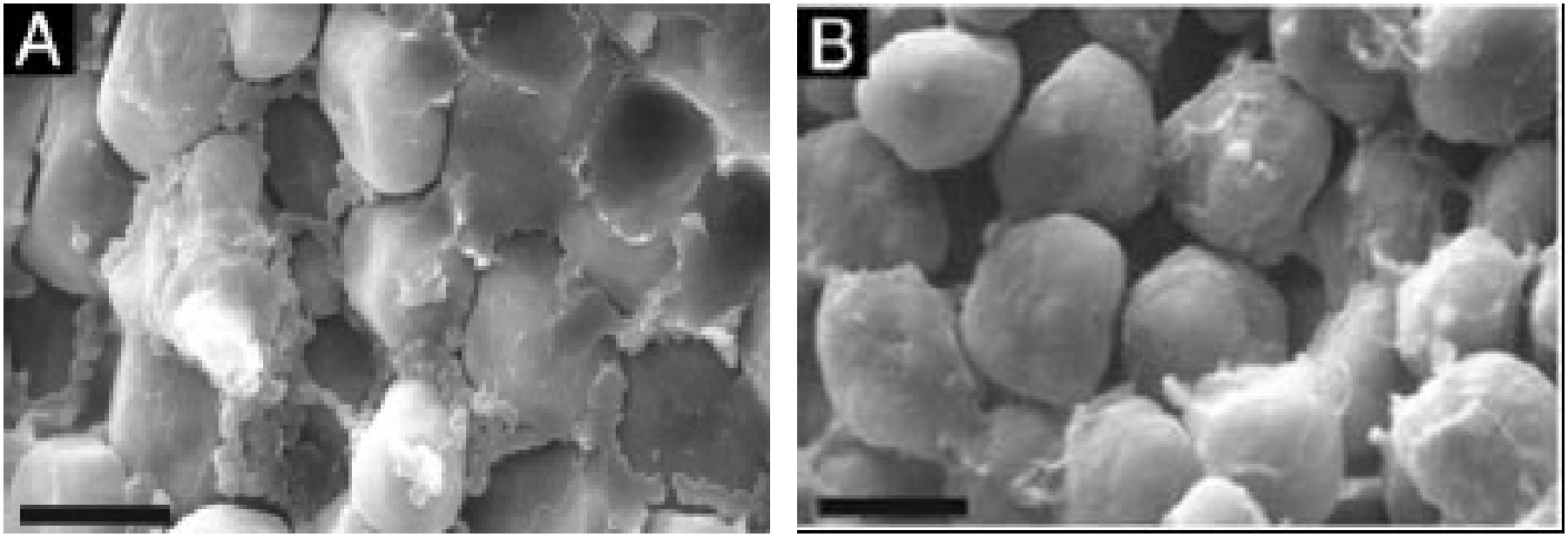
Prolamins: Corn Endosperm Protein of Interest

- **Prolamin Zein (4 Types) – άβγδ**
- **Form on the Starch Granule Surface**
- **Prolamin Proteins Can Cross-link**
- **Encapsulate Starch into a Matrix**
- ***Advances with maturity – (like NDF in forages)***
- ***Genetic differences in corn***
  - ***Floury/Opaque Corns are Missing the Y-zein Gene***
  - ***Floury/Opaque Corns are Low in Prolamins***
  - ***Flint Corns are Very High in Prolamins***
  - ***Common Corn Hybrids are Moderately-High in Prolamins***

The Starch-Protein Matrix

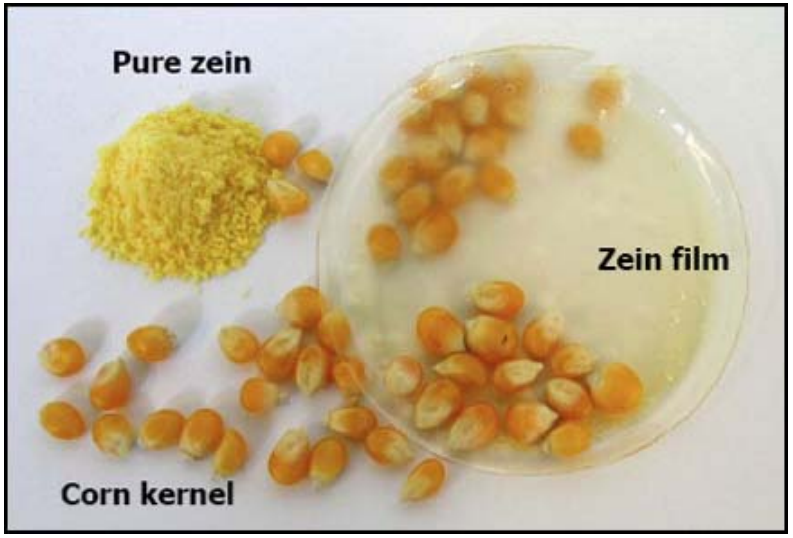
Vitreous Endosperm

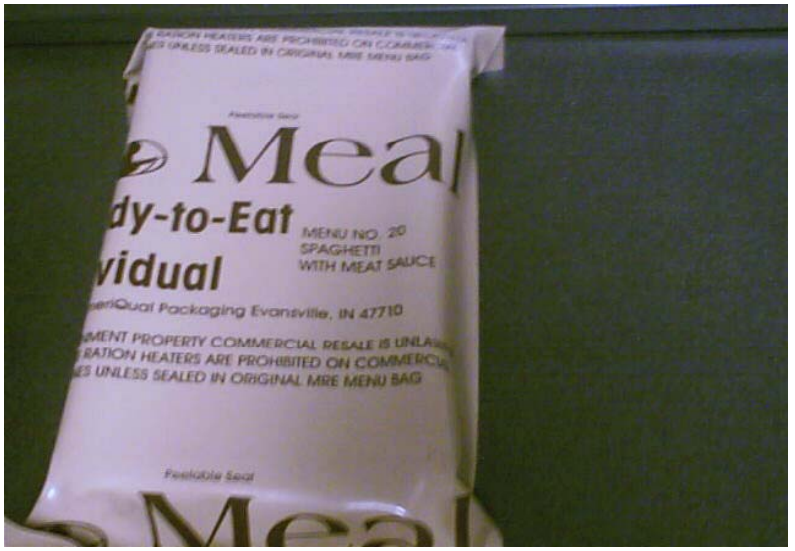
Floury Endosperm



Scanning electron microscopy of starch granules in corn: A) starch granules heavily imbedded in prolamin-protein matrix, B) starch granules in opaque corn endosperm with less extensive encapsulation by prolamin-proteins (Gibbon et. al., 2003).

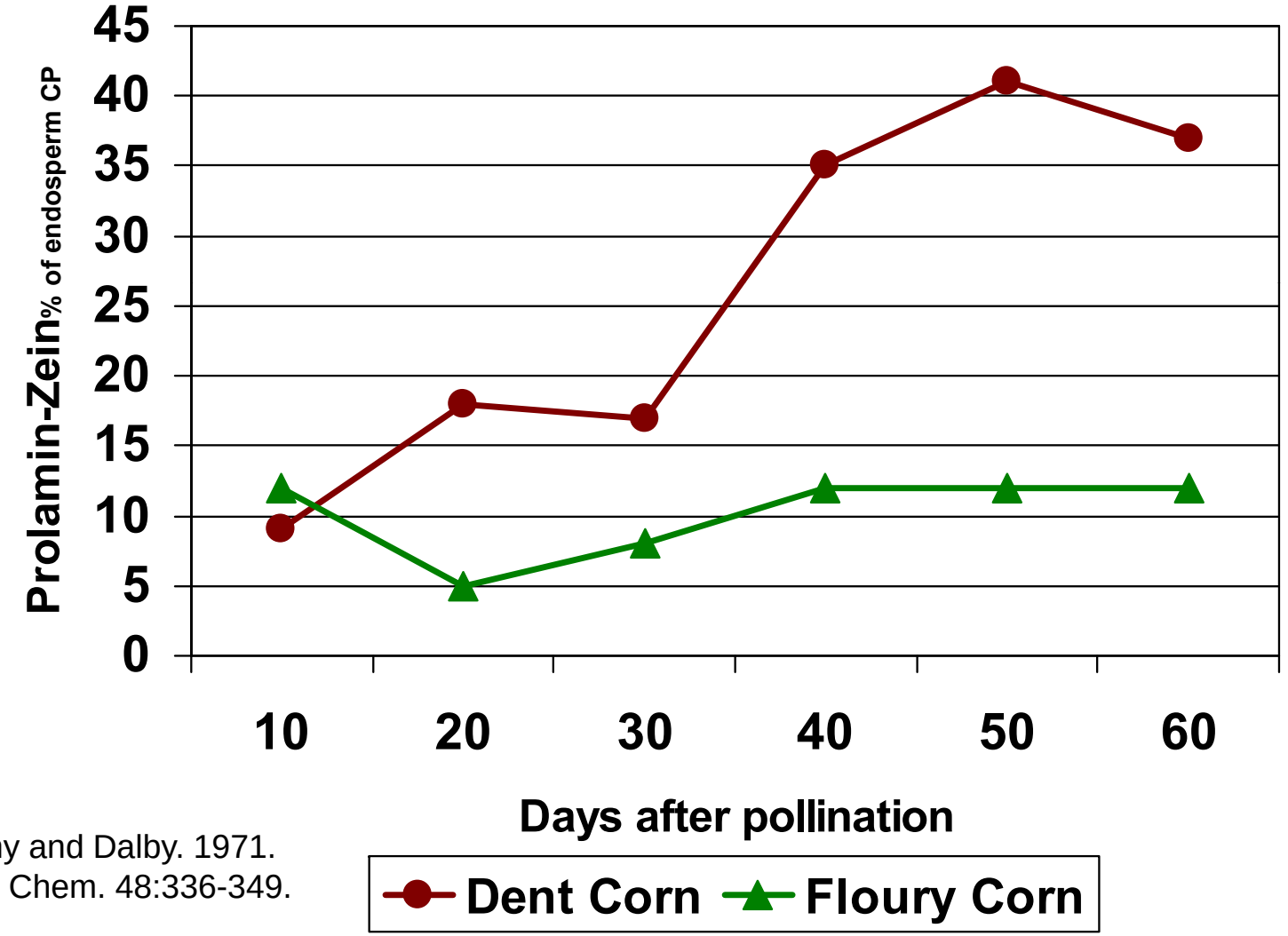
Prolamin (Zein) Industrial Uses





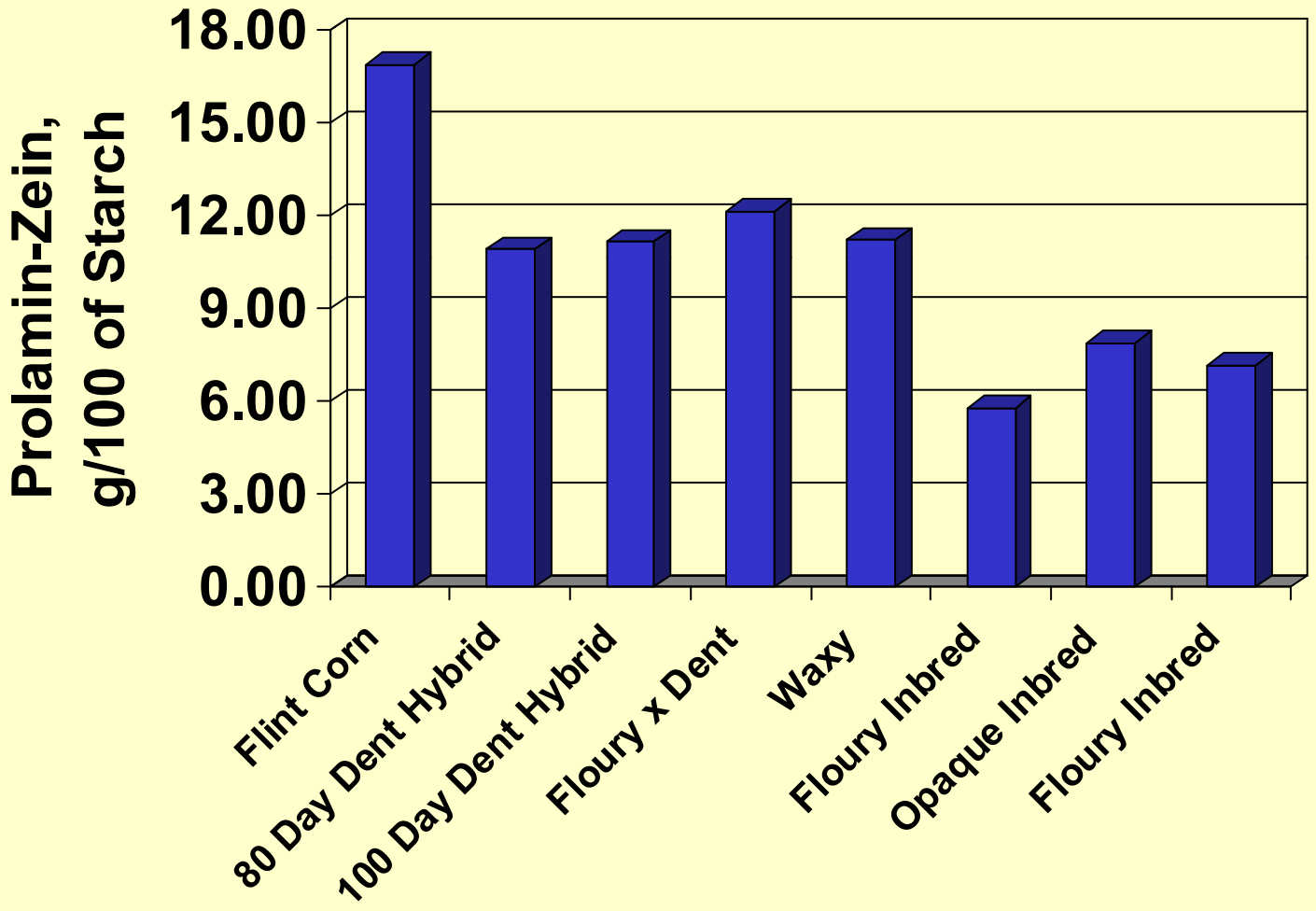
Prolamin-Zein Advances With Maturity

In Normal Hybrids but not Floury Corn



Murphy and Dalby. 1971.
Cereal Chem. 48:336-349.

Corn Types and Varieties Contain Different Amounts of Prolamin-Zein



Laboratory evaluation of the experimental corn varieties. (Shaver et al. 2008)

Item	Iso-Dent	Floury	Opaque
DM, % as fed	87.4	86.9	86.0
CP, % DM	10.4	10.8	10.2
Starch, % DM	69.2	62.9	67.5
Mean Particle Size, µm	1792	1394	1456
Prolamin Protein			
% DM	7.50	2.80	1.73
% CP	72.2	26.2	17.4
% Starch	10.8	4.5	2.6
Degree of Starch Access[2]			
% Starch	53.5	69.4	71.5
Ruminal In Vitro Starch Digestibility[3]			
7-h, % Starch	62	91	85

[1]Treatments were dry rolled shelled corn from W64AxOH43 (**ISO**), W64AxOH43 *fl2/fl2* (**FL**) and W64AxOH43 *o2/o2* (**OP**) varieties.

Effect of corn endosperm type on least squares means for total tract apparent nutrient digestibilities. (Shaver et al. 2008)

%	ISO	Floury	Opaque	ISO vs. Modified	FL vs. OP
				(*P* <)	
DM	73.1	73.6	73.4	NS[3]	NS
OM	73.6	75.3	75.1	0.06	NS
CP	74.6	75.1	74.6	NS	NS
NDF	60.3	55.1	54.0	0.002	NS
Starch	89.6	95.1	96.6	0.002	NS

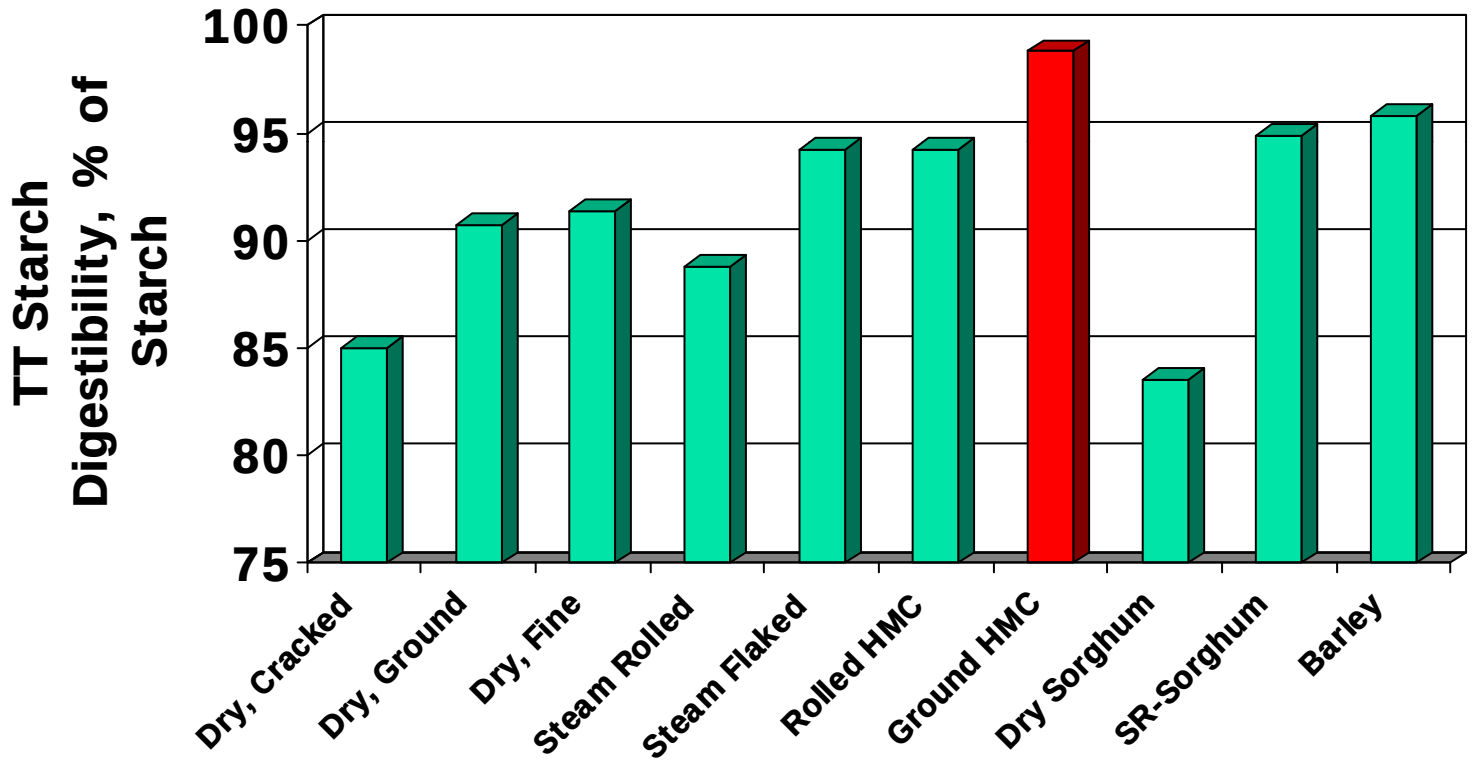
[1]Treatments were dry rolled shelled corn from W64AxOH43 (**ISO**), W64AxOH43 *fl2/fl2* (**FL**) and W64AxOH43 *o2/o2* (**OP**) varieties fed in TMR.

- One More Question

- **What about Prolamins in High Moisture Corn?**

Variation in Starch Digestibility,

Firkins et al., 2001



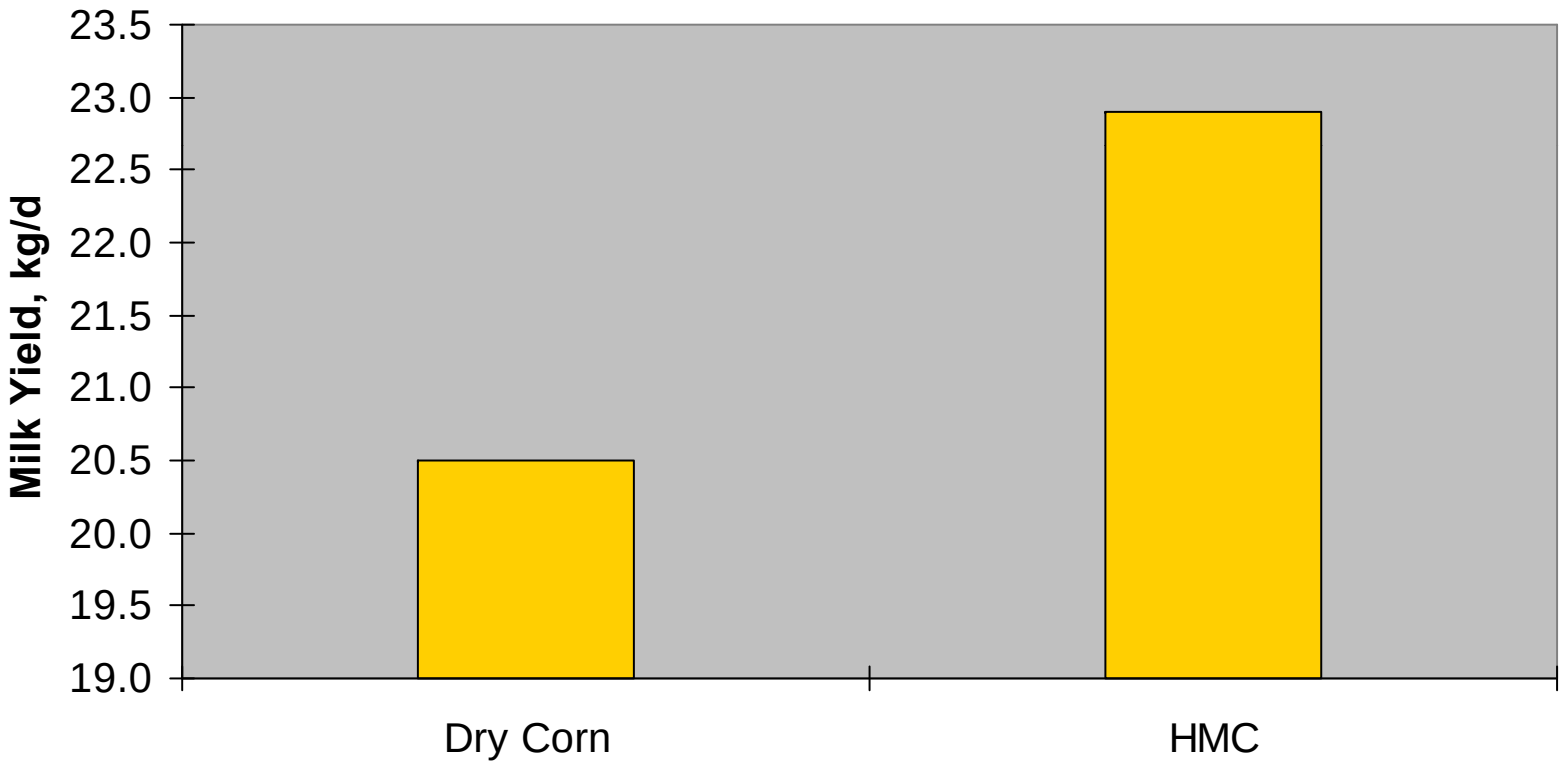
Performance of Lactating Cows fed Ground or Rolled HMC or Dry Corn. Knowlton et al., 1998

SD = Starch Digestibility

	Dry Corn		HMC	
Item	Ground	Rolled	Ground	Rolled
MPS, μm	618	1725	489	1789
DM	85.0	85.0	70.0	70.0
Ruminal SD	60.9	69.2	86.8	81.2
Total SD	88.9	76.4	98.2	95.7
Ruminal pH	6.14	6.27	6.14	6.16
NDFD	30.4	33.0	26.3	25.7
Milk Yield, kg	35.2	33.4	35.0	35.2
Fat, %	4.36	4.36	4.10	4.46

Forage: All Alfalfa Silage

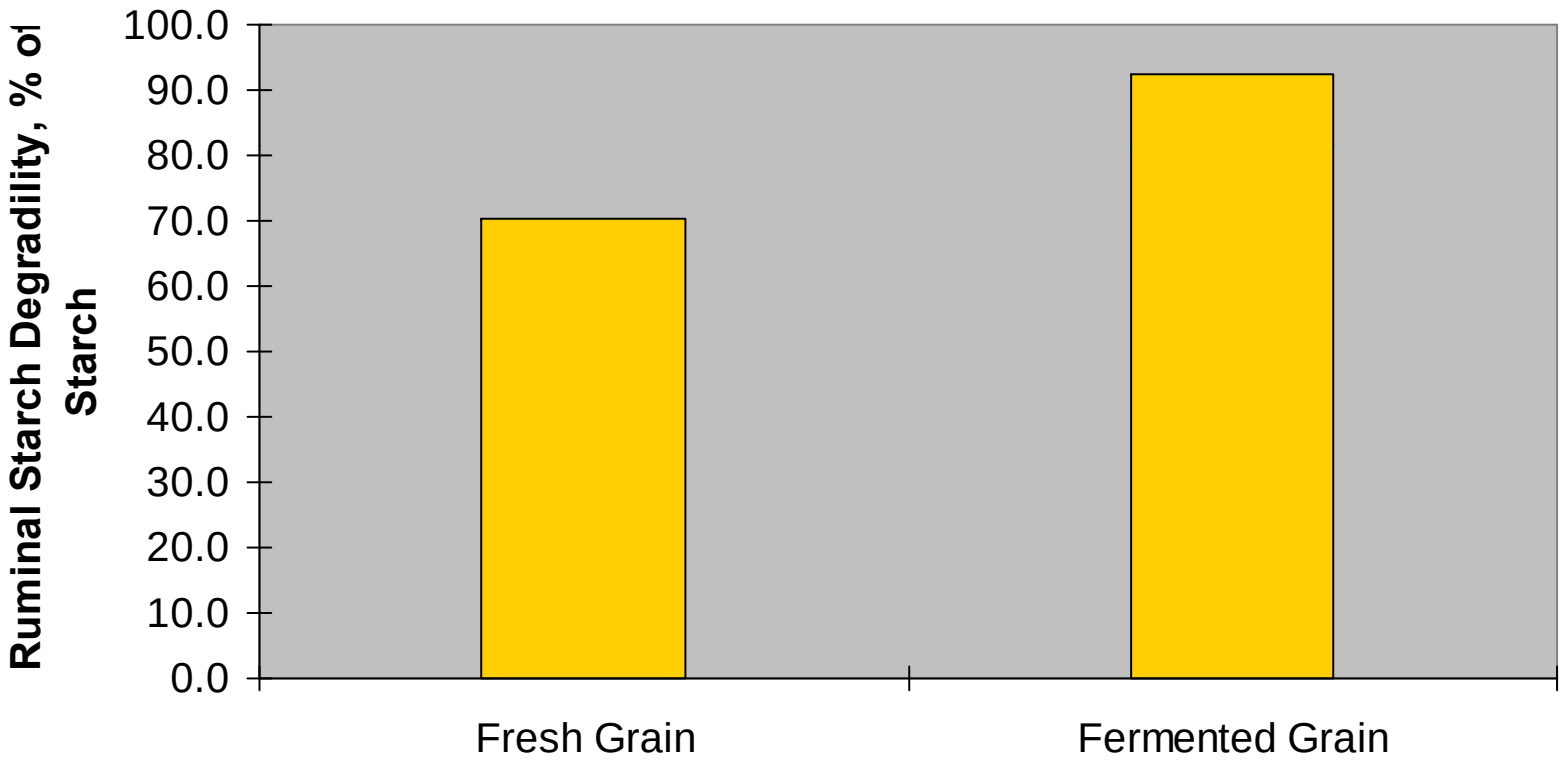
Supplementation of Grazing Cows with High Moisture Corn or Dry Cracked Corn. Wu et al., 2001



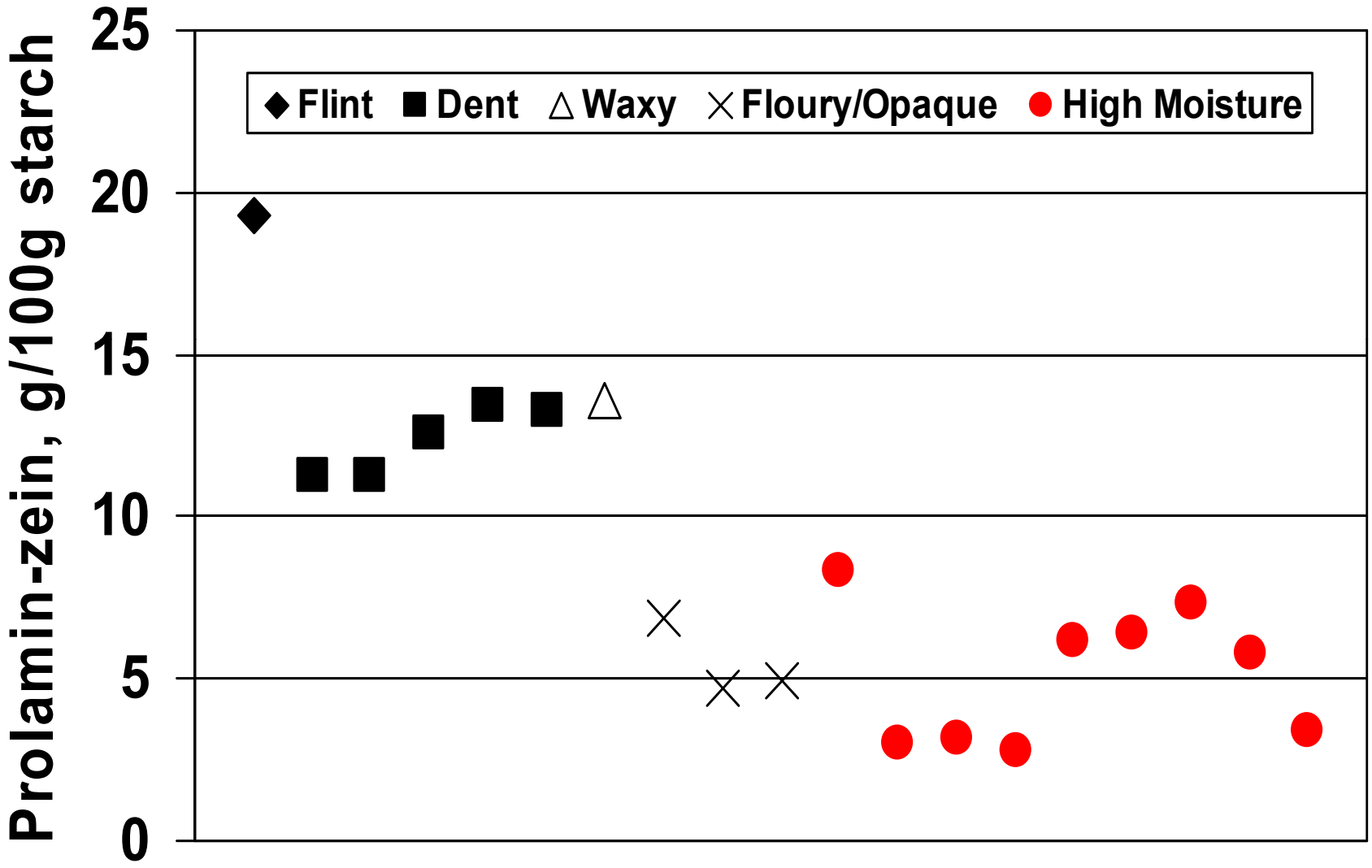
Grazing Cows Supplemented with 6.3 kg of grain DM/d

Fermentation Increases Starch Degradability

Jurjanz and Montels. 2005.
Anim. Res. 3:15-23.



High Moisture Corn is Low in Prolamins



Larson and Hoffman. 2009.
J. Dairy Sci. (In press).

Fermentation Degrades Prolamins ?

- ***Dry Corn is Commonly Harvested at 25-30 % Moisture and Mechanically Dried***
- ***High Moisture Corn is Commonly Harvested at 25-30 % Moisture and Ensiled***
- ***Thus High Moisture Corn and Dry Corn are Commonly Harvested at Similar Maturities***

Proteolysis (Protein Breakdown) is However a Normal Fermentation Process

Prolamins are Not Soluble in Water or Rumen Fluid but Lactic and Acetic Acids are Primary Solvents of Prolamins

All Grains Have Prolamins

Prolamins for each cereal grain have specific and historical names:

Grain	***Prolamin Name***	***Prolamin Level***
wheat	***(gliadin)***	***Med-Low***
barley	***(hordein)***	***Low***
rye	***(secalin)***	***Med-Low***
oats	***(avenin)***	***Low***
corn	***(zein)***	***High***
sorghum	***(kafirin)***	***Very High***

Vitreousness and Prolamins: Can my Lab Test It?

Vitreousness

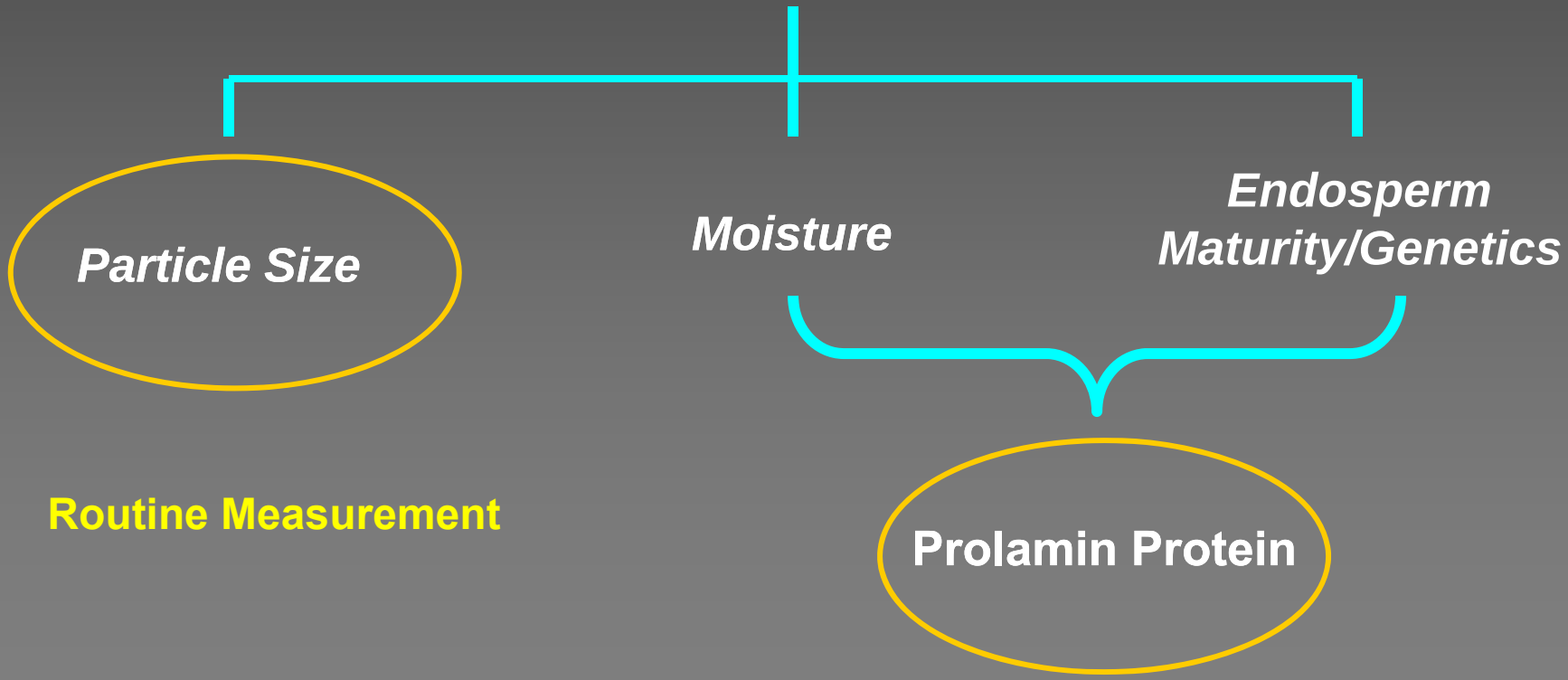
- Evaluated by Manual Dissection of Whole Corn Kernels
- Not Applicable to Ground Feed Samples
- NIRS has Potential to Determine Vitreousness in Ground Samples
- Ngonyamo-Majee, et al., Anim. Feed Sci. Technol. 142:247-258.

Prolamins

- First Method (Osborne, 1897)
- Landry and Moureaux, 1970
- Labor Intensive
- Simplified Method (Larson and Hoffman, 2009)
- Larson and Hoffman- Potential For Routine Analysis

Starch Digestibility

Principal Components of Starch Digestion



Conclusions

- **Corn is a seed and is comprised of three basic morphologic parts, pericarp, germ and endosperm. Starch is contained in the endosperm and thus the biochemistry of the endosperm would be most logical in influencing starch digestibility in ruminants.**

- **Vitreous endosperm is negatively related to starch degradability and in vivo starch digestibility in ruminants.**

- **Vitreous endosperm is visually determined and represents a starch-protein matrix where hydrophobic prolamin proteins are commissural with starch.**

- **Dry flint and dent corns contain more hydrophobic prolamin-zein per g of starch as compared to floury or opaque corns. Prolamin-zein contents of high moisture corn are similar or lower than dry opaque or floury corn.**

- **Lower prolamin-zein contents and correspondingly higher starch digestibility of high moisture corn is hypothesized to be the result of degradation starch encapsulating proteins by fermentation acids and proteolysis during fermentation and not solely due to moisture or harvest maturity per se.**

- **Traditional forage-fiber chemistry techniques may not be well suited for cereal grains in determining biochemical factors that influence starch digestibility in ruminants.**

- **The influence of starch type and starch granule size on starch digestibility in ruminants is not well defined.**

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