Starch, from corn grain & silage, utilization by cattle

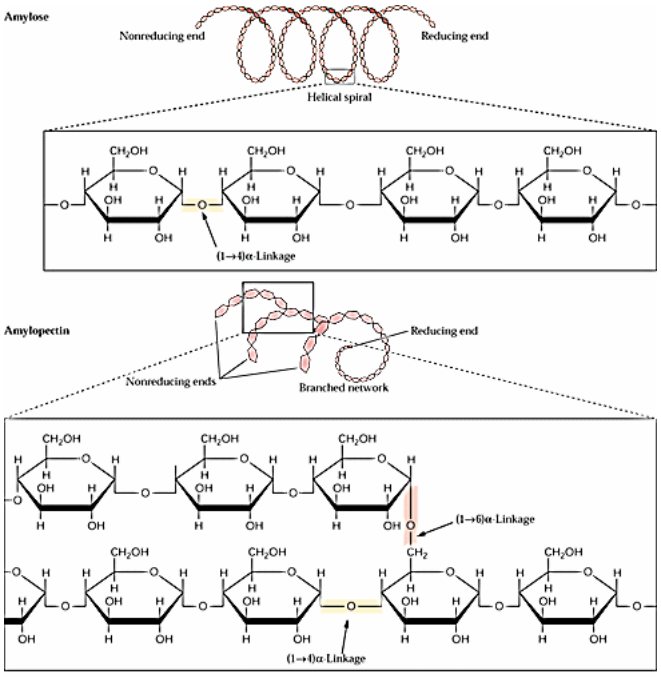
Randy Shaver, Ph.D., PAS, Dipl. ACAS
Extension Dairy Nutritionist

- Starch is broad term
  - Amylose
  - Amylopectin

Starch structure

Normal Dent Corn
- 72:28 Amylopectin:Amylose

Waxy Mutant Corn
- 100% Amylopectin

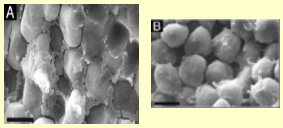


Primary Factors Influencing Starch Digestibility in Corn Grain

Processing
i.e. Particle size; Steam Treatment

Harvest/Storage
i.e. Dry vs. HMC DM of HM/Maturity; Fermentation Time

Endosperm Type
i.e. Prolamin; Prolamin-starch matrix; Hardness

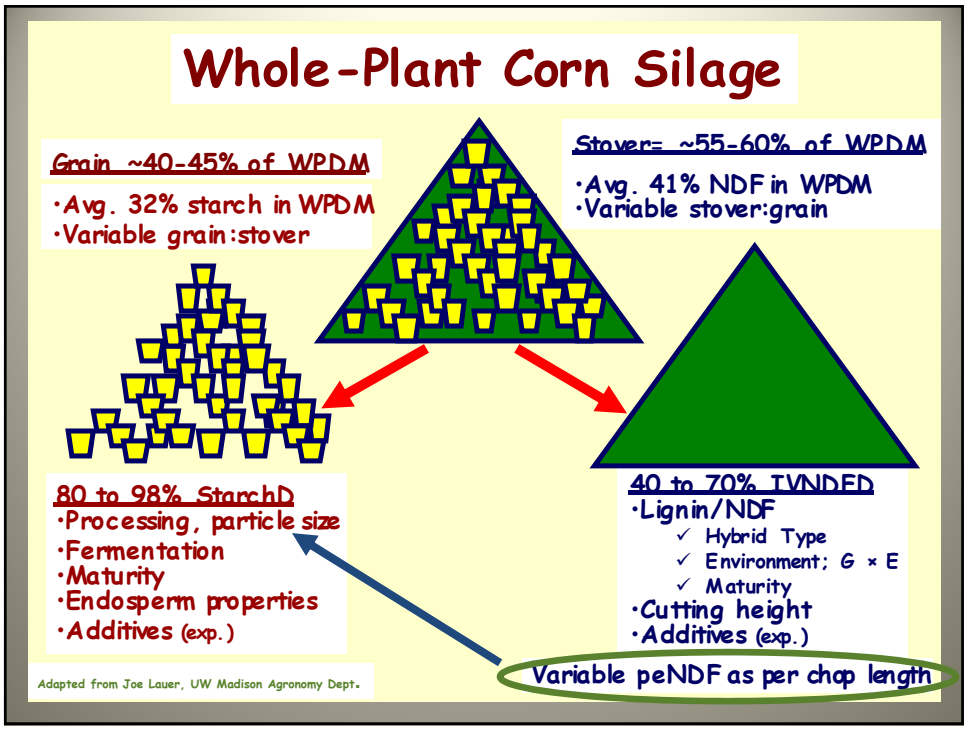


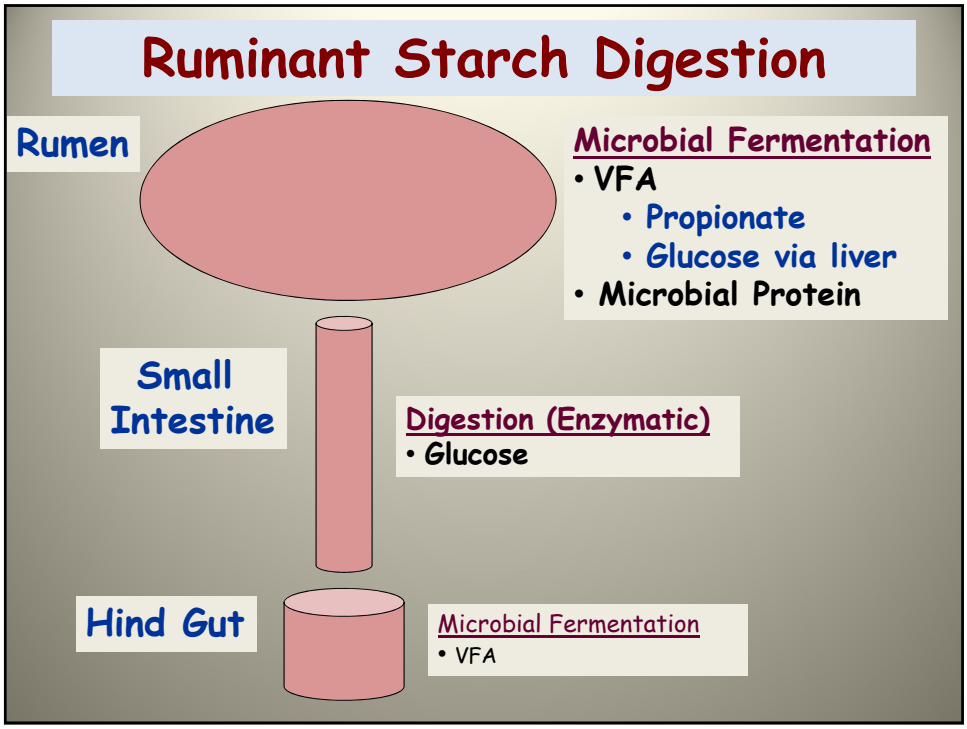
Adapted from Pat Hoffman, UW Madison Dairy Sci. Dept.

Table 4. Impact of various processing techniques on grain and its digestion.

Grain treatment/ processing	Disrupts pericarp or exposes endosperm	Reduces particle size	Disrupts endosperm matrix	Disrupts starch granules	Increases fermentation rate	Increases intestinal digestion
Dry rolling	+++	+	-	-	++	+
Grinding	+++	+++	-	-	++	+
Steam flaking	+++	++	+	+	+++	++
Extrusion	+++	-	++	+	++	++
Pelleting	+++	-	+	?	+	++
Ensiling	+		++	-	++	+
Micronization	+	+	?	?	?	++
Popping	++	-	+	+++	?	+++
Protease	-	-	?	?	++	?

Source: Dr. Fred Owens, Conf. Proc. paper, UMN web site





Starch Digestibility of Corn in Feedlot Cattle

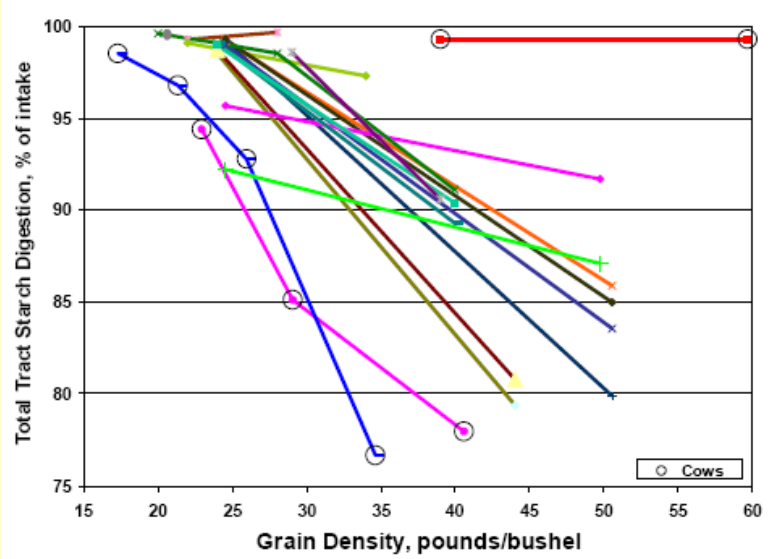
Source: Dr. Fred Owens, Conf. Proc., UMN web post, 2018

	Whole	Dry Rolled	High Moisture	Steam Flaked
# of Diet Observations	6	42	8	94
% of Starch Intake				
Ruminal	68	64	87	84
Post-Ruminal	19 (0.59)	27 (0.75)	12 (0.92)	15 (0.94)
Total Tract	87 (78:22)	91 (70:30)	99 (88:12)	99 (85:15)

Starch Digestibility of Corn in Lactating Dairy Cows *Owens & Zinn, SWNC, 2005*

	Dry Rolled	High Moisture	Steam Rolled or Flaked
# of Diet Observations	14	4	7
% of Starch Intake			
Ruminal	49	76	54
Post-Ruminal	42 (0.78)	20 (0.83)	40 (0.88)
Total Tract	91 (54:46)	96 (79:21)	94 (57:43)

Impact of Flake Density on Total Tract Starch Digestibility *Owens & Zinn, SWNC, 2005*



Greater Proportion of Starch Digested in the Rumen

Potential Advantages

- Energy from VFA
- Microbial Protein
- Greater total tract starch digestion or total energy

Potential Disadvantages

- Low Rumen pH Issues
  - Acidosis
    - Intake
    - Liver Abscess
    - Laminitis

Greater Proportion of Starch Digested in Small Intestine

Potential Advantages

- >Energetic Efficiency
  - Paradoxical
    - Gain benefits very hard to document
    - Glucose used by gut tissue
    - > Visceral fat deposits
- Less Rumen pH Issues

Potential Disadvantages

- May require more costly processing
- <Ruminal MCP output
- More starch passes into hindgut
  - No MCP from digestion
  - HBS
- Reduced total tract starch digestion & total energy

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DM of HM/Maturity; Fermentation Time

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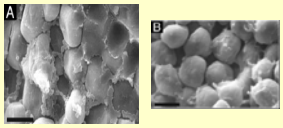
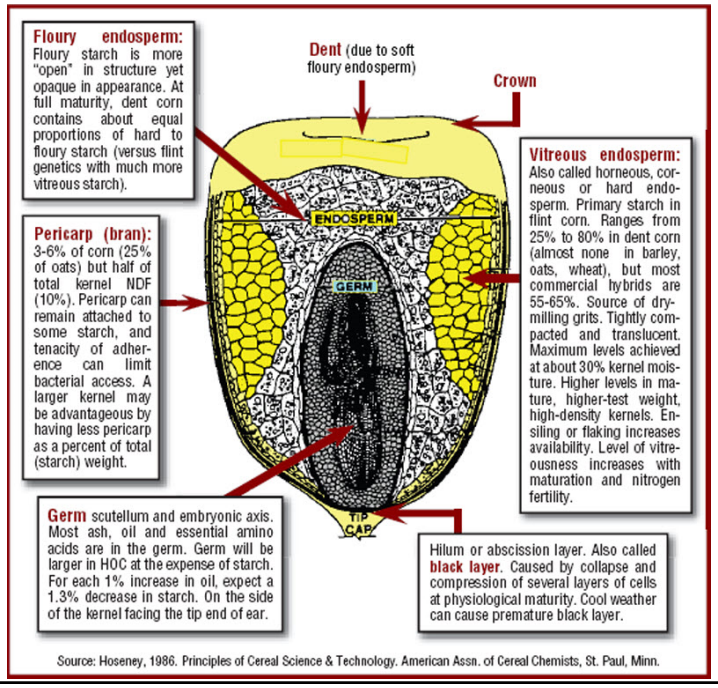
i.e. Prolamin; Prolamin-starch matrix; Hardness



Adapted from Pat Hoffman, UW Madison Dairy Sci. Dept.



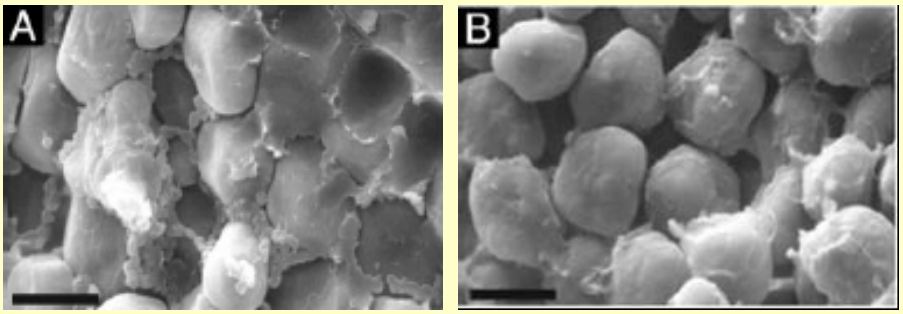
Source: Hoseney, 1986. Principles of Cereal Science & Technology. American Assn. of Cereal Chemists, St. Paul, Minn.

The Starch-Protein Matrix

- Prolamin Zein (4 Types) – άβγδ
- Form on the Starch Granule Surface
- Prolamin Proteins Can Cross-link
- Hydrophobic (not soluble in rumen fluid)
- Increases with kernel maturity
- Encapsulate Starch into a Matrix
  - *Sorghum = kafrin*
  - *Corn = zein*
  - *Wheat = gliadin*
  - *Oats = avenin*
  - *Barley = hordein*

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).

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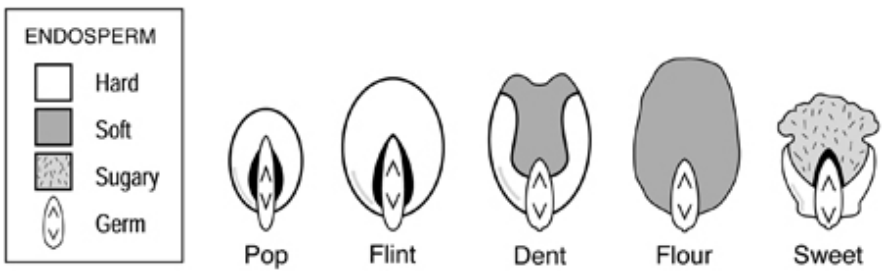
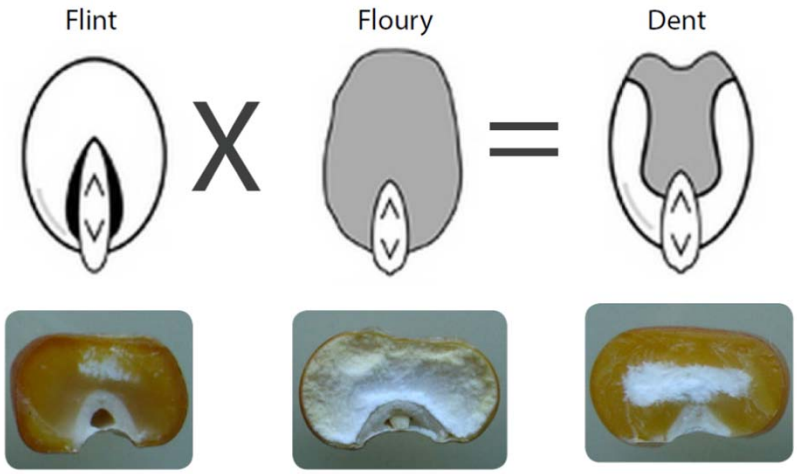
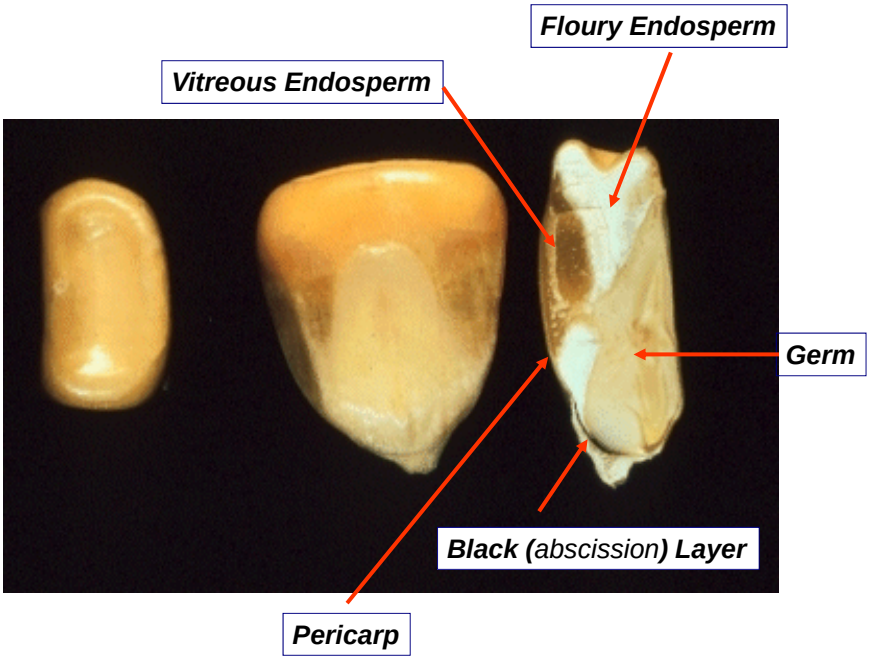

ENDOSPERM
Hard
Soft
Sugary
Germ
Pop
Flint
Dent
Flour
Sweet


Flint
X
Floury
=
Dent



Light table opaque endosperm scores

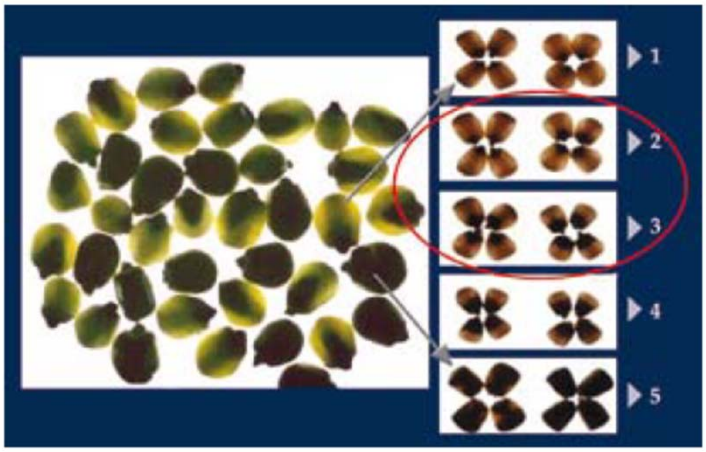


Figure 17. Kernels on a light table (left) and modification classes in F2 seed from normal x QPM donors.

Source: Adapted from Krivanek and Vivek (2006).

HMC & Corn Silage StarchD

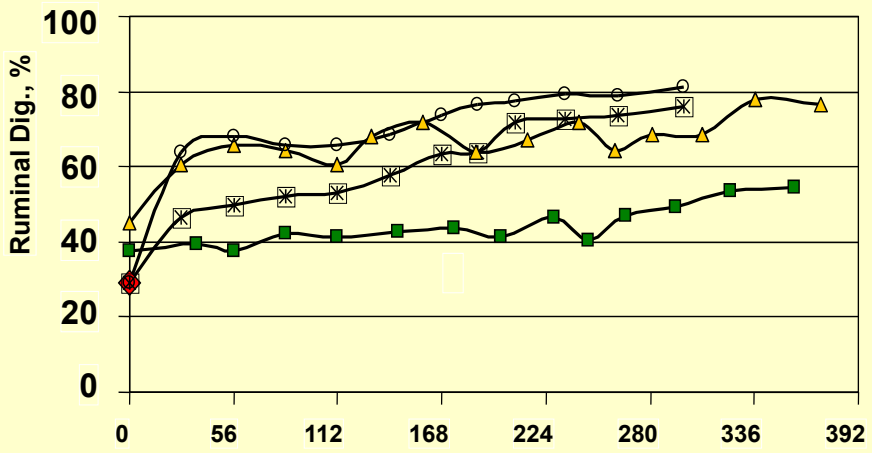
- Hybrid selection for kernel endosperm properties to improve StarchD very slow to evolve
- Genetic effects on StarchD tempered
  - Harvest should be completed pre- or at blacklayer
  - Kernel processed during or at harvest
  - Prolonged silo storage increases StarchD
- No standardized agreed upon method for assessing differences in StarchD among samples
  - Test Sample/Assay Sample particle size a challenging confounder
  - Ruminal vs. post-ruminal starch digestion

StarchD

- **Genetic or transgenic modifications studied**
  - **Comparisons of Flint, Dent, Reduced-Vitreousness Dent, Floury, Opaque, Waxy Endosperm in Conventional Hybrids** (numerous citations but few feeding trials)
  - **α-Amylase expressed in kernel** (Hu et al., 2010, JDS; trials in progress)

HMC Silo Fermentation Increases Starch Digestibility

Increasing Length of Storage Increases Starch Digestion in HMC



Benton et al., 2004
Univ. of Nebraska

Ensiling Period (d)

◆ DRC ■ 24 HMC * 28RECON ▲ 30 HMC o 35RECON

Recommended Moisture Contents

		High-Moisture Corn Grain
Silo	Kernel Moisture %	
Horizontal		27 – 32[a]
Tower		27 - 32

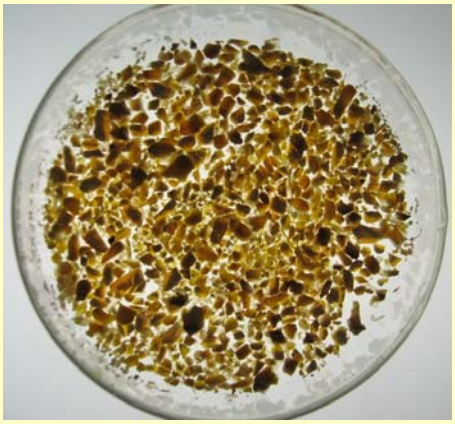
[a]Earlage/Snaplage target at 35%-45% moisture in product

Analysis for nutrient composition & fermentation profile on feed-out samples

	HMSC	Snaplage
Starch, % of DM	71.2% ± 1.2	61.0% ± 0.8
CP, % of DM	8.2 ± 0.1	7.7 ± 0.2
pH	4.4 ± <0.1	4.0 ± 0.1
Ammonia, % of CP	**1.9 ± 0.1**	**5.1 ± 0.7**
Lactic Acid, % of DM	0.6 ± <0.1	1.3 ± 0.1
Acetic Acid, % of DM	0.2 ± <0.1	0.5 ± 0.1

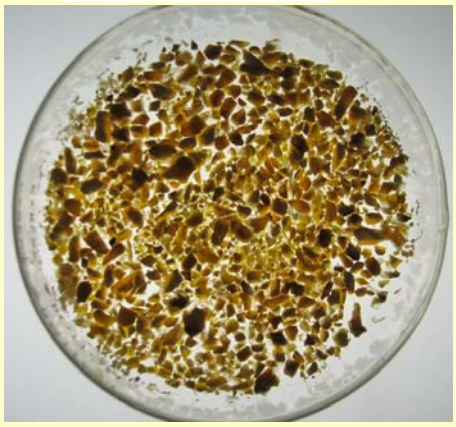
Feeding trial conducted during months 8 -10 in storage

Snaplage	HMC
Ammonia = 6.0% of CP Kernel MPS = 1456 μ	Ammonia = 1.8% of CP MPS = 1335 μ



Feeding trial conducted during months 8 -10 in storage

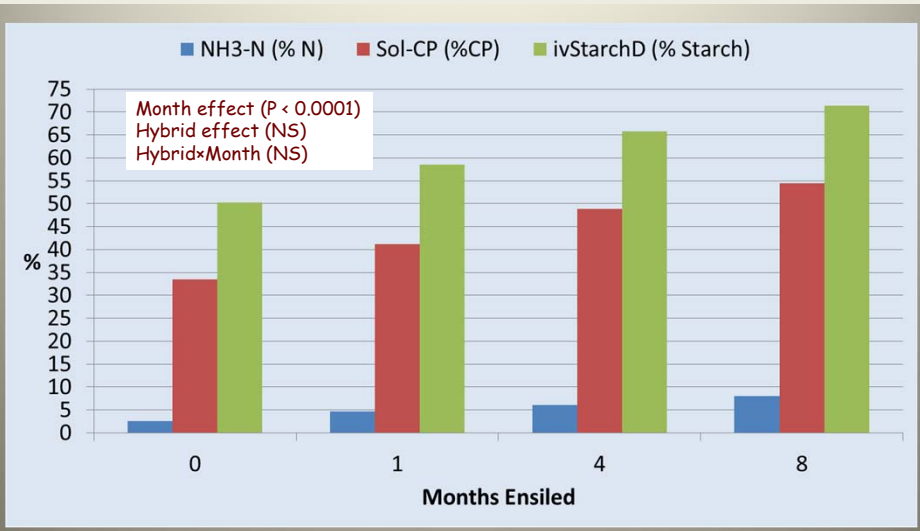
Snaplage	HMC
kd = 26%/hr RSD = 69% TTSD = 97%	kd = 19%/hr RSD = 62% TTSD = 95%



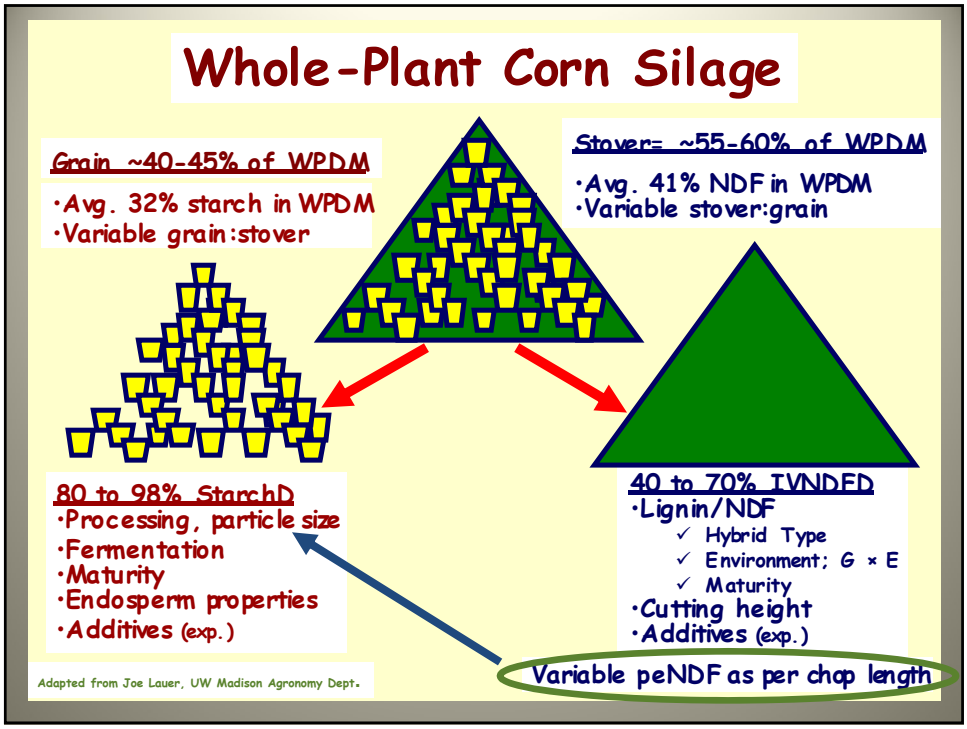
Kd, RSD & TTSD estimated from Ammonia & MPS with FeedGrainv2.0 - Hoffman et al. 2012

Corn Silage Fermentation Increases Starch Digestibility!

Results from Mini-Silo Trial



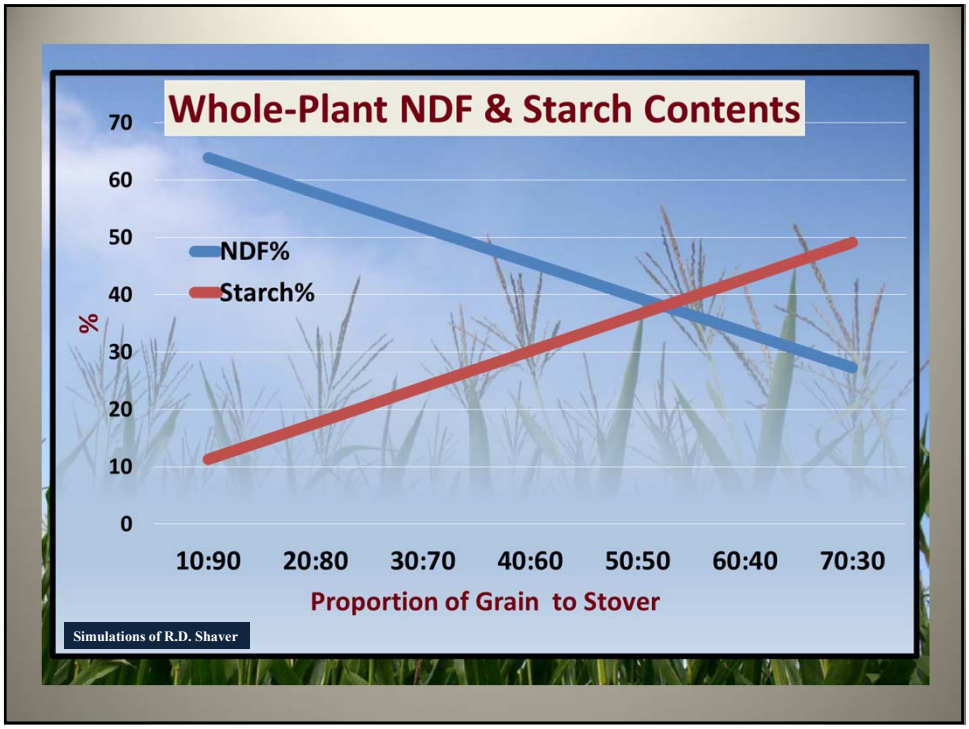
Ferraretto et al., 2014, ADSA abstracts



Corn Silage Quality Indicators for High-Producing Dairy Herds

Parameter	Indicates Better Quality	n	Average ± 1 STDEV
NDF (% DM)	↓	384,715	41 - 36
Lignin (% DM)	↓	344,134	3.3 - 2.6
$uNDF_{240}$ (% NDF)	↓	81,418	27 - 24
$NDFD_{30}$ (% NDF)	↑	170,634	54 - 60
TTNDFD (% NDF)	↑	27,954	41 - 46
Starch (% DM)	↑	347,759	32 - 39
Milk per ton	↑	136,056	3320 - 3683

Summary of combined multi-year, multi-lab (CVAS, DairyOne, RRL, DLL) data, except TTNDFD only from RRL


Whole-Plant NDF & Starch Contents
70
60
50
40
30
20
10
0
%
NDF%
Starch%
10:90
20:80
30:70
40:60
50:50
60:40
70:30
Proportion of Grain to Stover
Simulations of R.D. Shaver


Height of Cutting

High vs. Normal Cut Corn Silage

11 trial average summarized by Wu & Roth; DAS 03-72

Item	15 cm Ht.	45 cm Ht.
DM, %	38	40
NDF, %	42	39
IVNDFD, % of NDF	51	54
Starch, %	31	32
Tons DM per acre	8.1	7.5

Kernel Processing Score

Mertens, USDFRC

- Ro-Tap Shaker
  - 9 sieves (0.6 thru 19 mm) and pan
  - Analyze for starch on 4.75 mm & > sieves

% of starch passing 4.75 mm sieve	KPS
>70%	Excellent
70% to 50%	Adequate
< 50%	Poor

Focus on Forage

Wisconsin TEAM Forage

Making Sure Your Kernel Processor Is Doing Its Job

by Kevin J. Shinners and Brian J. Holmes

www.uwex.edu/ces/crops/uwforage/KernelProcessing-FOF.pdf

Figure 1. Chopped whole-plant corn placed into water.

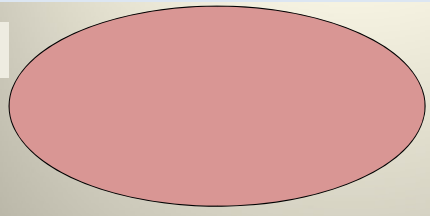
Figure 2. Gently agitating material to help the kernels sink to the bottom of the container.

Figure 3. Skimming and removing the floating stover.

Figure 4. Carefully draining the water so only the kernels remain in the container.

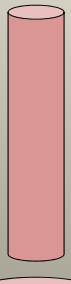
Figure 6. Separated kernels showing three levels of kernel processing. Only the material on the right could be considered adequately processed.

Ruminant Starch Digestion



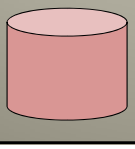
Rumen

Microbial Fermentation
- VFA
  - Propionate
  - Glucose via liver
- Microbial Protein



Small Intestine

Digestion (Enzymatic)
- Glucose

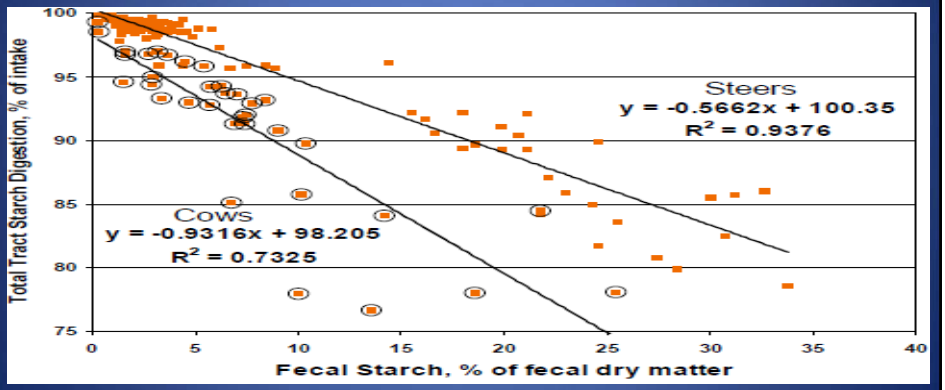


Hind Gut

Microbial Fermentation
- VFA

Owens and Zinn, 2005. Proc. Southwest Nutr. Conf.: 86-112.

- Data from literature review of published research trials with steers and lactating dairy cows



Questions?

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