Corn Silage Digestibility:
Can we make a difference?

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VITA PLUS

Custom Harvester Meeting 2015

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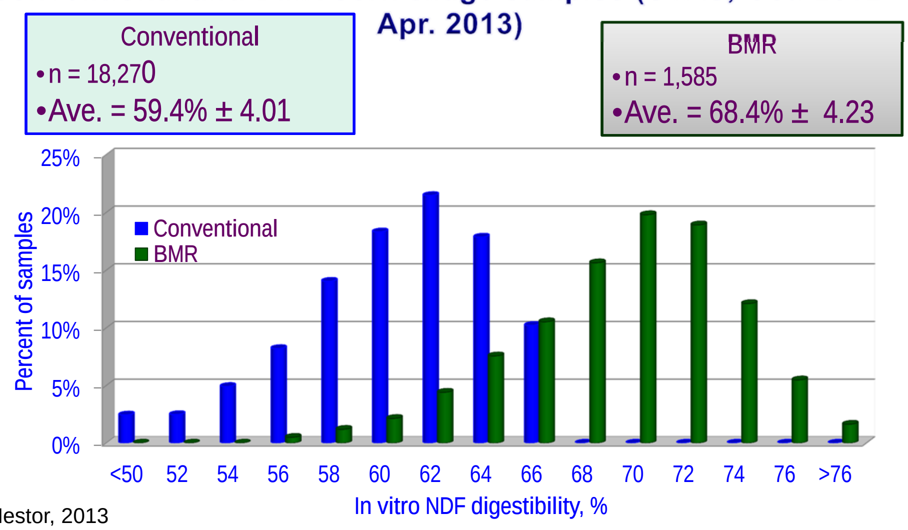
Primary Factors Contributing to Corn Silage Digestibility

- High starch with high starch digestion
- High fiber digestion (NDF-D)
- Every increase 1 unit increase in NDF-D has the potential to increase ~ 0.4 lb DM intake and about 0.5 lb milk
  Oba and Allen, 1997

Brown Midrib Corn Mutants Have Low Lignin => High NDF-D

- Four natural mutations identified in the 1930-40's in dent corn
  bm1, bm2, bm3, bm4
- Low in lignin therefore higher fiber digestion
- Brown to red pigment in the leaf midrib, rind and pith

Distribution of in vitro NDF digestibility at 30 h between conventional and BMR corn silage samples (CVAS, Oct. 2012 – Apr. 2013)



Nestor, 2013

How Does BMR Compare to Normal Hybrids?

	Control		bm3	
	Average	Std. Dev.	Average	Std. Dev.
DM, % of as fed	33.5	3.3	32.5	3.9
Starch, % of DM	30.5	2.9	29.9	4.2
NDF, % of DM	42.0	1.7	40.9	2.1
ivNDFD[2], % of NDF	46.1	9.2	57.6	7.7

[1]In vitro NDF digestibility measured after in vitro fermentation for 30 h except for trial of Weiss and Wyatt, 2006 where a 48 h determination was performed.

Gencoglu, Shaver and Lauer, UW Madison

Effect of BMR on Production – UW Meta Analysis

Item	Normal	BMR
DMI, kg/d	24.2	25.4
Milk, kg/d	37.7 (83 lb)	39.4 (87 lb)
Fat, %	3.67	3.59

Results are least-square means from meta-analysis (St. Pierre, 2001) performed on data from 11 trials with 17 treatment comparisons published in the Journal of Dairy Science since 1999;Gencoglu, Shaver and Lauer, UW Madison

Normal Corn Hybrids and NDFD

- Company selections
- Leafy
- High sugar
- Soft pith

- Research data is inconclusive
- *True selections/evaluations vs random screenings*
- Multi year evaluations vs 1-2 yr evaluations
- Is unbiased information available?

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110-DAY HYBRID TRIAL AVERAGE##						65.6										
NK Brand	N70J-3011A	CB,LL,RR,RW-wo	11.1	3170	35200	65.6	52	61	29	11.4	* 10.7					
Legacy Seeds	L7253	CB,LL,RR,RW	10.4	* 3220	33500	65.8	51	62	30	10.9	9.9	12.1	* 3350	* 40600	* 13.2	* 11.0
DuPont Pioneer	P1498AM1	CB,LL,RR,RW-wo	11.0	* 3230	35600	65.8	53	65	28	11.0	* 12.1					
Masters Choice	MCT6153	CB,LL,RR,RW	9.4	* 3240	30400	65.9	51	63	31	9.4	9.4	12.2	* 3330	* 40600	12.3	* 12.0
InVision	FS 61JX1RIB	CB,LL,RR,RW	10.6	3170	33500	66.0	52	62	28	10.7	* 10.4					
Golden Harvest	G12J11-3011A	CB,LL,RR,RW-wo	* 11.4	3130	35800	66.0	53	61	29	* 11.8	* 11.1	11.5	3190	36700	11.7	* 11.3
Dairyland	DS9311RA	CB,LL,RR,RW	10.5	3170	33300	66.2	52	61	30	10.5	* 10.4					
NuTech/G2 Genetics	5F-811	CB,LL,RR	10.4	* 3220	33400	66.6	51	63	29	10.8	9.9	* 13.3	* 3300	* 44000	* 14.8	* 11.8
Dairyland	DS9713RA	CB,LL,RR,RW	10.9	* 3200	34900	67.2	51	61	31	11.6	10.2					
AgriGold	A6538STX	CB,LL,RR,RW	10.7	3110	33400	67.3	54	61	28	10.6	* 10.8					
115-DAY HYBRID TRIAL AVERAGE##						67.4										
DuPont Pioneer	P1339AM1	CB,LL,RR,RW	11.2	3130	35000	67.4	53	62	27	11.1	* 11.2	11.7	* 3310	38800	11.8	* 11.7
Masters Choice	MC6470	None	9.8	* 3210	31400	67.6	52	63	30	10.6	9.1					
Renk	RK930VT3P	CB,RR,RW	11.1	3140	34900	67.7	54	62	27	11.1	* 11.1					
Masters Choice	MCT6583	CB,LL,RR,RW	10.4	3160	32900	67.7	52	61	29	11.4	9.4	11.4	3240	37100	12.3	10.0
NuTech/G2 Genetics	5F-612	CB,LL,RR	11.1	3120	34600	67.9	54	62	26	11.1	* 11.0					
Mycogen	TMF2R737	CB,LL,RR,RW	* 11.7	3130	* 36600	68.1	53	62	27	* 12.4	* 11.0	* 12.6	3180	* 40300	* 13.6	* 11.7
AgriGold	A6559STXRIB	CB,LL,RR,RW	10.9	3080	33600	68.5	55	61	26	10.9	* 11.0					

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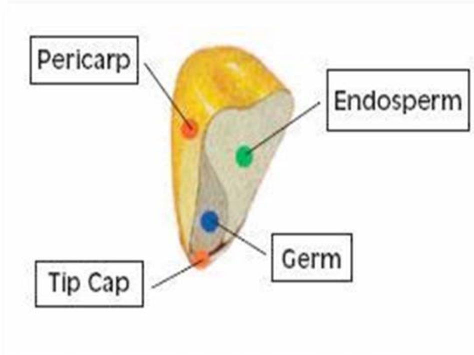
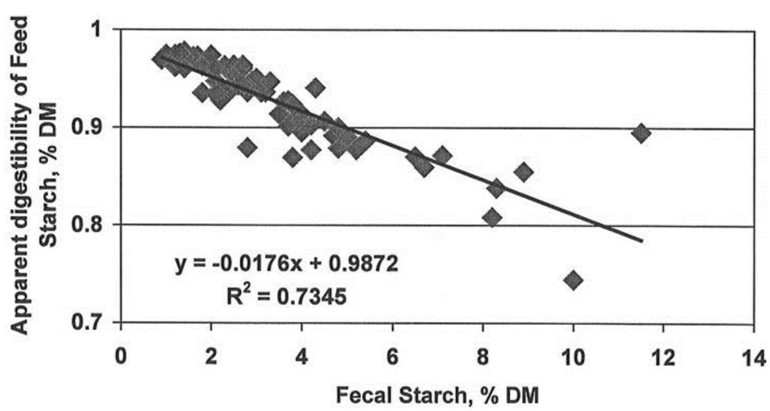
Accessibility of Starch in Corn Silage

- Starch must be accessible by bacteria in the rumen
- Factors that limit the access to starch
  - Pericarp
  - Surface area
  - Protein/starch matrix



Fecal Starch and Digestibility

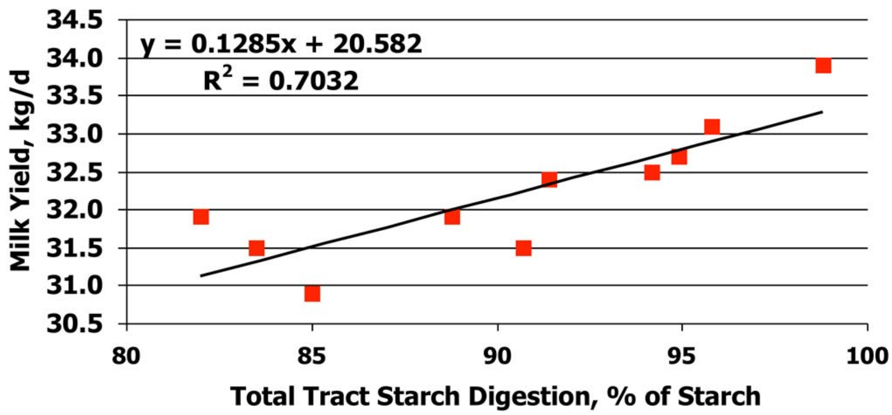


- 4.5% fecal starch ~ 90% starch digestibility
- 1%-unit decrease in fecal starch ~ 1 pound more milk
- Range in starch: 2.3 – 22.4%

(Ferguson, 2006)

Starch Digestibility is Positively Correlated with Milk Yield

Firkins et al., 2001



Mechanical Processing Effects on Corn Silage

(34% DM - BMR)

Item	Unprocessed	Processed
DM intake, lb/d	52.7	56.8*
Milk, lb/d	93.4	98.0*

Ebling and Kung, 2004

Shredlage - Potential for High Level of Kernel Processing With Long Effective Fiber (potentially even in relatively high DM samples)

Shredlage

Conventional Kernel Processed

Photos provided by Kevin Shinners, UW Madison, BSE

Kernel Processing Score

Samples obtained during feed-out from the silo bags

	Shredlage	KP
% Starch Passing 4.75 mm Sieve	75.0% ± 3.3	60.3% ± 3.9

Shaver, 2013

	Shredlage®	KP	*P* <
Rumen StarchD, % of Starch	88.3%	76.0%	0.05

Industry Makes Advances in Corn Silage Processing
(CVAS Data, 2006 to 2014)

Crop Year	Number	Average	Percent Optimum	Percent Poor
2006	97	52.8	8.2	43.3
2007	272	52.3	9.2	37.9
2008	250	54.6	5.2	34.8
2009	244	51.1	6.1	48.0
2010	373	51.4	5.9	43.4
2011	726	55.5	12.3	33.1
2012	871	60.8	14.8	19.9
2013	2658	64.6	36.0	12.9
2014	322	61.8	24.2	9.0

Adapted from slide provided by Ralph Ward of CVAS

Assuming Access to Corn Starch is Not Limiting, What Options are There to Improve Ruminal Starch-D?

- Allow natural proteolytic mechanisms during ensiling to occur which increase starch-D
- Use enzymes to accelerate this process
  - Amylases
  - Proteases

Reports of Increase in Ruminal Starch-D in Corn Silages and HMC with Ensiling

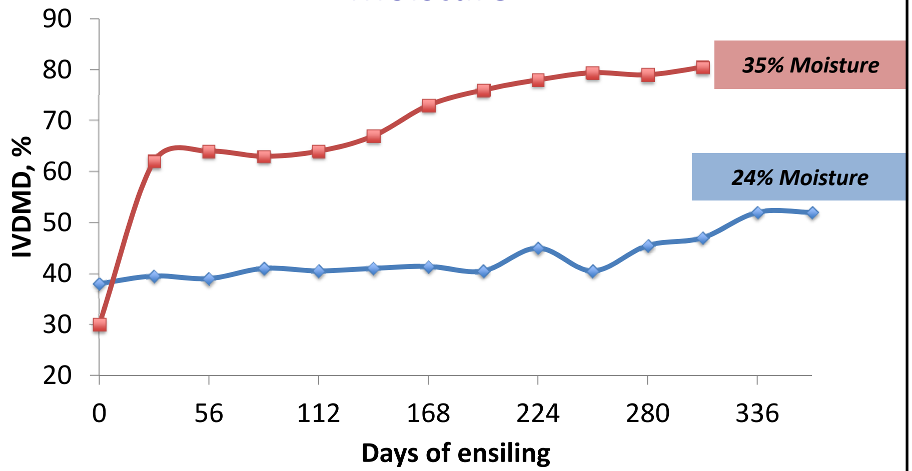
HMC

- Philippeau and Michalet-Doreau, 1998 (short period of ensiling)
- Allen et al., 2003 (moderate)
- Benton et al., 2005 (long)

Corn silage

- Jurjanz and Monteils, 2005 (short)
- Newbold et al., 2006 (long)
- Hallada et al., 2008 (long)
- Snyder, 2011 (long)
- Der Bedrosian et al., 2012 (long)

In Situ Ruminal DM Disappearance for HMC is Influenced by Length of Ensiling (long term) and Moisture

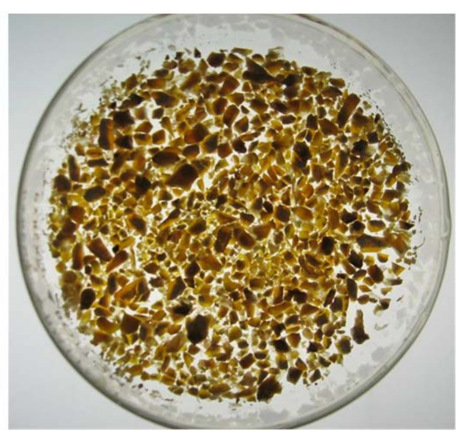


Benton et al., 2004

Degradation of Endosperm Proteins (Same Hybrid)

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

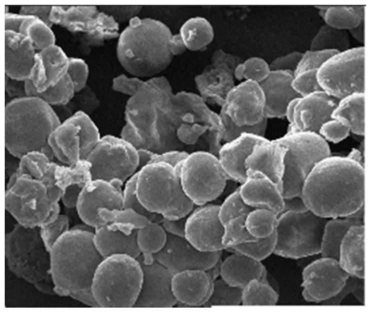
0 % translucent



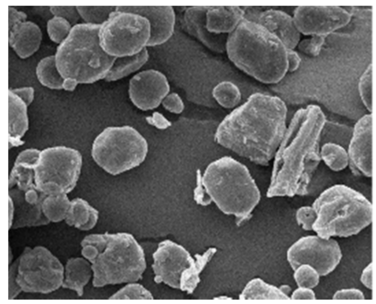
80 % translucent

Proteolysis of the Protein/Starch Matrix During Storage Results in Increases in Starch-D

Prior to ensiling

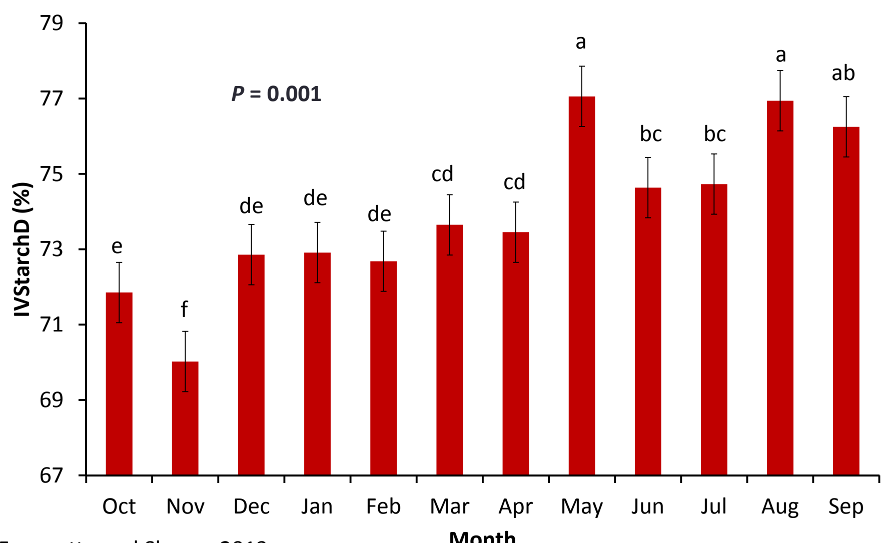


After 240 d of ensiling



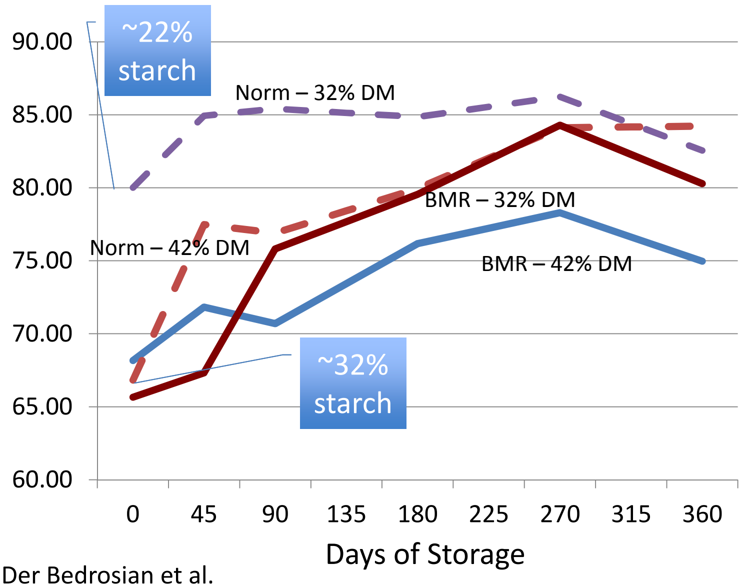
Hoffman et al., 2011

IVStarchD Increased by Length of Ensiling in HMC (summary of commercial lab data)



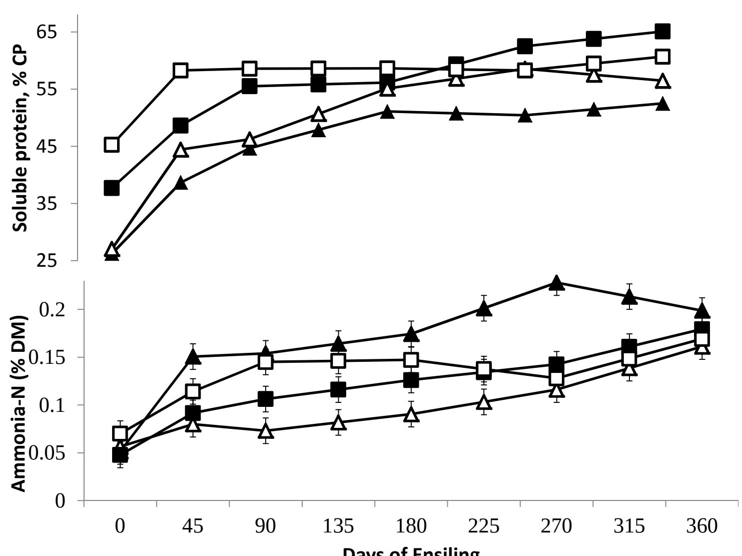
Ferraretto and Shaver, 2013

Prolonged Ensiling Improves In Vitro Starch Digestion of Corn Silage



2012 Der Bedrosian et al.

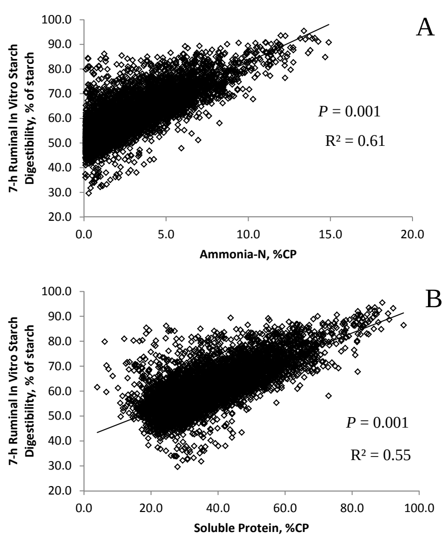
Soluble Protein and Ammonia-N Continue to Increase with Prolonged Ensiling



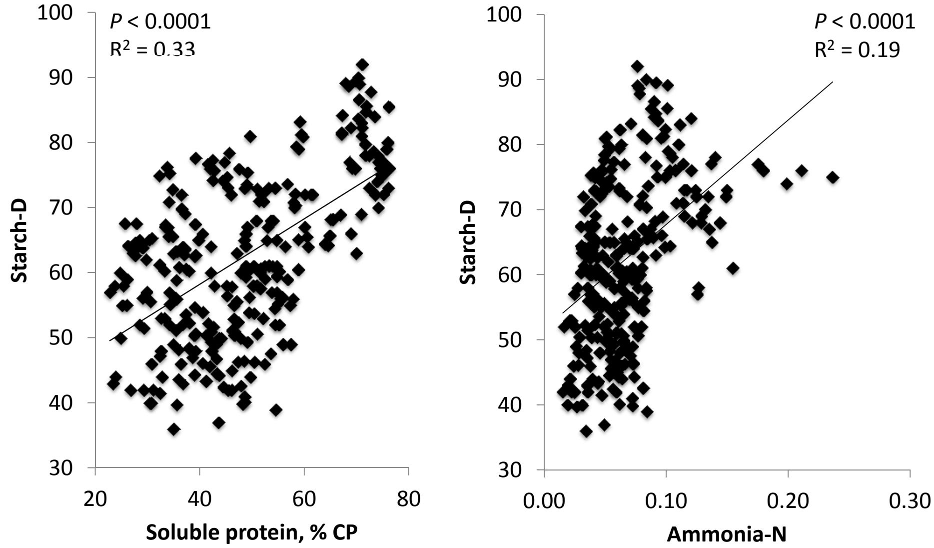
2012 Der Bedrosian et al.

Correlations Between Markers of Proteolysis and Starch-D

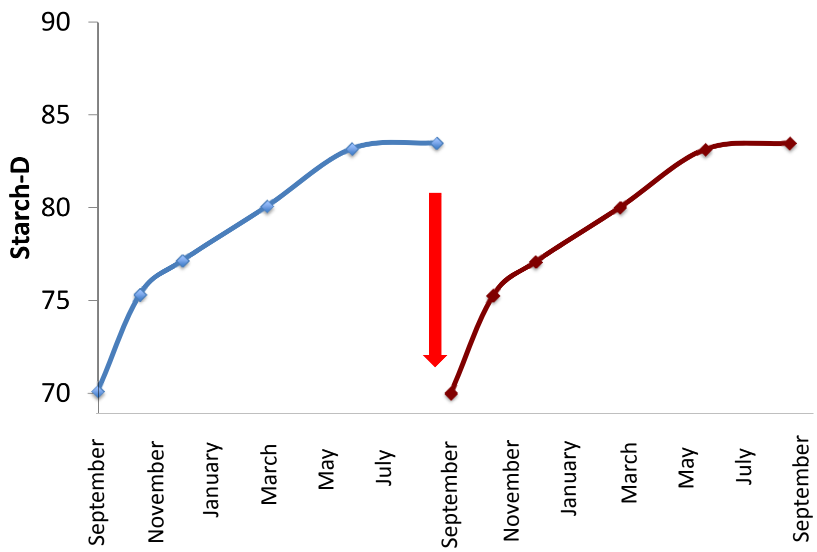
Soluble Protein, % of CP (Krishnamoorthy, et al., 1983)
NH3-N, % of total N, (NH3-N probe, Kjedahl, NIRS, etc)



Correlation Between Protein Degradation and Starch-D in Corn Silages



Effect of Days of Ensiling on Starch Digestion in Corn Silage



Issues With Storing Silages for Prolonged Times In Order Achieve High Potential Ruminal Starch-D

- Resources (land, storage capacity?
- Cost of prolonged storage?
- Challenges
  - keeping silage from spoilage during storage
  - plastic integrity

Assuming Access to Corn Starch is Not Limiting, What Options are There to Improve Ruminal Starch-D?

- Allow natural proteolytic mechanisms during ensiling to occur which increase starch-D

- Use enzymes to accelerate this process
  - Amylases
  - Proteases

Adding Amylases at Ensiling –

Spoelstra et al., 1992

Item	Control	Amylase
DM, %	38	35
Starch, %	31	24
Sugars, %	2	18
Lactic acid, %	6.2	7.3
Acetic acid, %	1.9	1.5
Ethanol, %	0.7	5.0
Yeasts, log cfu/g	<2	5
Aerobic stability, h	148	76

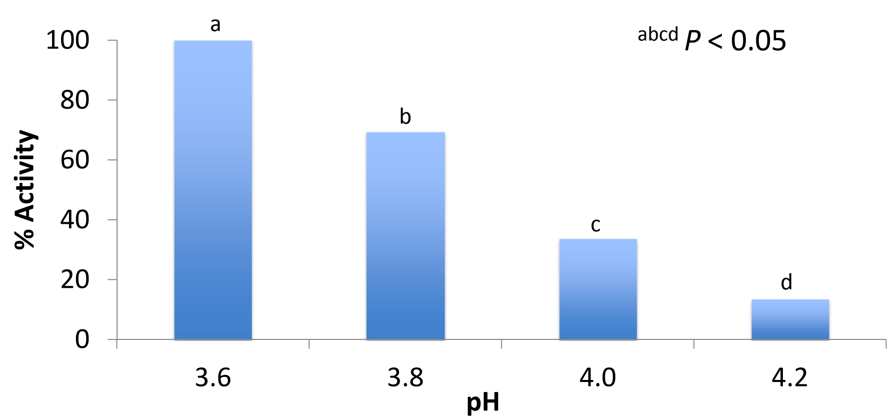
Proteases

- Biofuels industry to yield higher growth of yeasts and more ethanol (usually acid proteases)
- Feed additive (usually neutral or alkaline proteases)– some research showing improved in vitro starch D
  - Lichtenwalner et al., 1978
  - McAlister et al., 1993
  - DePeters et al., 2007
- Historically not used as a silage additive because proteolysis is already excessive

Description of Protease Experiments at UD

- Supplied by
  - AB Vista, UK
  - Novozymes, Denmark
- Acid proteases
- Low pH optimum of ~3.5
- No carbohydrase activities
- Silages stored at ~22C unless otherwise stated

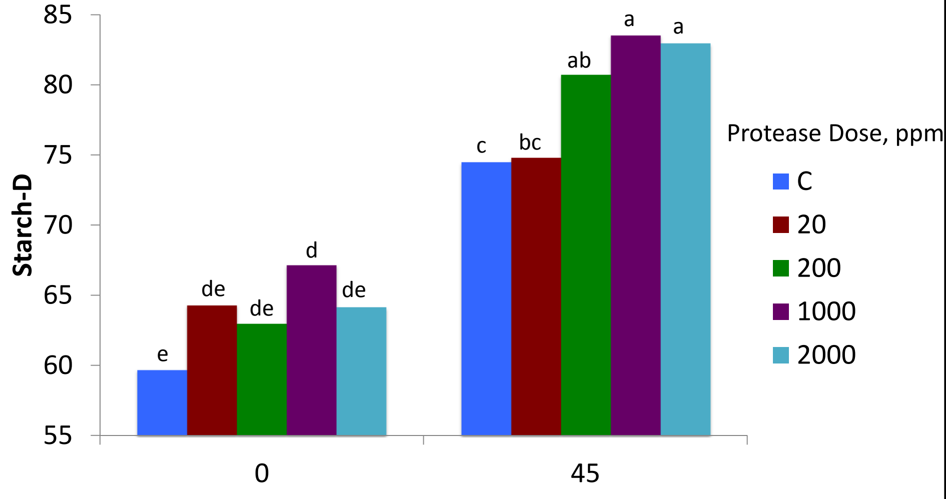
Activity for AB Vista Protease



Windle and Kung, University of Delaware

% activity relative to 100% at pH 3.6

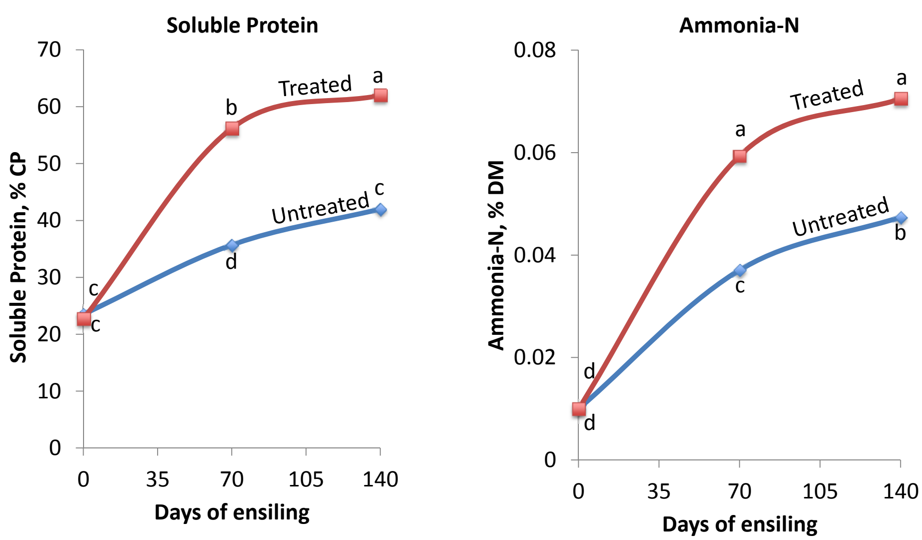
Effect of Protease Dose on 7 h *in vitro* Digestibility of Starch of Corn Silage



Windle and Kung, University of Delaware

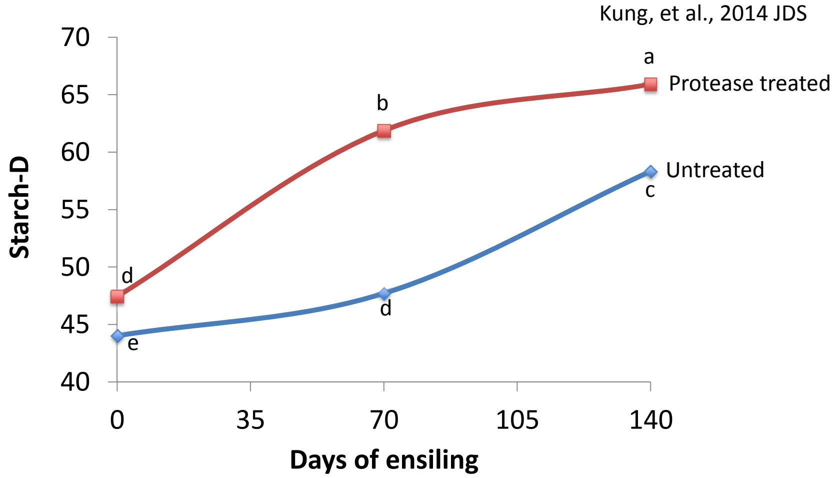
Effect of a Protease on Indicators of Proteolysis in HMC

Kung, et al., 2014 JDS



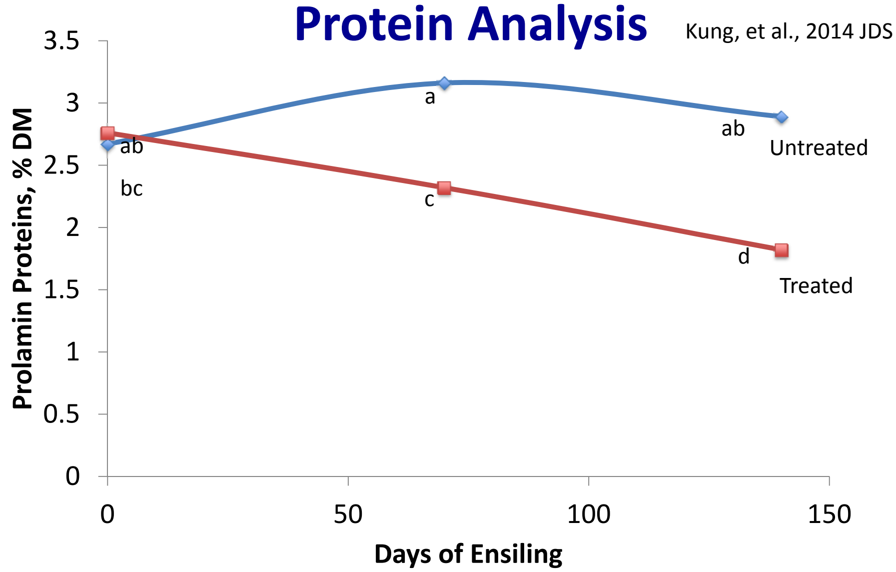
Effect of a Protease on In Vitro Ruminal Starch-D of HMC

Kung, et al., 2014 JDS



Effect of a Protease on Prolamin Protein Analysis

Kung, et al., 2014 JDS



Other Options to Improve Ruminal Starch D?

- Proteases + amylases?
- CS hybrid selection? (Floury, opaque)
- Designer inoculants

What Can We Do Today to Maximize Starch D From CS and HMC?

- Avoid harvesting dry (mature) CS
- Process adequately
- Feed less mature (wetter) CS first, store dry (mature) CS longer
- Can’t win the battle…..post ensiling processing?

Summary

BMR is the primary technology to increase corn silage NDFD

Selection or inoculant technologies to alter NDFD in normal corn silage hybrids are less defined

Intensity and duration of fermentation is the primary mechanism that increases corn silage starch digestibility LEARN TO FOLLOW CP FRACTIONS!

Corn silage processing increases starch digestibility and milk yield.

Factors that influence starch digestibility in cows are now well defined and technologies such as enzymes, custom designed inoculants and or designer hybrids are all possible.