Penn State Dairy Cattle Nutrition Workshop

November 15 – 16, 2017

Starch Digestibility: How It's Measured, Reported, and used

Ralph Ward, President

Cumberland Valley Analytical Services

CVAS

Introduction

- Cumberland Valley Analytical Services is a forage and feed testing laboratory.
- I am not a formal researcher or academic.
- Experience bridges across laboratory feed characterization for application in dairy nutritional settings.

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Focus Points

- Re-cap on sampling
- Corn silage starch relationships
- The StarchD challenge
- StarchD concepts
- How to manage StarchD characterization

CVAS's new 33,000 sq. ft. facility devoted to feed and forage testing.

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Please, we welcome your visit !

Waynesboro, PA (Just off Rt. 81 at the PA / MD line)

Starch Considerations

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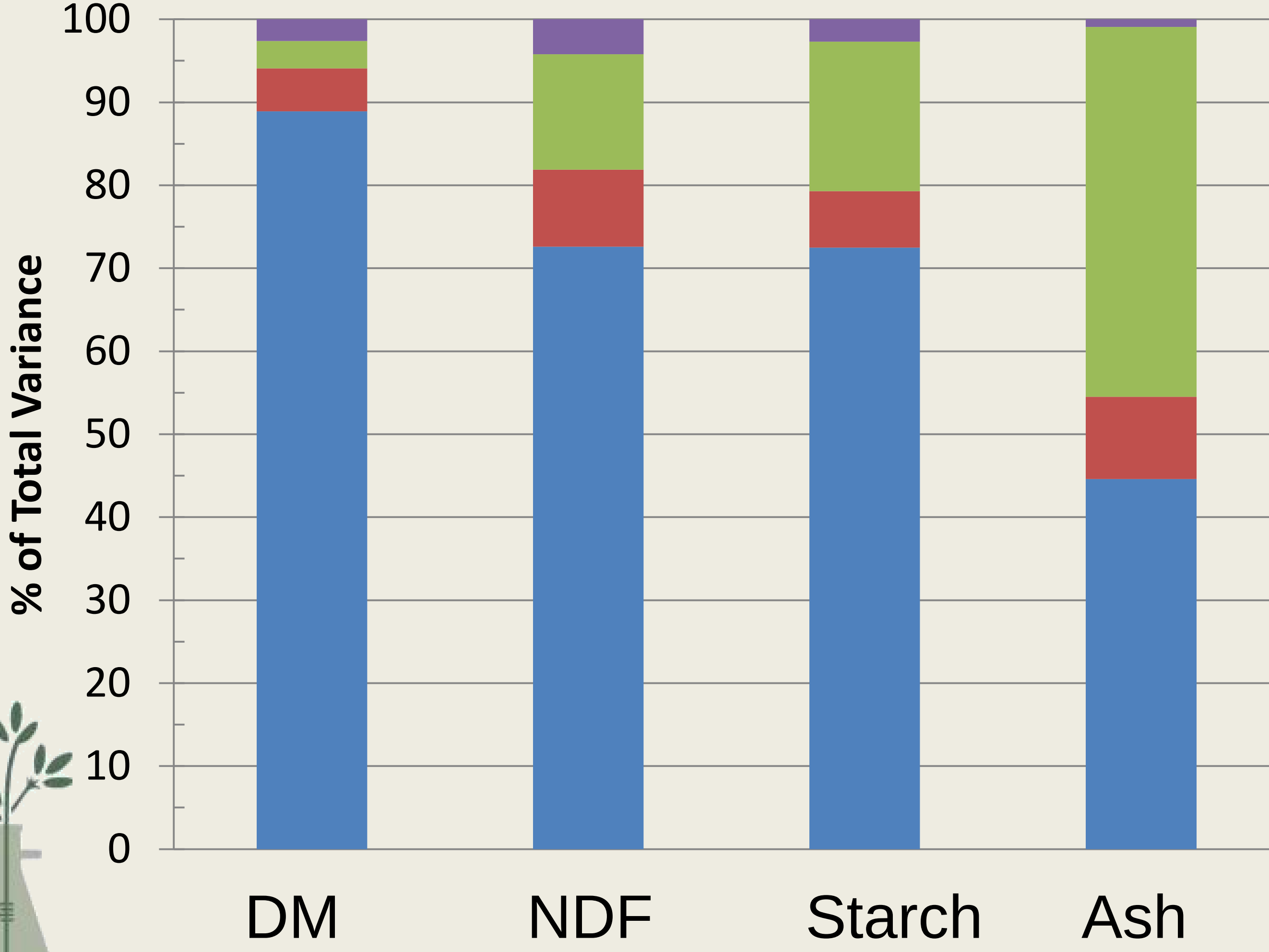
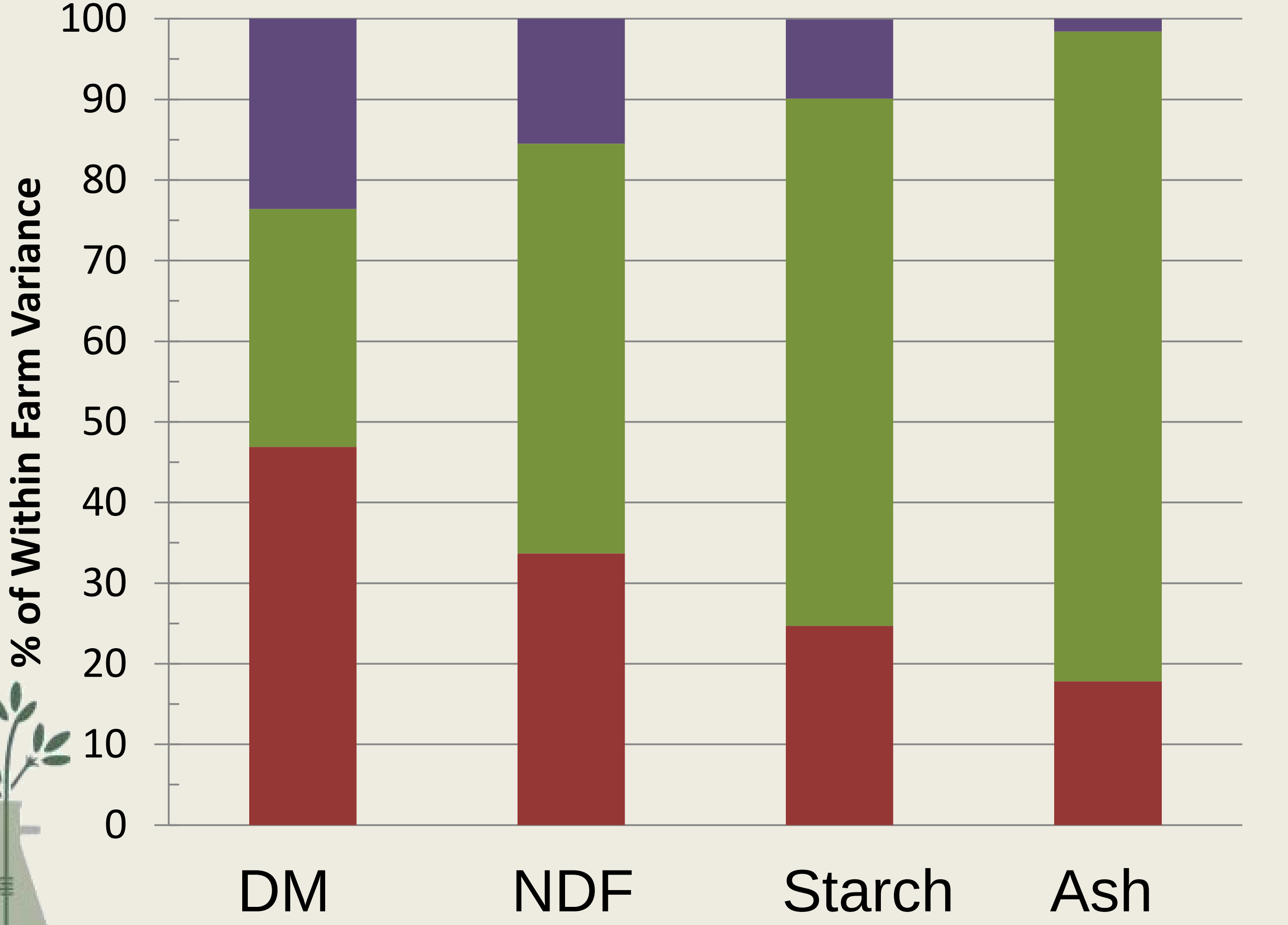
Corn Silage:
Farm to farm is major source of variation



Within Farm Variation
Corn Silage over 14 days



Sampling Project

- Objective is to evaluate “duplicate sample” approach to sampling corn silage.
- Concept is to take two totally different samples of material and send in to evaluate sampling variation as a component of true variation.
- Can’t take a sample and split, must take two totally different samples using same technique.

Sampling Project

- Project guidelines:
  - Pick-up a handout as you leave. One per person.
  - Opportunity is for sampling a corn silage at one farm location.
  - Use good technique, but don't deviate too much from your normal protocol. Do two totally different samplings.
  - Fill a quart Ziploc bag one half to two-thirds full.
  - Mark as "duplicate sample project" and send in with paper.

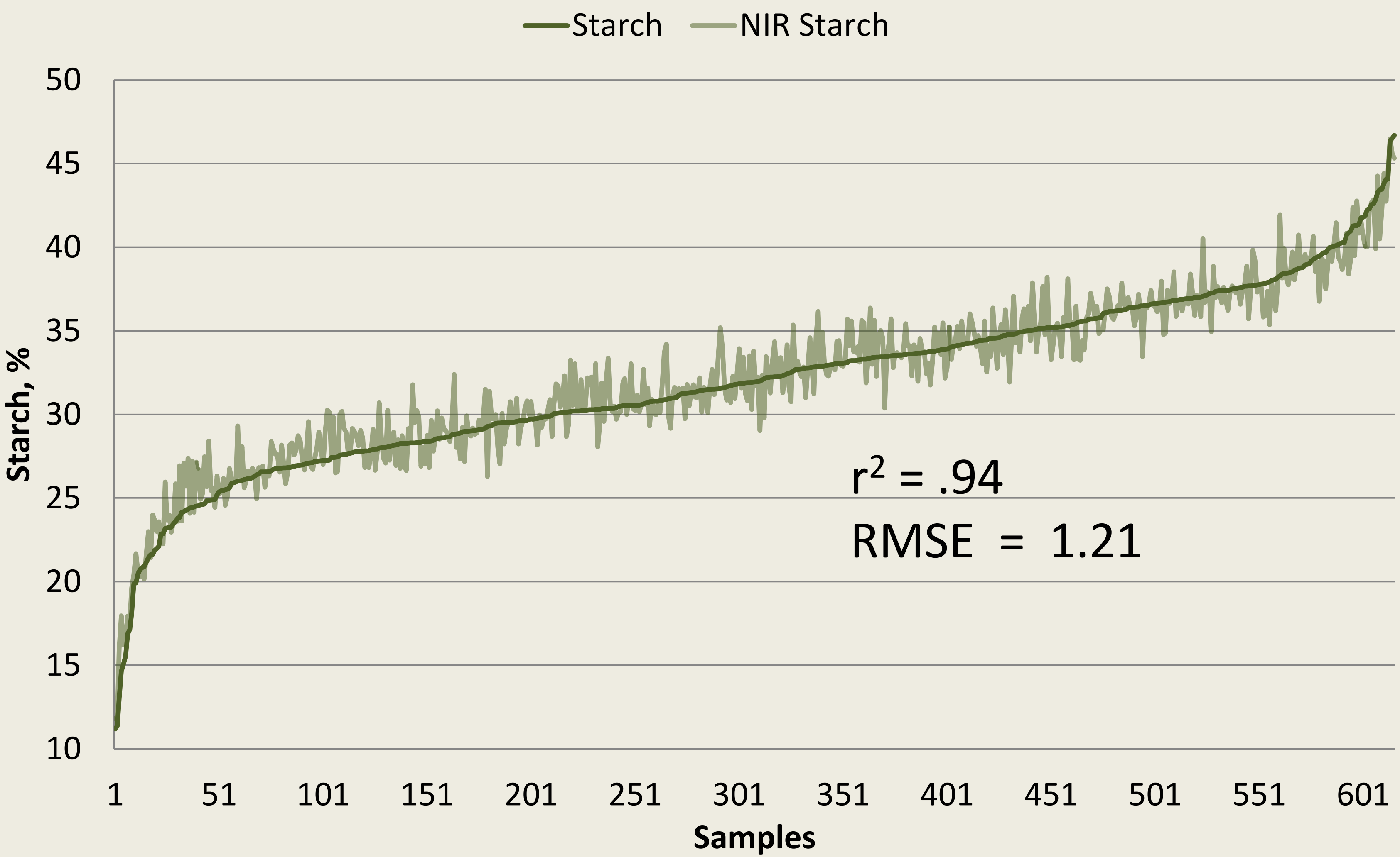
Sampling Project

- Project guidelines:
  - Samples under the project should be sent in by December 8th.
  - Samples will be processed as duplicates at CVAS, drying and grinding the whole samples to minimize lab sample variation.
  - Samples will take about 1 day longer to process due to modified lab procedure.
  - A project report will be sent by e-mail to all participants.
  - **The duplicate sample will be free.**

Starch Evaluation by NIR
CVAS Calibration Statistics

	N	Mean	RSQ	SEC
Corn Silage	1677	28.1 %	.98	1.01
Corn Grain	1302	71.2 %	.99	.45

Comparison of Starch by Chemistry and NIR



Modeling Starch Content in Corn Silage

- Modeling from CP, NDF, Ash
  - 2718 samples
  - R^2: .81
  - RMSE: 2.71
  - Equation:

    Starch = 89.4 - 1.48(CP) - 1.03(aNDF) - .678(ash)

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Modeling Starch Content in Corn Silage

- Modeling from CP, NDF, Soluble Fiber, Ash, Fat, Sugar, Lactic acid, Acetic acid
  - 40737 samples
  - R^2: .96
  - RMSE: 1.32
  - Equation:

    Starch = 106.3 - .574(CP) - 1.10(aNDF) - 1.14(soluble fiber) -.978(ash) - 3.38(fat) - 1.28(sugar) - .567(lactic) - .108(acetic)

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Modeling Starch

- Modeling from aNDF
  - 2720 samples
  - R^2: .73
  - RMSE: 3.27
  - Equation:

    Starch = 80.4 – 1.17(aNDF)

The StarchD Challenge

- The industry says:

"The use of starch digestibility information from labs is not working."

Translated: When I use the numbers from the lab they are not consistent with anticipated cow response.

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The StarchD Challenge

- Limitations in the process:
  - StarchD is a complex and not fully understood process: What are we attempting to measure?

The StarchD Challenge

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  - StarchD is a complex and not fully understood process: What are we attempting to measure?

Starch digestibility is not a “nutrient” - it is a complex set of interactions defined within a dynamic and complex rumen environment.

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Impacting StarchD

- Particle size
- Fragility
- Moisture
- Weather impact during ear development
- Dry-down of kernels in the field
- Fermentation
- Time in fermentation
- Protein, Zein protein, Zein-starch ratio
- Amount of shell relative to starch flour
- Other physiological characteristics of starch in kernel

Corn Grain Fragility – 4mm knife mill

(CVAS, 2014)

Corn Type	MPS (microns)	Surface Area (cm^2 gm)	Particles / gm	IVSD7 (% Starch)	IVSD7 (% Starch) (1mm grind)
Floury	848	65.5	7788	73.7	83.5
Hybrid	905	61.5	6282	57.6	66.5
Flint	966	57.9	5632	50.6	61.9

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Cutter Mill for executing 4mm grind

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Impacting StarchD

- Cow Perspective:
  - Particle size as fed
  - Mastication
  - Level of starch fed
  - Associative effects
  - Rumen environment
  - Time of feeding
  - Various enzyme concentrations
  - Rate of passage

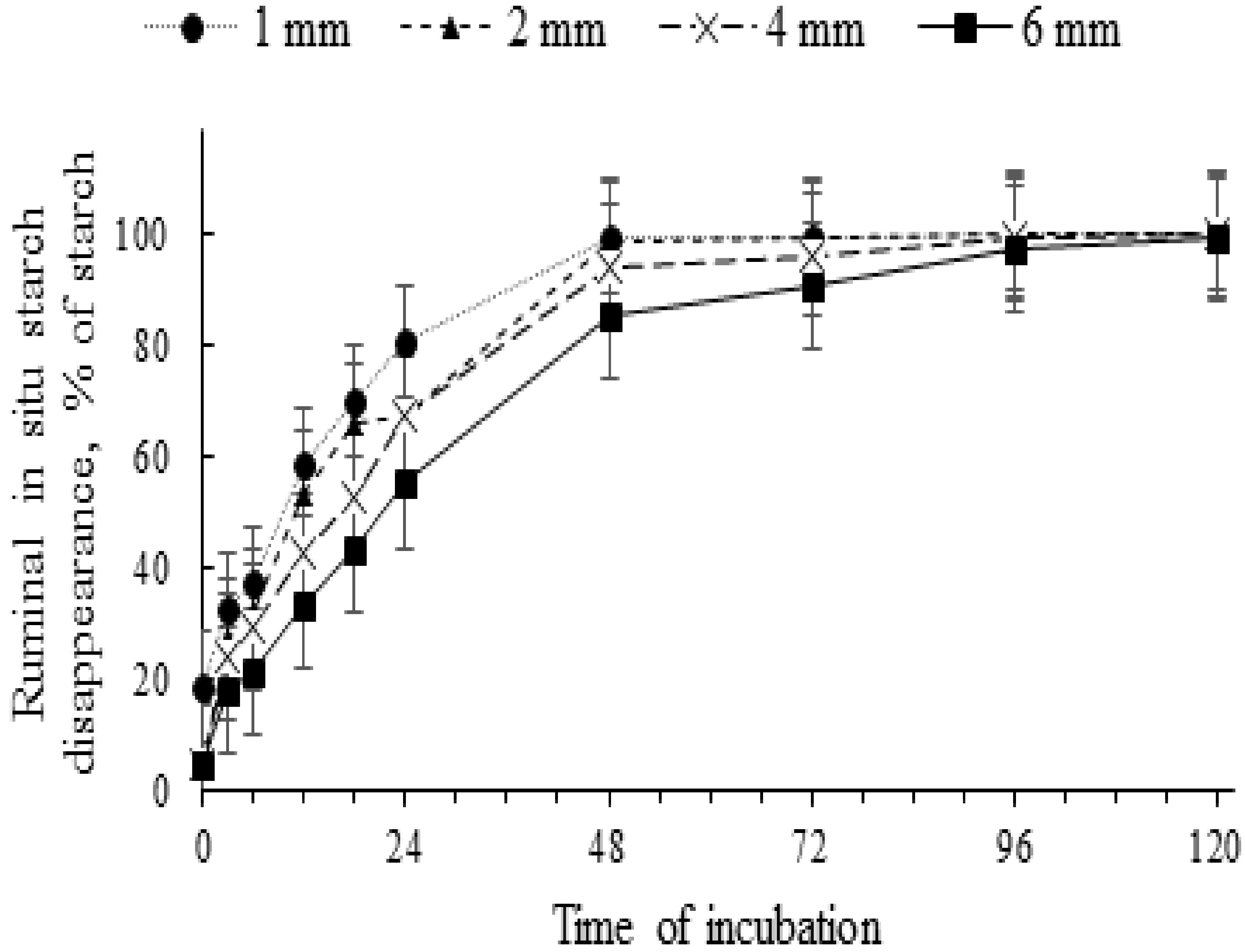

Figure 4. Effect of grinding size on ruminal in situ starch disappearance (% of starch) at 0, 3, 6, 12, 18, 24, 48, 72, 96 and 120 h of dry dent corn.

The StarchD Challenge

- Limitations in the process:
  - StarchD is a complex and not fully understood process: What are we attempting to measure?
  - Lab limitations require that our sample for analysis is not what we feed the cow.

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NIR Grind vs Analyzed Grind

NIR Grind vs Analyzed Grind

The StarchD Challenge

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  - StarchD is a complex and not fully understood process: What are we attempting to measure?
  - Lab limitations require that our sample for analysis is not what we feed the cow.
  - For routine use in the context of ration work we need to move evaluation process to NIR – this is problematic.
  - The use of in vitro analysis for starch digestibility analysis has large inherent variability.

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The StarchD Challenge

- Limitations in the process:
  - Lab data does not necessarily “fit” into current models.
  - Rate of passage significantly impacts realized rumen starch degradability and by implication how we want to benchmark StarchD.

The StarchD Challenge

- Limitations in the process:
  - Lab data does not necessarily "fit" into current models.
  - Rate of passage significantly impacts realized rumen starch degradability and by implication how we want to benchmark StarchD.
  - We have an incorrect mind-set as to use the information at hand.

The StarchD Challenge

- Limitations in the process:

"We" as a nutritional industry want to use a static evaluation (IVSD) to define function in a dynamic process.

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Relationships among in vitro starch digestibility (IVSD), Mertens Innovation & Research LLC rate of digestion (MIR_kd™) and predicted starch digestibilities (SD) in the rumen (kp = 0.0669 h^{-1}) and total tract of dairy cows.

IVSD[a] (% of starch)	MIR_kd™[b] (%/h)	Predicted Ruminal SD[c]	Predicted Total Tract SD[d]	Predicted Fecal Starch (%DM)[e]
25[f]	4.8%	41.4%	89.9%	8.0
35	7.2%	51.4%	91.7%	6.6
45	10.0%	59.5%	93.2%	5.4
55	13.3%	66.2%	94.5%	4.4
65	17.5%	72.0%	95.5%	3.5
75	23.1%	77.3%	96.5%	2.7
85	31.6%	82.3%	97.4%	2.0
95	49.9%	88.0%	98.5%	1.2
99[f]	76.8%	91.9%	99.2%	0.6

[a] In vitro starch digestibility measured after 7 h of fermentation.
[b] Rae of starch digestibility (kd) calculated from IVSD (7 h) using the method of Mertens Innovation & Research LLC for a single pool of starch with a lag time of 1 h and no indigestible starch (MIR_kd-P1T1u0™).
[c] Ruminal starch digestibility calculated using the steady-state formula: Ruminal SD% = 100*[kd / (kd + kp)] assuming a kp for starch of 6.69%/h.
[d] Adj. Total Tract Starch Digestibility = 82.224 + 0.185*Ruminal Starch digestibility – 0.002. (Ferraretto et al., 2013).
[e] Total Tract Starch Digestibility = 100.0 – 1.25*Fecal starch (% fecal DM) solved for fecal starch. (Fredin et al., (2014)
[e] These extreme values are rarely measured, but provide limiting boundaries on ruminal and total tract starch digestibilities when using MIR_kd.

Relationships among in vitro starch digestibility (IVSD), Mertens Innovation & Research LLC rate of digestion (MIR_kd™) and predicted starch digestibilities (SD) in the rumen (kp = 0.089 h^{-1}) and total tract of dairy cows.

IVSD[a] (% of starch)	MIR_kd™[b] (%/h)	Predicted Ruminal SD[c]	Predicted Total Tract SD[d]	Predicted Fecal Starch (%DM)[e]
25[f]	4.8%	35.0%	88.7%	9.0
35	7.2%	44.7%	90.5%	7.6
45	10.0%	52.8%	92.0%	6.4
55	13.3%	59.9%	93.3%	5.4
65	17.5%	66.3%	94.5%	4.4
73	23.1%	72.2%	95.6%	3.5
85	31.6%	78.0%	96.7%	2.7
95	49.9%	84.9%	97.9%	1.7
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Relationships among in vitro starch digestibility (IVSD), Mertens Innovation & Research LLC rate of digestion (MIR_kd™) and predicted starch digestibilities (SD) in the rumen (kp = 0.155 h^{-1}) and total tract of dairy cows.

IVSD[a] (% of starch)	MIR_kd™[b] (%/h)	Predicted Ruminal SD[c]	Predicted Total Tract SD[d]	Predicted Fecal Starch (%DM)[e]
25[f]	4.8%	23.7%	86.6%	10.7
35	7.2%	31.7%	88.1%	9.5
45	10.0%	39.2%	89.5%	8.4
55	13.3%	46.2%	90.8%	7.4
65	17.5%	53.1%	92.0%	6.4
75	23.1%	59.9%	93.3%	5.4
85	31.6%	67.1%	94.6%	4.3
95	49.9%	76.3%	96.3%	2.9
99[f]	76.8%	83.2%	97.6%	1.9

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[e] These extreme values are rarely measured, but provide limiting boundaries on ruminal and total tract starch digestibilities when using MIR_kd.

The StarchD Challenge

- Productive mindset:

Consider StarchD (IVSD) information as a tool to rank feeds, to understand feed potential or limitations, and to bias nutritional models.

We need to realize that IVSD information at this time needs to be used more in a qualitative manner, not quantitative.

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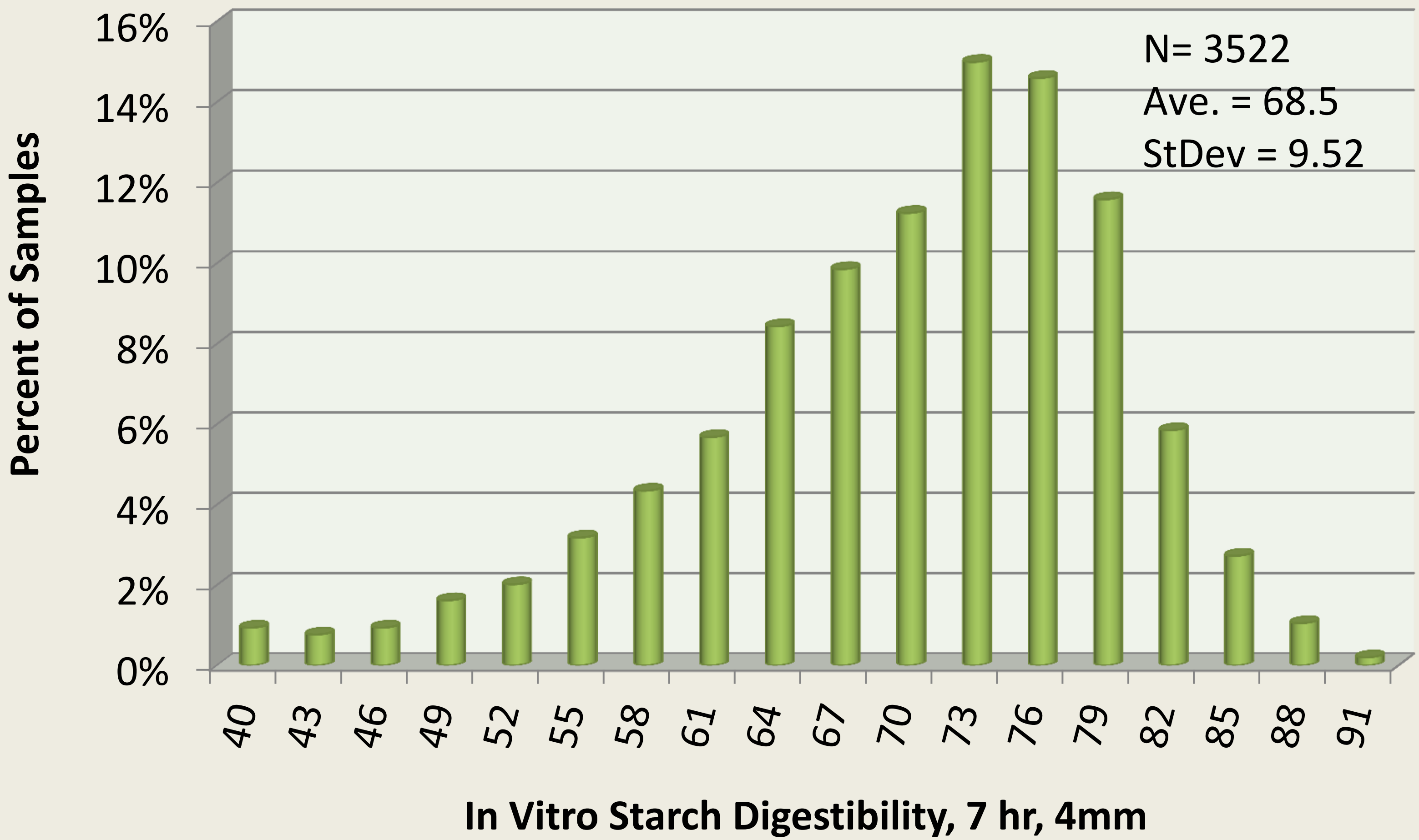
In Vitro Starch Digestibility, 7 hr, 4mm

(CVAS, chemistry, 2014 - 2017 crop years)



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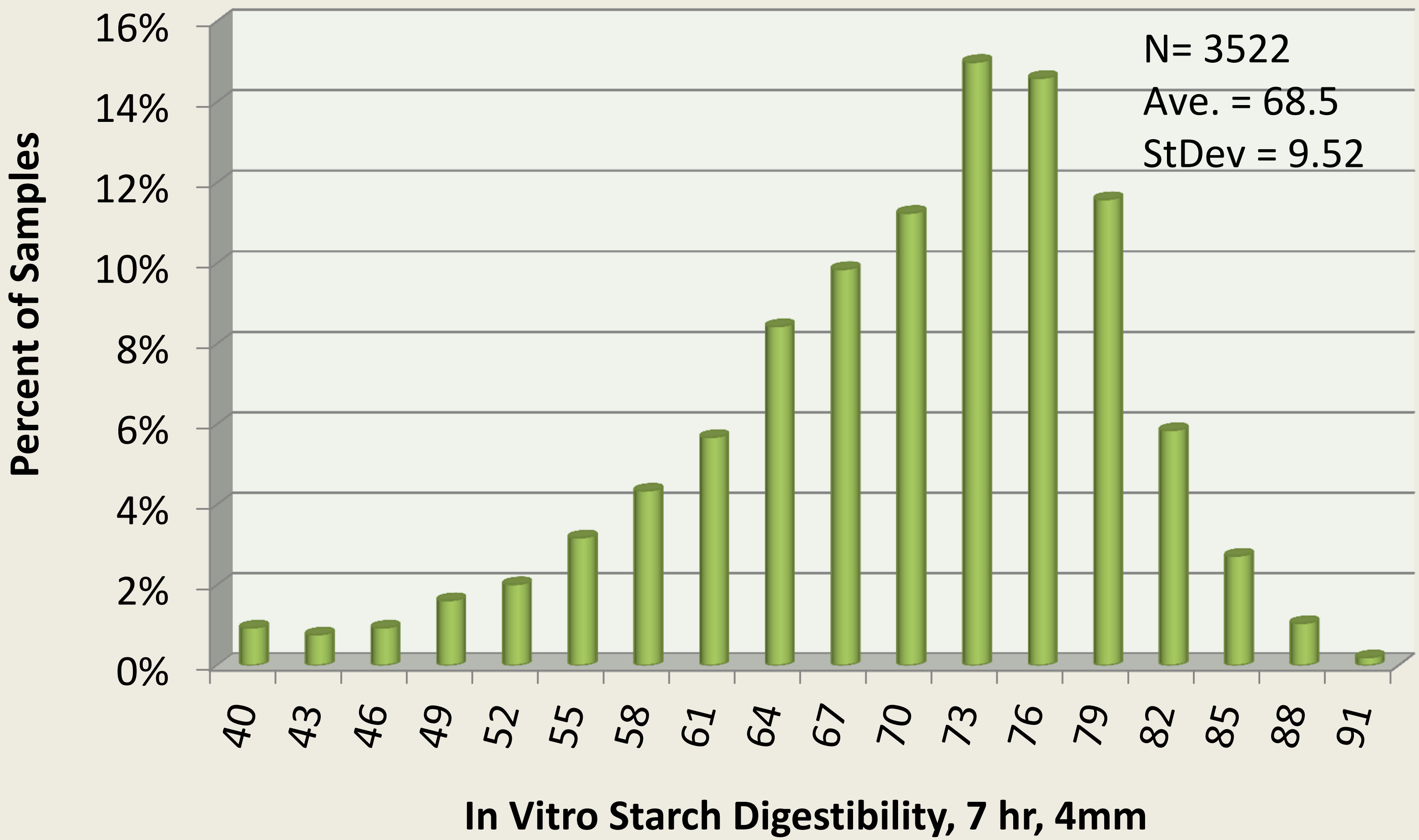
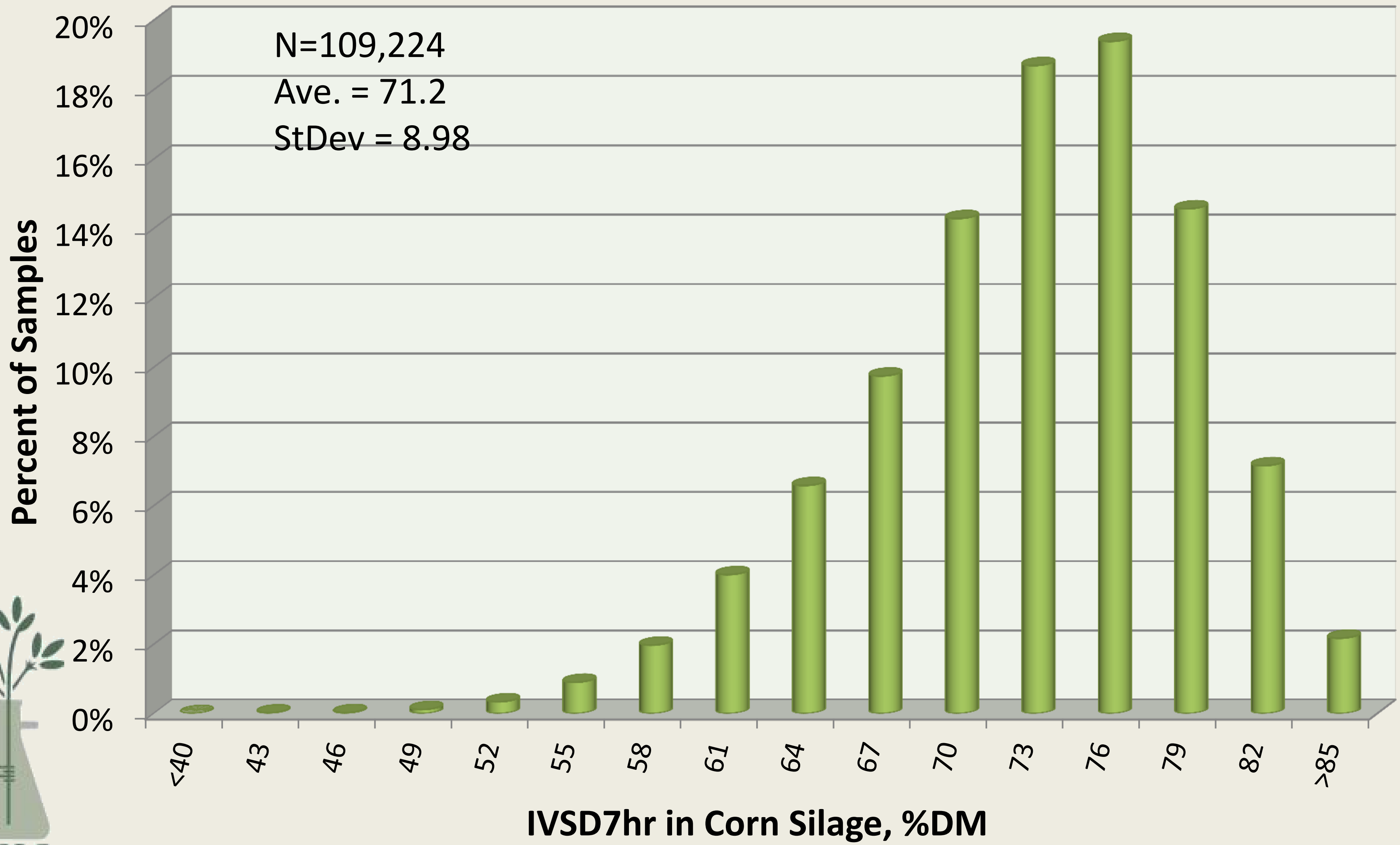
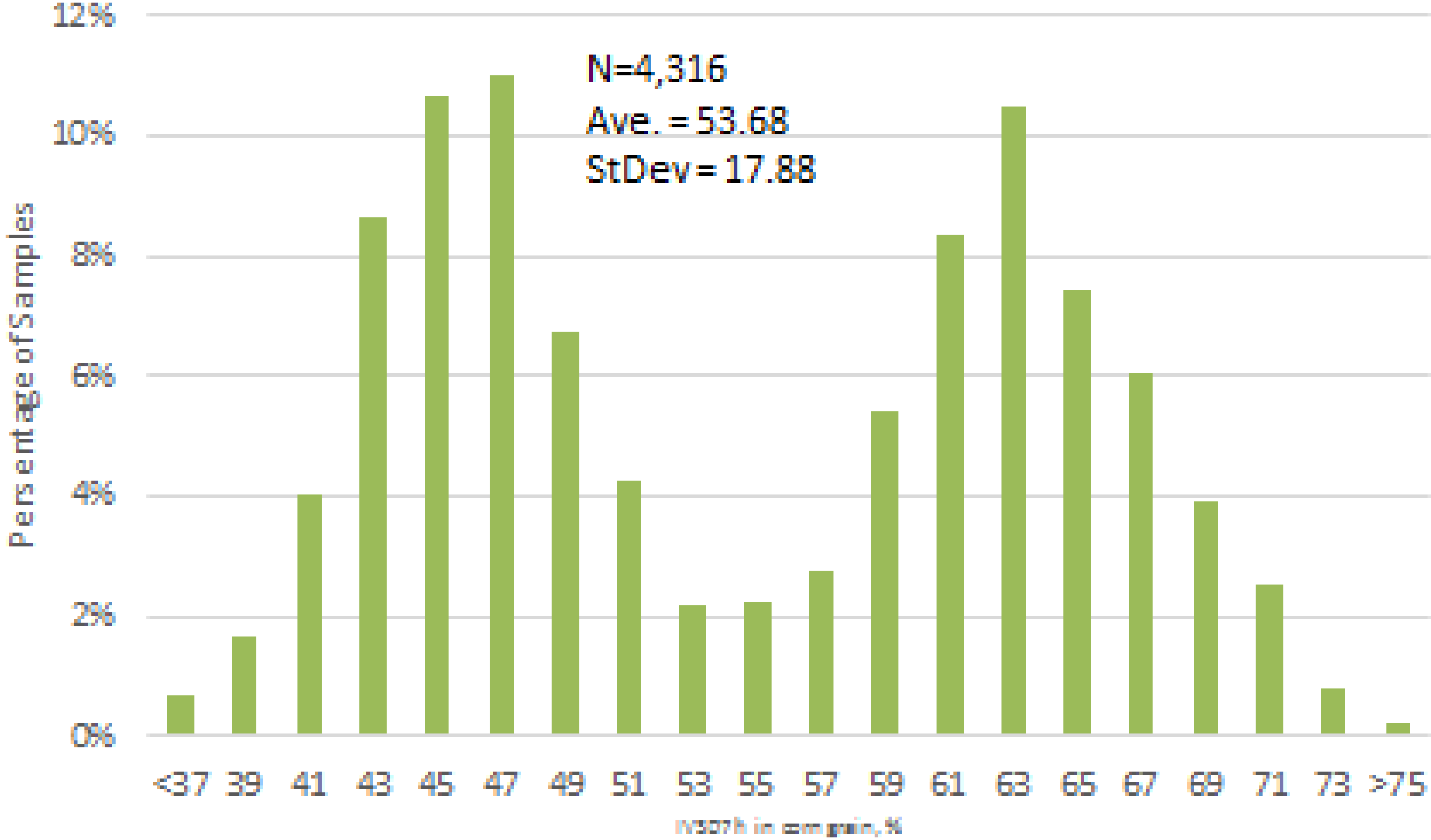


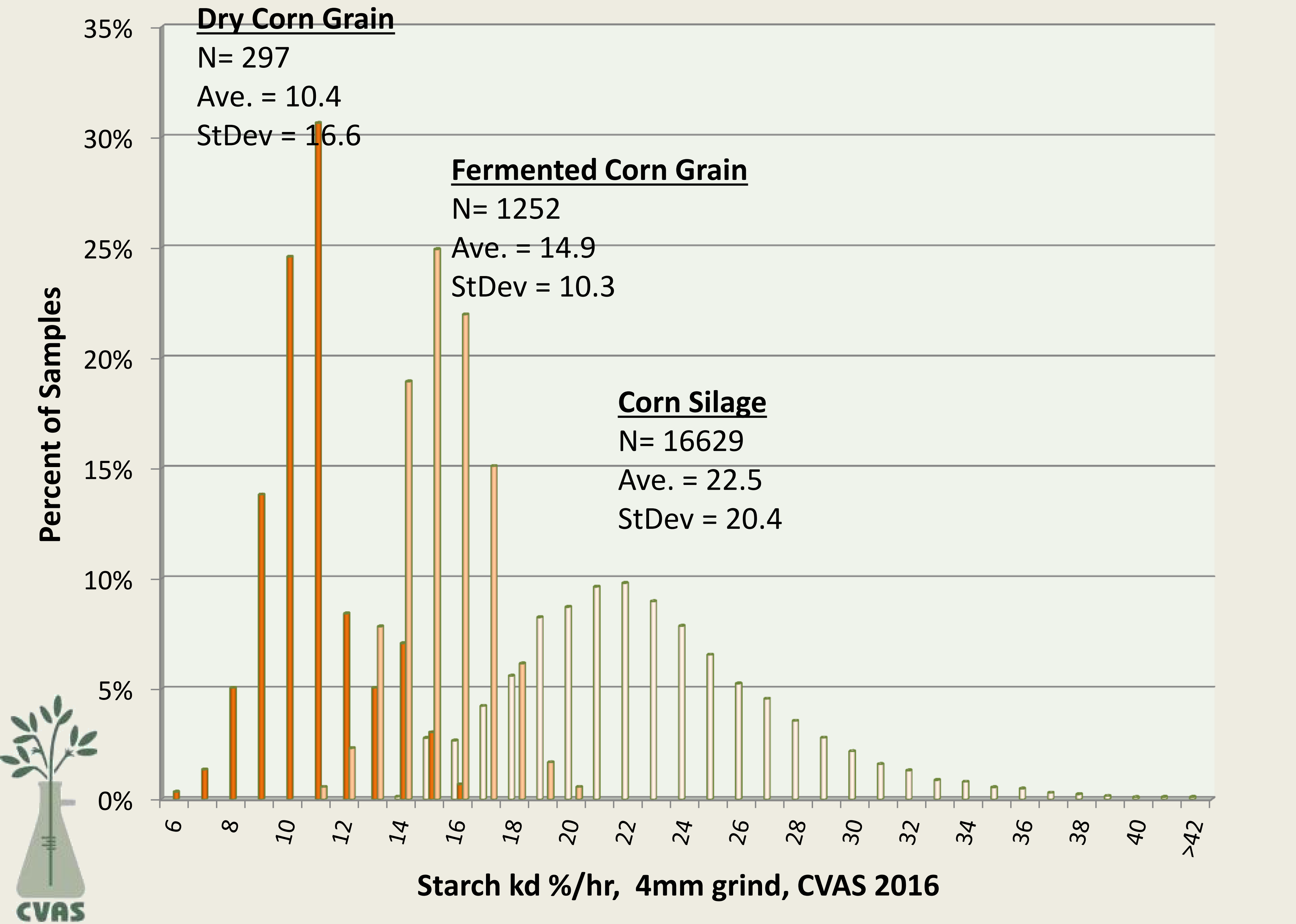
Corn Silage In vitro Starch Digestibility at 7hrs

(CVAS, 2013 - 2014 crop years, 4mm grind)



In vitro Starch Digestibility at 7hr in Corn Grain (CVAS, 2014 Crop, 4mm grind)




Dry Corn Grain
N= 297
Ave. = 10.4
StDev = 16.6
Fermented Corn Grain
N= 1252
Ave. = 14.9
StDev = 10.3
Corn Silage
N= 16629
Ave. = 22.5
StDev = 20.4
Percent of Samples
35%
30%
25%
20%
15%
10%
5%
0%
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
>42
Starch kd %/hr, 4mm grind, CVAS 2016
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Where do we go from here?

- Modeling approach to estimating static IVSD:
  - Particle Size
  - Moisture
  - Fermentation
  - Protein Fractions
  - Multiple time points to estimate rates

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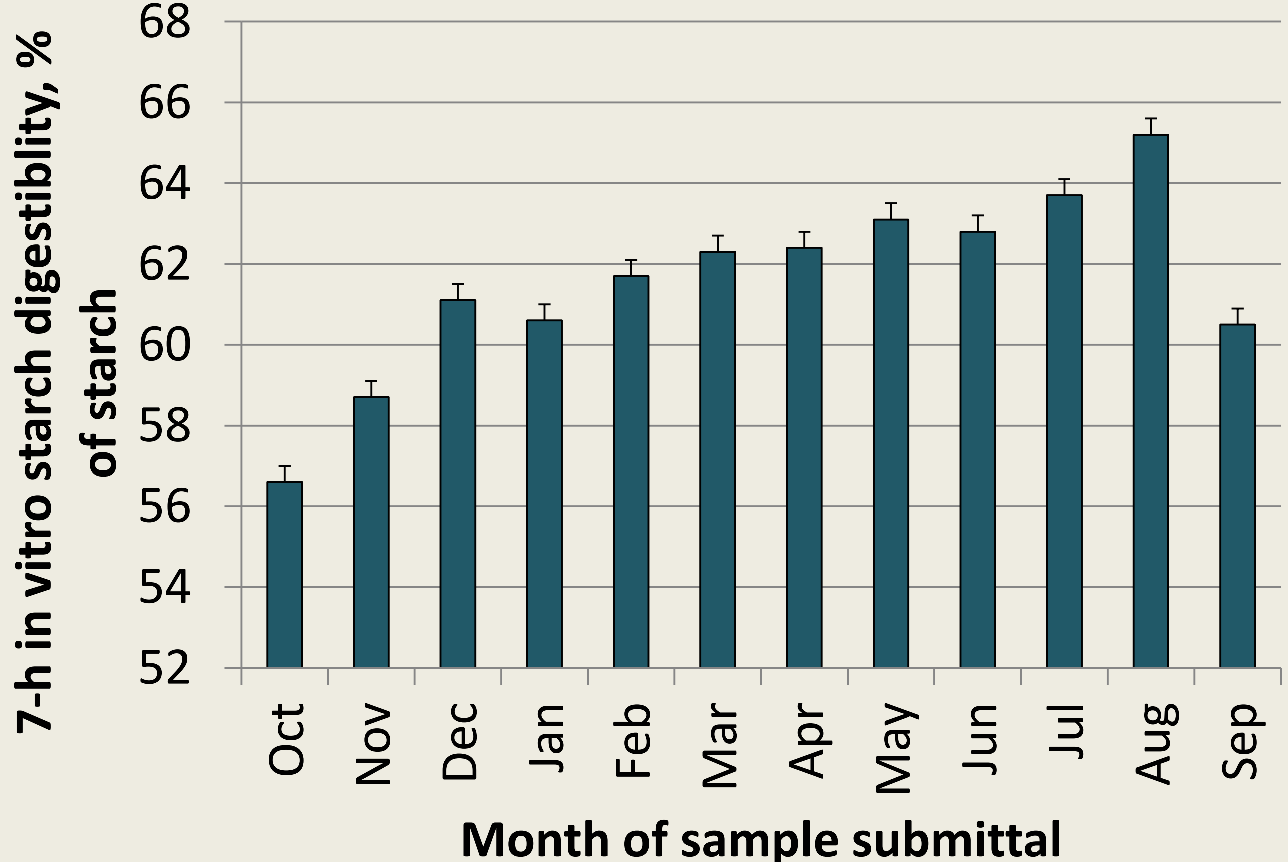
Effect of ensiling time on starch digestibility in HMC



***P* ≤ 0.05**

Ferraretto et al., 2014

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Modeling IVSD7 in Corn Grain

Summary of Fit

RSquare	0.766384
RSquare Adj	0.763323
Root Mean Square Error	2.40158
Mean of Response	60.38398
Observations (or Sum Wgts)	465

Effect Summary

Source	FDR LogWorth	FDR PValue
CP	74.975	0.00000
ADF	14.975	0.00000
Acetic	10.691	0.00000
DM	4.945	0.00001
pH	4.798	0.00002
Lactic	1.129	0.07436

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Modeling IVSD7 in Corn Grain

Summary of Fit

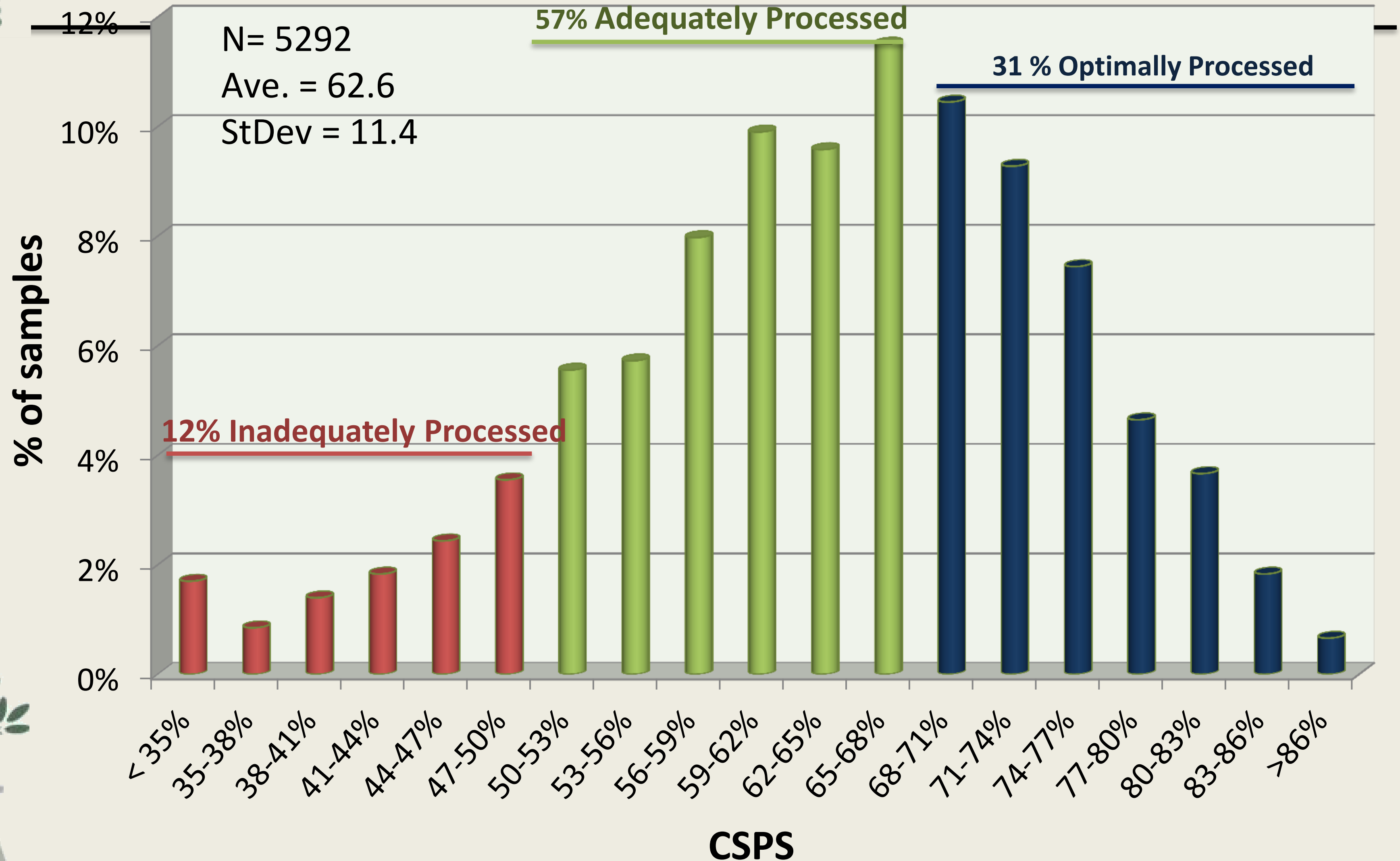
RSquare	0.835134
RSquare Adj	0.833609
Root Mean Square Error	1.785329
Mean of Response	60.47418
Observations (or Sum Wgts)	656

Response IVSD 7hr, 4mm, %starch
Effect Summary using CNCPS Protein Fractions

Source	FDR LogWorth	FDR PValue
A2, %DM	101.649	0.00000
B1, %DM	82.980	0.00000
B2, %DM	36.278	0.00000
A1, %DM	32.812	0.00000
DM	20.036	0.00000
pH	2.985	0.00103

Rotap shaker showing 4.75mm screen and corn retained on the sieve

Distribution of Corn Silage Processing Scores, CVAS, 2015 and 2016 Crop Years



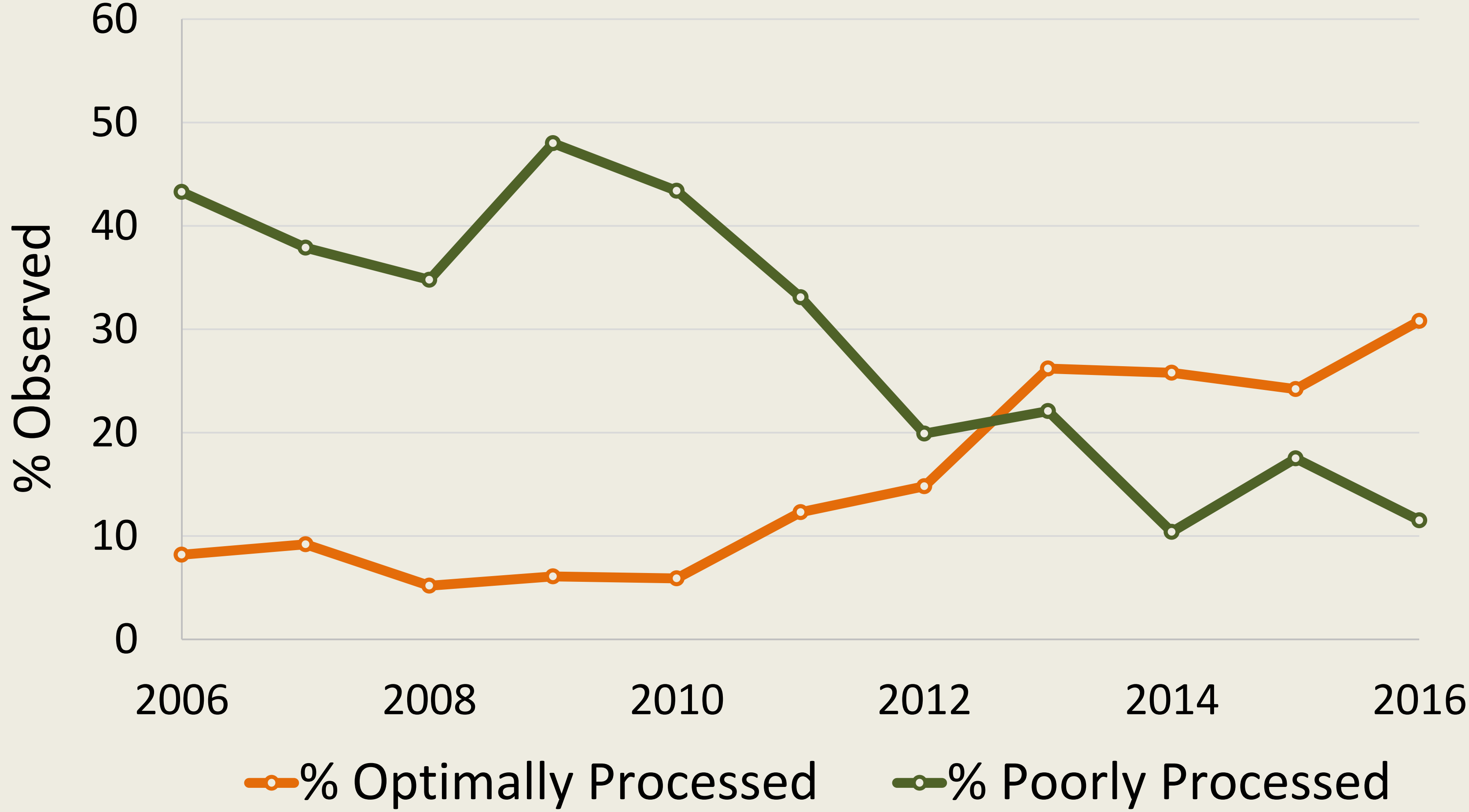
Industry Makes Advances in Corn Silage Processing Past 10 YRS

(CVAS Data, 2006 - 2016)

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	26.2	22.1
2014	4634	62.2	25.8	10.4
2015	3231	61.1	24.2	17.5
2016	3598	63.5	30.8	11.5

Industry Makes Advances in Corn Silage Processing Past 10 YRS

(CVAS Data, 2006 - 2016)



Apparent (whole tract) Digestibility

- There has been interest in evaluating fecal starch as an indicator of digestion efficiency.
- This approach does not account for beginning starch level or the concentration effect in the manure.
- Several U.S. labs are using undigested NDF at 240 hr in vitro incubation (uNDF240) as a marker to relate the starting and ending starch levels.

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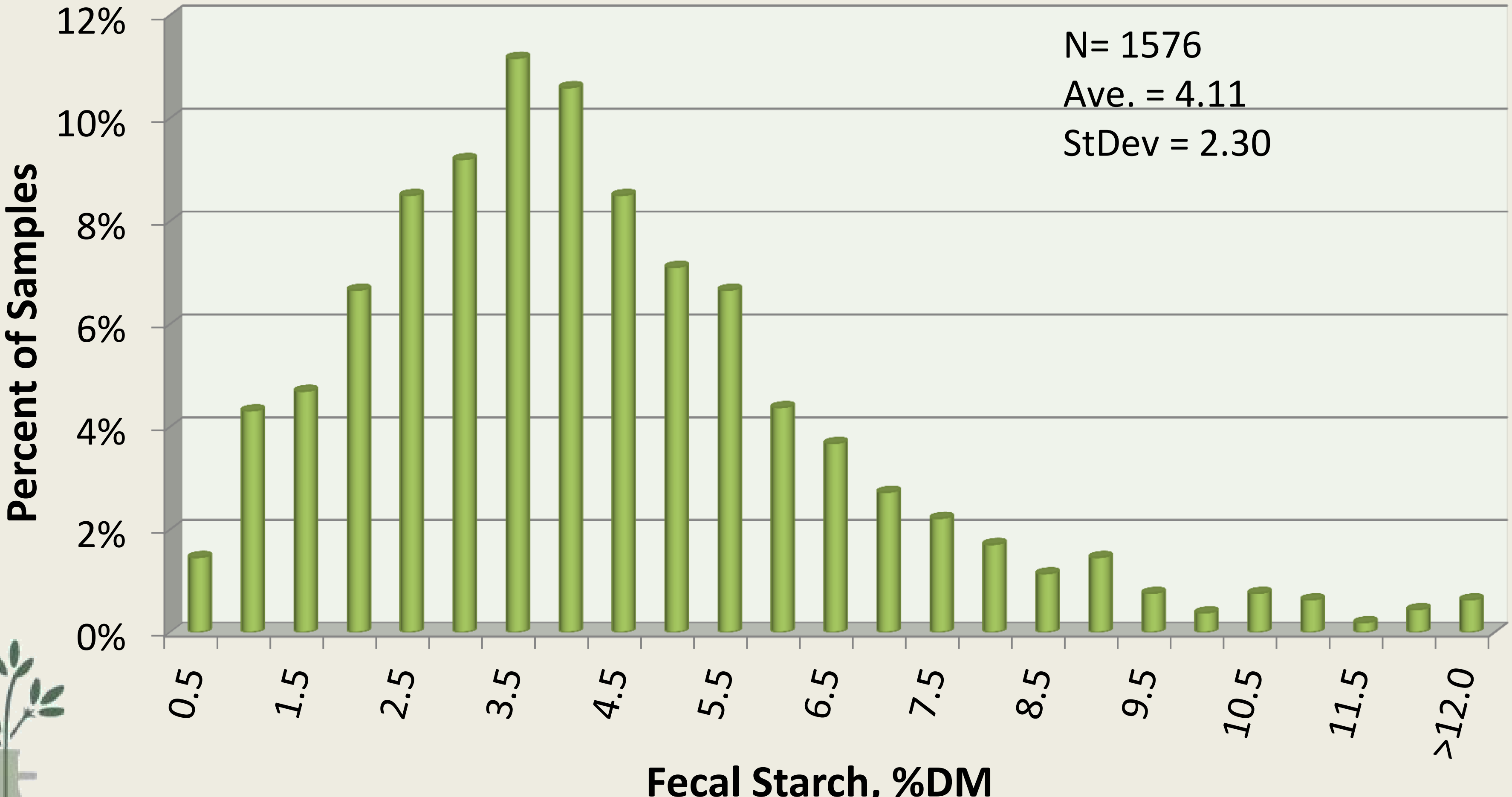
Apparent (whole tract) Digestibility

- CVAS has developed NIR equations for 240 hour indigestible NDF in TMR and fecal material.
- Clients submit samples of TMR and associated fecal material to the laboratory.
- CVAS provides an analysis of the TMR and fecal material and a report of Apparent Digestibility for Starch and pdNDF.
- This information can be used as a diagnostic tool to evaluate ration efficiency and for educating the producer about nutritional concepts.

Distribution of Fecal Starch in Dairy TMR
(CVAS, 2017)



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Fecal starch interpretation

- < 3% fecal starch = good, no need to investigate individual feeds
- 5% fecal starch = Total tract starch digestibility ~93.75%. Potential to investigate individual feeds
- > 5% fecal starch = evaluate individual feeds and/or management practices

Adapted from Dr. Larry Chase

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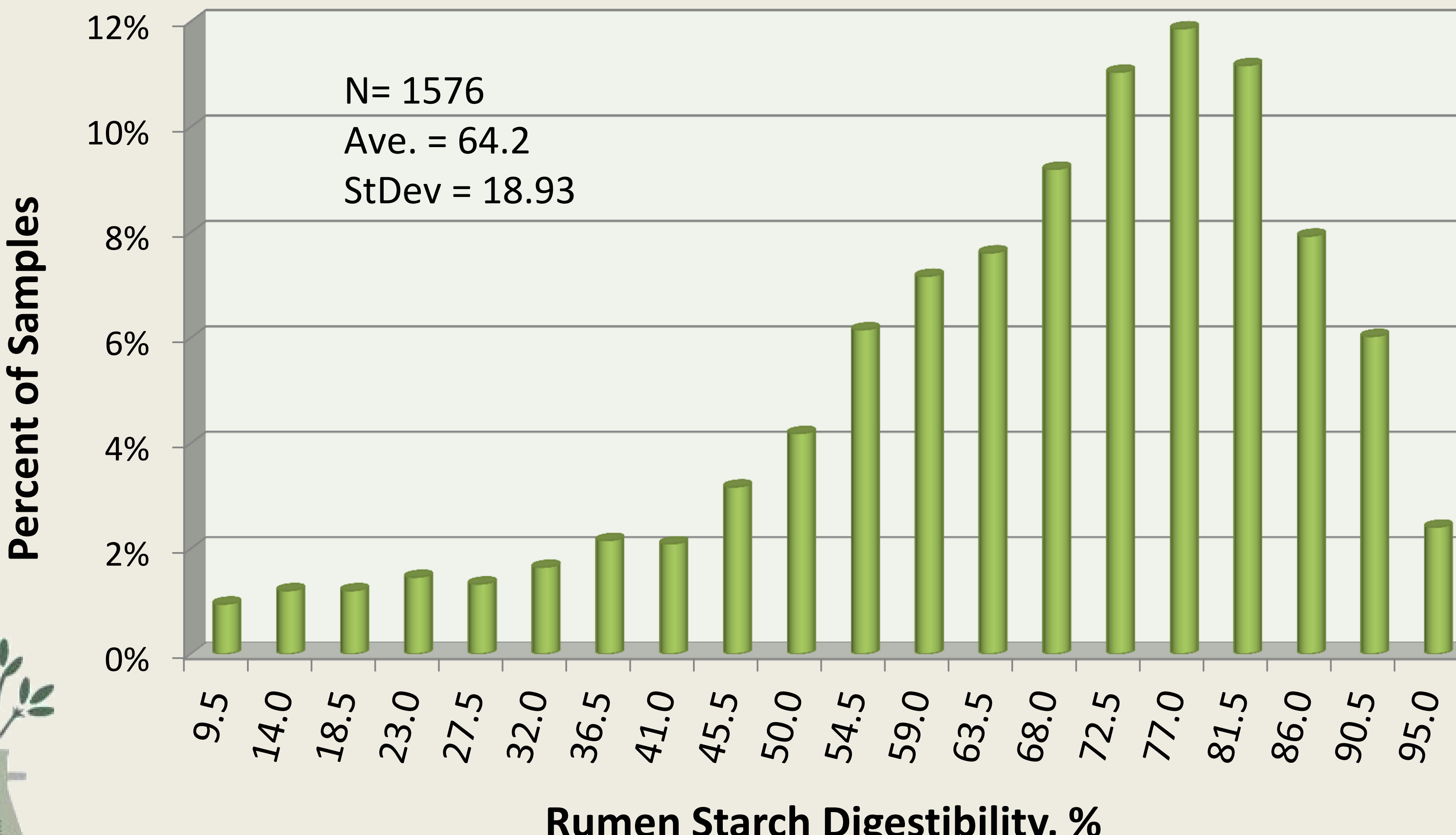
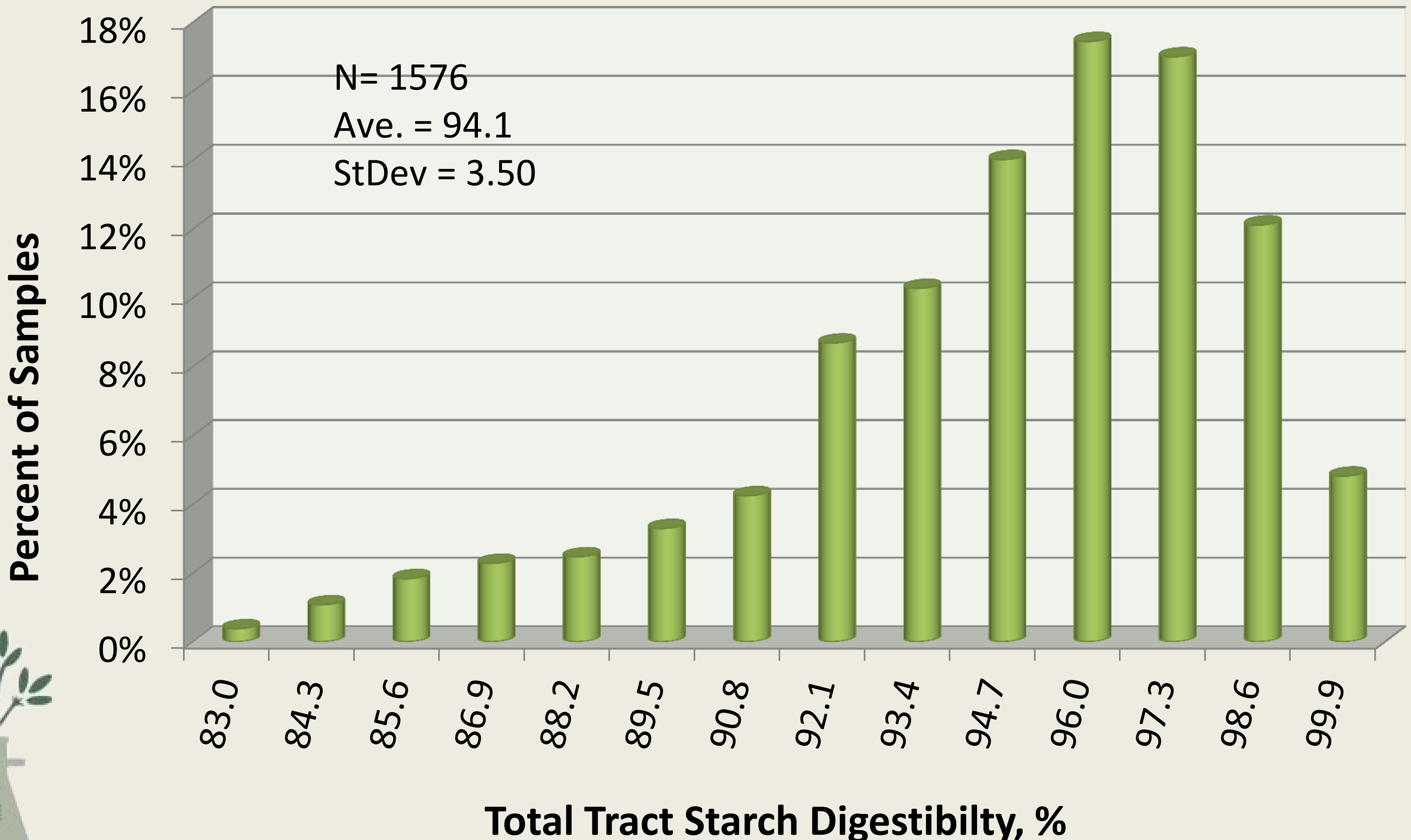
Calculated Rumen Starch Digestibility using Paired TMR and Fecal Samples (CVAS 2017)



Calculated Total Tract Starch Digestibility using Paired TMR and Fecal Samples (CVAS, 2017)



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Penn State Dairy Cattle Nutrition Workshop

November 15 – 16, 2017

Starch Digestibility: How It's Measured, Reported, and used

Ralph Ward, President

Cumberland Valley Analytical Services

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