Mid-South Ruminant Nutrition Conference
“High Res Forage Testing”

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Characterizing Starch

Starch Concepts in the Ruminant

- We can do a reasonably good job of determining total starch in a feed material.
- We do not have a good means of characterizing of rumen degraded starch
- We do not have a good means of understanding passage rate of undigested starch
- As a result, we do not have a good understanding of partition of starch digestibility in rumen vs the hindgut.

Starch Concepts in the Ruminant

- Nutritionists would generally agree that we want to maximize starch digestion in the rumen up to the point where it significantly impacts the fiber digestibility.

Starch Feeds to Characterize

- Corn
- High Moisture Corn
- Barley, Wheat, Oats, Triticale
- Sorghum
- Milo
- Starch byproducts
- Corn Silage
- Sorghum silage
- Small grain silages
- Milo silage

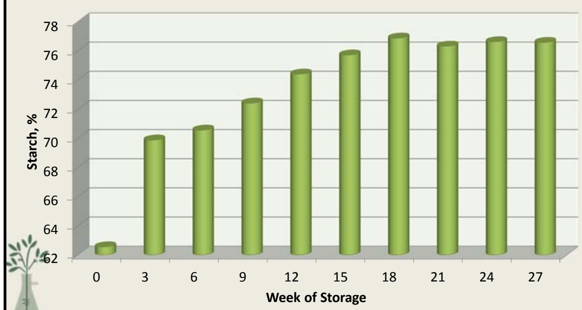
Relationship of Various Nutrients to Starch Digestibility in Corn Silage over Time in Storage

(CVAS, 2012 Crop Year, NE US Samples)

Storage Week	IVSD7	Total VFA	Lactic Acid	Soluble Protein	Ammonia
0	62.6	1.31	0.88	2.30	1.01
3	69.9	4.57	3.23	3.26	1.19
6	70.6	4.96	3.53	3.35	1.18
9	72.4	5.78	4.07	3.61	1.24
12	74.4	6.34	4.47	3.89	1.32
15	75.7	6.57	4.68	4.09	1.29
18	76.9	7.33	5.08	4.31	1.41
21	76.3	7.50	5.27	4.33	1.37
24	76.6	7.66	5.40	4.42	1.43
27	76.6	7.62	5.41	4.39	1.38

Impact of Storage Time on Starch Digestibility in Corn Silage

(CVAS, 2012 Crop Year, North-East US Samples)



Corn Silage Processing Score

- Measure of the % of starch in corn silage that passes through a 4.75mm screen
- Dried corn silage is shaken for 10 minutes on a Ro-Tap Sieve Shaker.
- Material not passing the 4.75 mm screen is collected and assayed for starch.
- Properly processed corn silage will have a processing score of greater than 60%, Optimum over 70%
- Poorly processed corn silage will lead to lower rumen starch degradation and lower total tract digestibility.

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

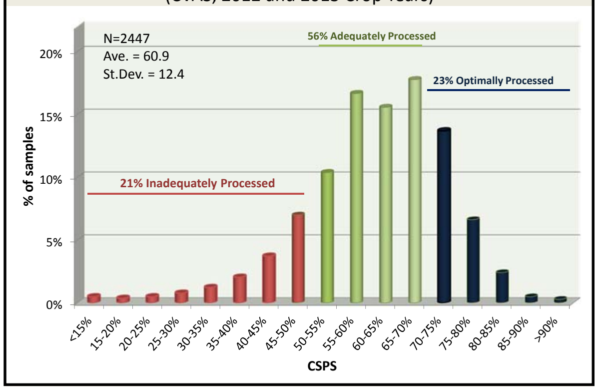
Industry Makes Advances in Corn Silage Processing

(CVAS Data, 2006 to 2014)

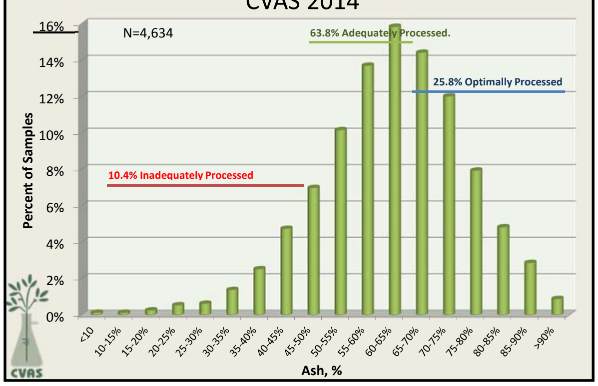
Crop Year	Number	Average	Percent Optimum	Percent Poor
2006	97	52.8	8.2	43.3
2007	272	52.3	9.2	37.9
2008	250	54.6	5.2	34.8
2009	244	51.1	6.1	48.0
2010	373	51.4	5.9	43.4
2011	726	55.5	12.3	33.1
2012	871	60.8	14.8	19.9
2013	2658	64.6	26.2	22.1
2014	4634	62.2	25.8	10.4

Distribution of Corn Silage Processing Scores

(CVAS, 2012 and 2013 Crop Years)



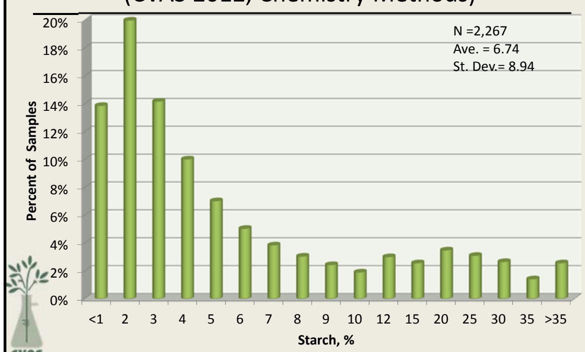
Distribution of Corn Silage Processing Scores CVAS 2014



Apparent (whole tract) Digestibility

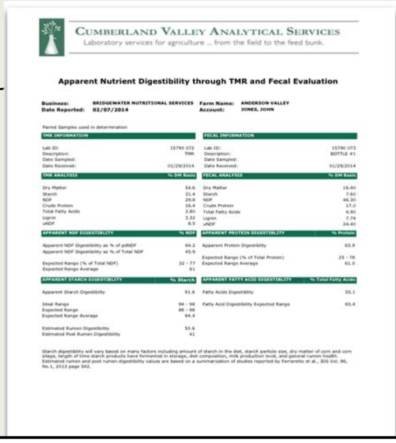
- There has been interest in evaluating fecal starch as an indicator of digestion efficiency.
- This approach has limited value because it does not account for beginning starch level or the concentration effect in the manure.
- One new approach is using indigestible NDF as a marker to relate the starting and ending starch levels.

Distribution of Starch Values in Feces
(CVAS 2012, Chemistry Methods)



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, pdNDF, and Protein.
- This information can be used as a diagnostic tool to evaluate ration efficiency, evaluate additives and help make management decisions.



Cumberland Valley Analytical Services
Laboratory services for agriculture ... from the field to the feed bunk.

Apparent Nutrient Digestibility through TMR and Fecal Evaluation

Business: BRIDGEWATER NUTRITIONAL SERVICES **Farm Name:** ANDERSON VALLEY
Date Reported: 02/07/2014 **Account:** JONES, JOHN

Paired Samples used in determination

TMR INFORMATION		FECAL INFORMATION	
Lab ID:	15790 072	Lab ID:	15790 073
Description:	TMR	Description:	BOTTLE #1
Date Sampled:		Date Sampled:	
Date Received:	01/29/2014	Date Received:	01/29/2014

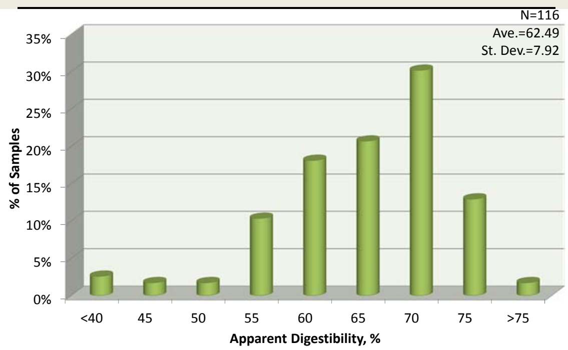
TMR ANALYSIS	% DM Basis	FECAL ANALYSIS	% DM Basis
Dry Matter	54.6	Dry Matter	16.40
Starch	21.4	Starch	7.60
NDF	29.8	NDF	46.30
Crude Protein	16.4	Crude Protein	17.0
Total Fatty Acids	3.80	Total Fatty Acids	4.90
Lignin	3.32	Lignin	7.74
uNDF	8.5	uNDF	24.40

APPARENT NDF DIGESTIBLITY	% NDF	APPARENT PROTEIN DIGESTIBLITY	% Protein
Apparent NDF Digestibility as % of pdNDF	64.2	Apparent Protein Digestibility	63.9
Apparent NDF Digestibility as % of Total NDF	45.9		
Expected Range (% of Total NDF)	32 - 77	Expected Range (% of Total Protein)	25 - 78
Expected Range Average	61	Expected Range Average	61.0

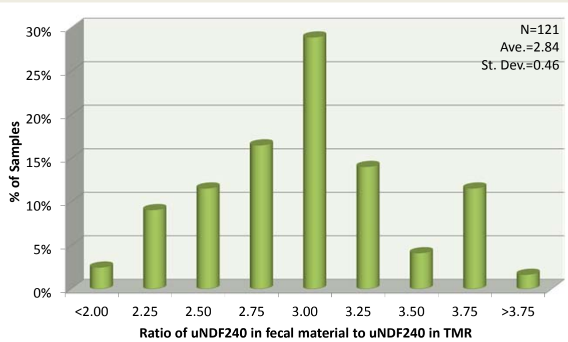
APPARENT STARCH DIGESTIBLITY	% Starch	APPARENT FATTY ACID DIGESTIBLITY	% Total Fatty Acids
Apparent Starch Digestibility	91.6	Fatty Acids Digestibility	55.1
Ideal Range	94 - 98	Fatty Acid Digestibility Expected Range	65.4
Expected Range	88 - 98		
Expected Range Average	94.4		
Estimated Rumen Digestibility	50.6		
Estimated Post Rumen Digestibility	41		

Starch digestibility will vary based on many factors including amount of starch in the diet, starch particle size, dry matter of corn and corn silage, length of time starch products have fermented in storage, diet composition, milk production level, and general rumen health. Estimated rumen and post rumen digestibility values are based on a summarization of studies reported by Ferraretto et al., JDS Vol. 96, No.1, 2013 page 542.

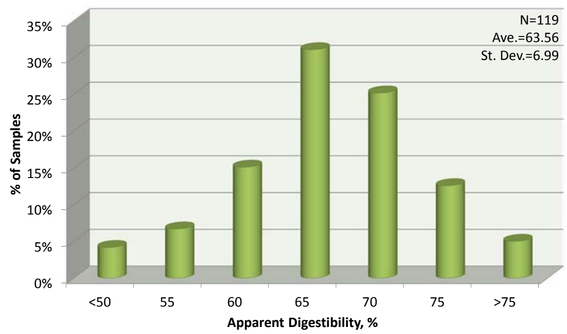
Distribution of Apparent Digestibility of TMR pdNDF Data



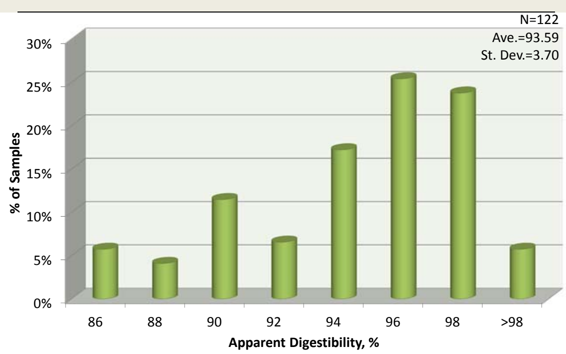
Distribution of Ratio of uNDF240 in Fecal Material to uNDF240 in TMR



Distribution of Apparent Digestibility of TMR Protein Data



Distribution of Apparent Digestibility of TMR Starch Data



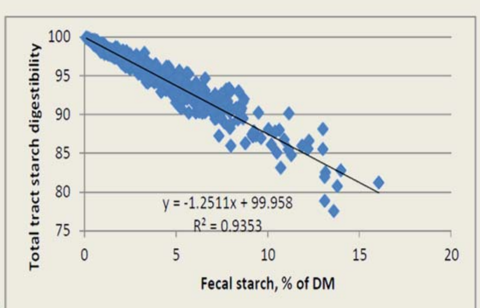


Figure 2. Regression plot of fecal starch and total tract starch digestibility.
$Y = 99.96 (\pm 0.065) - 1.25 (\pm 0.014) X$; RMSE = 0.936; $R^2 = 0.94$; $P < 0.0001$; n = 564.

Updated equation from Ferraretto & Shaver, 2012, PAS

In vitro and In situ

- In vitro methods are the most common used for starch digestibility evaluations in the U.S.
- The primary dairy laboratories in the U.S. have now all adopted this approach.
- At CVAS we maintain a 1800 flask incubation system and approximately 10 cannulated cows for In vitro and In situ work.
- CVAS provides significant In situ evaluations for protein, starch, and NDF.

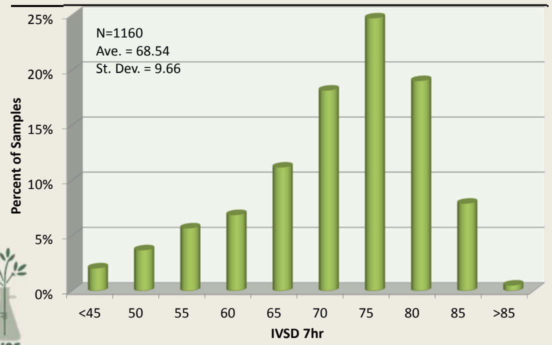
Comparison of 7hr in situ method with 7hr in vitro method for evaluating Starch Digestibility in Selected Samples (CVAS, 2013)

Feed Type	7hr in situ	7hr in vitro
Box Canyon Ground Corn (as is)	58.5	57.5
Box Canyon Ground Corn (ground	74.0	74.8
30# Flaked Corn GNE (as is)	44.5	40.8
30# Flaked Corn GNE (ground)	75.8	74.8
26# Flaked Corn GNE (as is)	53.9	46.7
26# Flaked Corn GNE (ground)	73.6	75.4
Ground Corn GNE (as is)	54.1	56.8
Ground Corn GNE (ground)	72.0	73.0

7-Hour In Vitro Starch Digestibility of Corn Samples (CVAS, 2010)

Feedstuff	No. of Samples	DM	7h IV Starch Digestibility	SD
Corn Grain	123	87.5	60.9	8.1
HM Corn	103	72.9	64.1	8.9
HM Ear Corn	20	58	73.9	8.5
Corn Silage	107	<28	80.1	7.5
Corn Silage	204	28 to 32	79.7	8.7
Corn Silage	224	32 to 36	77.5	9.5
Corn Silage	102	36 to 40	73.3	10.2

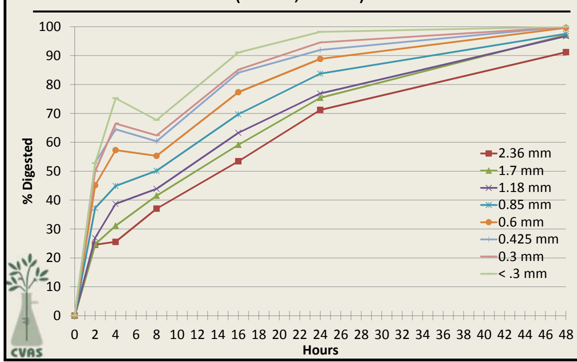
Distribution of IVSD 7HR in Corn Silage (CVAS, 2013)



Nutrient Characteristics of Sieved Fermented Corn Grain (CVAS, 2013)

Particle Size, MM	2.360	1.700	1.180	0.850	0.600	0.425	0.300	0.212
CP, %	9.3	8.5	8.5	8.6	7.9	6.6	6.4	5.8
ADF, %	6.8	6.9	6.1	4.2	3.2	2.3	2.3	2.6
NDF, %	14.3	13.9	12.1	8.6	5.9	4.0	2.6	2.8
Ash, %	4.24	4.19	2.45	1.88	1.76	1.56	1.21	0.95
Starch, %	66.4	67.4	69.6	75.4	78.7	81.6	83.7	84.9
Sugar, %	1.69	1.70	1.73	1.74	1.80	1.73	1.75	1.70
Fat, EE, %	3.78	3.96	3.89	3.49	2.77	2.66	2.48	2.49
SP%CP	11.5	8.73	7.98	6.71	6.13	2.35	3.35	1.25

Starch Digestion by Particle Size Over Time (CVAS, 2013)



Sampling Error & Technique

Weiss et al.

Studied over 448 samples, 8 farms, 14 days.

The variation attributed to sampling technique

Corn Silage	Hay Crop Silage
Dry Matter 25 to 55 %	5 to 30 %
NDF 15 to 65%	8 to 52 %
Starch 11 to 78 %	Protein 12 to 72%

CVAS

Sampling Techniques

Bunker & Bag Silos – similar in sampling protocols.
Clean 5 gal bucket and clean surface.

Uprights – 2 to 3 gal of silage and proper subsampling

Hays and Baleage- a hay probe with sharp teeth.
Depending on the size of the crop – several probe samples are necessary.

Good samples are the foundation of good diet formulation.

CVAS

NDFom

NDF (organic matter basis) or ash free

- What effects the ash level in forages?
- Why move to ash free?
- How does the lab make this adjustment?
- Does ash make that much difference?
- Does ash effect NDFD as well?

CVAS

What effects ash level in forages?

- Rain splash of soil on a wilting crop
- Irrigation splash
- Flooding
- Incorporation of soil at harvest
- Incorporation of soil/mud while packing

Why move to ash free?

- To give credit where due…Dr. Charlie Sniffen had CPM built on ash free values
- Europeans has traditionally utilized an organic matter approach.
- Has not been perceived as a major issue and labs have not been volunteering to do this…
- Newer harvesting methods/equipment has increased soil contamination

How does the Lab make this adjustment?

- First we need to understand how an NDF is ran to understand the problem:
  - To extract NDF, a portion of the forage or feed material is boiled in a detergent solution that is buffered to a pH of 7.0, hence the term 'Neutral Detergent Fiber'
  - Some ash may be soluble in hot neutral detergent solution, but most will not.

How does the Lab make this adjustment?

- When the residue is collected on the glass fiber filter, the remaining insoluble ash is collected as well and appears as undigested fiber.
- For many samples this difference is small but can help explain some things for others.

To get to an 'ash free' basis, that filter and residue is placed into an ashing furnace at 600 degrees centigrade for two hours.

How does the Lab make this adjustment?

- After this treatment, all that is left is the glass fiber filter and the residual ash.
- This is weighed to determine ash content and by difference the Lab can determine the organic NDF that was present.

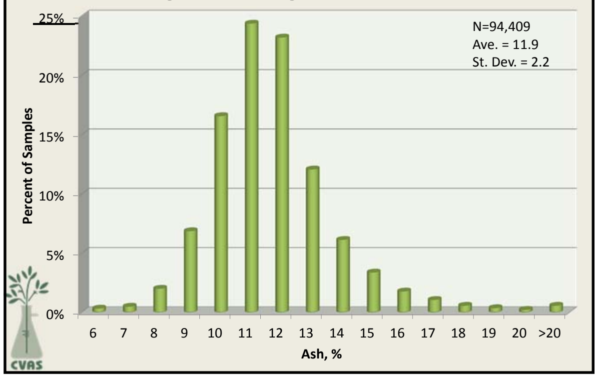
- See why the labs were not volunteering…? This can delay results by a day when done by chemistry.

Does ash make that much difference?

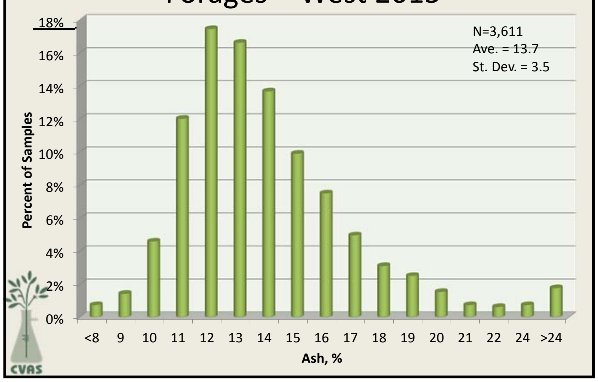
- Ash creates a challenge in the lab whether we are doing NIR or chemistry
- Fibers are inappropriately elevated creating a need for fibers to be reported 'ash free'

- Lets look at some data

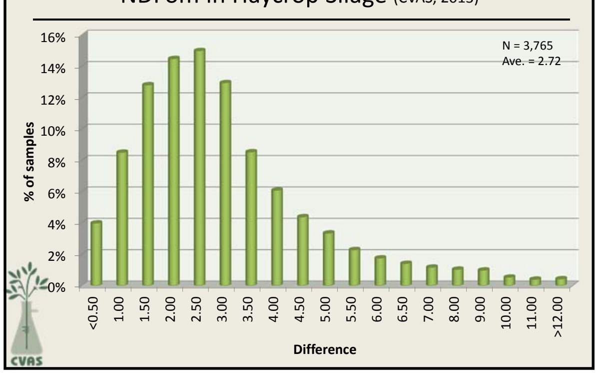
Ash in legume forages, CVAS 2013-2014



Distribution of Percent Ash in Legume Forages – West 2015

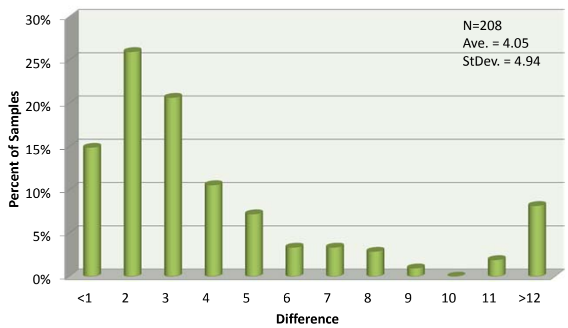


Distribution of Differences between NDF and NDFom in Haycrop Silage (CVAS, 2013)



Difference Between aNDF and aNDFom (organic matter basis) in Selected Sorghum and Sorghum/Sudan Samples

(CVAS, 2012 crop, chemistry)



aNDF - How does NIR see NDF?

- Will see difference between aNDF by chemistry, aNDF by NIR, and aNDFom by chemistry
- Example: Legume, 15% ash
  - aNDF by chemistry 38.4%
  - aNDF by NIR 36.2%
  - aNDFom by chemistry 34.2%

Example of the Impact of Ash Contamination on NDF and NDF Digestibility Recovery

Sample	NDF	NDFom	NDFD30	NDFD30om
15081-068	54.6%	**48.3%**	56.3%	**65.9%**

Example of the Impact of Ash Contamination on NDF and NDF Digestibility Recovery

Sample	NDF	NDFom	NDFD30	NDFD30om
15081-68	54.6%	**48.3%**	56.3%	**65.9%**
15085-56	60.1%	**50.9%**	49.7%	**61.9%**

Labs traditionally have not run NDF on organic matter basis …

- Potential problems are generally not recognized
- Ash contamination is more of an issue today than 10 years ago
- Significantly more work / cost to lab, cost to client
- NIR calibrations generally do not exist for aNDFom (CVAS has developed these for forage equations)
- Not only NDF but NDF digestibility needs to be run on an ash-free basis
- Education / acceptance component

High Res Forage Testing

- NDF In vitro digestibility
  - Allows for proper ranking of forages and hybrids (plot study work)
  - Allows for more appropriate rate calculations, 6.5 Biology
  - Forages 30, 120, 240 Non Forages 12, 72, 120 time points
  - Properly labeling fast vs slow pools of NDFD
  - Great for troubleshooting herd performance

High Res Forage Testing

uNDF240

- Historically estimated as lignin * 2.4
- Based on early research by Van Soest
- 2.4 factor used within and across various feedstuffs
- Distinguished from "iNDF" which is a theoretical term
- U.S. Ration Models will be making the switch to 6.5 CNCPS
- More accurate rate predictions

Relationship Between uNDF as Lignin *2.4 and uNDF as uNDF240

	NDF	uNDF Lig2.4	uNDF240	Lignin Factor
Western Alfalfa	41.7	17.1	22.7	3.2
Legume	41.8	15.9	21.6	3.3
MM Legume	50.1.	16.5	24.3	3.5
Mixed	53.5	14.6	23.0	3.8
MM Grass	60.0	14.3	25.1	4.2
Grass	58.9	12.9	23.7	4.3
Corn Silage- Conv.	40.0	7.4	10.6	3.4
Corn Silage – BMR	40.4	6.2	8.0	3.1
Sorghum – Forage	59.6	9.8	18.0	4.4
Sorghum - Grain	48.5	10.5	9.7	2.3

NDF Characteristics of Byproduct Feeds (CVAS, 2014)

Feed Name	NDF	Dig NDF (% NDF)	uNDF (%NDF)	Kd (%/hr)	Lbs NDF/hr
Soy Hulls	69.9	96.3	3.7	10.6	0.72
Beet Pulp	46.4	84.2	15.8	15.4	0.60
Dry Distiller's Grains	35.3	88.8	11.2	6.9	0.22
Cotton Hulls	81.5	63.5	36.5	2.2	0.11
Almond Shells	61.2	19.9	80.1	4.1	0.05
Cotton Gin Trash	74.9	31.0	69.0	1.9	0.05
Rice Hulls	71.7	4.7	95.3	3.7	0.01

MSPE (Ross) uN Step 1: In vitro

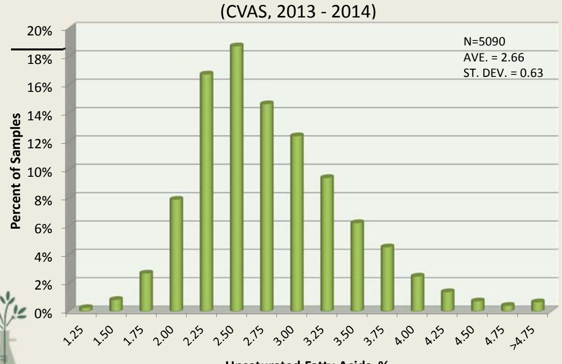
RUP is measured by incubating a sample in vitro with rumen fluid from high group lactating dairy cattle for 16 hours.

How do products compare?

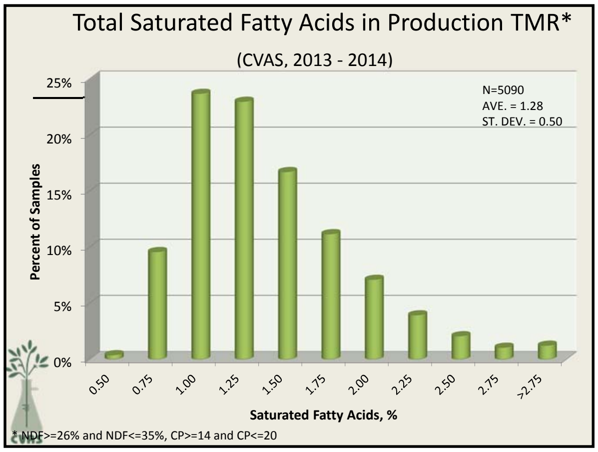
Source	SP, % CP	RUP at 16HR, % CP	RDP, % CP	Intest. Dig CP, % CP	Total Tract Digest. CP, % CP
Blood 1	58	40	60	37	97
Blood 2	9	91	9	74	82
Blood 2, Burnt	8	92	8	6	12
Soybean Meal	14	32	68	26	95
Canola	16	42	58	30	88
Gluten Meal	11	78	22	60	81
Commercial Soy 1	9	77	23	68	91
Commercial Soy 2	15	57	43	51	94
Commercial Blend 1	10	73	27	50	77
Commercial Blend 2	8	45	55	36	91

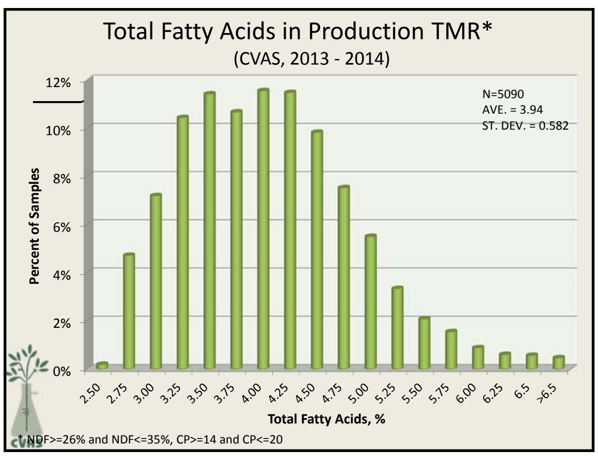
Unsaturated Fatty Acids, Production TMR*

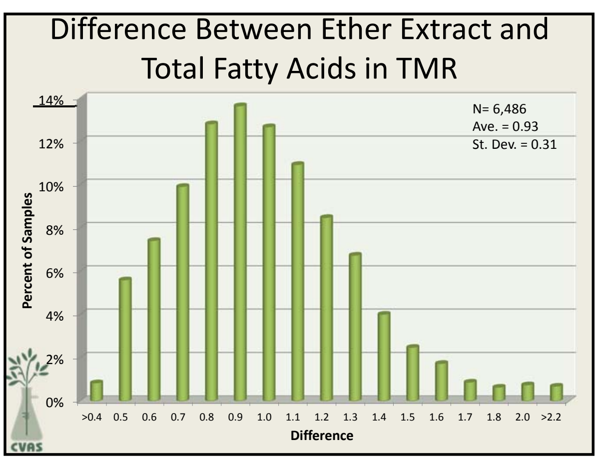
(CVAS, 2013 - 2014)



* NDF>=26% and NDF<=35%, CP>=14 and CP<=20


Total Saturated Fatty Acids in Production TMR*
(CVAS, 2013 - 2014)
N=5090
AVE. = 1.28
ST. DEV. = 0.50
Percent of Samples
25%
20%
15%
10%
5%
0%
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
>2.75
Saturated Fatty Acids, %
* NDF>=26% and NDF<=35%, CP>=14 and CP<=20


Total Fatty Acids in Production TMR*
(CVAS, 2013 - 2014)
N=5090
AVE. = 3.94
ST. DEV. = 0.582
Percent of Samples
12%
10%
8%
6%
4%
2%
0%
2.50
2.75
3.00
3.25
3.50
3.75
4.00
4.25
4.50
4.75
5.00
5.25
5.50
5.75
6.00
6.25
6.5
>6.5
Total Fatty Acids, %
* NDF>=26% and NDF<=35%, CP>=14 and CP<=20


Difference Between Ether Extract and Total Fatty Acids in TMR
N= 6,486
Ave. = 0.93
St. Dev. = 0.31
Percent of Samples
14%
12%
10%
8%
6%
4%
2%
0%
>0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
2.0
>2.2
Difference
CVAS

Better Tools=Better Nutrition=Better Performance

- NDFom
- NDF Digestibility
- uNDFD 240
- Fermentation Evaluation
- Starch Characterization
- Apparent Nutrient Digestibility (TMR/Fecal)
- Multi Step Protein Evaluation
- Dry Methods/Sample Preparation
- CVAS Mobile App
- Database Summaries
- Report Validation

Conclusion

- Efficient utilization of starch in ruminant diets is dependent on being able to properly characterize starch across feedstuffs and processing methods.

CSPS

- A unified and animal relevant approach needs to be developed to accomplish this task.

Apparent Nutrient Digestibility

- NDF on an "ash free" or organic matter basis is a better way of characterizing true NDF in forages.

Mid-South Ruminant Nutrition Conference

"High Res Forage Testing"

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