

# **Nonfiber Carbohydrates In Forages**

## **Lab Analysis and Cow Performance**

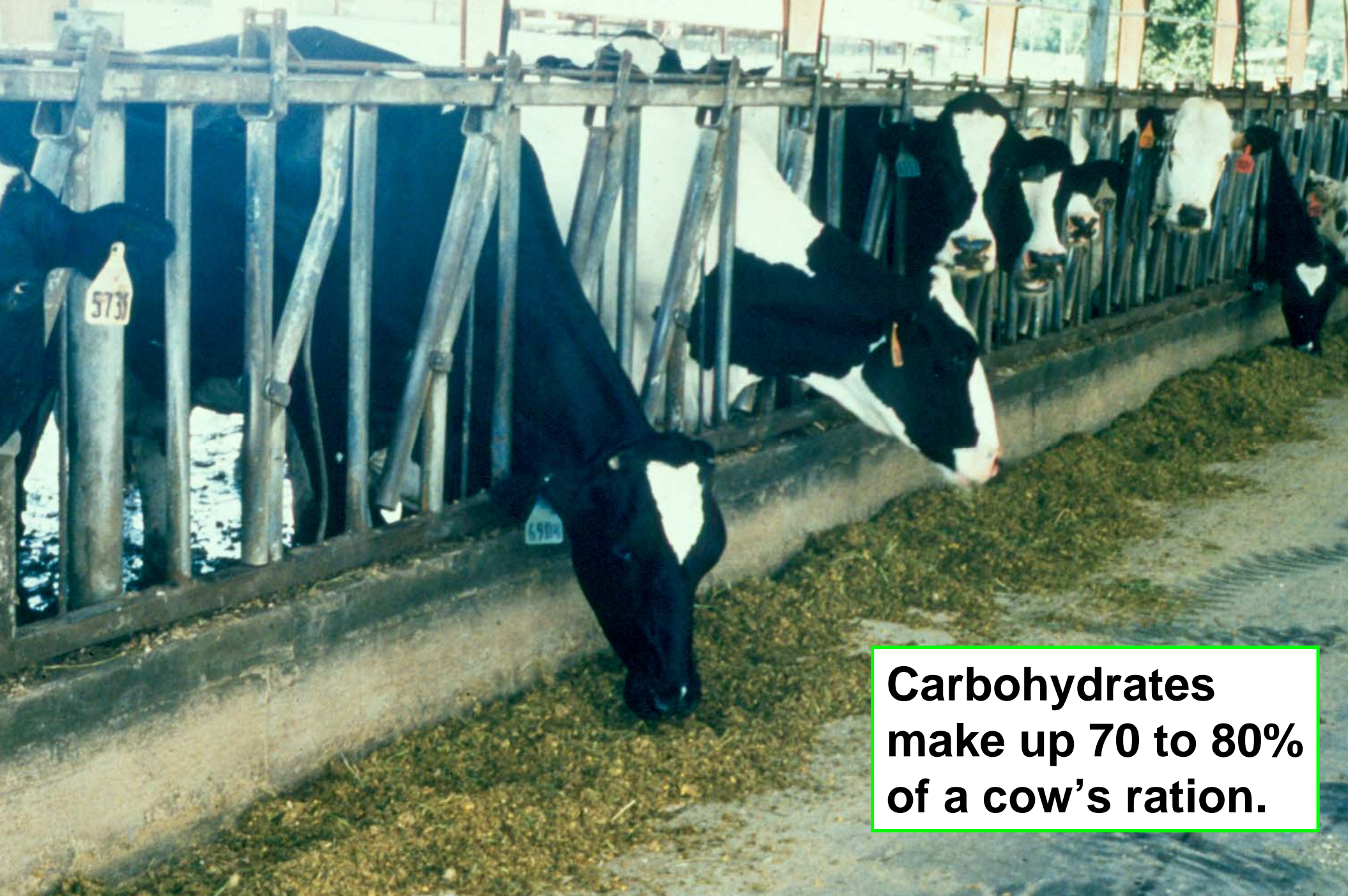
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**U. S. Dairy Forage Research Center**

**Madison, WI**





**Carbohydrates  
make up 70 to 80%  
of a cow's ration.**

**Carbohydrates provide the main energy source to support high production.**

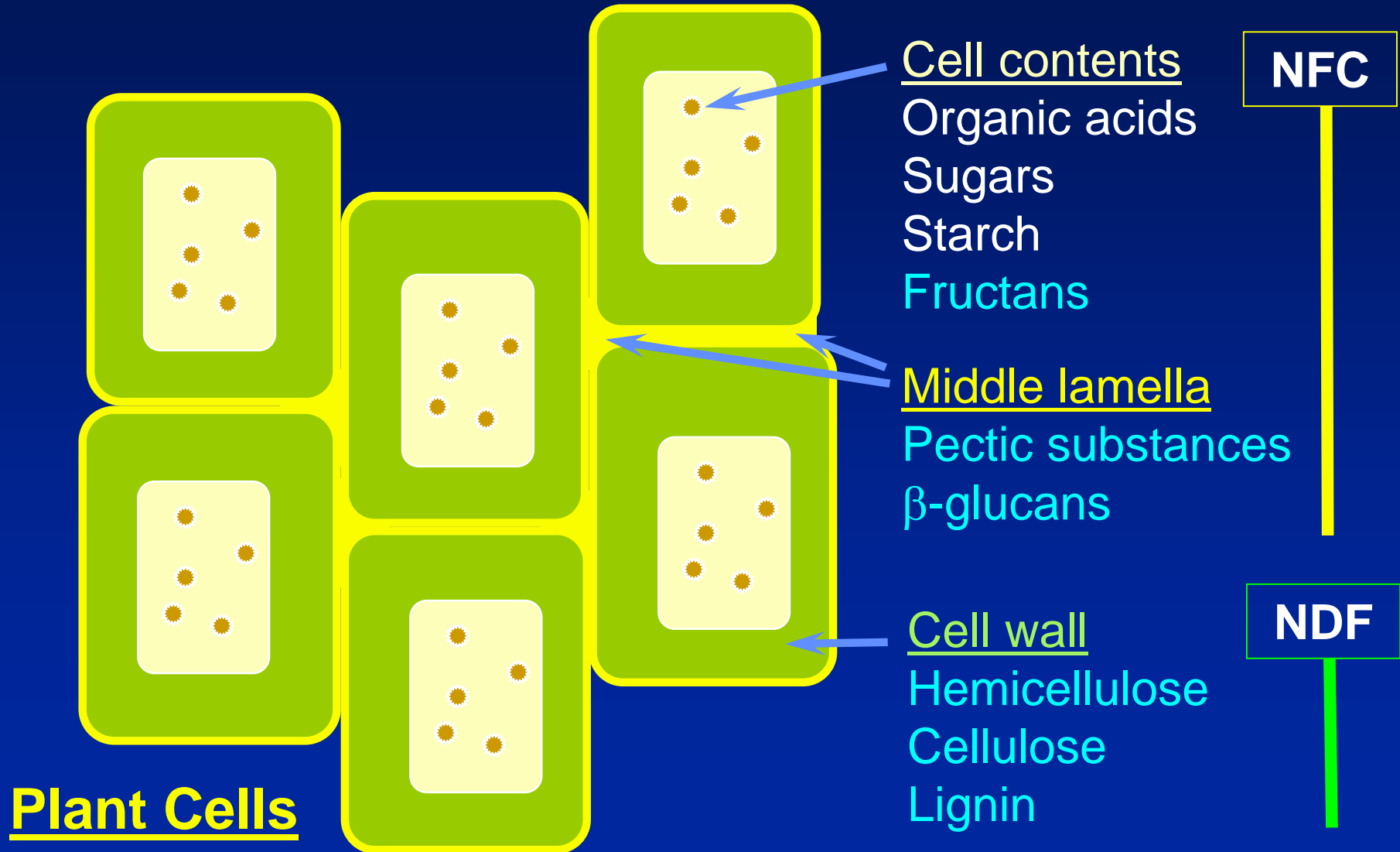
**However, CHO do not all function the same way in rations, or support similar performance.**



**Which can affect profitability.**

# Neutral Detergent Fiber (NDF)

$$\text{NFC} = 100 - \text{Crude Protein} - \text{NDF} - \text{Crude Fat} - \text{Ash}$$



# NFC Sources

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## Organic Acids

Silages

Whey

Steep liquor

## Sugars

Fresh forages/hays

Beet & citrus pulps

Almond hulls

Molasses

Bakery waste

## Starch

Grain silages

Corn, sorghum

Small grains

Bakery waste

Wheat midds

## Soluble Fiber

Legume forages

Beet & citrus pulps

Soybean meal



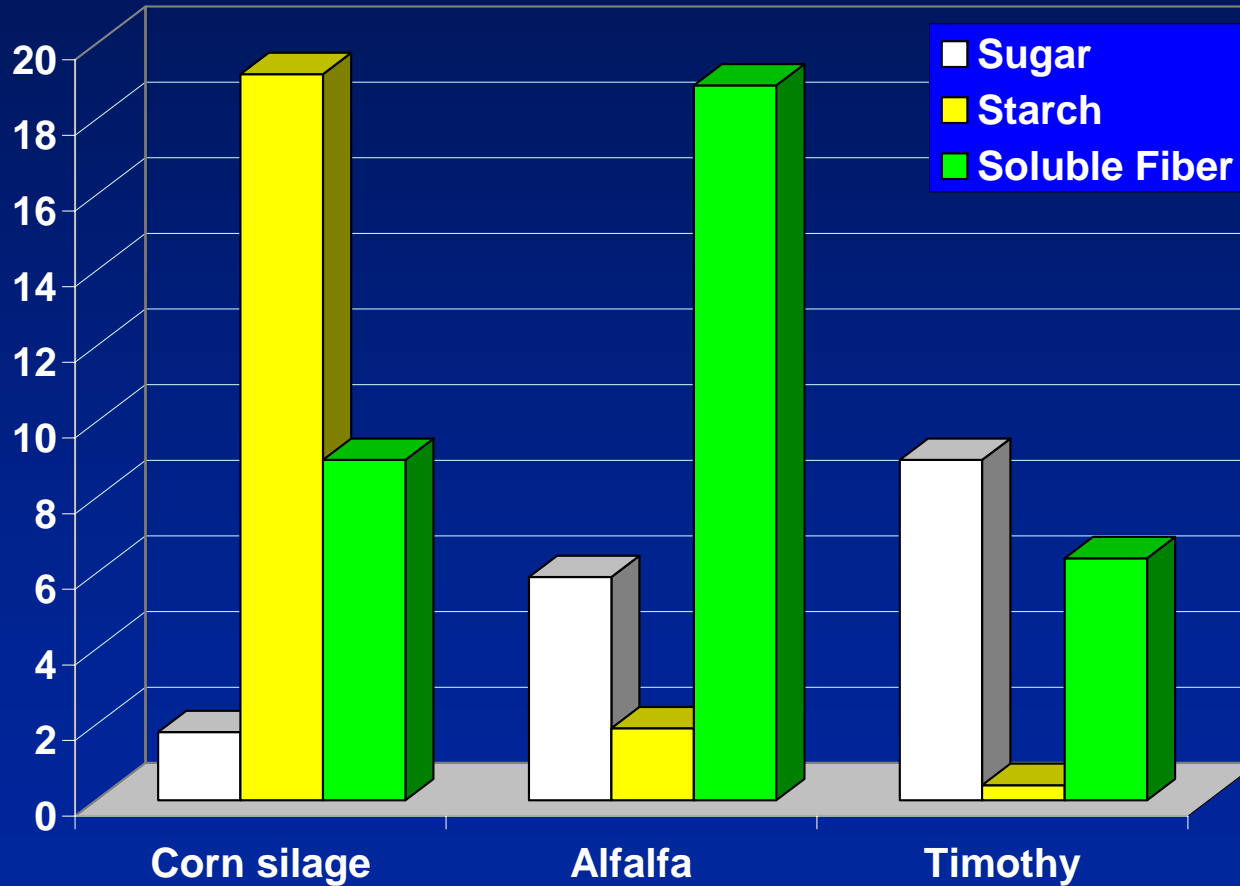
# NFC in Forages



- How do we measure NFC?
- How do they affect cow performance?
- How do we formulate rations for them?

# Forage NFC Composition

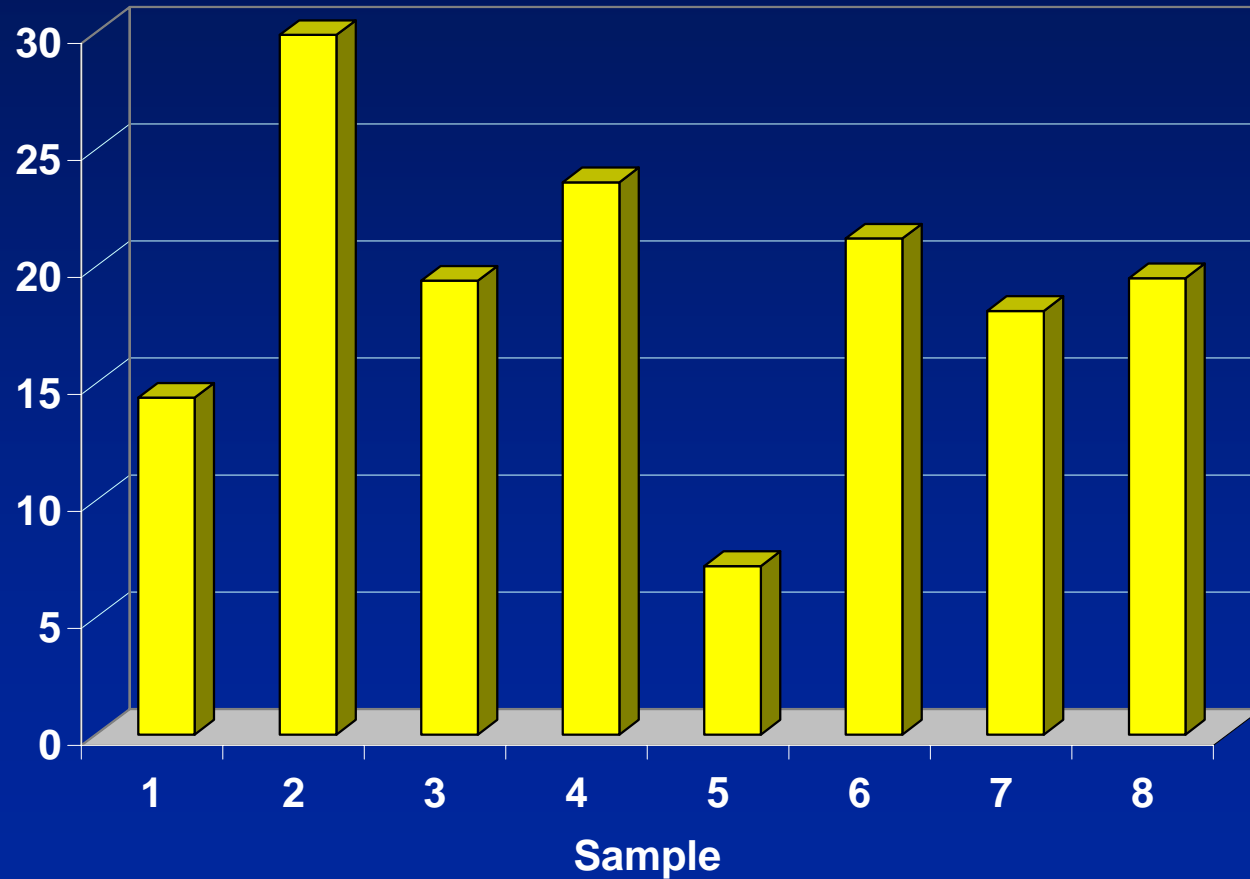
% of Dry Matter



Hall, 2000

# Corn Silage: Starch Content

Starch% of DM

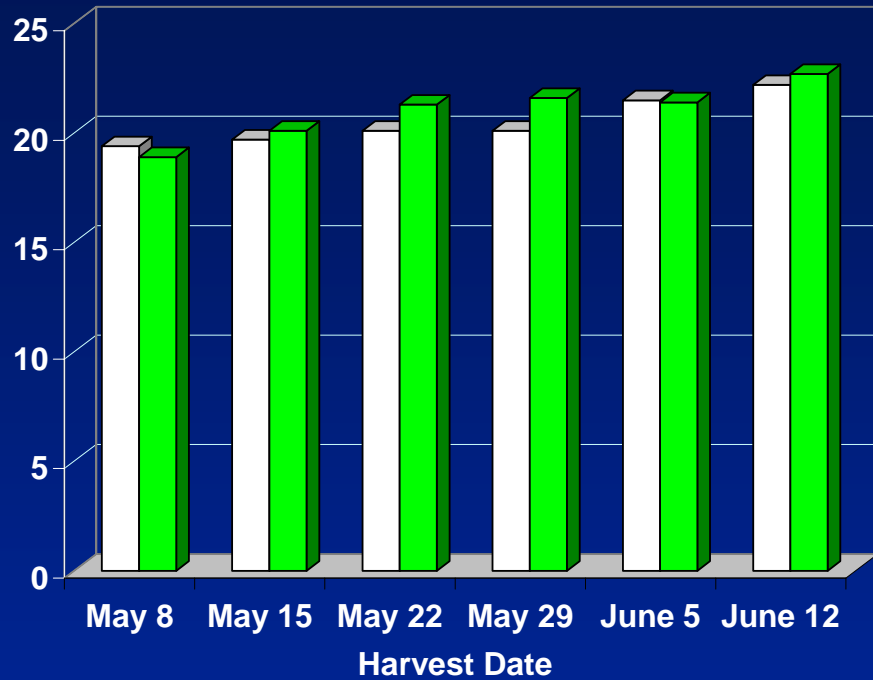


- ✱ Grain yield
- ✱ Cut height
- + energy
- - effective NDF

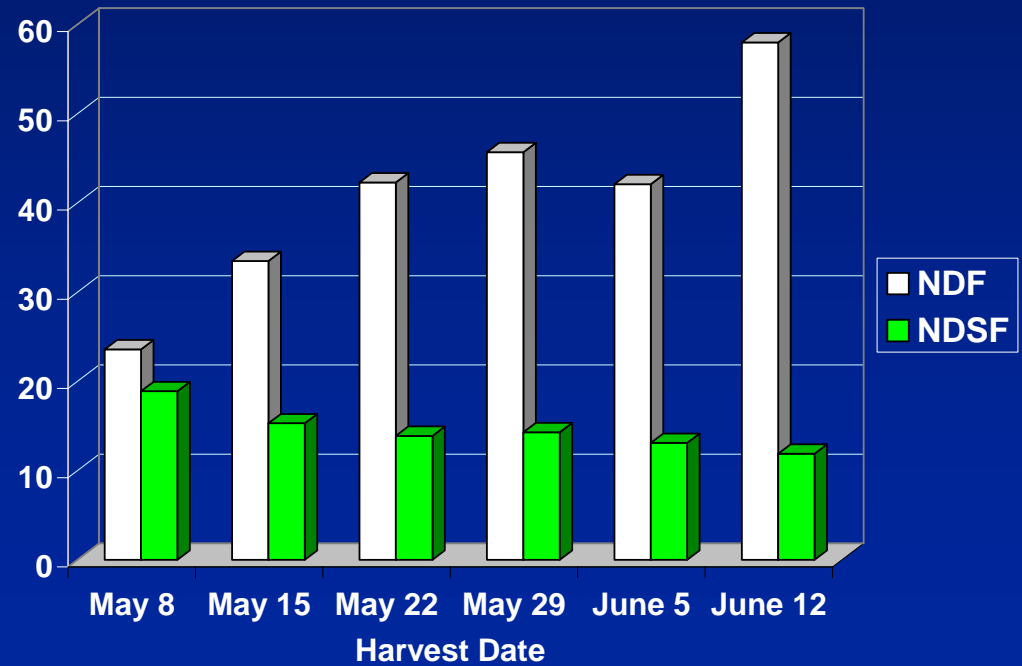


# Alfalfa Leaves: NDF & Soluble Fiber

% of Dry Matter



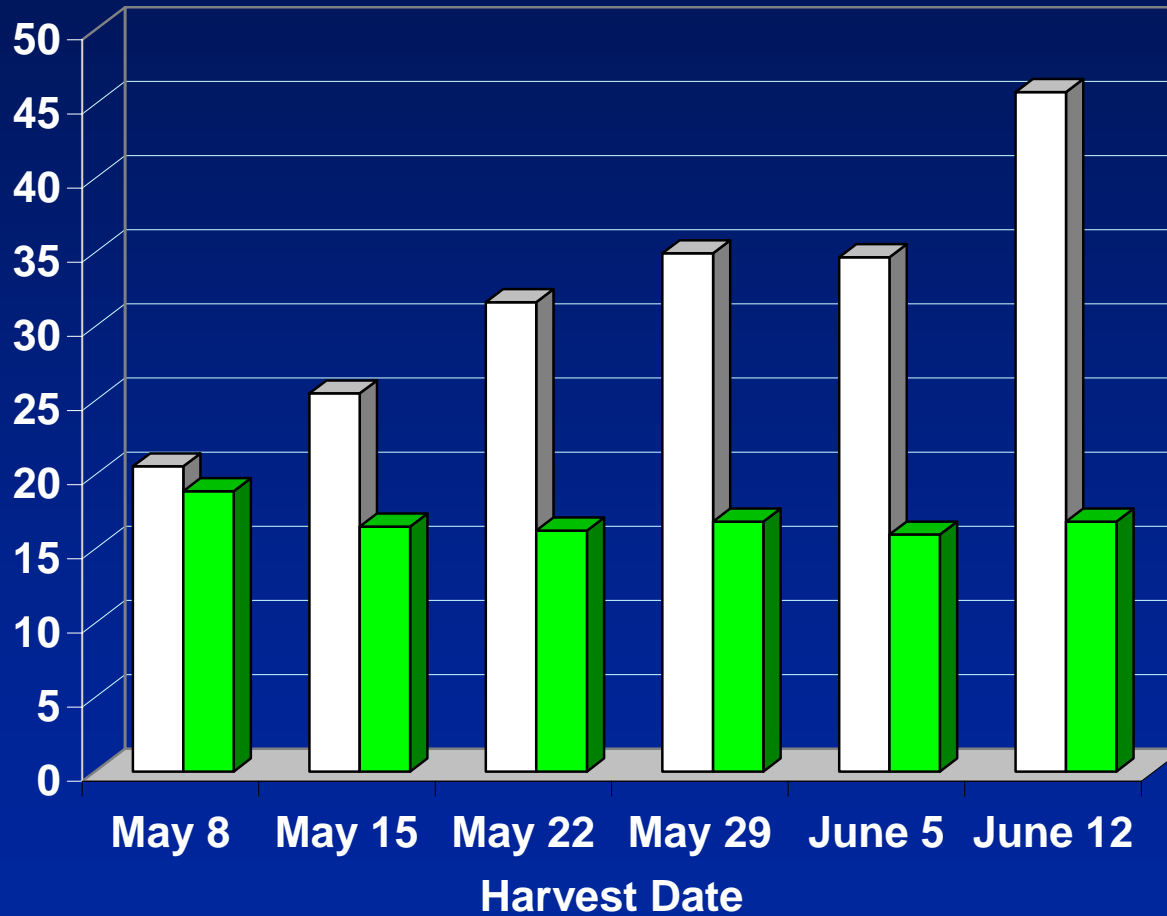
% of Dry Matter



Hall et al., 1997

# Alfalfa Plant: NDF & Soluble Fiber

% of Dry Matter



■ NDF  
■ NDSF

☀ Leaf loss

☀ Maturity

% Leaf

72

58

48

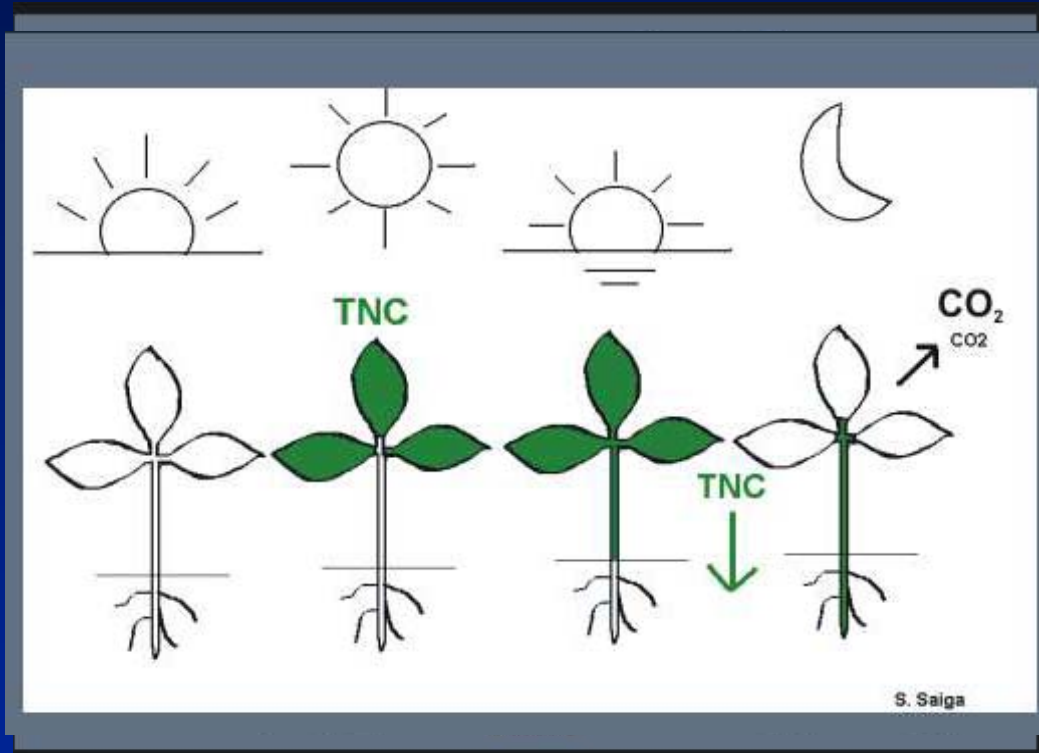
42

36

34

Hall et al., 1997

# PM vs AM Harvest of Hays

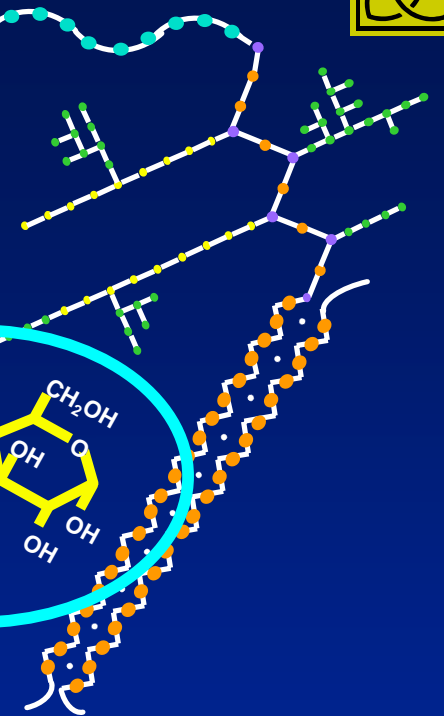
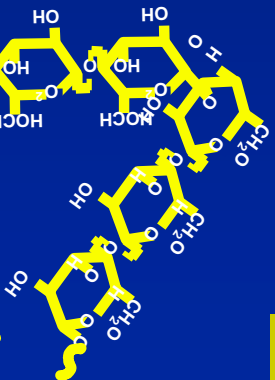
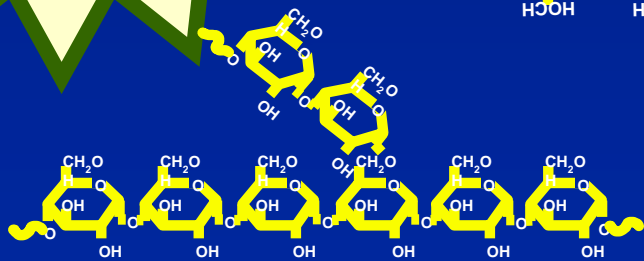
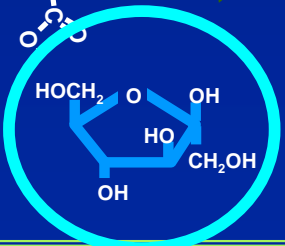
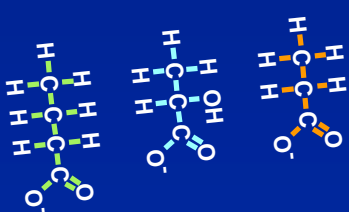
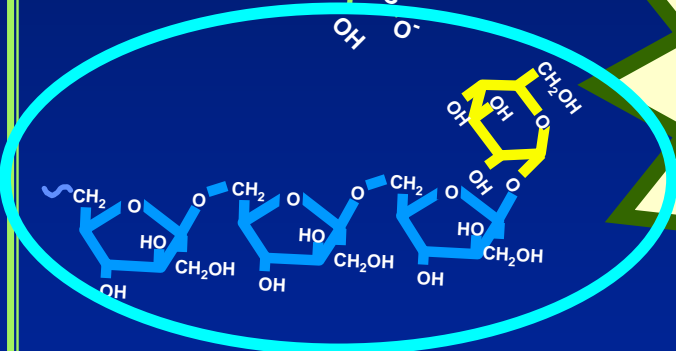
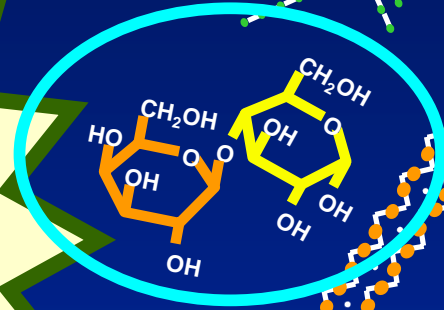
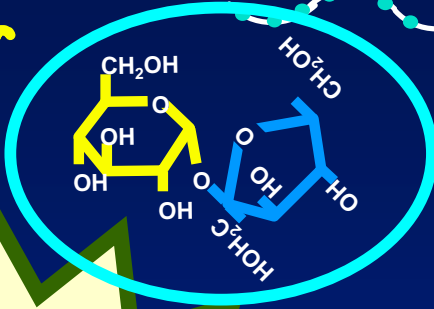
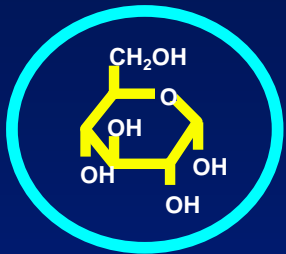
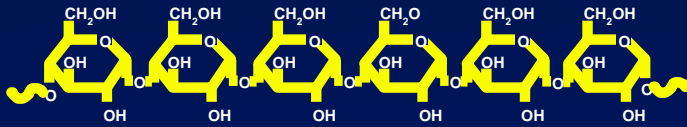


Harvest	PM	AM
Crude Protein%	15.9	18.2
NDF%	47.8	47.5
NSC%	7.9	4.5

Harvest	PM	AM
Intake, lb	1.4	0.7

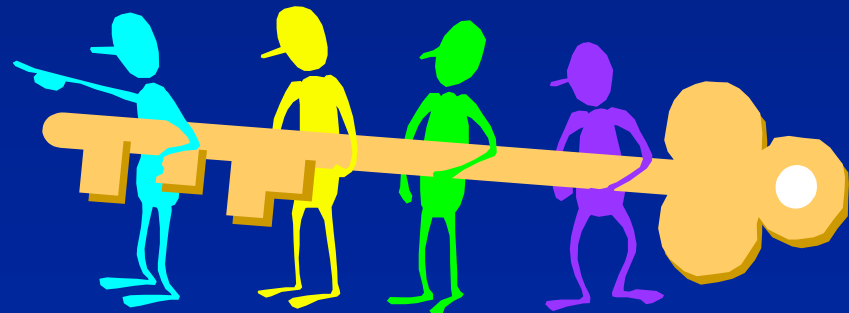


**All NFC  
are not  
created  
equal.**



# NFC in Forages

- You can change it by types, varieties, and management.
- You need to select supplements to complement the forages.



# What Nutrients Come From Carbohydrates?

## Rumen (Fermentation)

Microbial protein

Organic acids

(acetate, propionate, butyrate, lactate)

## Small Intestine (Enzymic)

Glucose

## Cecum & Large Intestine (Fermentation)

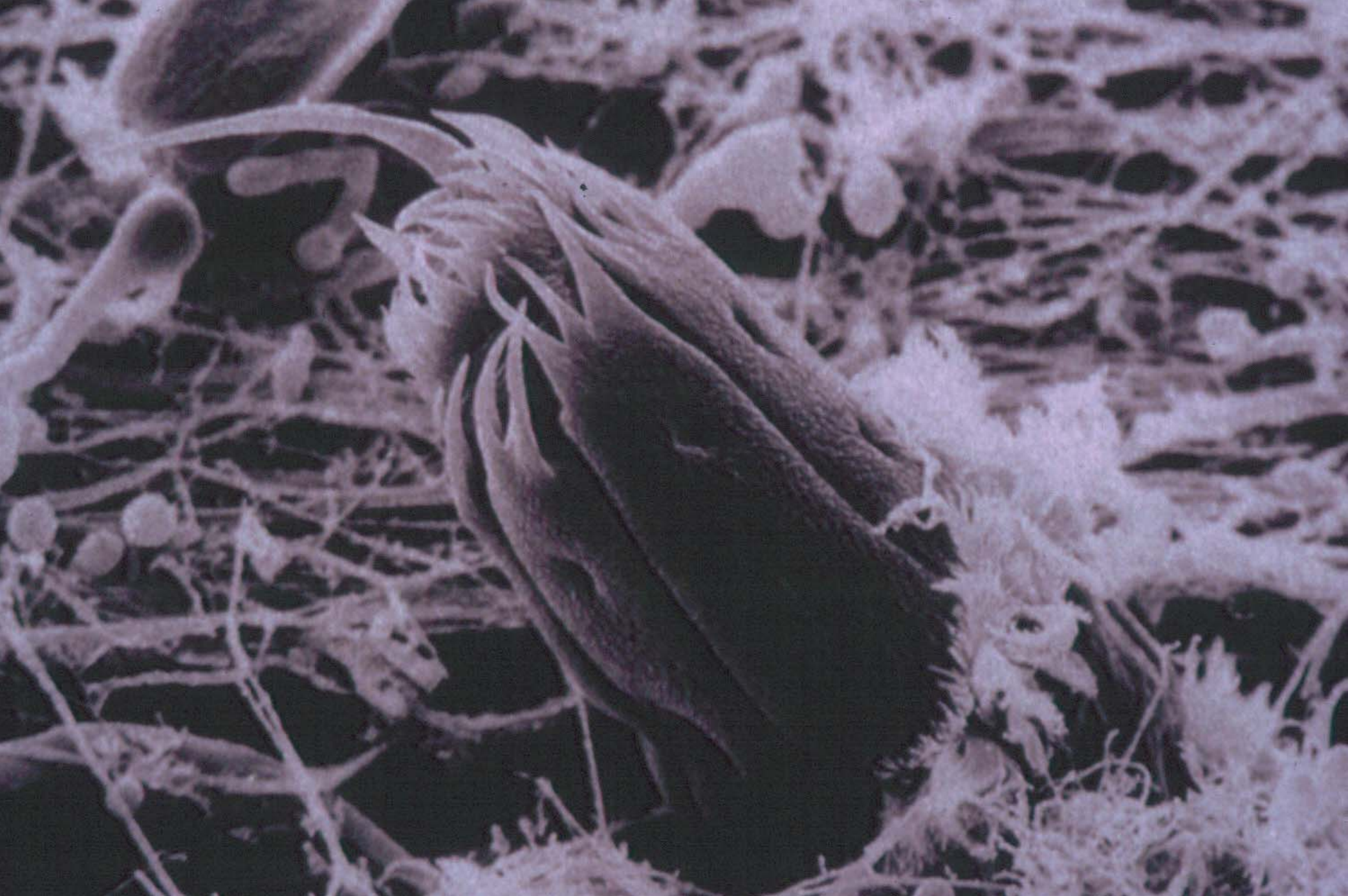
~~Microbial protein~~

Organic acids

**Carbohydrates differ in nutrient yield.**

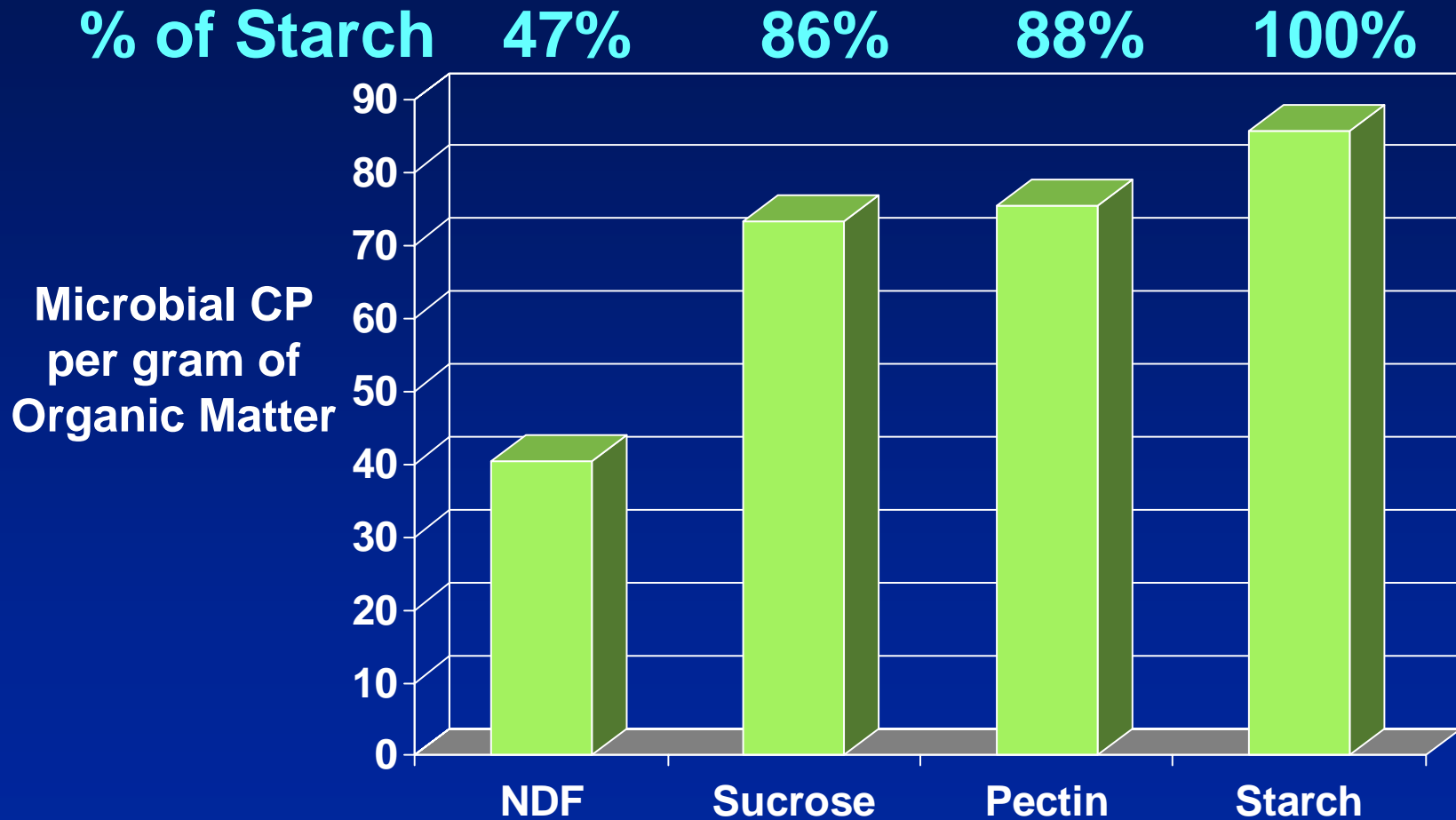








# Maximum Microbial CP Yield





**So?**

**Don't worry.  
She'll get around to  
why this matters.**

# Starch vs. Soluble Fiber + Sugar

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	1 Corn vs Beet Pulp	2 Corn vs Citrus Pulp	3 Hominy vs Citrus Pulp
DM Intake, lb	+2.6*	+1.2*	+1.1
Milk, lb	+0.7	+2.0	+3.3
Fat, %	-0.18	-0.05	-0.11
Fat, lb	-0.07	+0.04	+0.02
Protein, %	+0.09*	+0.07*	+0.12*
Protein, lb	+0.11*	+0.08‡	+0.18‡

\*  $P < 0.05$ , ‡  $P < 0.15$

Mansfield et al., 1994; Solomon et al., 2000; Leiva et al., 2000

# Carbohydrates: Sugar v. Starch

## Sugar:Starch (% Diet DM)

	<u>0:7.5</u>	<u>2.5:5.0</u>	<u>5.0:2.5</u>	<u>7.5:0</u>
DM intake <sup>L</sup>	54.0	56.4	57.3	57.3
Milk, lb <sup>L</sup>	85.8	89.1	88.2	86.9
Fat, lb <sup>L</sup>	3.24	3.37	3.64	3.57
Protein, lb	2.73	2.82	2.84	2.82
Rumen pH	6.19	6.16	6.19	6.21
Milk/DM <sup>L</sup>	1.60	1.58	1.54	1.52
FPCM/DM	1.64	1.63	1.66	1.64
MN/IN <sup>L</sup>	0.312	0.291	0.291	0.295

<sup>L</sup>  $P < 0.05$ , <sup>L</sup>  $P < 0.10$

Broderick et al., 2002

# Carbohydrate x Protein

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38 cows, 6 cannulated, 82 $\pm$ 19 DIM; Inc. Latin Square

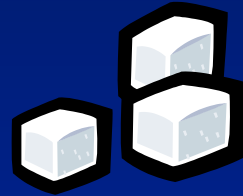
## NFC

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Corn Meal: Starch

Citrus Pulp: Soluble fiber and sugar

Molasses & Sucrose: Sugar

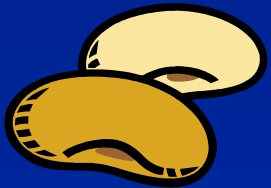


## Rumen Degradable Protein

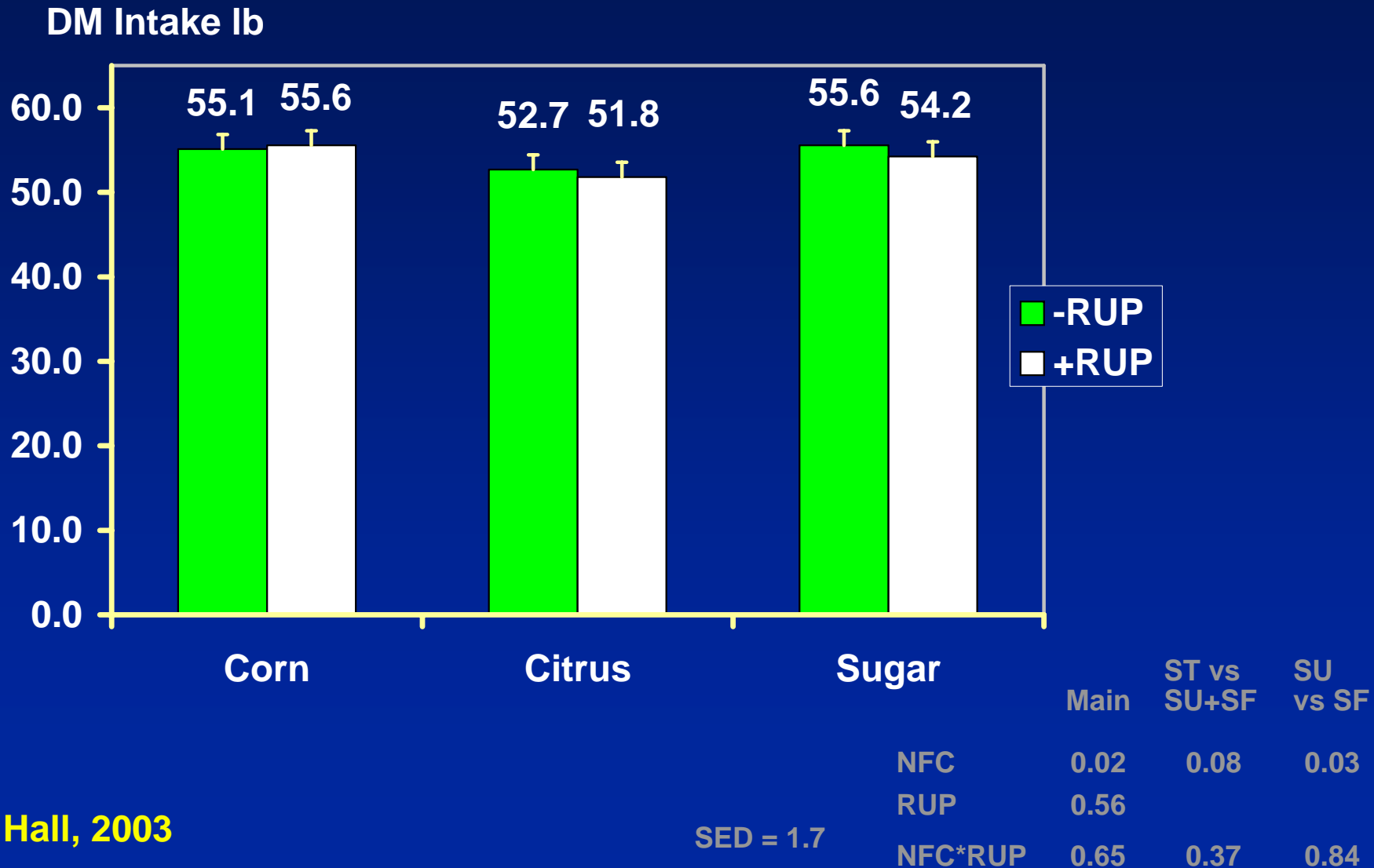
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48% Soybean Meal: More degradable

48% SBM + Expeller Soybean Meal: More bypass

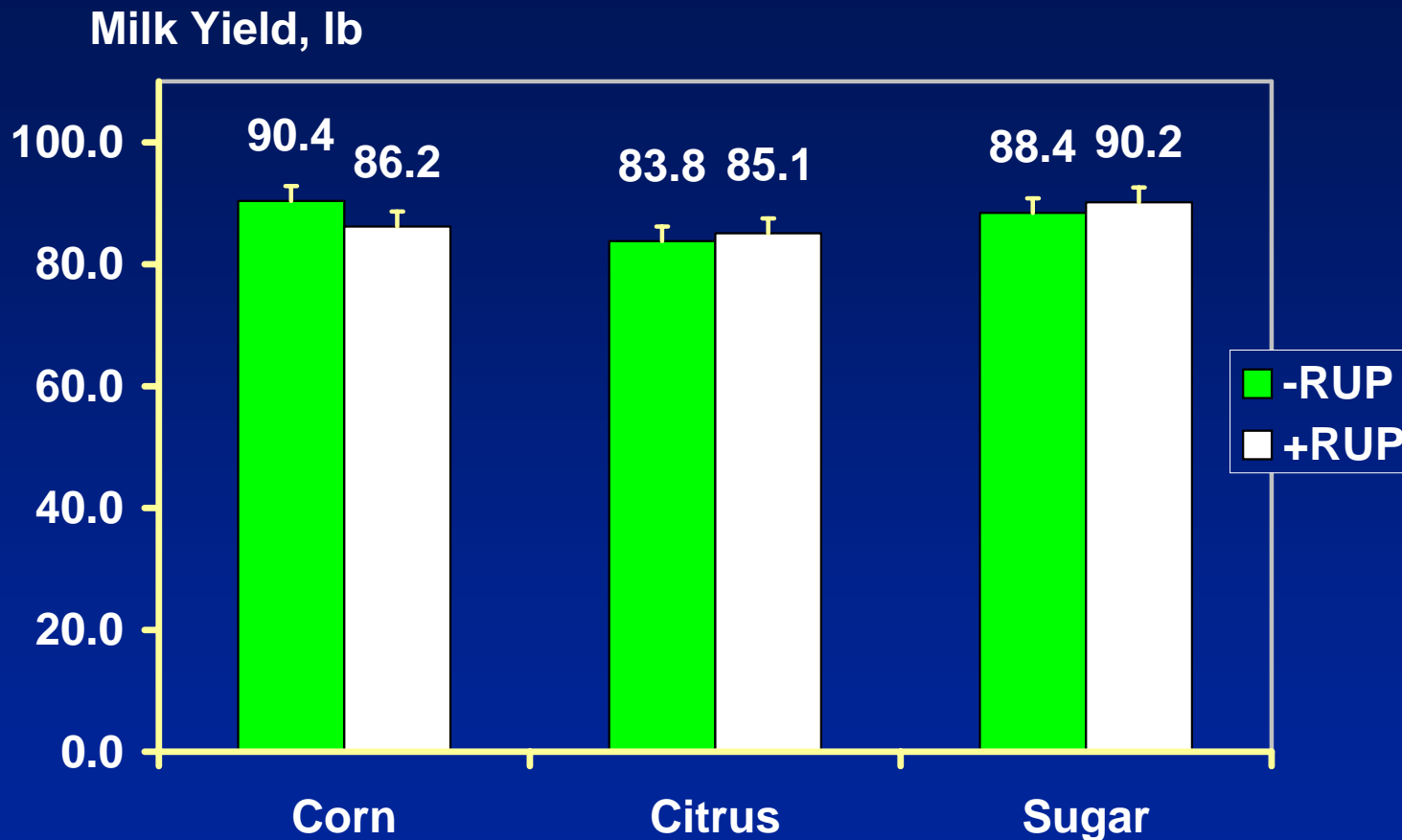


# NFC x Protein: Dry Matter Intake



Larson and Hall, 2003

# NFC x Protein: Milk Yield

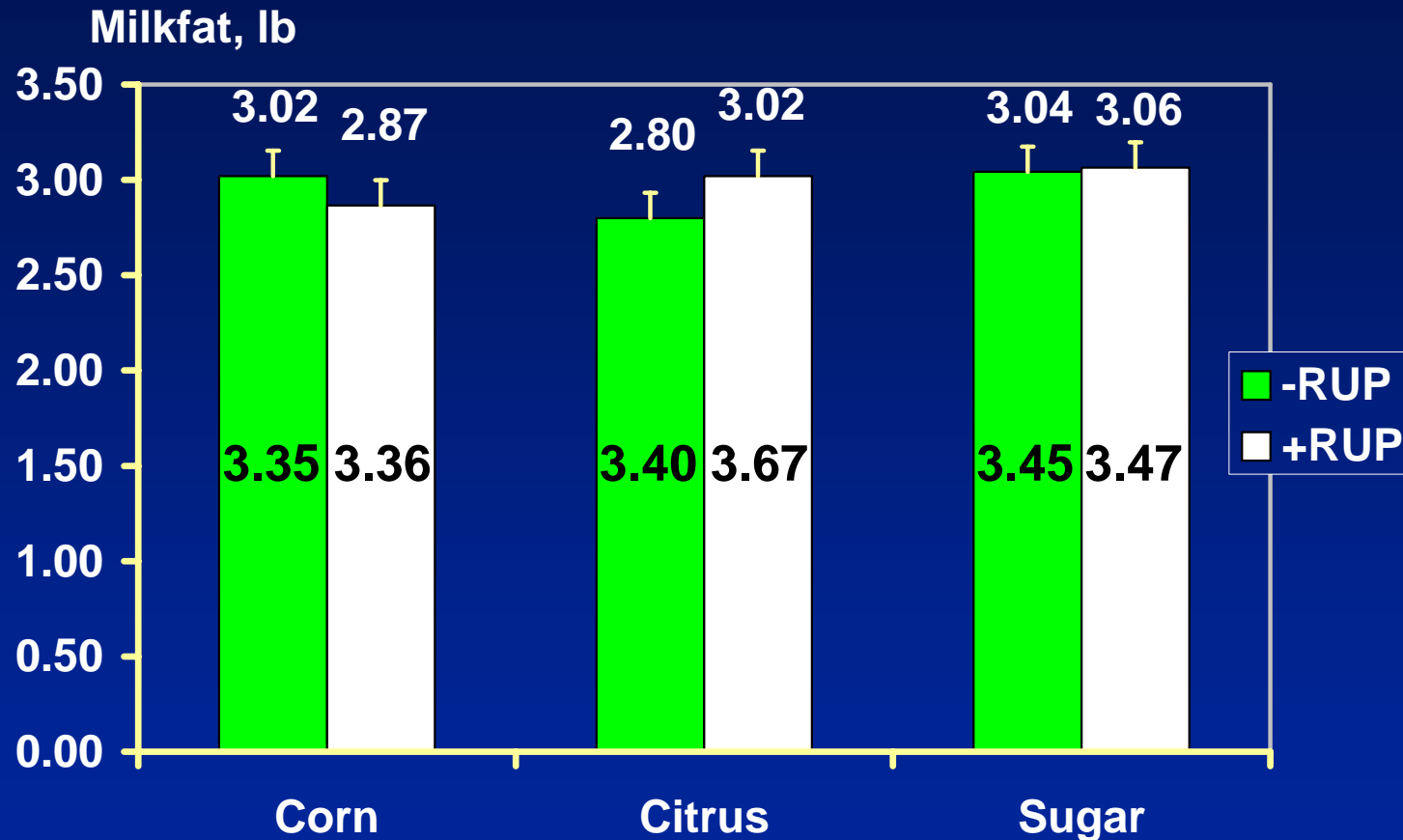


	Main	ST vs SU+SF	SU vs SF
NFC	0.01	0.33	0.01
RUP	0.82		
NFC*RUP	0.15	0.05	0.94

SED = 2.4



# NFC x Protein: Milk Fat Yield



3.35 3.36 3.40 3.67 3.45 3.47

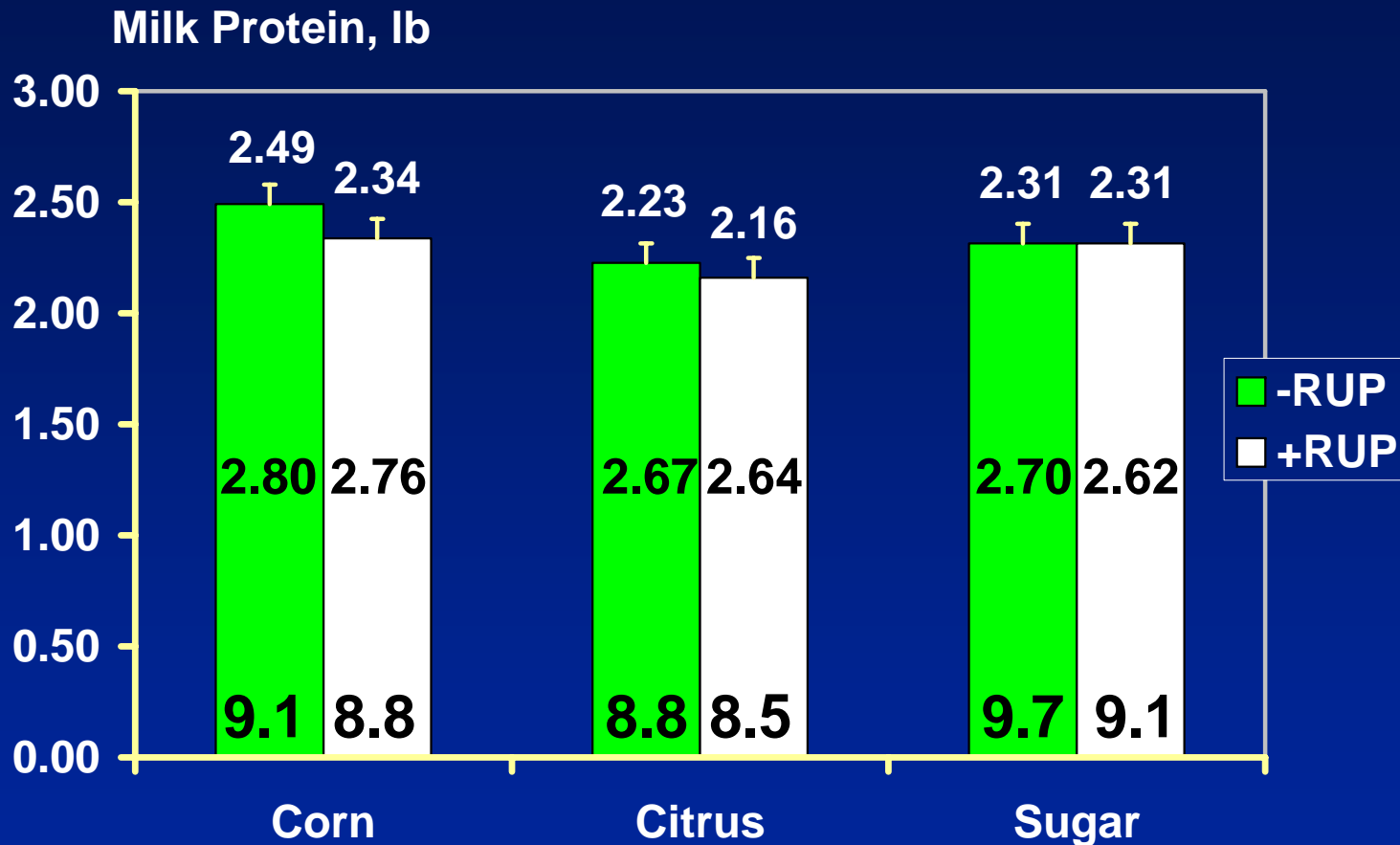
■ -RUP  
■ +RUP

Larson and Hall, 2003

SED = 0.13

	Main	ST vs SU+SF	SU vs SF
NFC	0.26	0.51	0.13
RUP	0.69		
NFC*RUP	0.13	0.07	0.36

# NFC x Protein: Milk Protein Yield

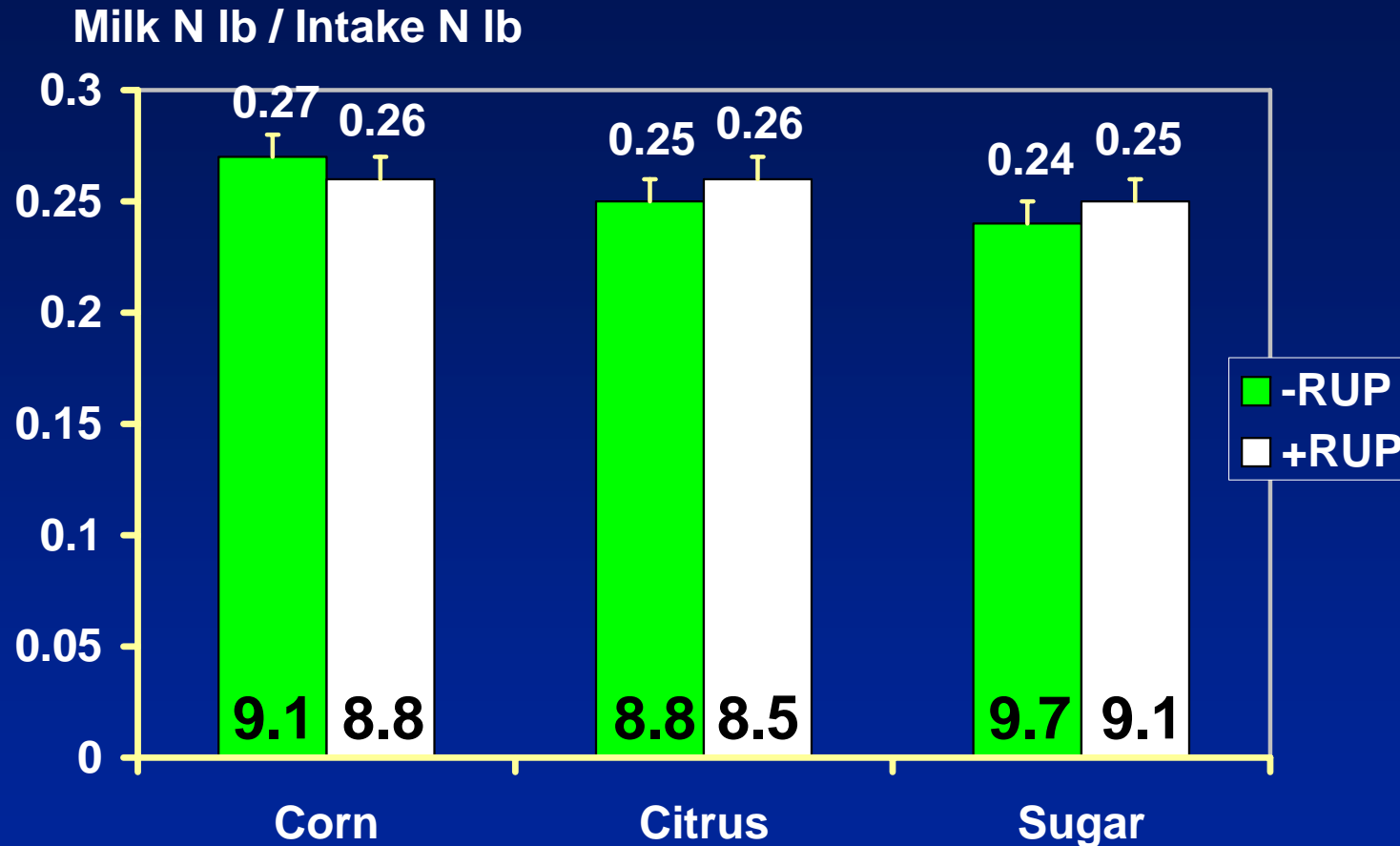


Larson and Hall, 2003

SED = 0.09

	Main	ST vs SU+SF	SU vs SF
NFC	<.01	0.01	0.06
RUP	0.18		
NFC*RUP	0.49	0.28	0.60

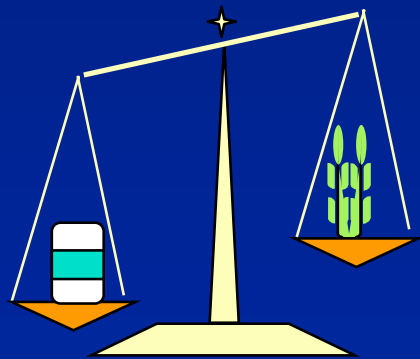
# NFC x Protein: Milk N / Intake N

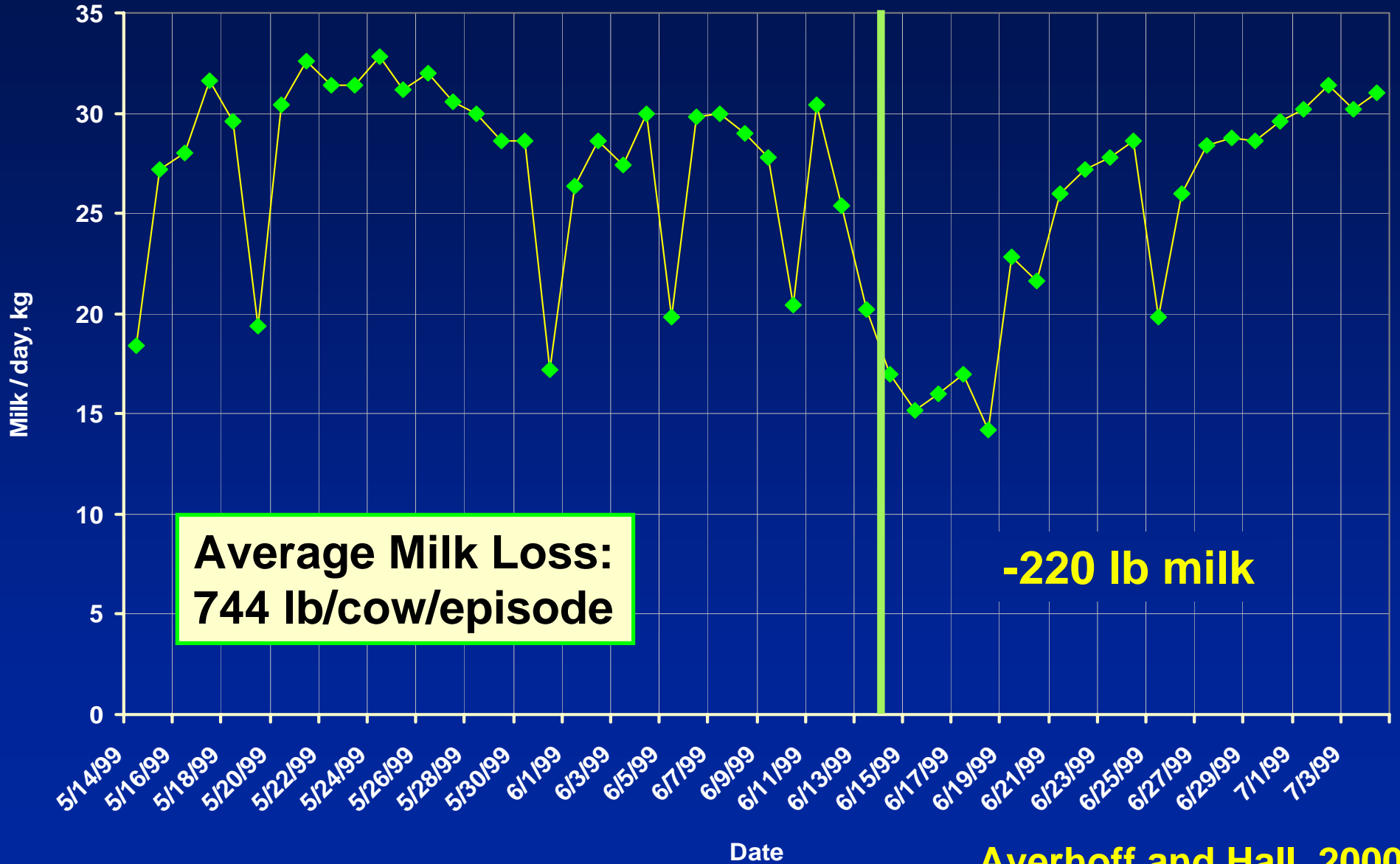


	Main	ST vs SU+SF	SU vs SF
NFC	0.06	0.03	0.29
RUP	0.76		
NFC*RUP	0.40	0.18	0.83

SED = 0.01

**Obviously, we  
should feed more  
starch.**



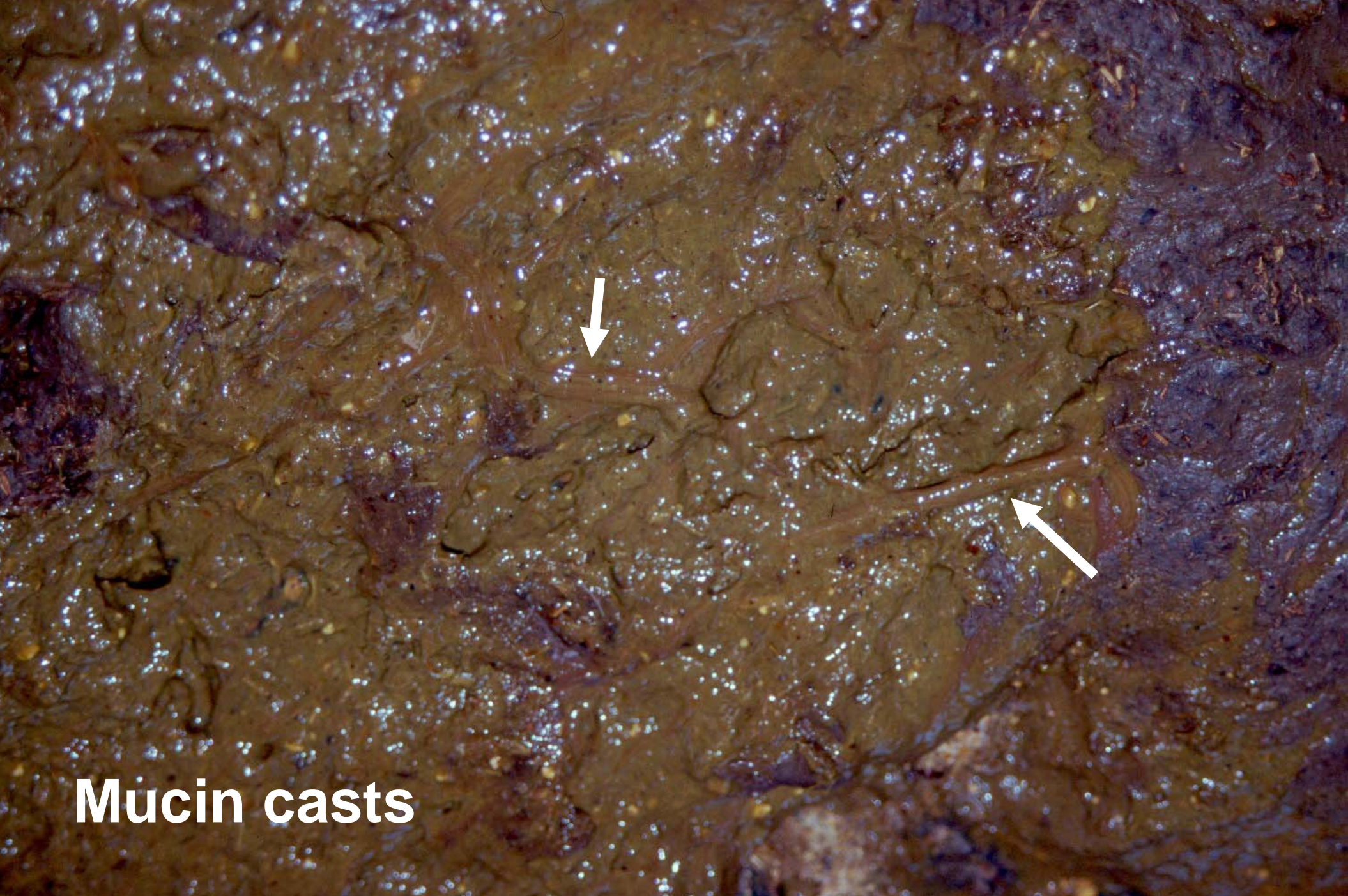






**Diarrhea**

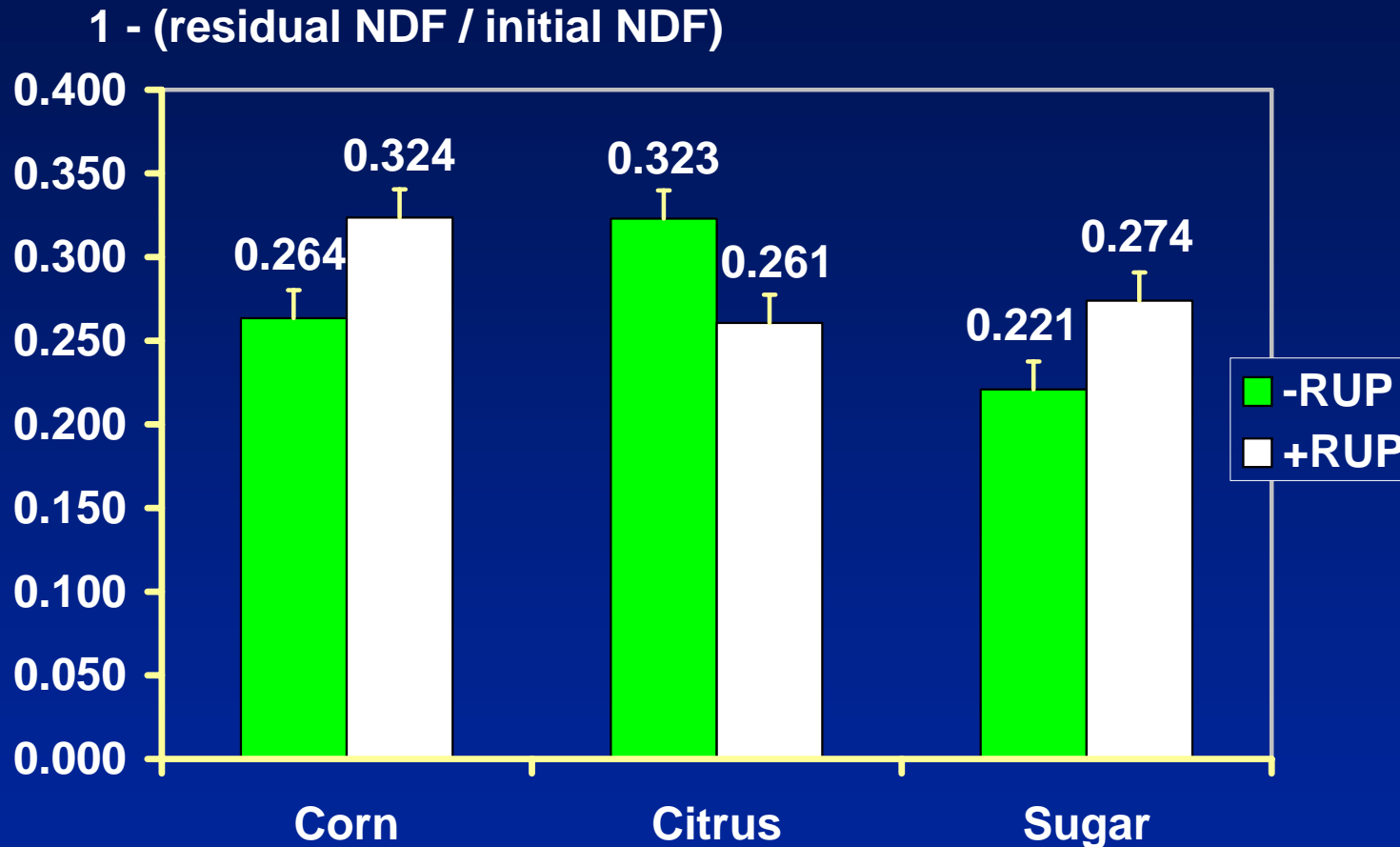




**Mucin casts**



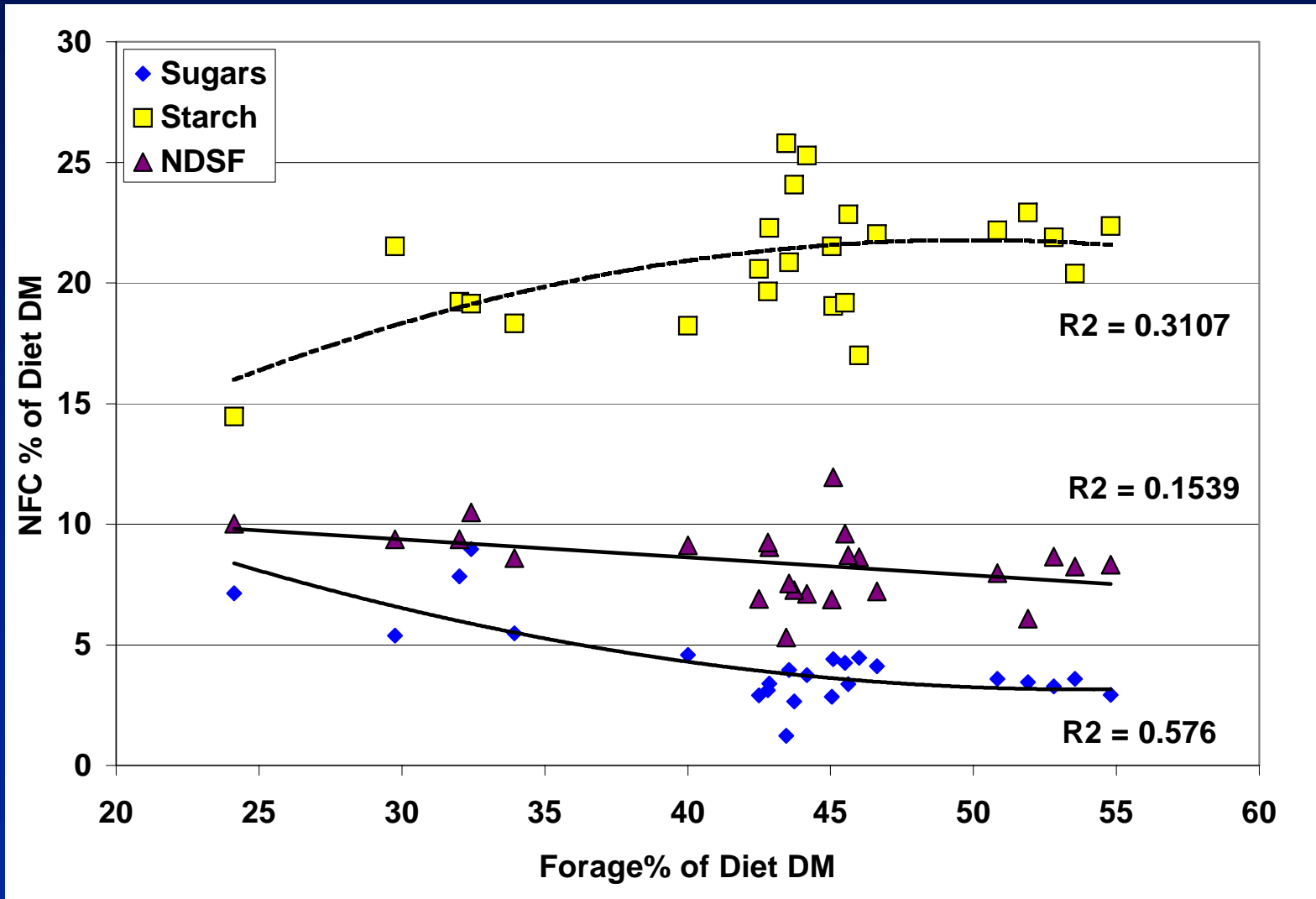
# NFC x Protein: 30 h Fiber Digestion



	Main	ST vs SU+SF	SU vs SF
NFC	<.01	0.04	<.01
RUP	0.07		
NFC*RUP	<.01	<.01	<.01

SED = 0.017

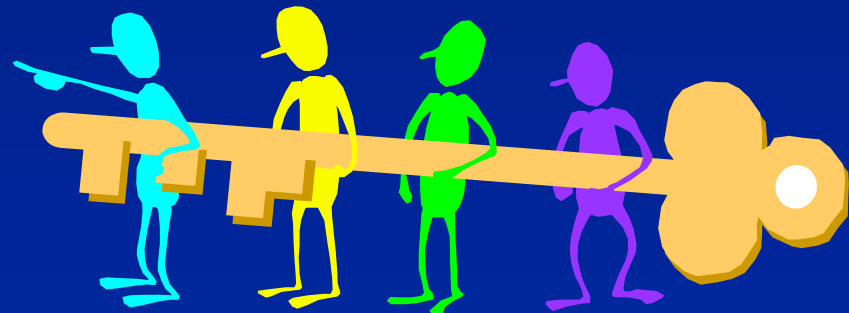
# NFC vs. Forage (% of ration DM)



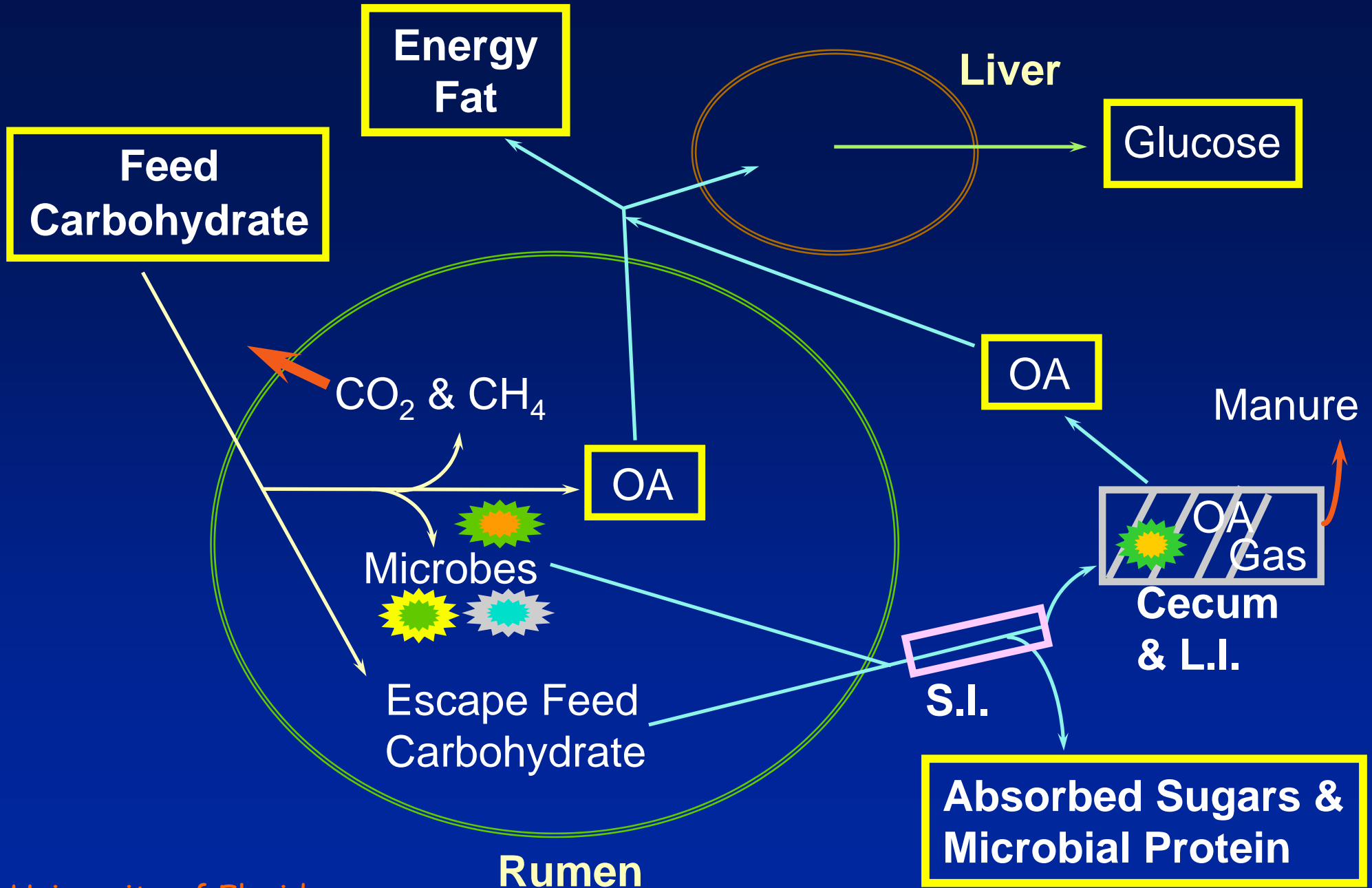
# NFC & Animal Performance

## Where we are headed:

- Ways to analyze: what kind of carbohydrates matter?
- Understand how carbohydrates affect dairy production, health, and feed efficiency.
- Develop feeding guidelines based on things we can measure.











5731

6904





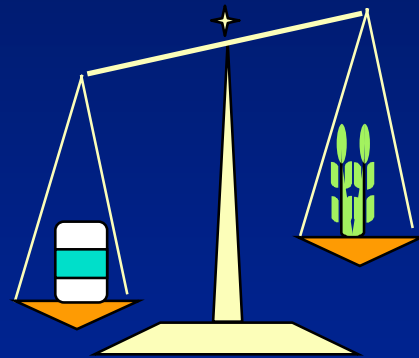
**Foamy manure with ground grain**







- ★ **Net Energy and TDN are not fixed values.**
  - ★ **They change with changing rations.**



- ★ **They decrease in unbalanced rations & when digestive processes are disturbed.**



# Effect of NFC on NDF Digestibility, %

<u>RDP %</u> <u>of BW</u>	<u>Sugars</u>				
	<u>Ctrl</u>	<u>Starch</u>	<u>Glc</u>	<u>Fru</u>	<u>Suc</u>
0.031	60.0	52.5	45.1	52.0	41.9
0.122	59.3	61.2	68.1	71.3	62.3

At the lower level of RDP, no difference among supplements.

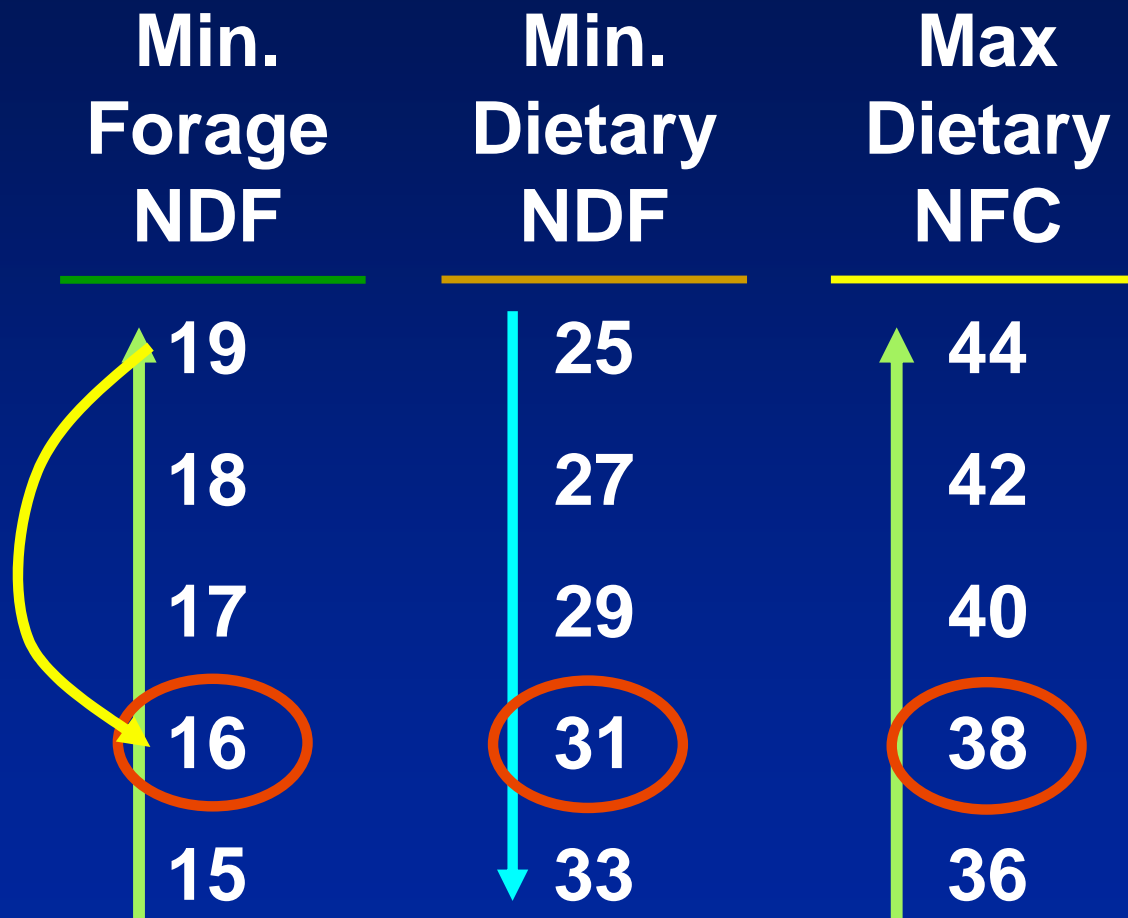
At greater RDP, starch differed from sugar ( $P=0.05$ ) and mono- differed from disaccharides ( $P=0.03$ ).

# Formulating Rations: NFC and Forage

- ✦ What balance among NFC and fiber?
- ✦ Collected rations
  - Healthy, productive cows
  - Feed analyses
  - Cows ration ~ paper ration
  - Estimated NFC fractions



# 2001 Dairy NRC NFC Recommendations



- ☀ Slug feeding
- ☀ Empty bunks
- ☀ Cows sorting
- ☀ Heat stress

Think

“Risk Man



# Eaten Does Not Mean Digested

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Poorly  
chopped/processed  
corn silage

Coarse corn meal



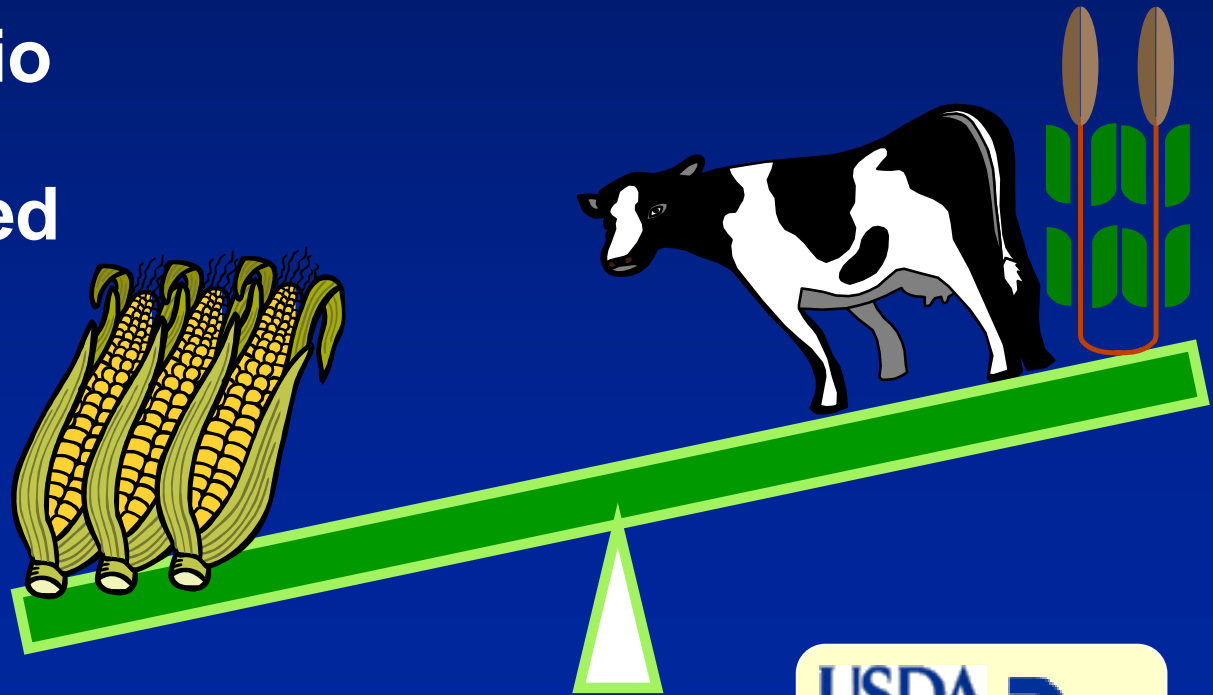
Henry, 1



# Carbohydrates and Problems

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- **NFC: Too much / wrong kind**
- **Feeding grain in large meals**
- **Forage:grain ratio**
- **Cows sorting feed**



# Things To Consider

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- ✦ NFC & effective NDF need to be looked at together.
- ✦ Forages will vary in NFC & effective NDF.
- ✦ Supplements must complement the forage.
- ✦ Feed for healthy, productive cows.
- ✦ We have more to learn.





# 3NFC x 2RUP: Starch, Sugar, Sol.Fiber

38 cows, 6 cannulated, 82±19 DIM; Inc. Latin Square

Corn Silage	26.0%
Sorghum Silage	12.0%
Ctsd hulls	3.9%
Whole ctsd	13.5%

48% SBM 5.8-16.6%

Soy Plus 0-10.9%

Corn meal 1.9-20.7%

Citrus pulp 3.8-20.7%

Molasses 0-7.1%

Sucrose 0-3.3%

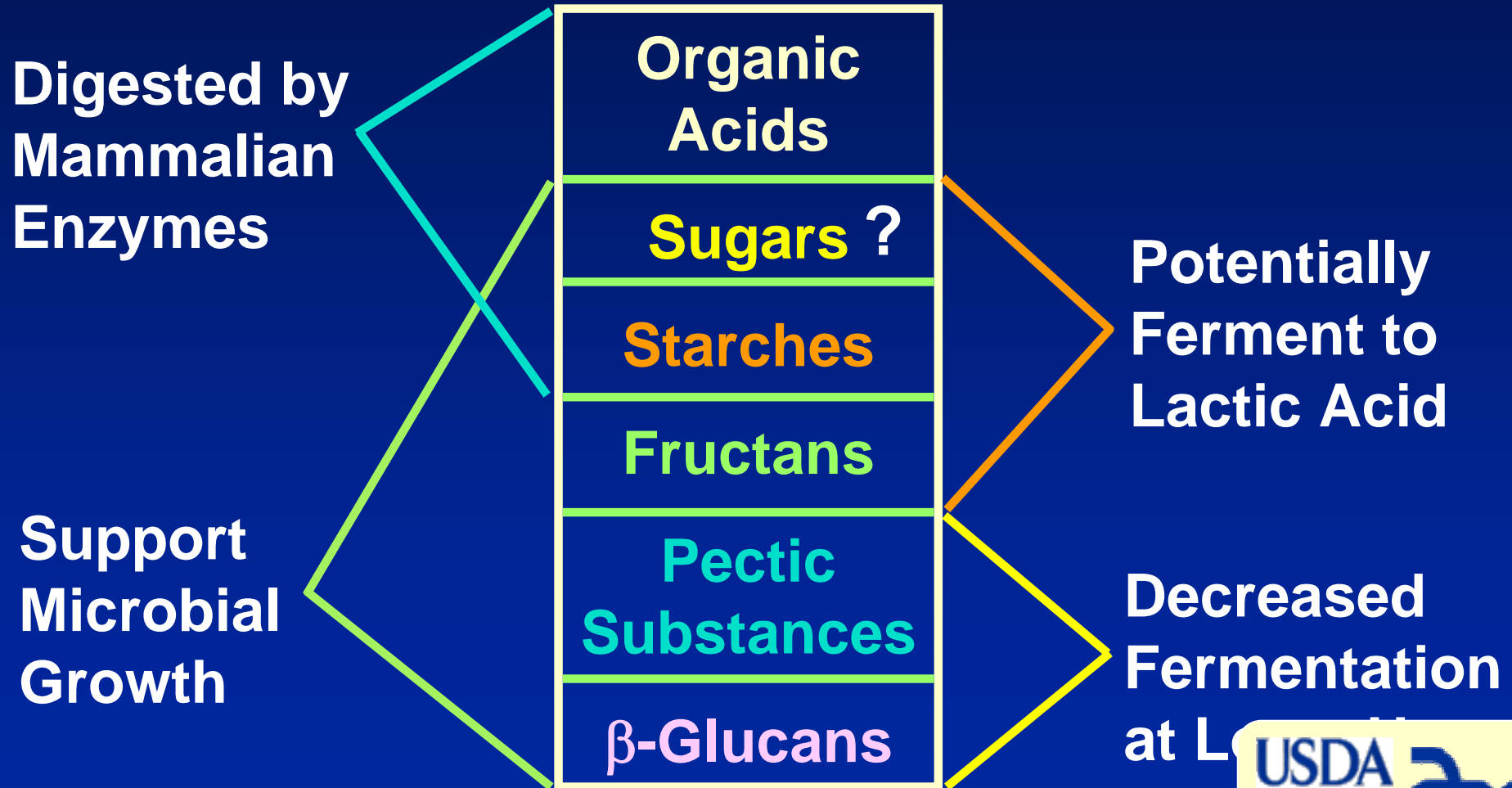
Minerals 4.9-5.5%

	<u>ST</u>	<u>SF</u>	<u>SU</u>
CP	15.9	16.2	16.8
NDF	39.4	40.6	38.3
NFC	29.6	28.2	30.2
Starch	23.5	15.0	13.2
Sugar	4.2	7.8	13.3
NDSF	1.9	5.4	3.6

MUN > 12 mg/dl

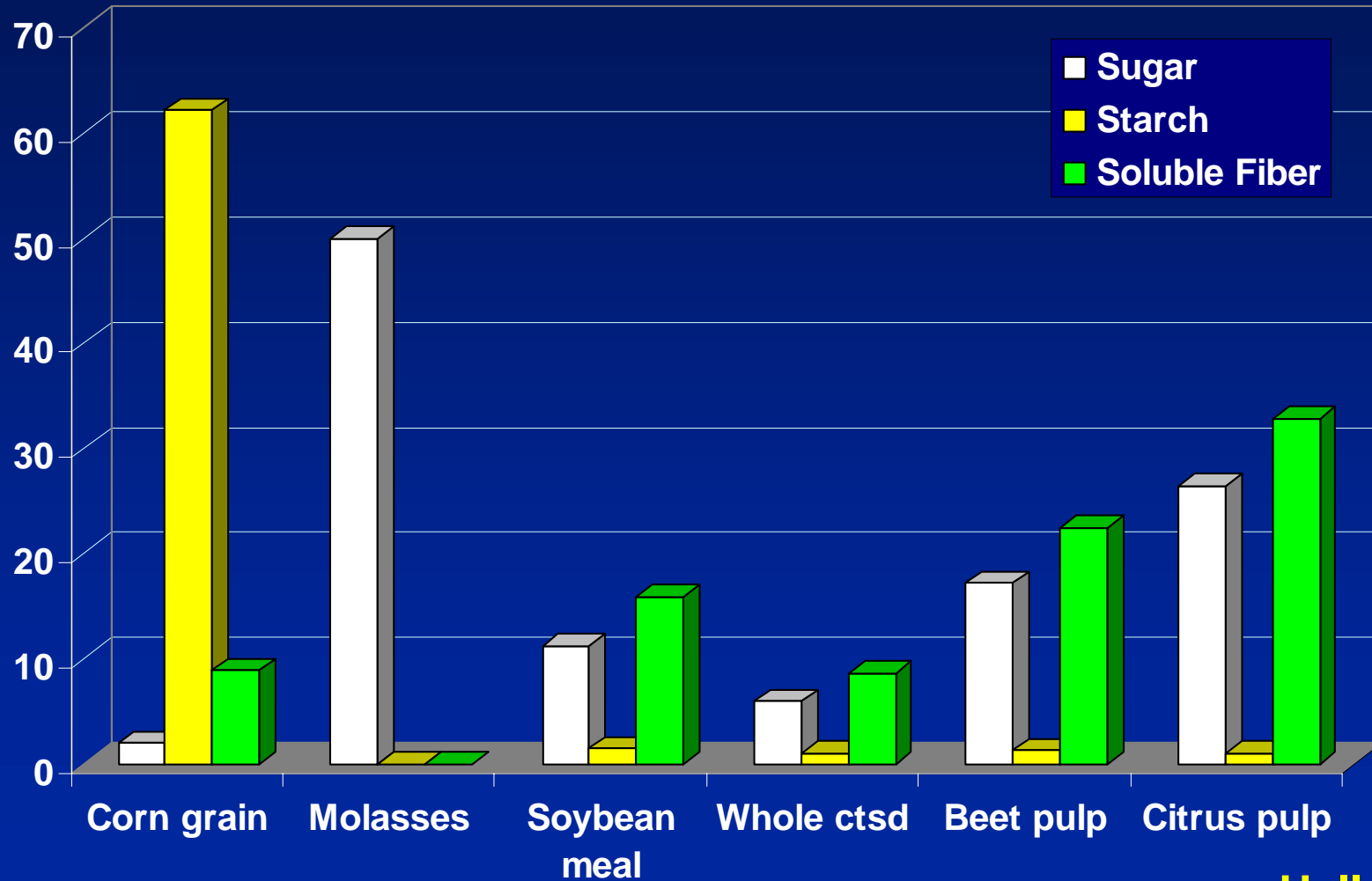
Larson and Hall, 2003

# NFC Digestion Characteristics



# Supplements: NFC Composition

% of Dry Matter



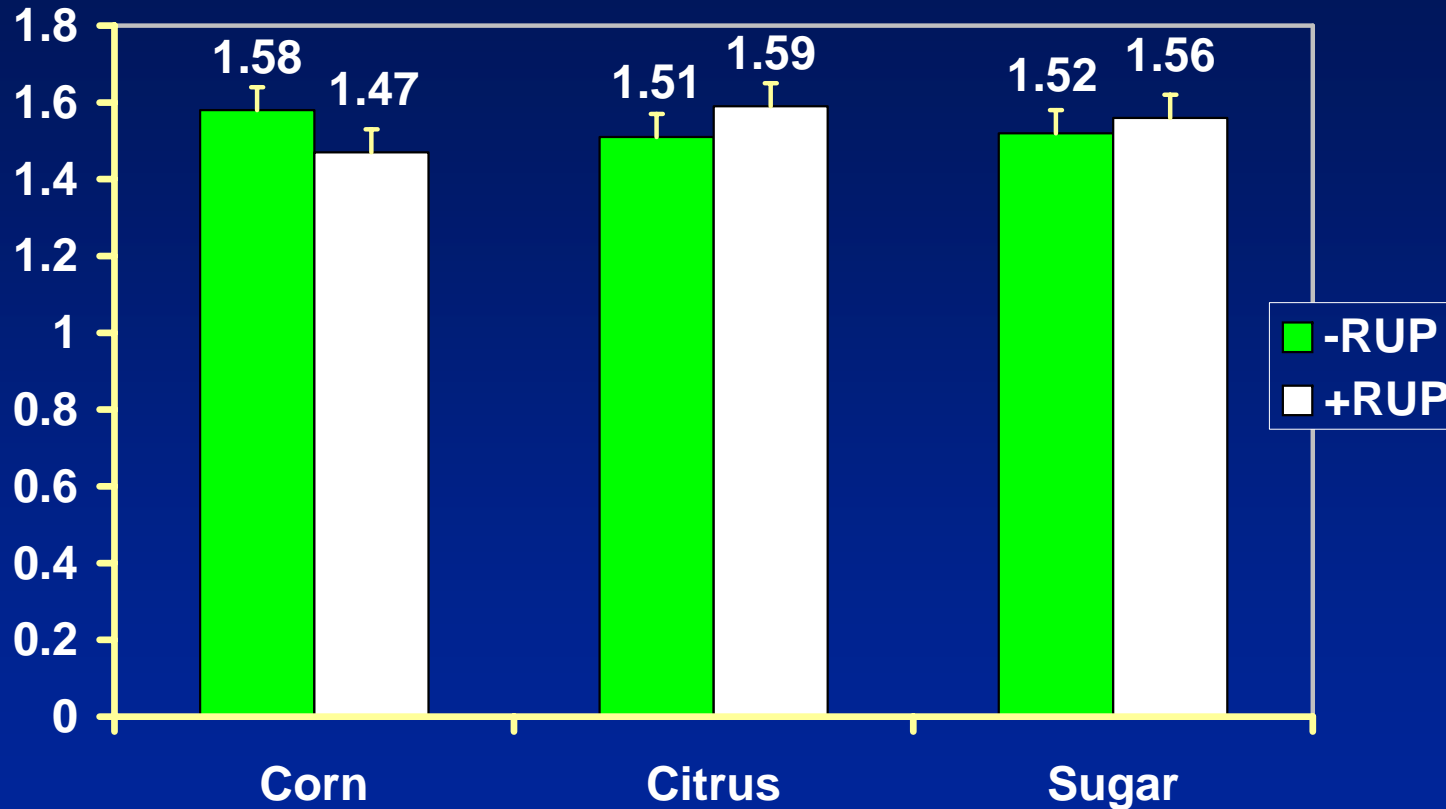
Hall, 2000

# Non-NDF Carbohydrates

<u>Ferm. Rates</u>	<u>VFA</u>		<u>NDSC Analysis</u>
30+%/h	Propionic Butyric	Organic Acids Mono- & Oligosacc.	Organic Acids Sugars
4 - 30%/h	Propionic	Starches	Starch
20 - 40%/h*	Acetic	Fructans Pectic Substances $\beta$ -Glucans	ND-Soluble Fiber

# NFC x RUP: 3.5%F-P-Corr. Milk / DM Intake

3.5% FPCM lb/ DM Intake lb



P-values

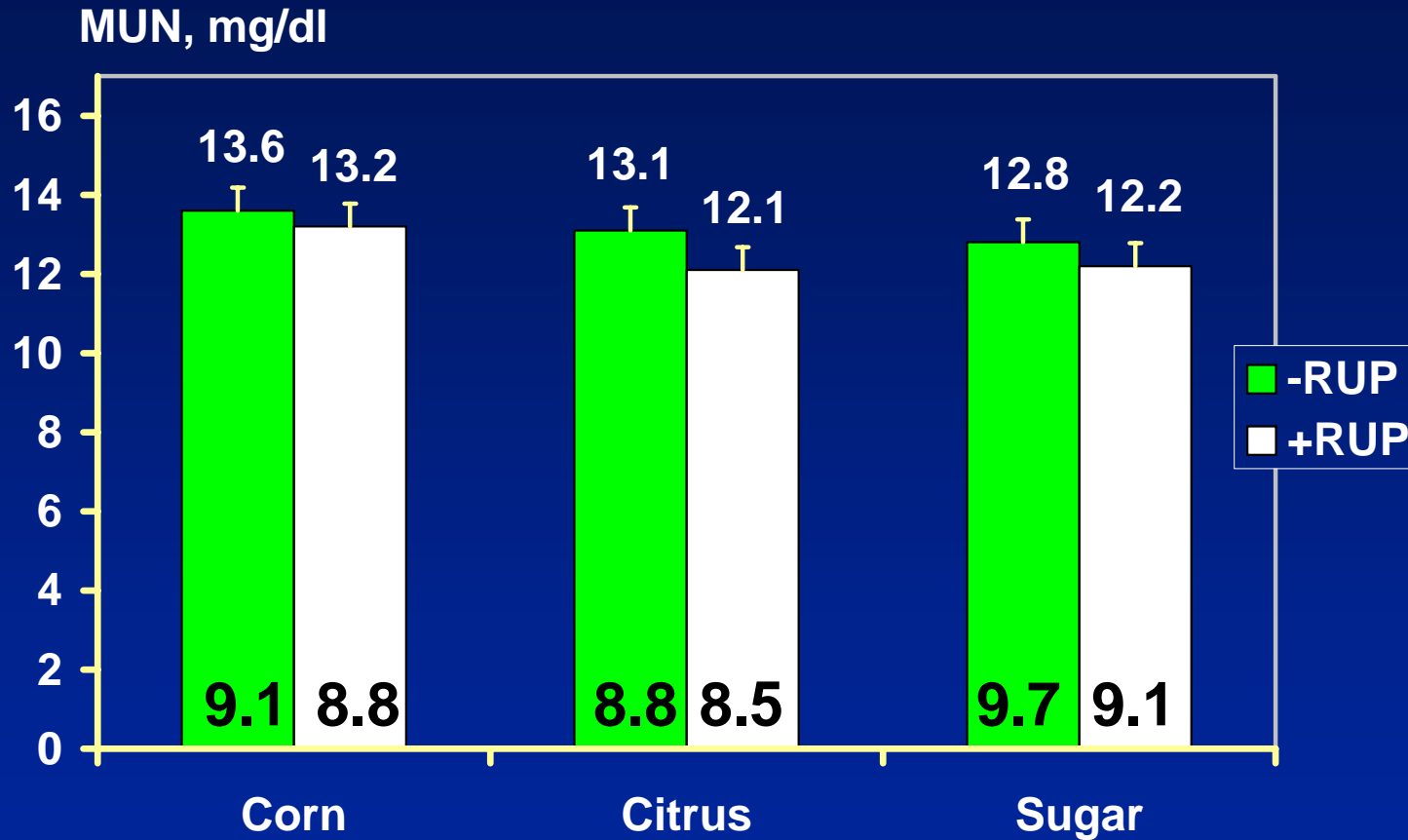
	Main	ST vs SU+SF	SU vs SF
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NFC	0.72	0.46	0.78
RUP	0.90		
NFC*RUP	0.03	0.01	0.54

Larson and Hall, 2003

SED = 0.06

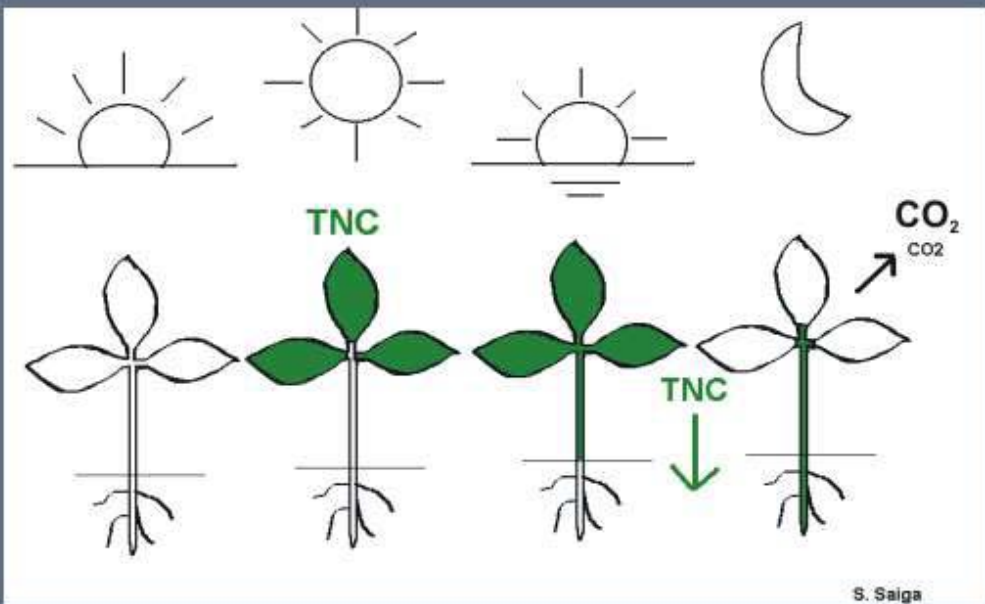
# NFC x RUP: Milk Urea Nitrogen



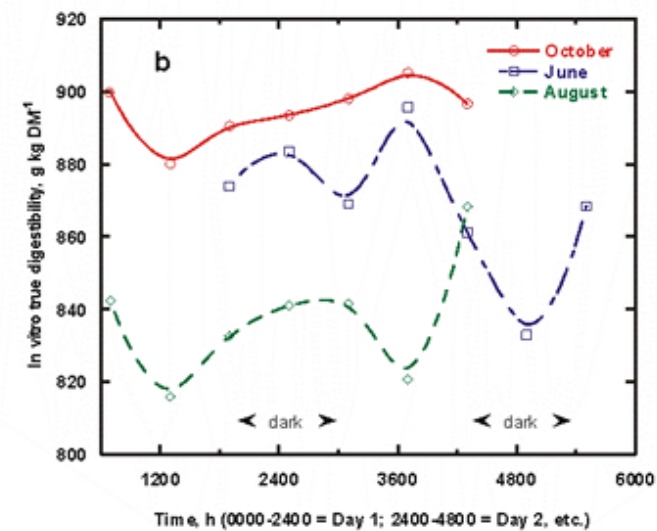
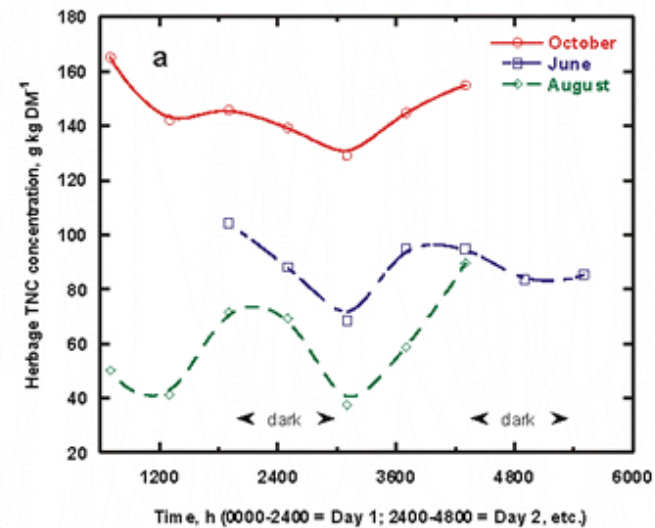
## P-values

	Main	ST vs SU+SF	SU vs SF
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NFC	0.05	0.02	0.88
RUP	0.07		
NFC*RUP	0.66	0.48	0.58

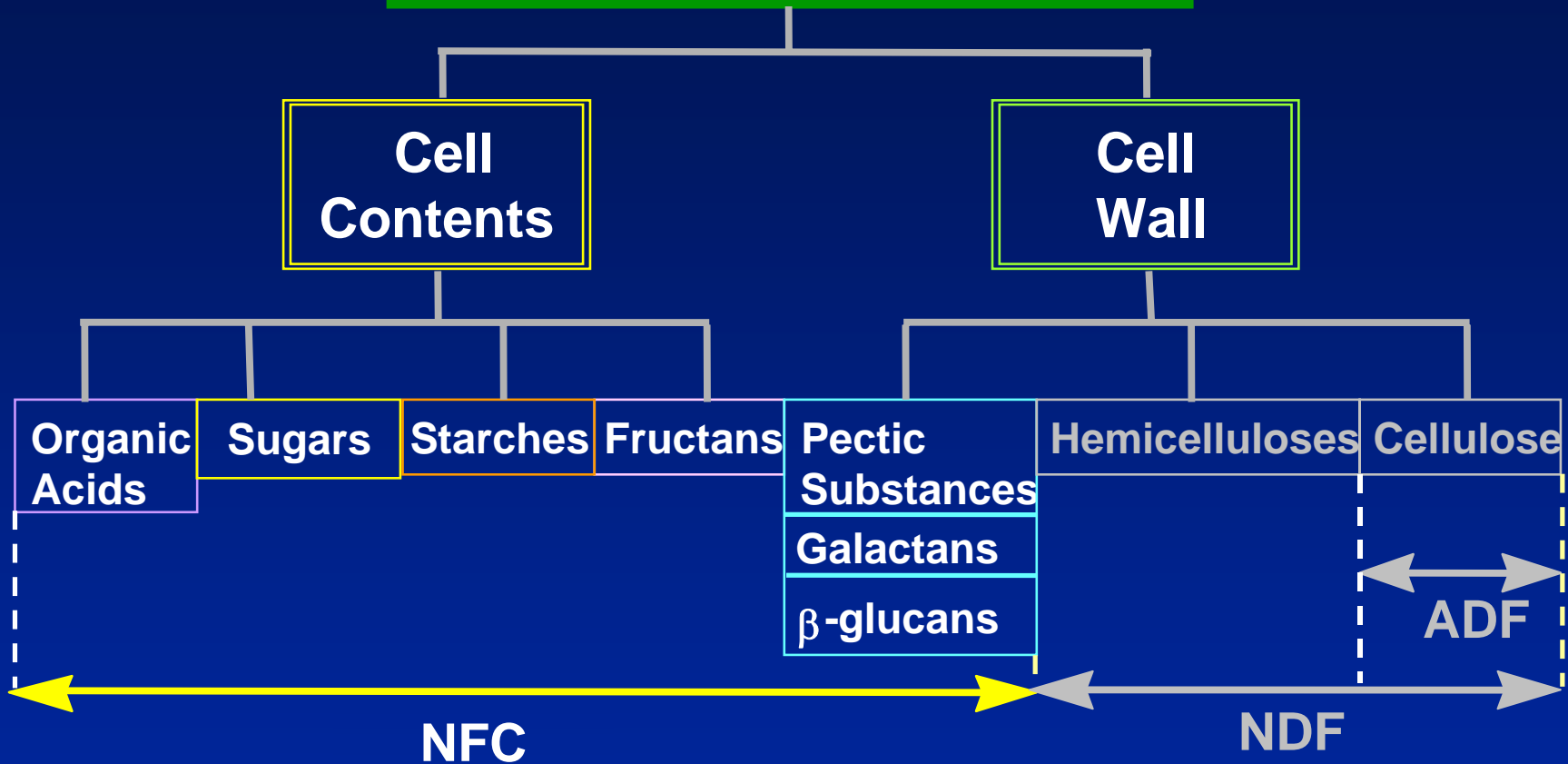


	Light	Dark
TNC in Leaves, g/kg	93a	58b
TNC in Pseudostems, g/kg	146a	150a
Leaf mass/Pseudostem mass, g/g	3.3a	2.5b





# Plant Carbohydrates



**Neutral Detergent Fiber (NDF)**

**$NFC = 100 - \text{Crude Protein} - NDF - \text{Crude Fat} - \text{Ash}$**

# Effective Fiber

