Strategies to optimize the use of starch in dairy diets

Luiz F. Ferraretto, Ph.D., PAS
Department of Animal Sciences
University of Florida

UF IFAS
UNIVERSITY of FLORIDA

Is starch a required nutrient?

- Dairy NRC (2001)
  - No. Commercial laboratories did not perform starch assays.
- 28th ADSA Discovery Conference - Starch
  - No, but it is very important!
- Why are we discussing starch today?

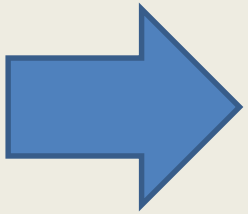
Cereal grain types

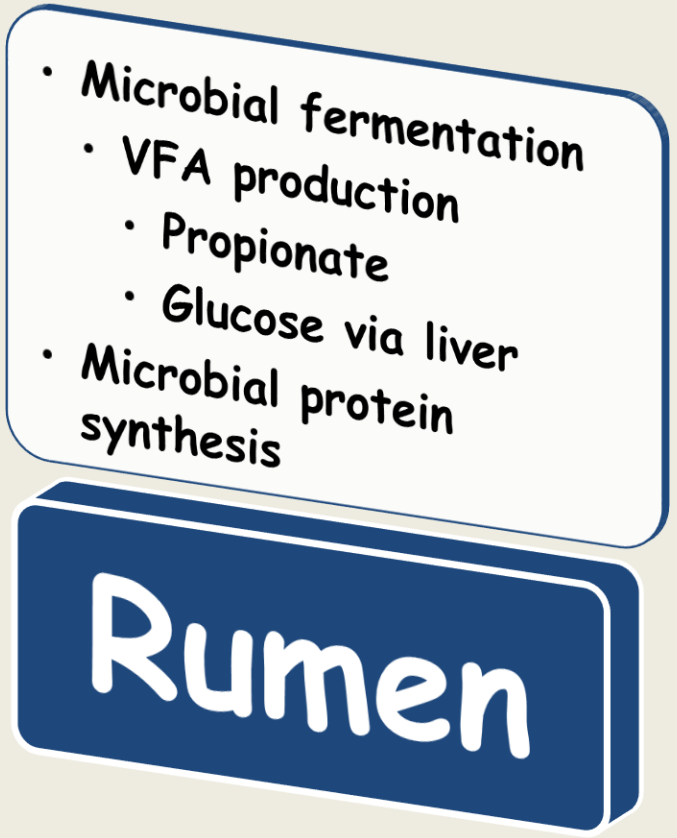
Cereal grains	Starch (% of DM)	Effective Ruminal Disappearance, % of starch	Ruminal Starch Digestibility, % of starch intake	Total Tract Starch Digestibility, % of starch intake
Barley	57.8	50.3 – 91.3	70.8 (46.1 – 91.0)	94.3 (76.1 – 99.5)
Corn	70.4	33.8 – 82.8	53.2 (9.7 – 80.2)	91.7 (69.5 – 99.4)
Oats	44.6	91.8	NA	NA
Sorghum	72.3	54.1 – 79.8	48.1	83.5
Wheat	67.6	66.9 – 93.9	78.9 (59.1 – 95.1)	93.9 (86.3 – 99.1)

Firkins et al., 2001; Offner et al., 2003; Ferraretto et al., 2013

Starch Digestion in Ruminants

Starch intake



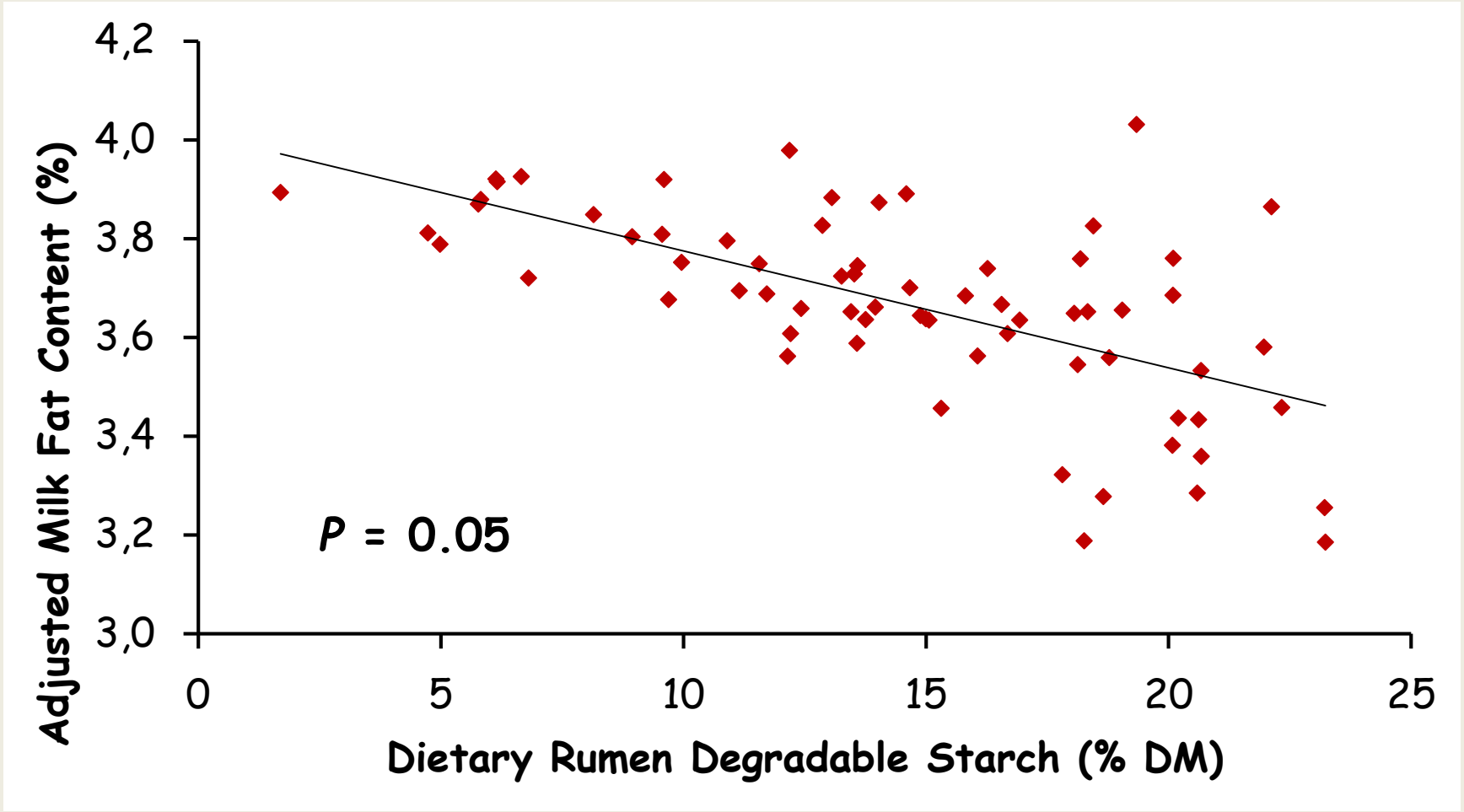


Adapted from slide provided by Dr. Shane Fredin

Dietary Rumen Degradable Starch

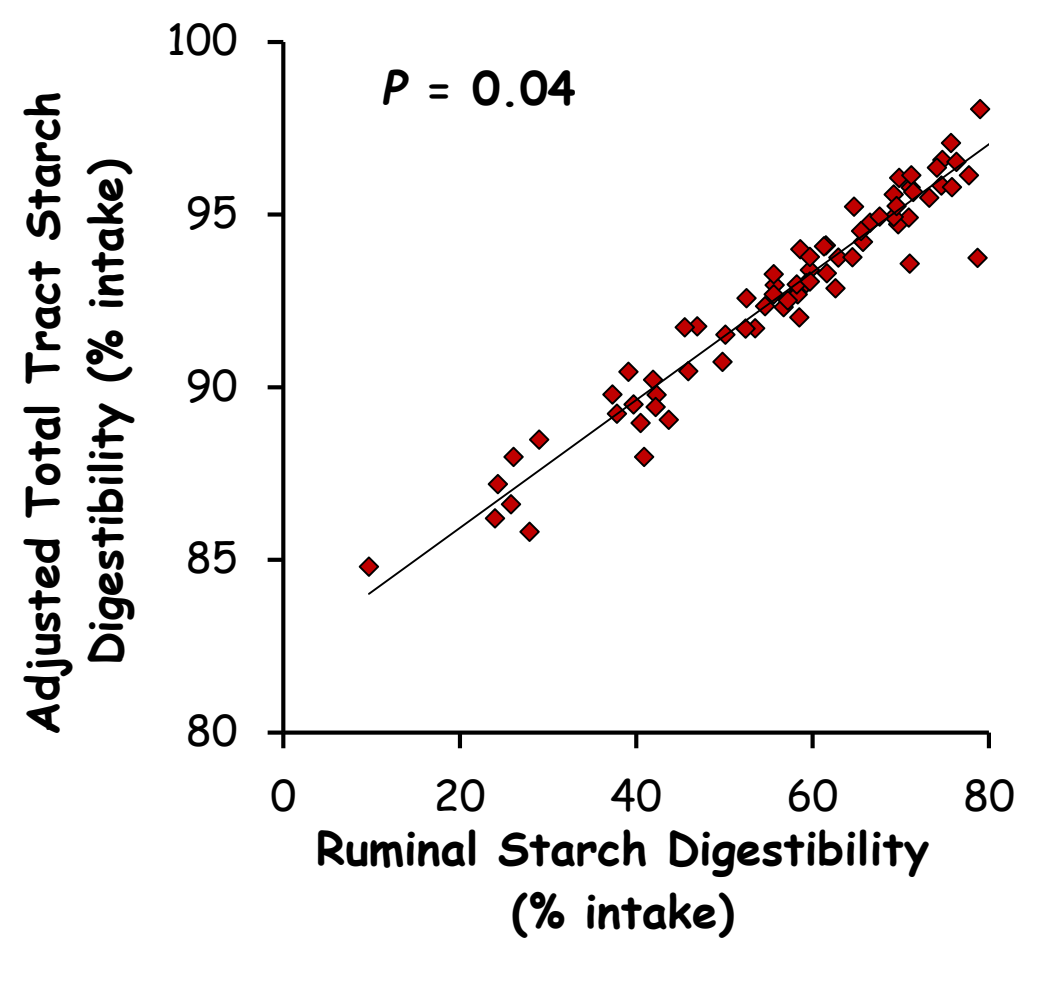
Ferraretto et al., 2013

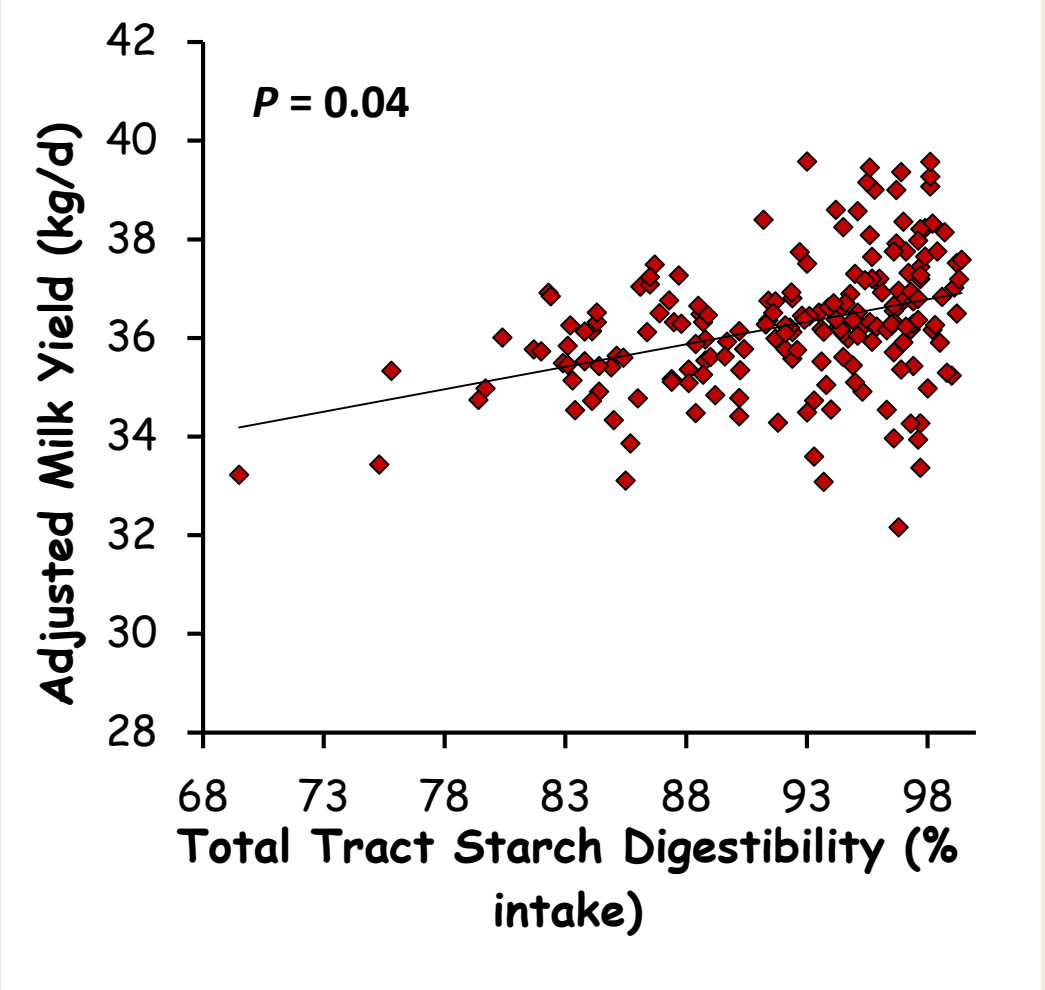
Dietary Rumen Degradable Starch



Ferraretto et al., 2013

Starch digestibility and milk yield



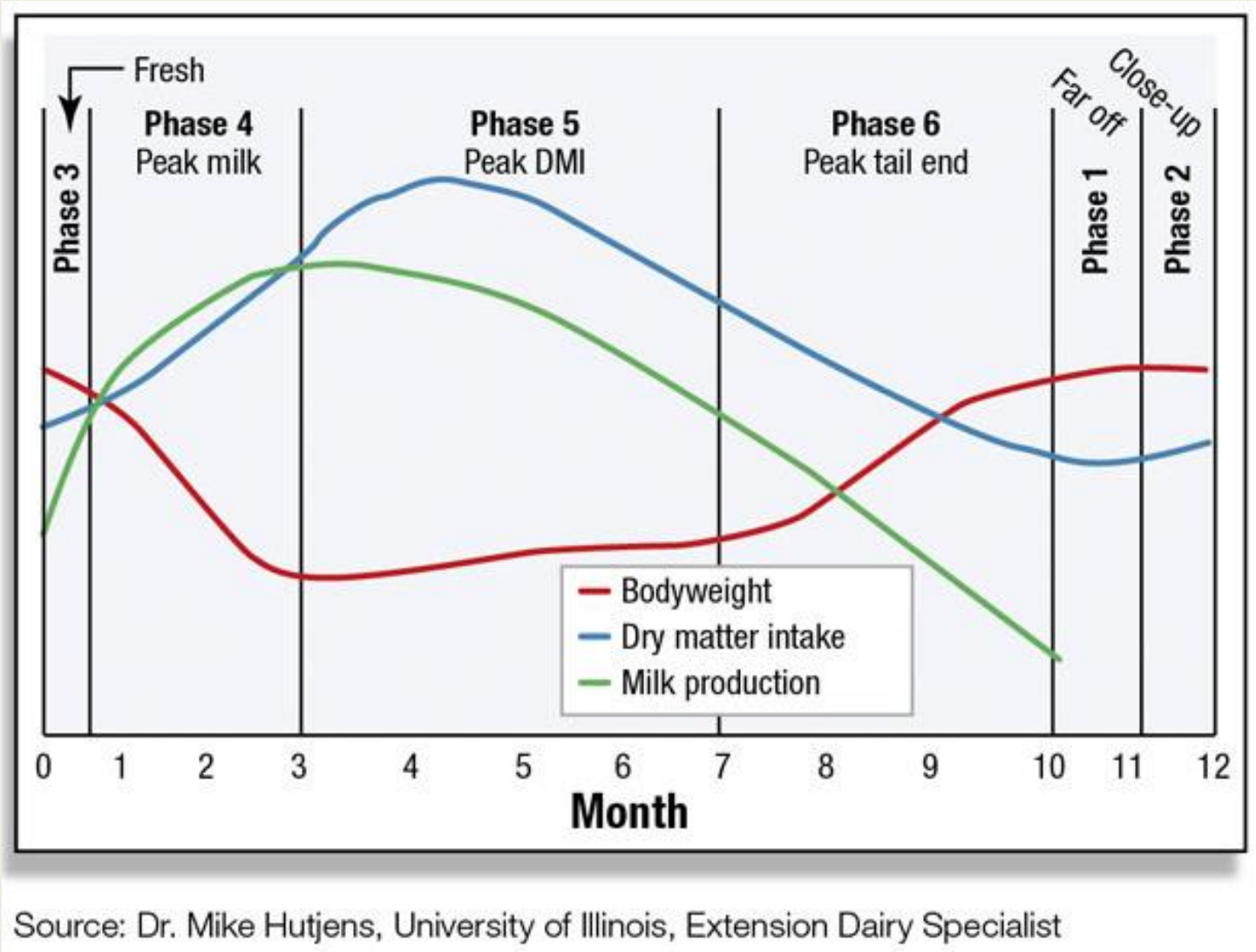


Ferraretto et al., 2013

Strategies to optimize total amount of starch digested in the rumen

- Dietary Starch
  - It is dependent of stage of lactation
  - Reduction in starch may impair performance
  - Excessive starch may cause acidosis and milk fat depression
- Improve starch digestibility

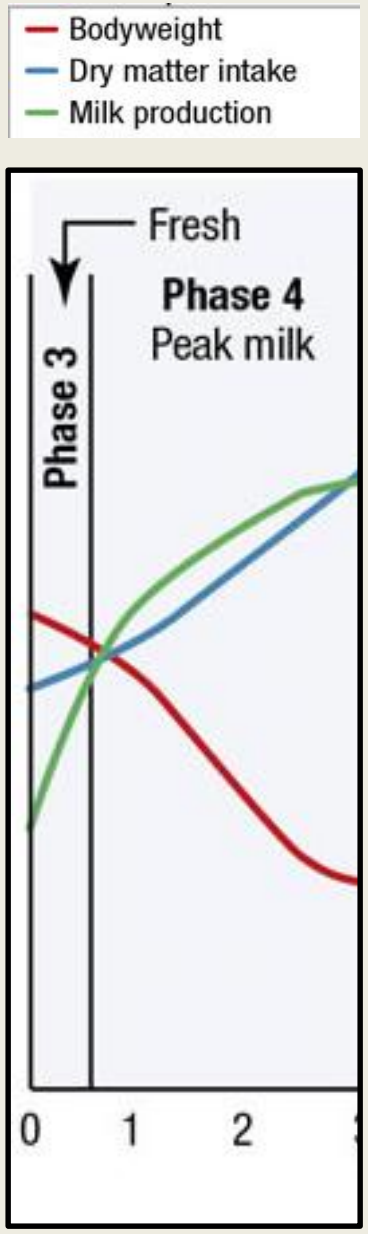
From an energy perspective…



Source: Dr. Mike Hutjens, University of Illinois, Extension Dairy Specialist

…feeding cows across lactation is challenging.

Early lactation



- Energy directed towards milk, total intake is limited
  - If energy requirements not met through diet formulation, cows mobilize body reserves
- At peak, still high-energy demand
  - But cows can meet their energy requirements by adjusting their consumption
  - Unless if limited by gut fill

Feeding starch to early lactating cows

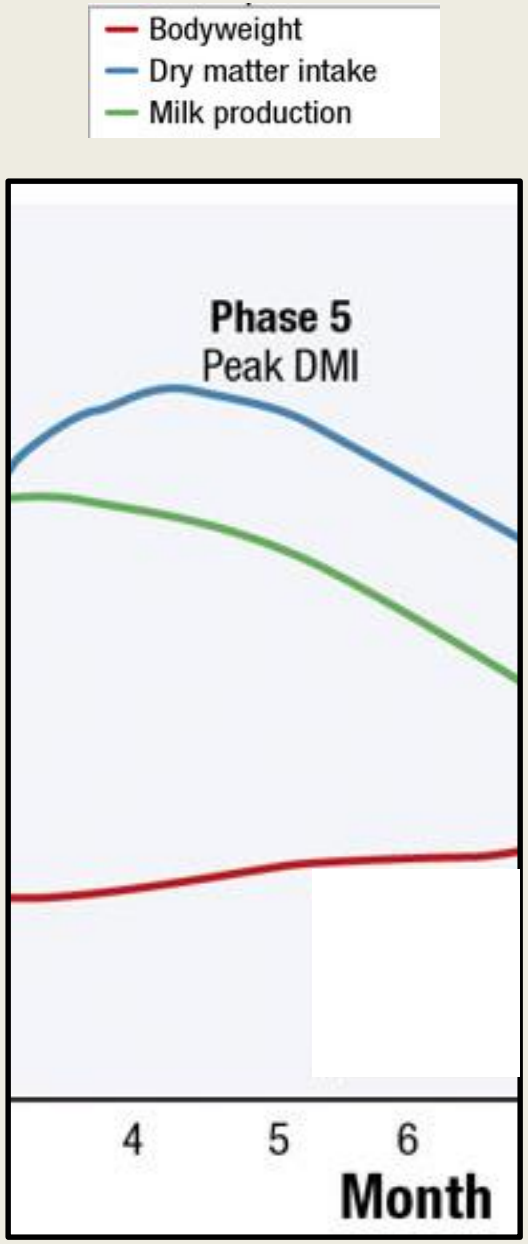
- Potential benefits of adding more starch
  - Greater energy density in the diet with corresponding greater energy intake
  - Reduced fat mobilization and metabolic disorders

- Potential negative effects of adding more starch
  - Acidosis
  - Displaced abomasum
  - Reduced intake (based on hepatic oxidation theory)

Feeding starch to early lactating cows

- **Results are not consistent**
  - Perhaps difference between pre- and post-partum levels of starch more important than starch concentration itself (not properly tested)
  - Relationship with other diet factors (starch sources, NDF physical and chemical characteristics) not studied (but make sure you add some peNDF)
- **Starting point**
  - Formulate diets within 10%-units of the starch provided in the close-up diet
  - Use a gradual increase approach

Mid lactation



- After peak, milk production declines gradually
  - Cows can adjust consumption
  - Unless if limited by gut fill
  - Focus on lower cost feedstuffs?
  - Increase forage content?

Effect of dietary starch on mid-lactation

Parameter	Effect	n	Magnitude
Milk (kg/d)	↑	320	0.09
Milk fat (%)	↓	317	0.02
Milk protein (%)	↑	315	0.01
MUN (mg/dL)	↓	208	0.09

Magnitude – expected response for each % unit increase in dietary starch

Ferraretto et al., 2013

Non-forage fiber sources

	DMI, kg/d	Milk production, kg/d	SCM, kg/d	kg milk/kg DMI	kg SCM/kg DMI
UW I	1.09	1.02	1.04	0.93	0.95
UW II	1.07	0.96	0.96	0.88	0.89
UW III	1.07	0.99	1.02	0.93	0.96
UW IV	0.99	0.96	0.98	0.99	0.99

Data presented as reduced-starch / normal-starch diet

DMI – dry matter intake, SCM – solids-corrected milk

Sources: Gencoglu et al., 2010; Ferraretto et al., 2011; Ferraretto et al., 2012; Akins et al., 2014

Estimated diet NEL (Mcal/kg of DM)

	Low starch	High starch
UW I	1.62	1.69
UW II	1.66	1.82
UW III	1.52	1.55
UW IV	1.63	1.64

Sources: Gencoglu et al., 2010; Ferraretto et al., 2011; Ferraretto et al., 2012; Akins et al., 2014

Is starch response dependent of the replacement source?

- Meta-analysis on the effects of reducing starch concentration in dairy diets
  - 223 treatments means (53 manuscripts, 4 abstracts)
  - Data from 1993 to 2014
- Partial replacement with:
  - Forages, non-forage fiber sources, sugar additives or byproducts rich in sugar
- Dietary starch of high-starch diet used as covariate

Fredin, 2015

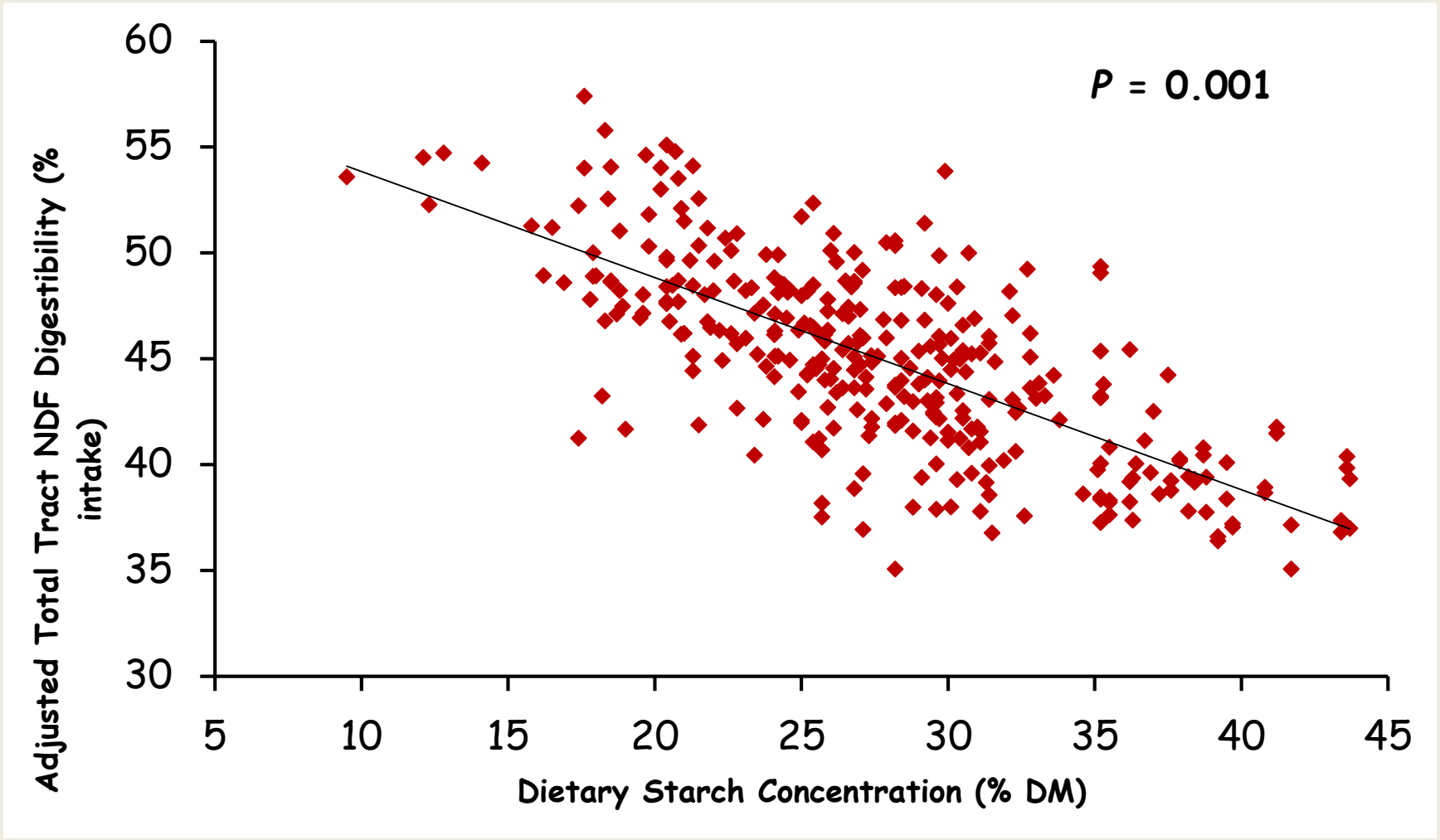
Effect of replacing starch on …

Parameter	Forage		NFFS	
	n	Effect	n	Effect
Intake (kg/d)	49	-0.12	61	-0.07
Milk (kg/d)	49	-0.32	61	-0.16
Milk fat (g/d)	49	-8.1	61	-5.4
Milk protein (g/d)	49	-11.1	61	-8.6
MUN (mg/dL)	34	0.2	41	0.1

Effect – expected response for each % unit REDUCTION in dietary starch

Fredin, 2015

Starch affects NDFD



Ferraretto et al., 2013

Starch for NDF: effects on energy

Assumptions:

- DE from NDF and starch = 4.2 Mcal/kg (NRC, 2001)
- Starch digestibility: 89 to 98% with and average of 92%
- NDF digestibility: 30 to 68% with an average of 48%
- Effect of starch on NDF digestibility is – 0.5%

Adapted from Weiss, 2014 Starch Discovery Conference (unpublished)

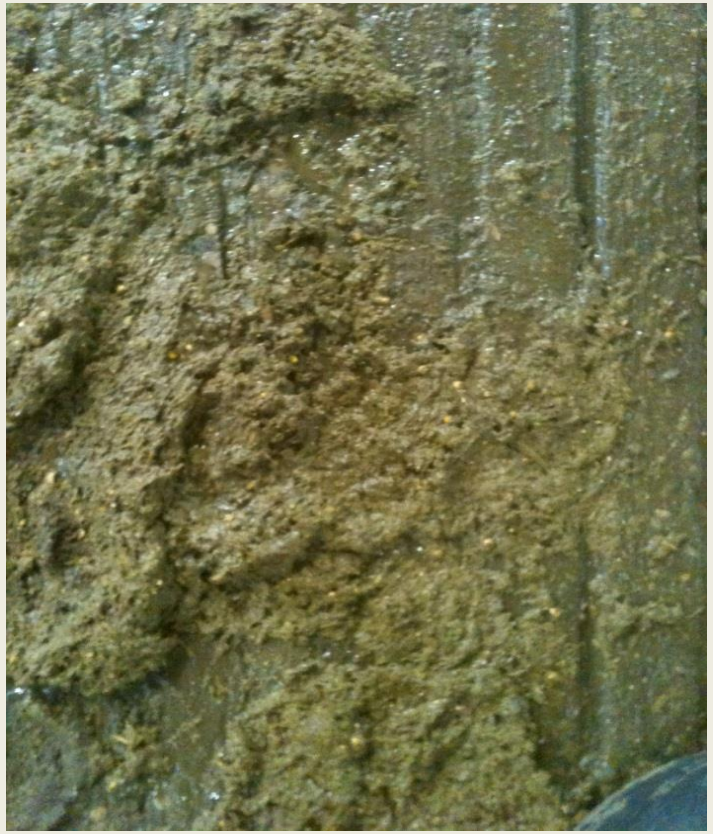
5% Substitution of starch with NDF: effect on NEL

Assumed decrease of 2.5%-units in NDF digestibility

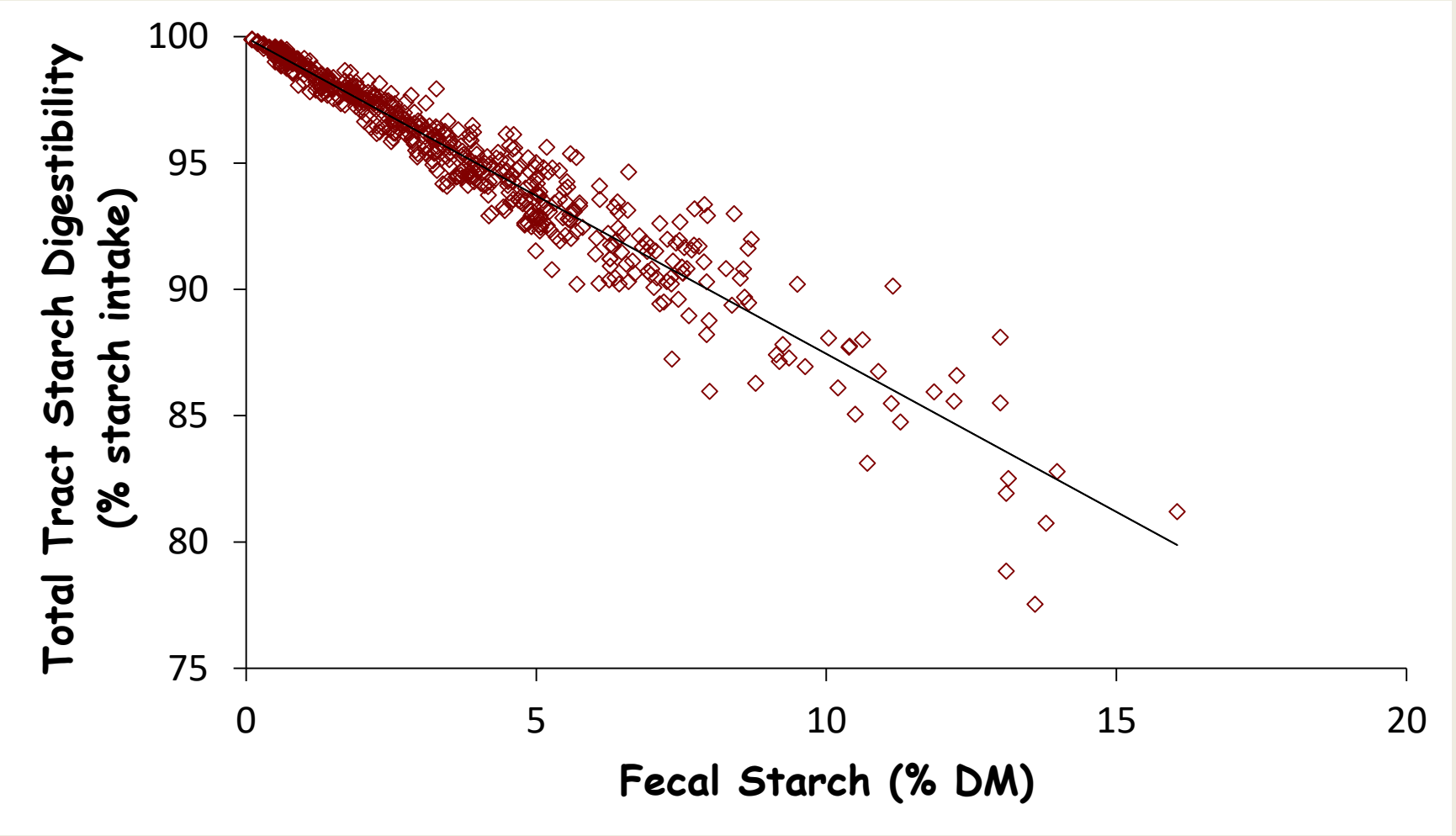
Item	Basal	+5% starch	Difference
DE, Mcal/kg	3.11	3.20	+2.9%
ME, Mcal/kg	2.69	2.79	+3.7%
NEL, Mcal/kg	1.70	1.79	+5.3%
If assuming not effect of starch on NDF digestibility (NEL)			+6.5%

Adapted from Weiss, 2014 Starch Discovery Conference (unpublished)

Fecal starch – tool to measure and manage starch digestibility on farm



Source Image: http://dairyinnovation.files.wordpress.com/2010/10/dsc_0083.jpg



$P < 0.001$

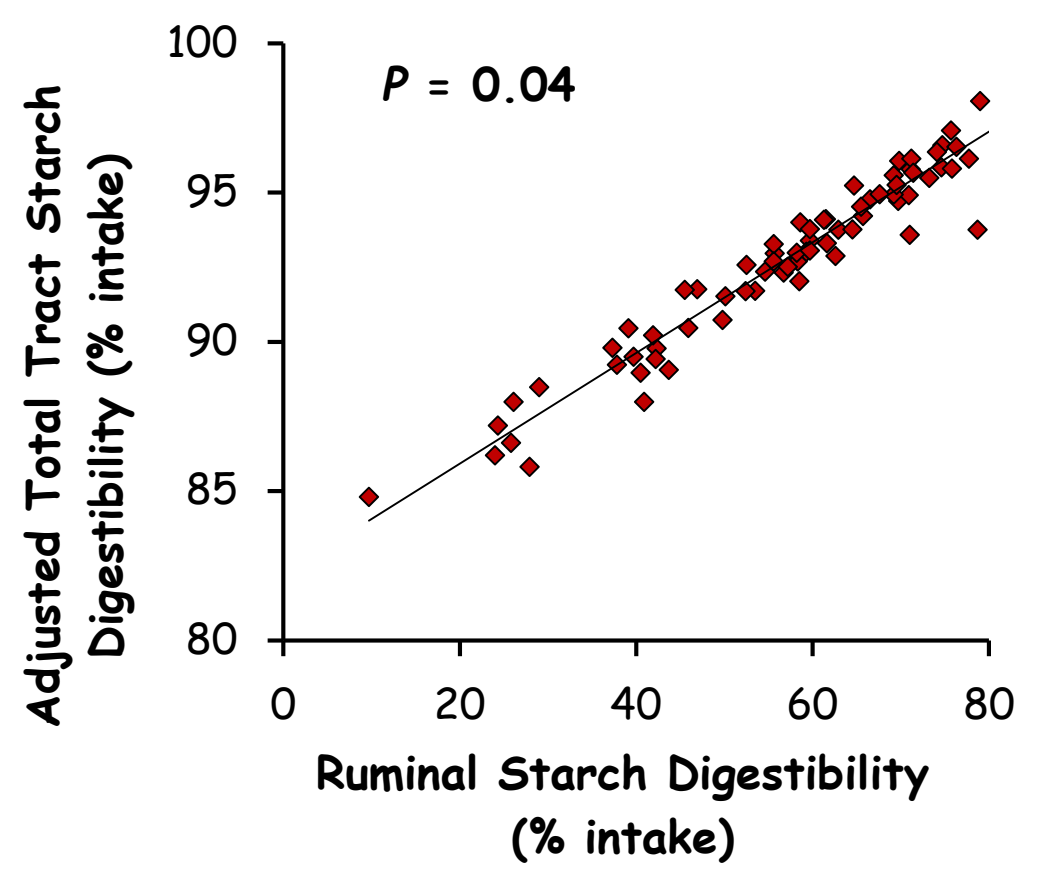
$R^2 = 0.94$

564 samples

TTSD % = 100.0% - (1.25 X fecal starch %)

Fredin et al., 2014

Site of starch digestion



- Inverse relationship
  - For each %-unit increase in TTSD, there is a 3.36% units change in RSD
  - 92, 95 and 98% TTSD may represent approximately 48, 58 and 68% RSD

TTSD – total tract starch digestibility
RSD – ruminal starch digestibility

Ferraretto et al., 2013

Starch quality indicators

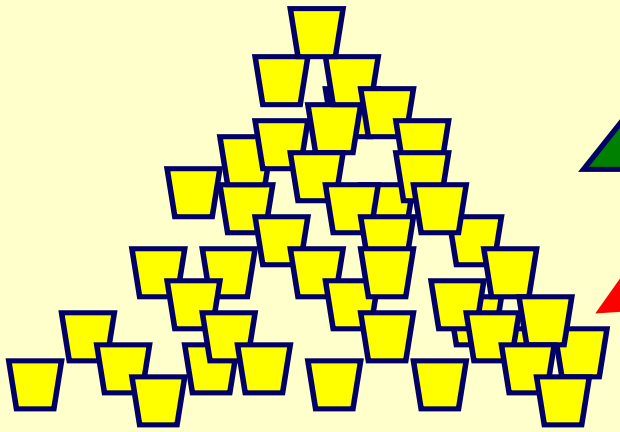
Indicator	Practical Implication
Starch (% DM)	▪ Alter energy density ▪ Impact milk yield or feed efficiency
StarchD (% starch)	
Prolamin (% DM)	
Corn silage processing score (% of starch below 4.75 mm sieve)	

Methods may vary across laboratories and may include calculation of rates of digestion.

Whole-Plant Corn Silage

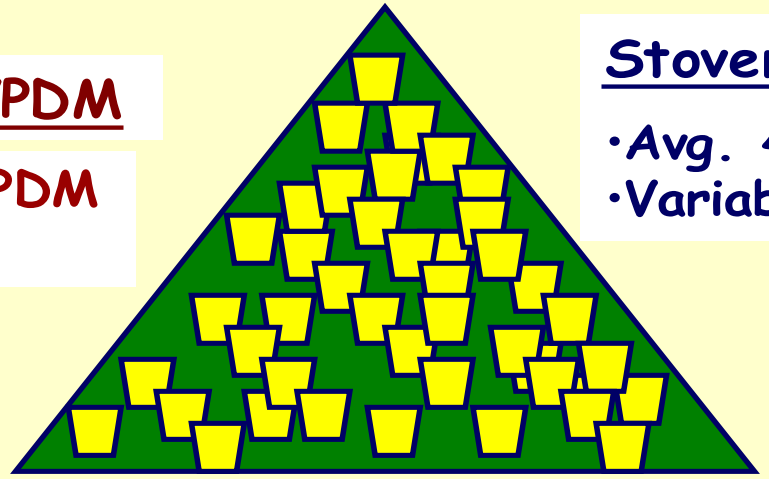
Grain ~40-45% of WPDM

- Avg. 30% starch in WPDM
- Variable grain:stover



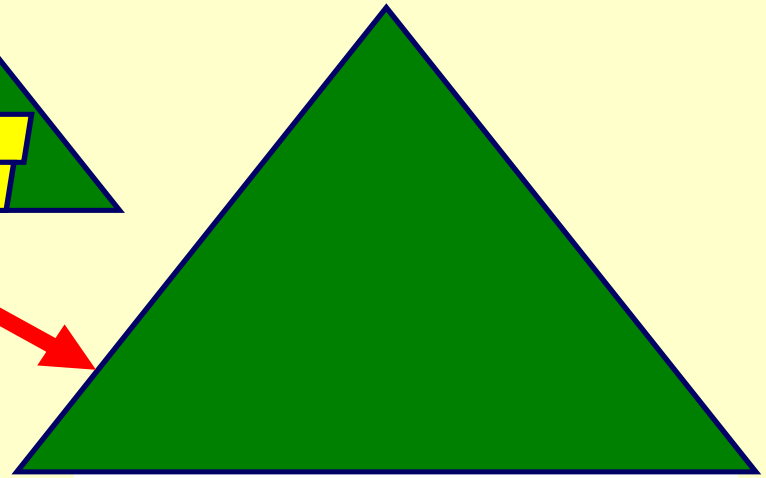
80 to 98% StarchD

- Kernel particle size
- Duration of silage fermentation
- Kernel maturity
- Endosperm properties
- Additives (exp.)



Stover= ~55-60% of WPDM

- Avg. 42% NDF in WPDM
- Variable stover:grain



40 to 70% IVNDFD

- Lignin/NDF
  - ✓ Hybrid Type
  - ✓ Environment; G × E
  - ✓ Maturity
- Cutting height
- Additives (exp.)

Variable peNDF as per chop length

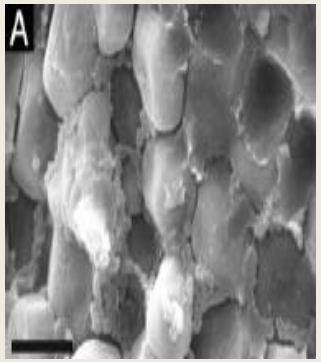
Adapted from Joe Lauer, UW Madison Agronomy Dept.

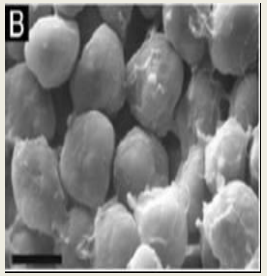
Primary Factors Influencing Starch Digestibility in Corn Grain

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

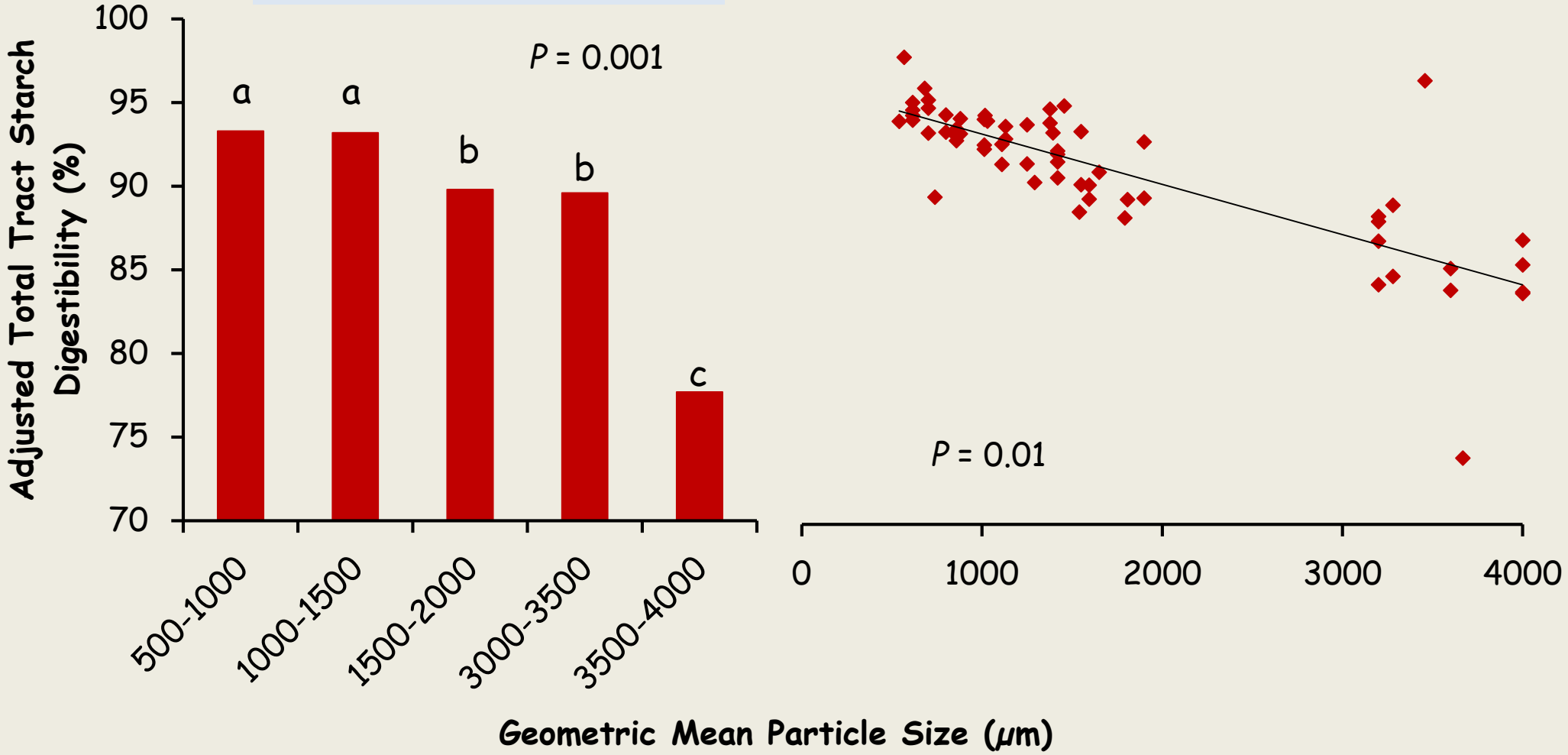




Adapted from Pat Hoffman, UW Madison Dairy Sci. Dept.

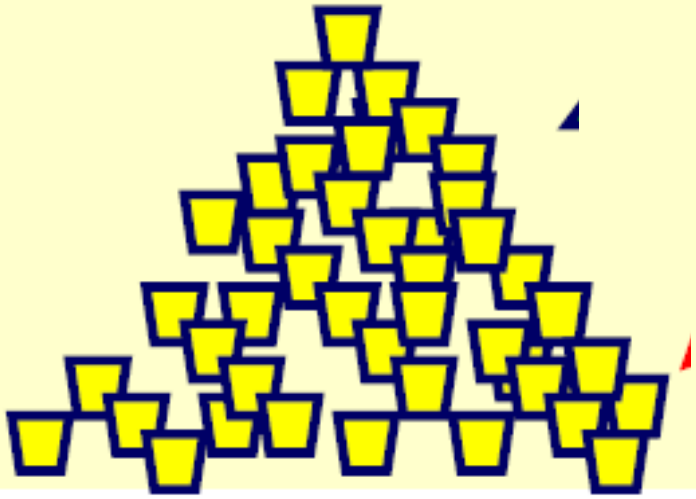
Dry ground corn

2.26 – 1.93 Mcal/kg



Ferraretto et al., 2013

Summary



80 to 98% StarchD

- Kernel particle size
- Duration of silage fermentation
- Kernel maturity
- Endosperm properties
- Additives

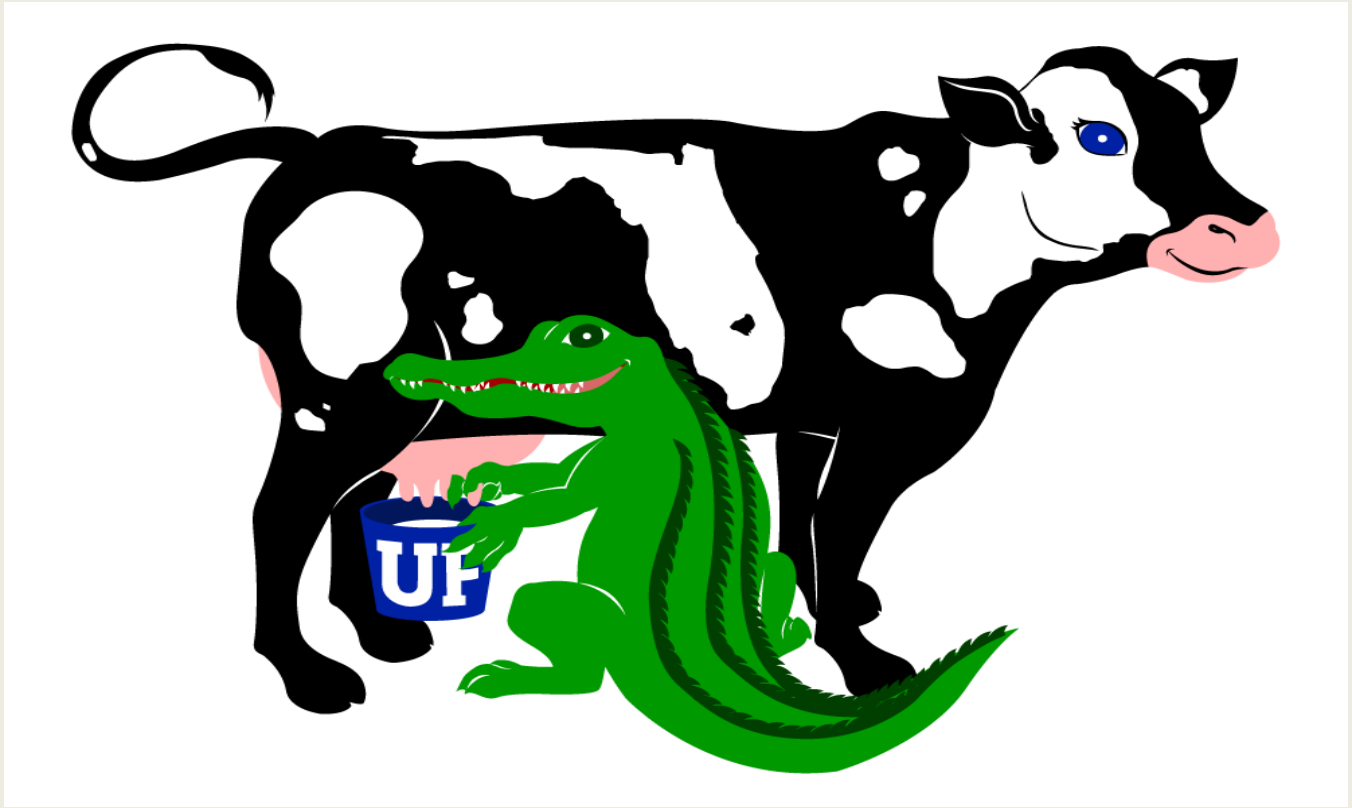
- Broken kernels are essential
- Allow silage to ferment for an extended period
- Harvest at the correct maturity
- Use hybrids with more floury endosperm if available
- Additives???

Implications

- Fecal starch is a viable tool to assess dietary starch digestibility on farm
- Several strategies that increase starch digestibility of individual feed ingredients
- Starch digestibility affect intake, milk and milk components production
- Combine fecal starch and milk samples analysis to optimize nutritional management

Questions?

lferraretto@ufl.edu



UF IFAS
UNIVERSITY of FLORIDA