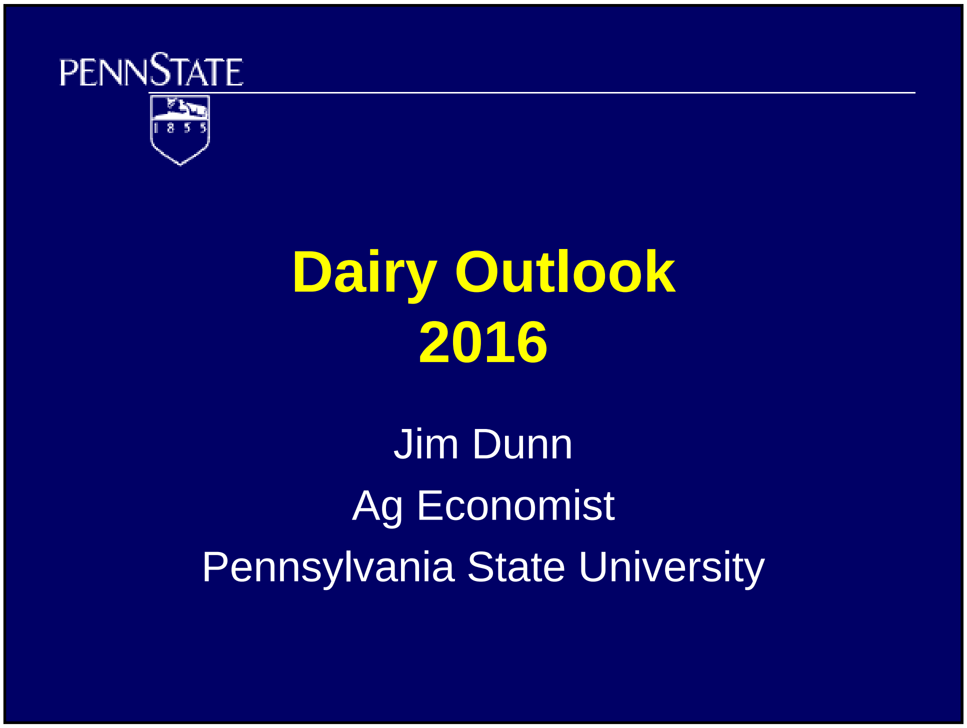

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Dairy Outlook
2016

Jim Dunn
Ag Economist
Pennsylvania State University

Current Situation

- Milk prices are up from earlier this year and feed prices are moderate
- Forecast of PA All Milk Price - $18.40/cwt. for 2016
- Feed prices will remain low

England

- Dairy situation in England is grim.
- Remember how 2009 was for dairying in the U.S.? A similar situation is unfolding in the U.K. this year.
- Farm milk prices have dropped by 40%. Feed prices have increased about 50%. Many farms are going out of business.
- European Union quotas ended on April 1.
- Supermarkets using milk as a loss leader

European Union

- Dairy quotas ended April 1.
- Farms can expand, or relocate
- The Dutch in particular are likely to do this
- Move to Poland, for example
- Milk production is up 2.9% since quotas ended
- Intervention remains

- China’s Inner Mongolia Yili Industrial Group Co. is setting up a powdered milk factory in Kansas with Dairy Farmers of America Inc
- The plant will be able to produce 80,000 metric tons of milk powder a year
- The company didn’t specify how much of the plant’s milk powder will be sold in China.

China

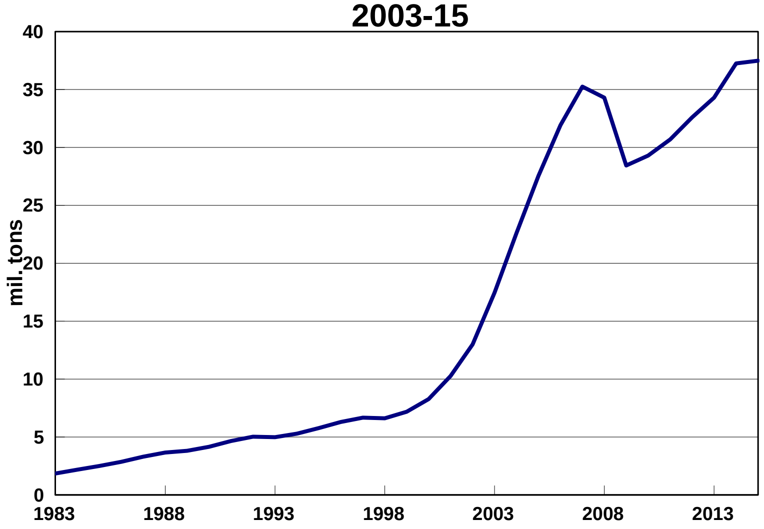
- Now world’s third largest milk producer
- One farm has 140,000 head
- Before long may not be a major importer
- All the small dairies are under severe pressure, on quality & price
- Very dependent on purchased feed

Issues in China

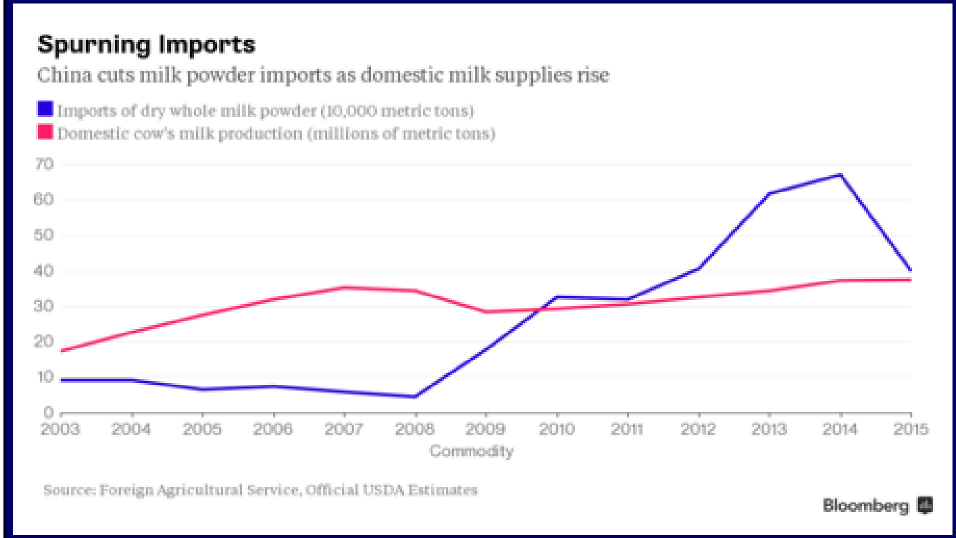
- Weather
- Foot-and-mouth disease
- Imports slowing – lots of inventory
- Slowing economy
- Devalued currency

Chinese Milk Production

2003-15



Source: USDA

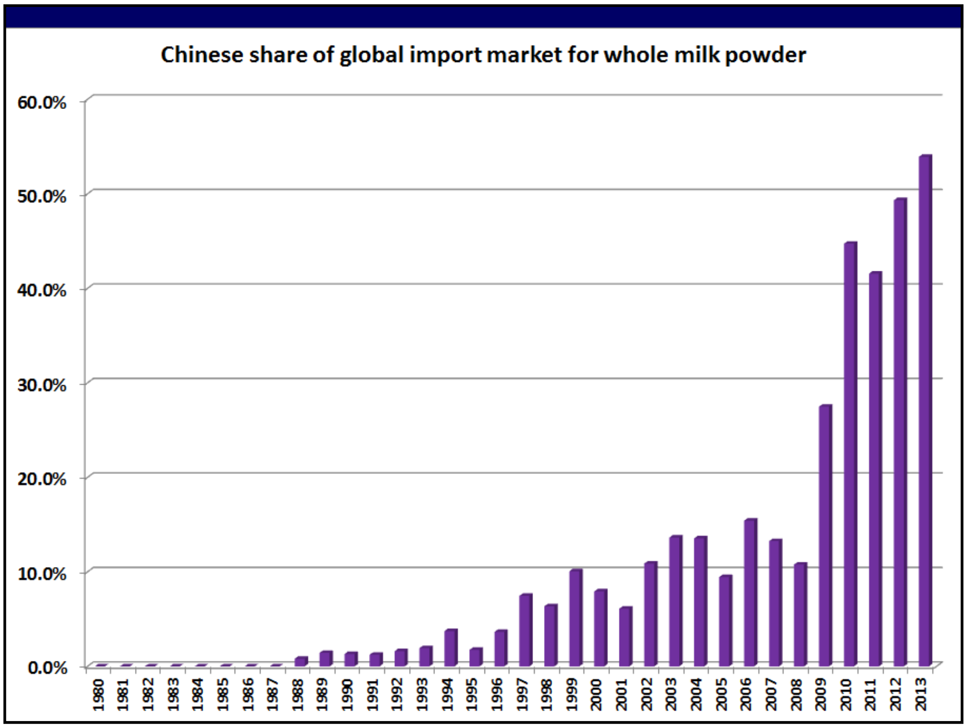


Spurning Imports

China cuts milk powder imports as domestic milk supplies rise

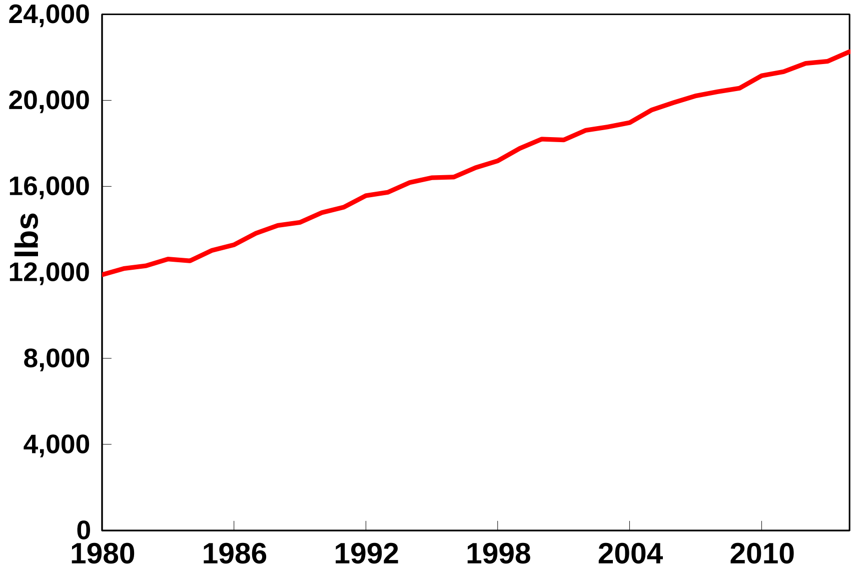
Source: Foreign Agricultural Service, Official USDA Estimates

Bloomberg

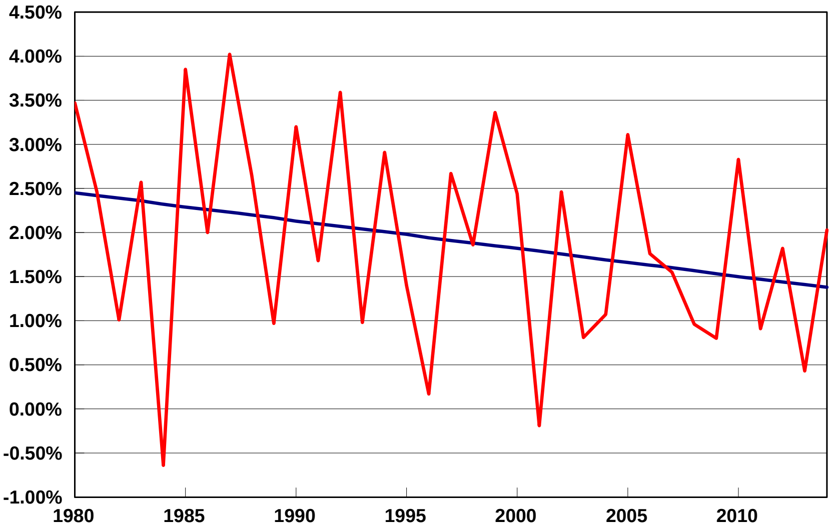


Chinese share of global import market for whole milk powder

Milk Per Cow

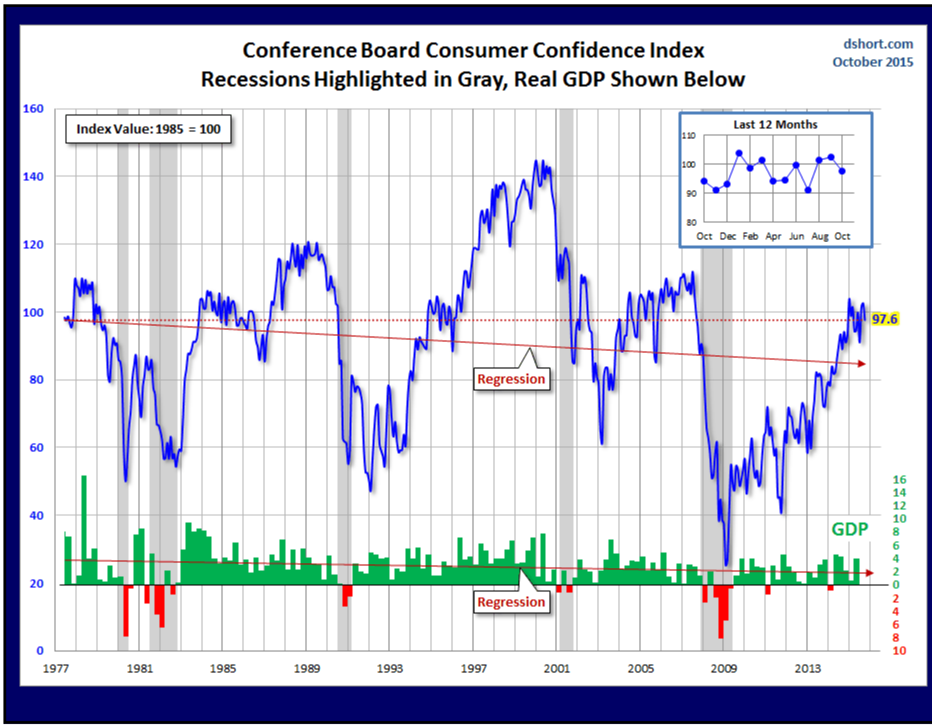


Changes in Milk per Cow and Trend



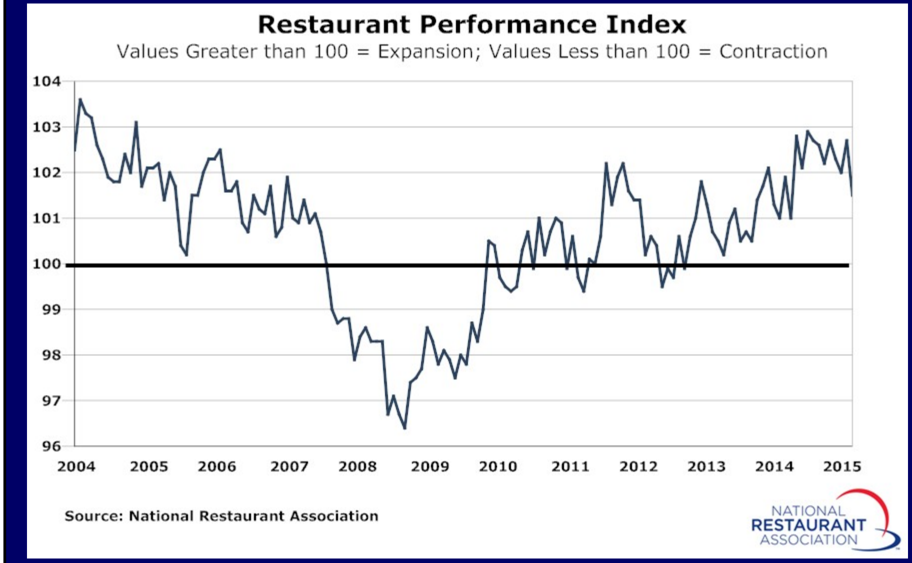
Economy

- Still improving
- Dairy isn't especially economy driven, although some products are more affected than others – fancy cheese
- Other products do well in recession – Macaroni & Cheese



Conference Board Consumer Confidence Index
Recessions Highlighted in Gray, Real GDP Shown Below

dshort.com
October 2015

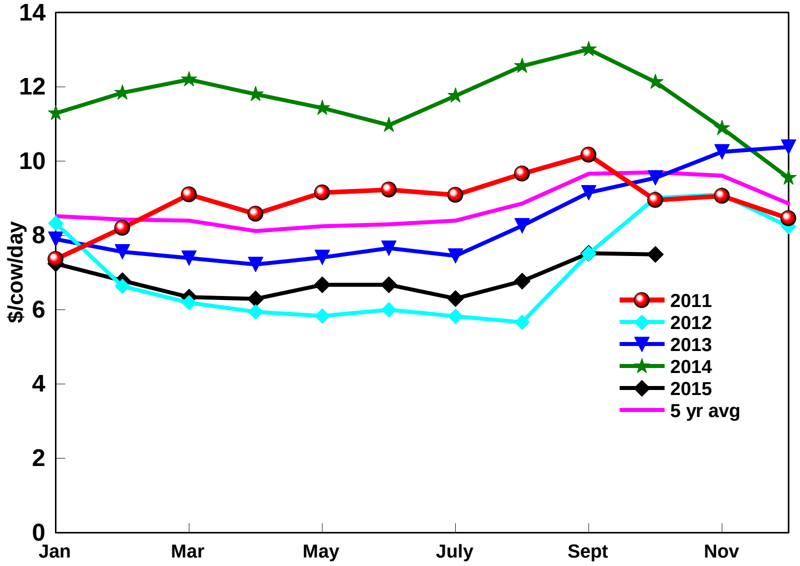


Restaurant Performance Index

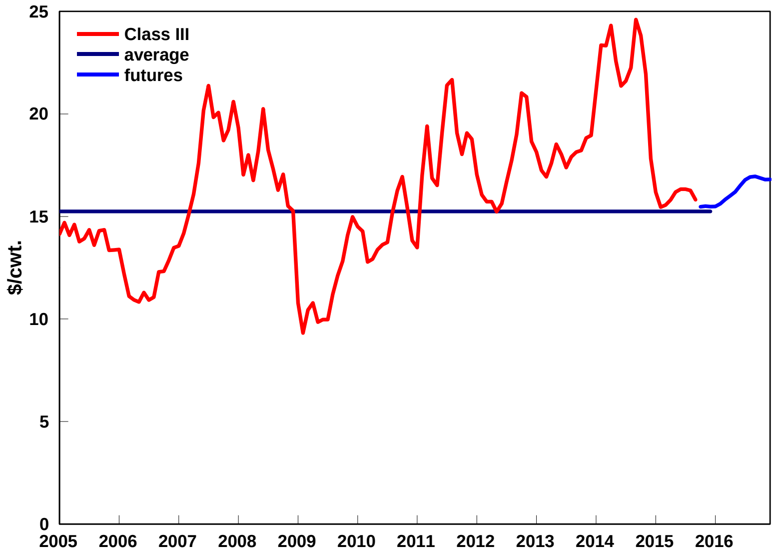
Values Greater than 100 = Expansion; Values Less than 100 = Contraction

Source: National Restaurant Association

PA Dairy Income over Feed Cost



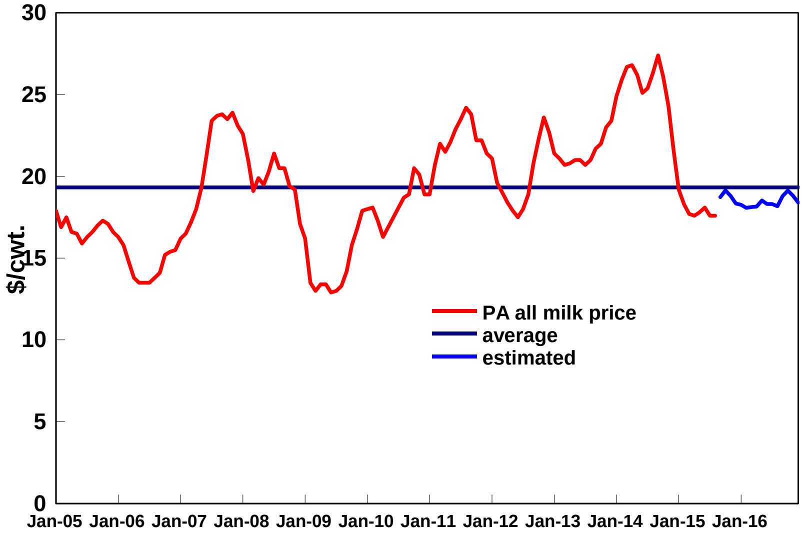
Class III Milk Price



Source: USDA

PA All Milk Price

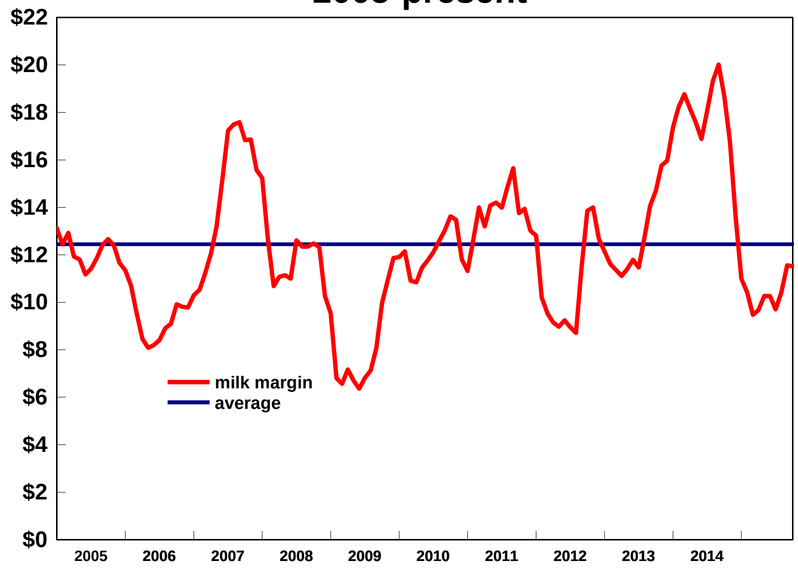
Jan 2005-present



Source: NASS

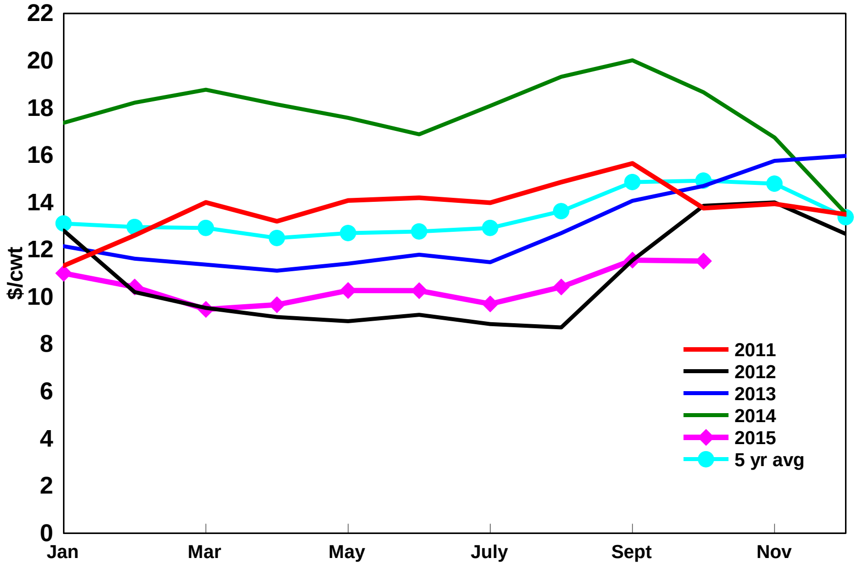
PA Dairy Milk Margin

2005-present



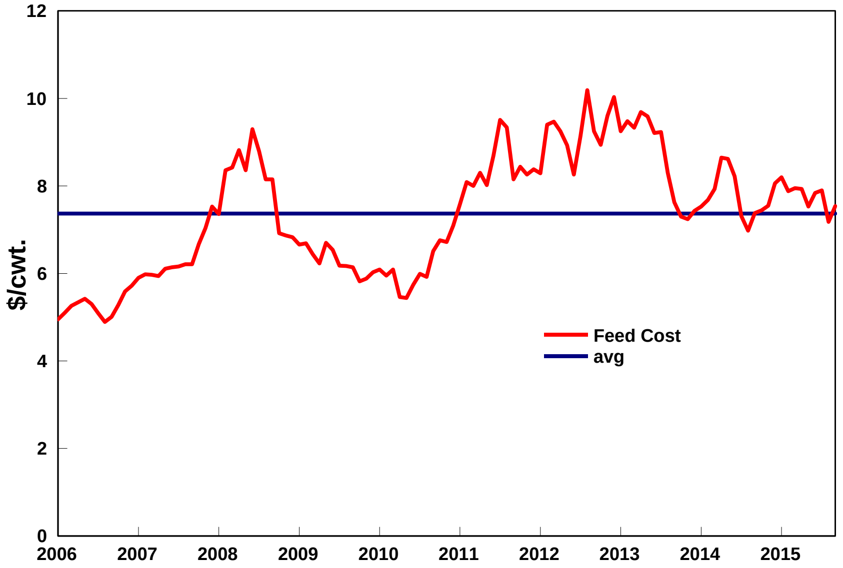
PA Milk Margin

2011-15



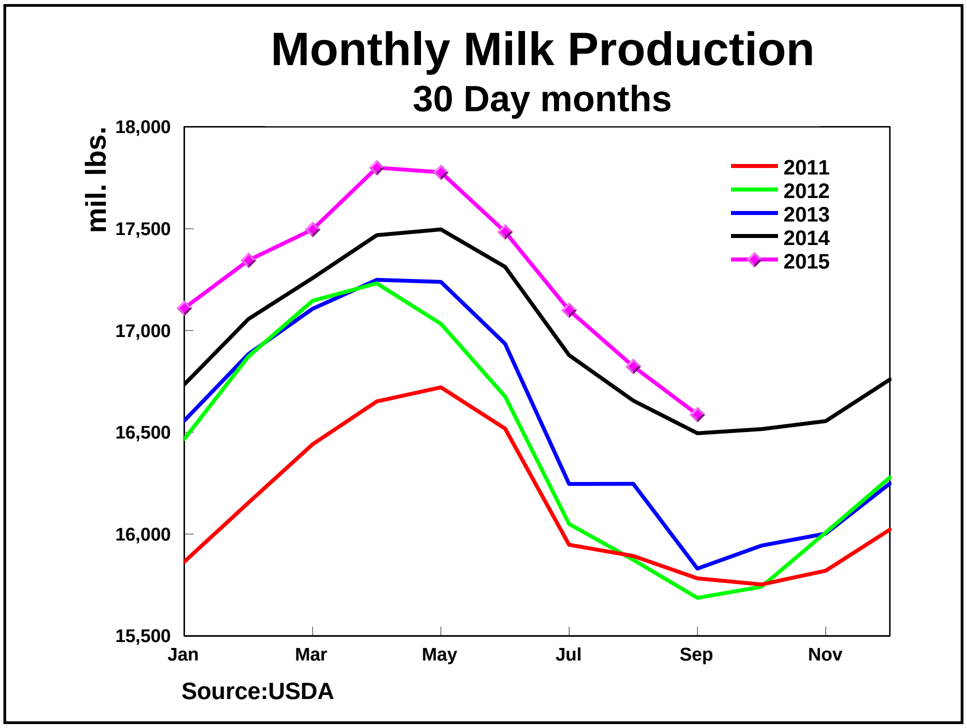
PA Feed Cost/cwt. Milk

Jan 2006 - present



Measures of Dairy Farm Profitability 2006-15

	Avg.	High	Low	Oct 2015
PA All-Milk Price	$19.74	$27.40	$12.90	$18.90
Feed Cost/cwt.	$7.37	$10.19	$4.89	$7.60
Milk Margin	$12.36	$20.02	$6.36	$11.52



Monthly Milk Production

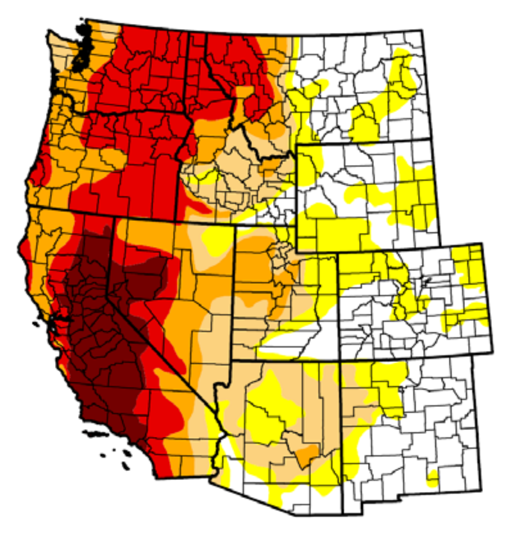
30 Day months

Source:USDA

Drought in West

- California officials will cut off water to local agencies serving 25 million residents and about 750,000 acres of farmland
- Severe drought in the California and Idaho dairy regions

Drought Monitor

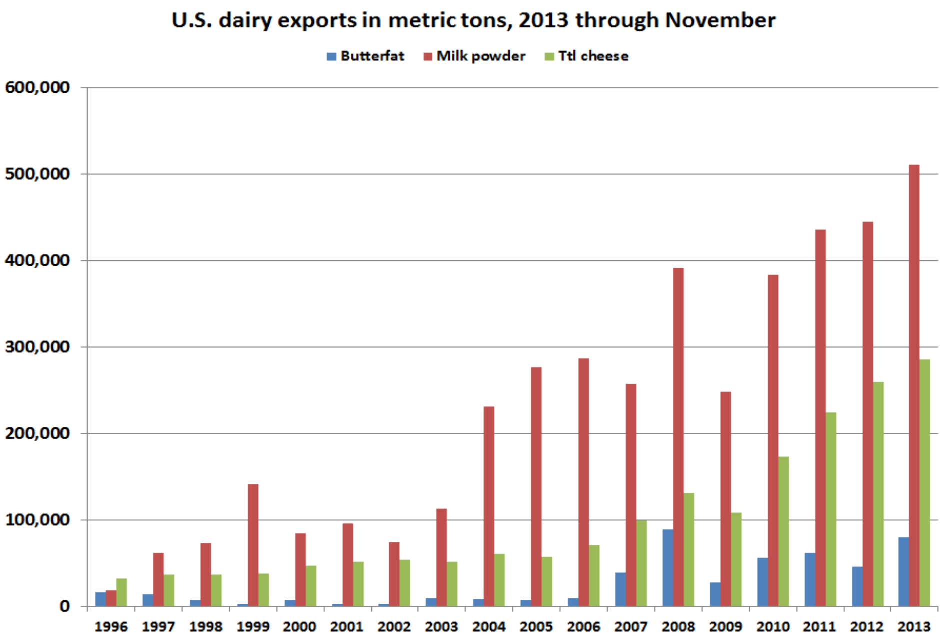


Not expected to improve this year

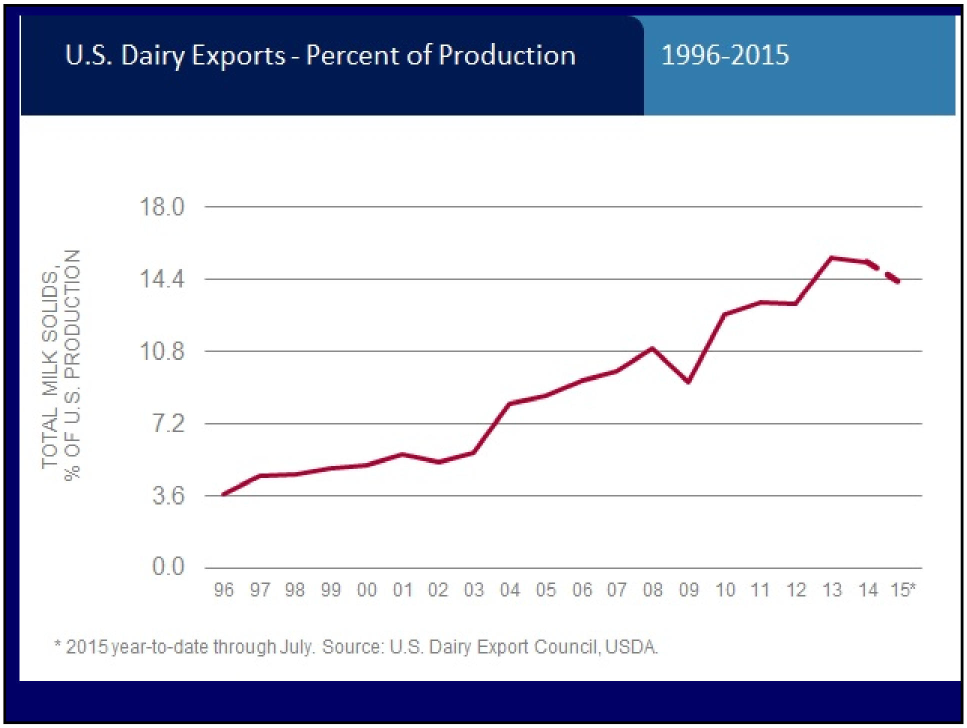
California’s milk production is falling

Milk per cow, not cow numbers

October 27, 2015



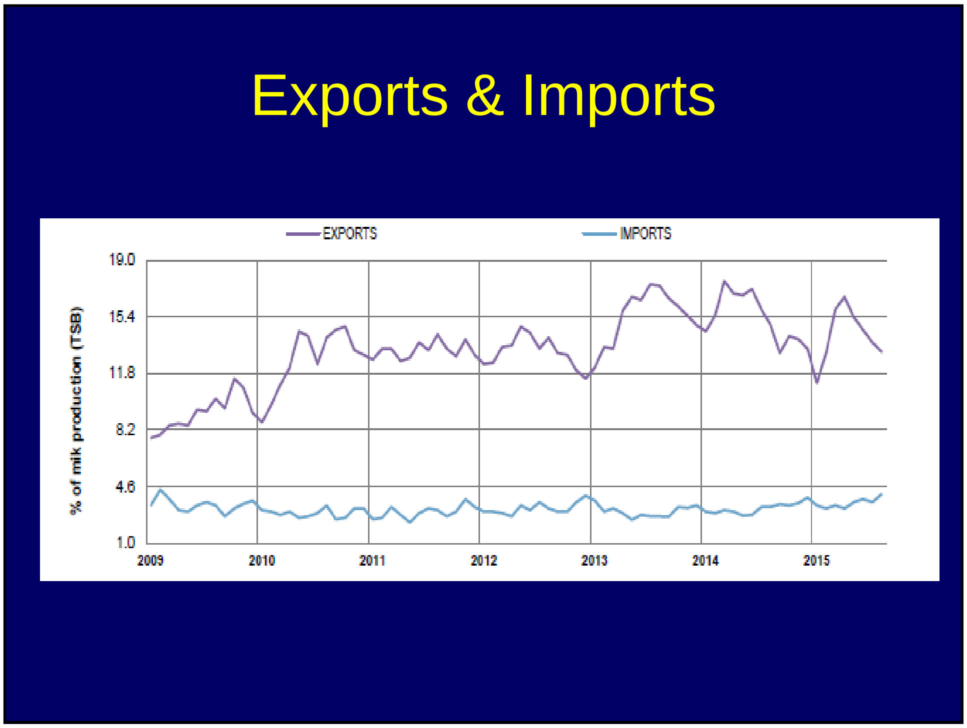
U.S. dairy exports in metric tons, 2013 through November



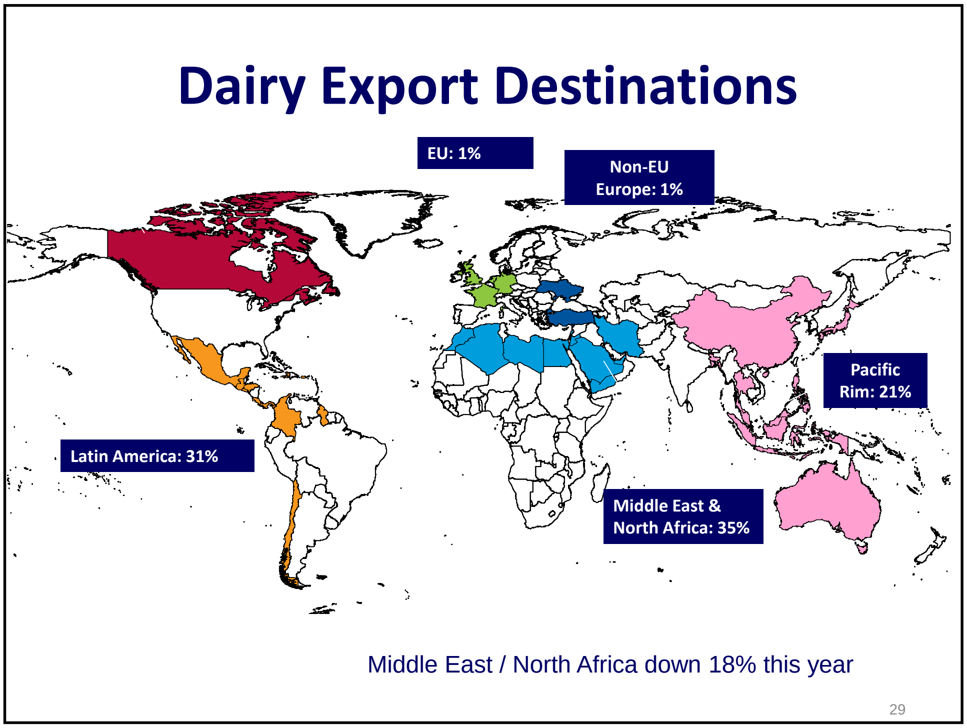
U.S. Dairy Exports - Percent of Production

1996-2015

* 2015 year-to-date through July. Source: U.S. Dairy Export Council, USDA.



Exports & Imports



Dairy Export Destinations

EU: 1%

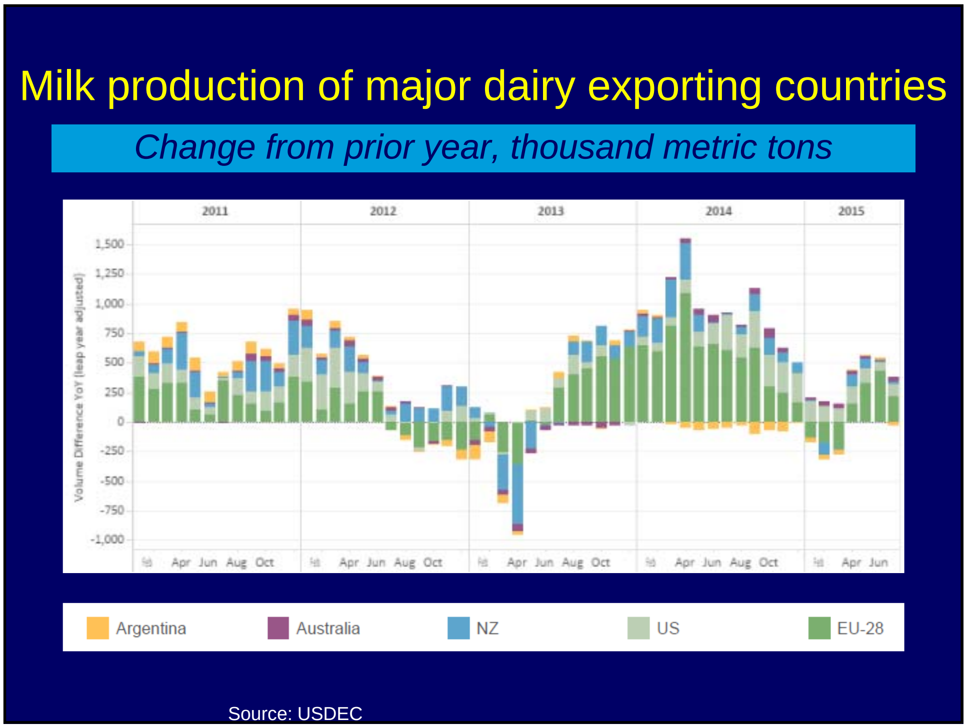
Non-EU Europe: 1%

Pacific Rim: 21%

Latin America: 31%

Middle East & North Africa: 35%

Middle East / North Africa down 18% this year

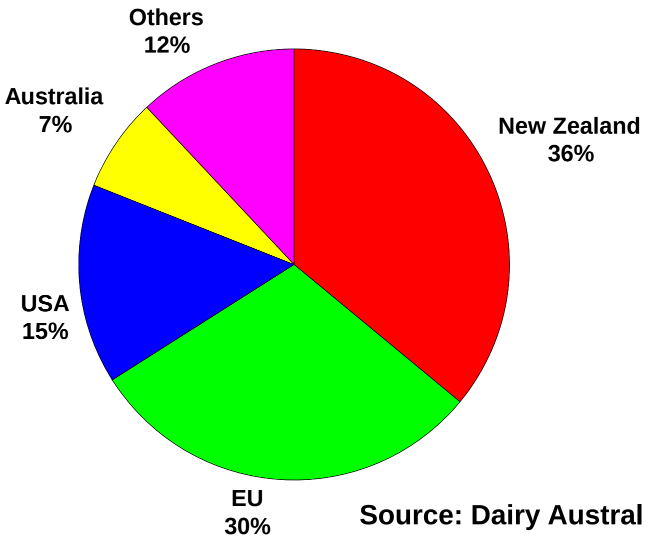


Milk production of major dairy exporting countries

Change from prior year, thousand metric tons

Source: USDEC

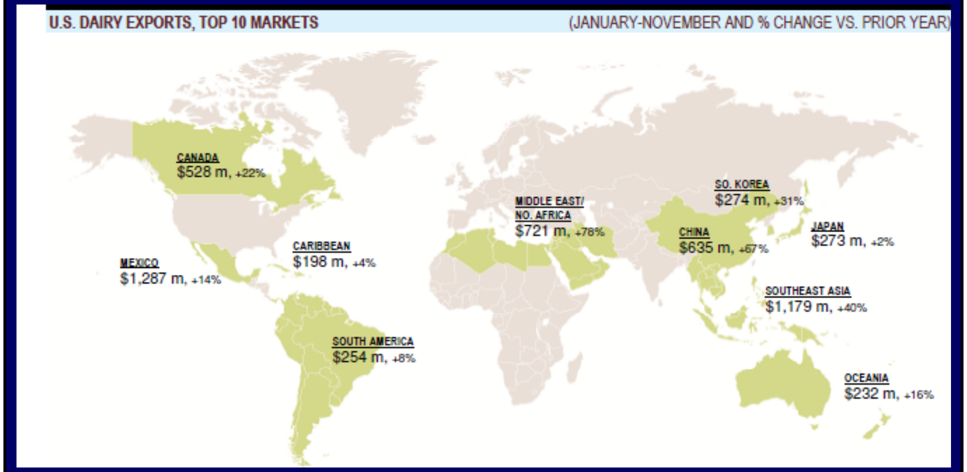
Share of World's Dairy Exports



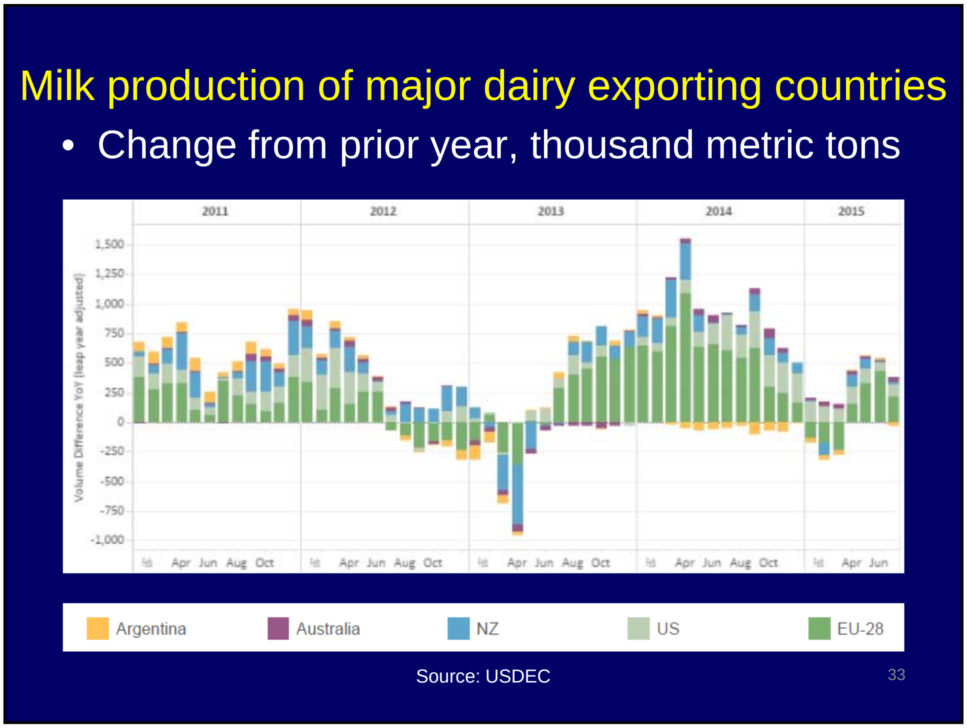
Source: Dairy Australia

US Dairy Exports 2013

Top 10 Markets



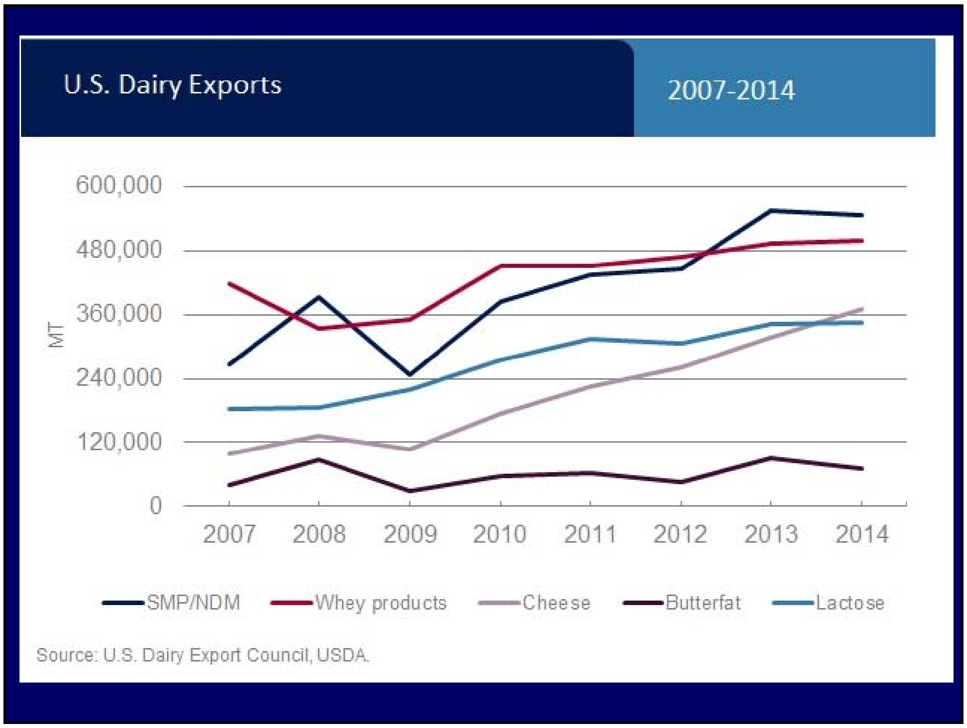
Source: U.S. Dairy Export Council



Milk production of major dairy exporting countries

- Change from prior year, thousand metric tons

Source: USDEC



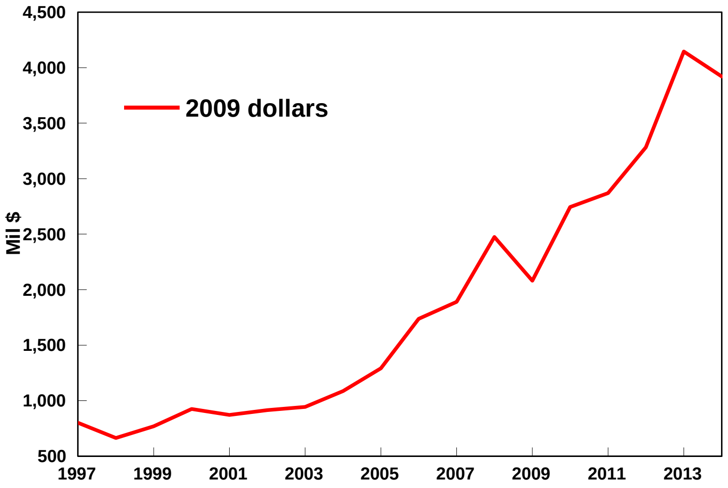
U.S. Dairy Exports

2007-2014

Source: U.S. Dairy Export Council, USDA.

US Dairy Exports

1997-2014

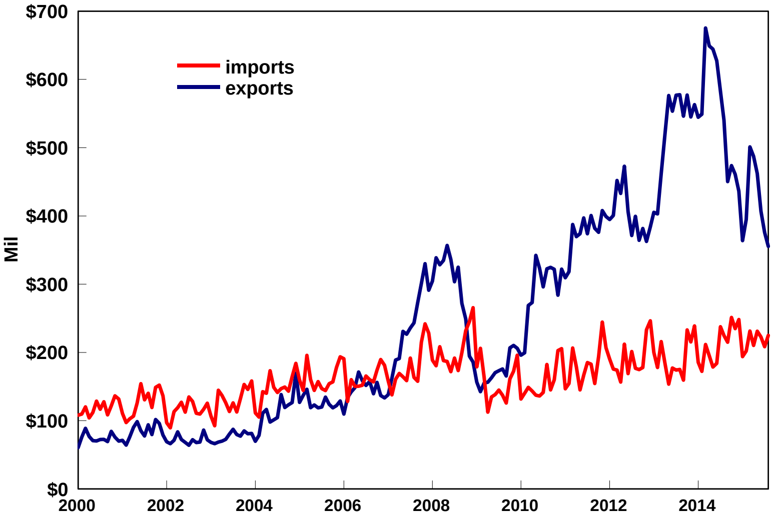


Source: USDA, BLS

Deflated by PPI Dairy

US Dairy Trade

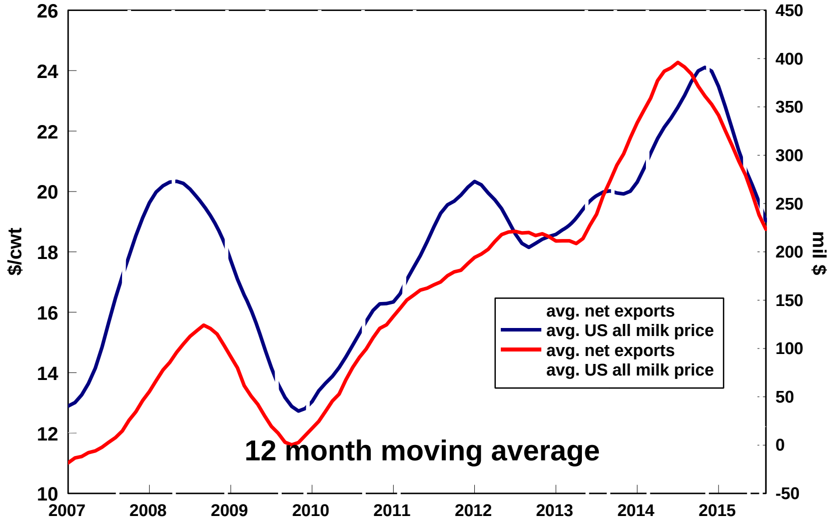
2000-15



Source: USDA

Net Dairy Exports and All Milk Price

2007-15

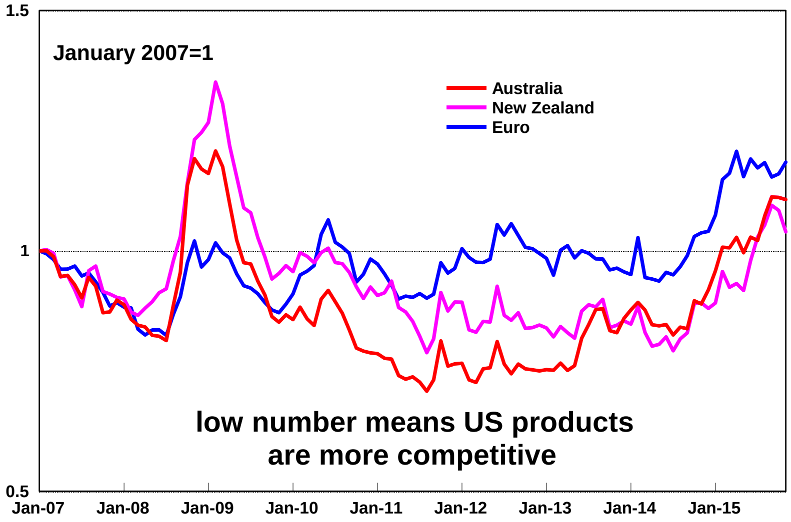


Source: USDA

The dollar

- Dollar stronger
- Aussie dollar down 17.5% against Greenback since July 2014
- Euro down 20%+
- Euro very shaky because of Russia
- Many Euro countries have serious economic problems

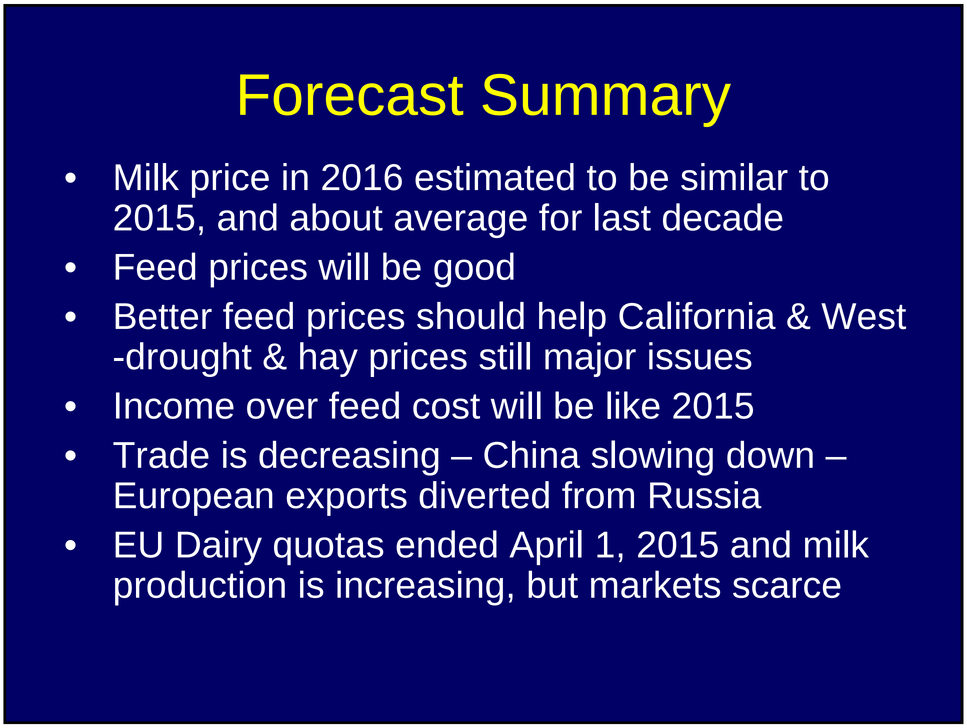
Selected Exchange Rates
Relative to US Dollar
2007-Present


January 2007=1

low number means US products are more competitive

Dairy Futures

- About the same over next year
- Class III around $15.10-$16.70 for 2016
- Class IV around $14.30-$16.90 for 2016
- Both climbing gradually on futures markets
- Feed prices about the same
- Margins depend on hay, not corn and beans



Forecast Summary

- Milk price in 2016 estimated to be similar to 2015, and about average for last decade
- Feed prices will be good
- Better feed prices should help California & West -drought & hay prices still major issues
- Income over feed cost will be like 2015
- Trade is decreasing – China slowing down – European exports diverted from Russia
- EU Dairy quotas ended April 1, 2015 and milk production is increasing, but markets scarce

Managing metabolism and immune function of transition cows

Thomas R. Overton, Ph.D.
Professor of Dairy Management
Director, PRO-DAIRY program
Cornell University
Ithaca, NY

Transition period goals

- High milk production
- Maintain/minimize loss of BCS
- Low incidence of metabolic disorders
- Minimize loss of immunocompetence
- Control/decrease days to first ovulation and maintain/enhance fertility
- Low stillborn rate and healthy calves

- Our high performing dairies achieve ALL of these

We've learned and implemented a lot in the last 10 to 15 years

- Nutritional strategies
  - DCAD diets
  - Controlled energy diets
  - Increasing MP supply prepartum and balancing AA
  - Fresh cow diets?

- Importance of nonnutritional factors
  - Stocking density
  - Grouping strategies/moves
  - Segregating cows and heifers during transition period
  - Heat abatement

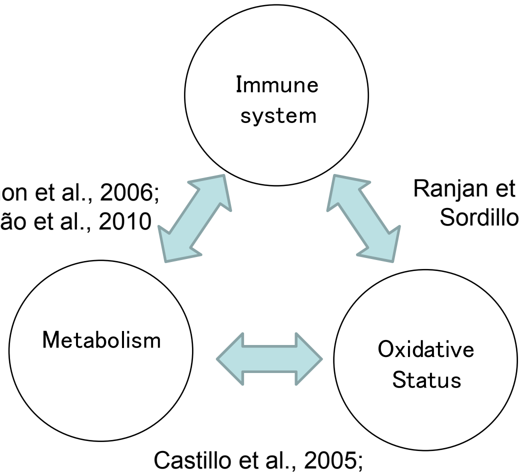
- Enhanced on-farm monitoring (hyperketonemia)
- Yet still much opportunity out there!!

Shift in mindset from the transition cow as a disease opportunity to the transition cow as a production and reproduction opportunity!!!

Physiological changes during the transition period and early lactation in dairy cows

- Tremendously increased nutrient and energy demands to support milk production regulated by homeorhetic adaptations (Bauman and Currie, 1980; Bell, 1995)
- Period of reduced immunological capacity during the periparturient period (Goff and Horst, 1997)
- Increased production of reactive oxygen species during the periparturient period (Sordillo and Aiken, 2009)

These systems are not independent of one another



Hammon et al., 2006;
Galvão et al., 2010

Ranjan et al., 2005;
Sordillo et al., 2007

Castillo et al., 2005;
Bernabucci et al., 2005

** “Delicate balance” ** important within and among these systems

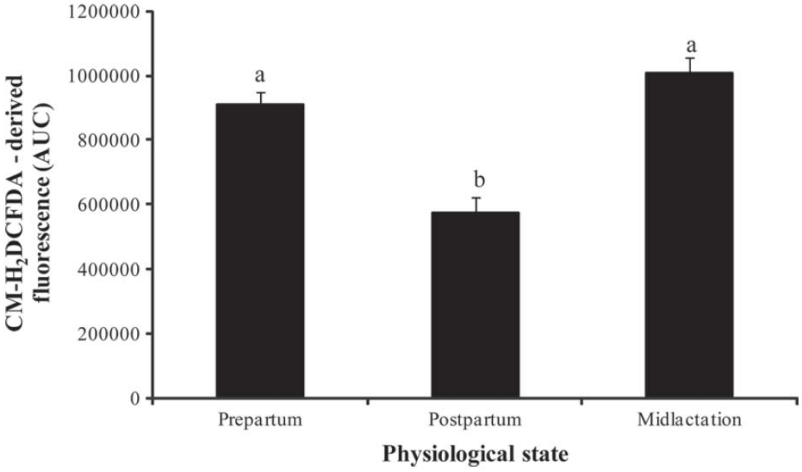
- Homeorhetic adaptations in energy metabolism that are important for the onset of copious milk production result in negative EB; however, excessive NEB is problematic
  - Bell, 1995; Ospina et al., 2010a,b,c
- Immune system must maintain balance between sufficient activity needed to eliminate the insult yet control the response to avoid bystander damage to host tissues
  - Sordillo et al., 2009
- Production of reactive oxygen species (ROS) critical for immunocompetence yet production of ROS in excess of antioxidant defense mechanisms results in oxidative stress
  - Spears and Weiss, 2008

** Sordillo et al., 2009

Periparturient immunosuppression

- Decreased sensitivity and responsiveness of immune system that makes the cow more susceptible to infection
  - ~3 weeks either side of calving
    - Mallard et al., 1998
- Leukocytes functionally compromised and hyporesponsive to pathogens; however, cytokine secretion hyperresponds when activated
  - Sordillo et al. 1995

Effect of stage of lactation on bovine neutrophil total ROS production

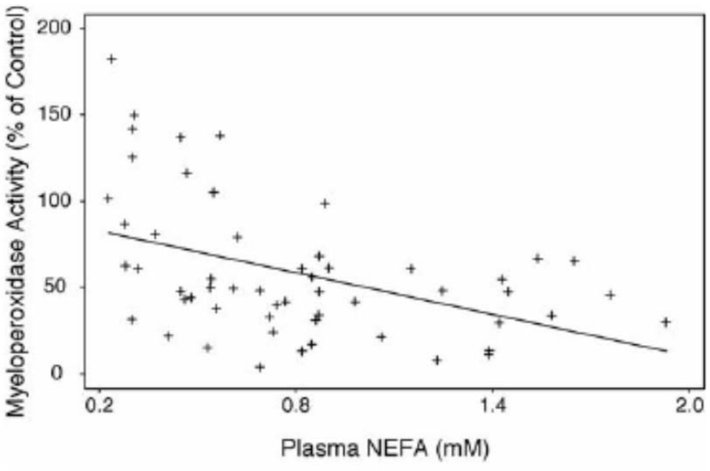


Revelo and Waldron, 2010

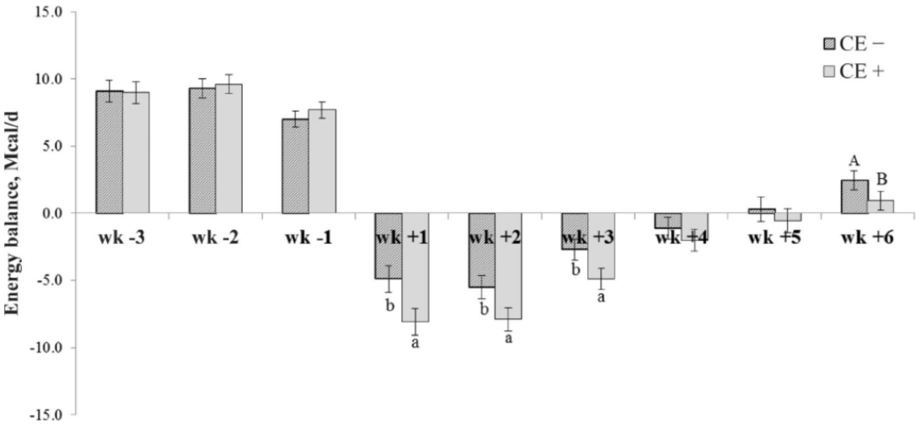
Interactions of nutrition and metabolism with immune function

- Energy metabolism
- Specific metabolites
  - NEFA
  - Ketone bodies
- Protein/AA
- Calcium
- Vitamin E and Se
- Other trace elements

Plasma NEFA and PMN Function

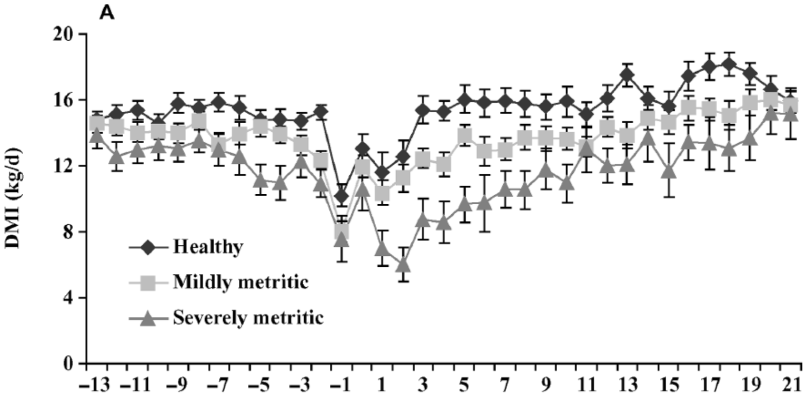


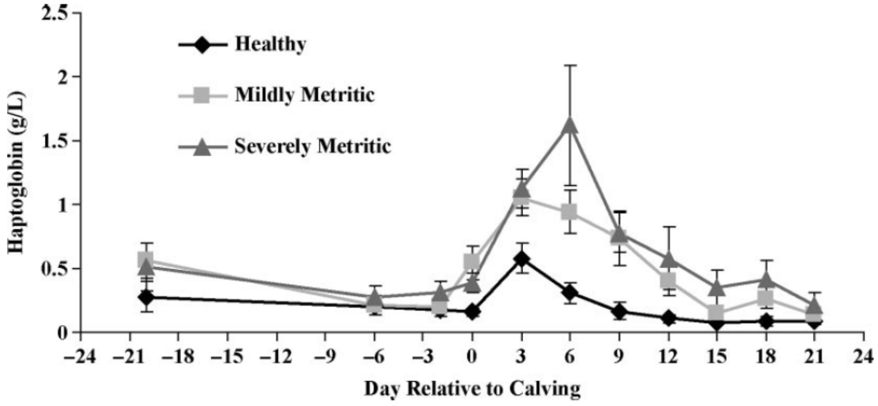
(Hammon et al., 2006)



Cows that go on to develop cytological endometritis (CE) are in more negative energy balance during the first three weeks postcalving. From Yasui et al., 2014.

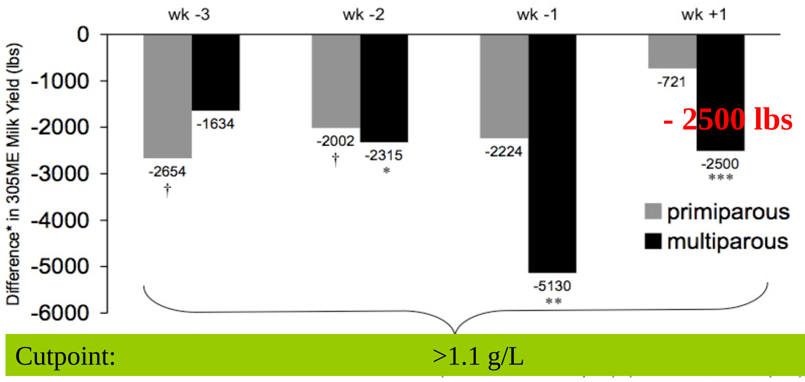
Dry matter intake for cows that developed metritis in early lactation. From Huzzey et al., 2007.





Mean (±SE) haptoglobin concentration of healthy (n = 23), mildly metritic (n = 32), and severely metritic (n = 12) cows during the period around calving (From Huzzey et al., 2009)

Haptoglobin & Subsequent Milk Yield (~60 DIM)

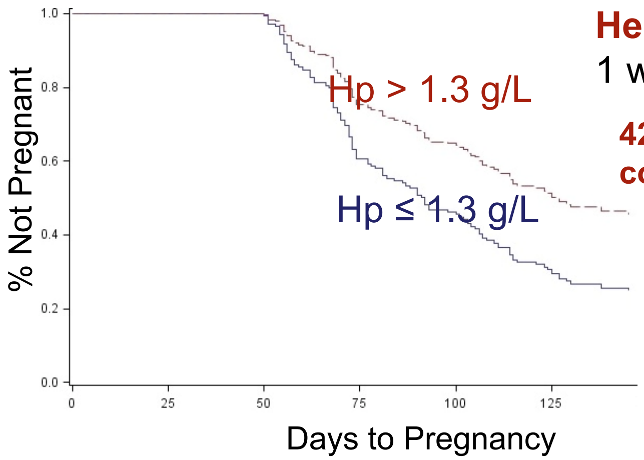


Cutpoint: >1.1 g/L

% Cows Above Cutpoint	wk -3	wk -2	wk -1	wk +1
Primiparous	4.9	7.7	6.0	39.0
Multiparous	3.0	4.8	3.0	27.4

Huzzey et al., 2012. J. Dairy Sci. 95(E. Suppl. 1):705.

Haptoglobin and Reproduction



Heifers sampled
1 wk **after** calving

42% lower rate of conception (P = 0.02)

- Heifers > 0.4 g/L Pre-partum - 41% lower rate of conception (P = 0.05)
- Among Cows Hp not associated with reproductive performance

Huzzey et al., 2012. J. Dairy Sci. 95(E. Suppl. 1):705.

Key components of transition cow management

- Nutritional management
  - Tight control of macrominerals in diet fed to cows as they approach calving
  - Controlling energy intakes both in far-off and close-up groups
  - Ensure cows consume diet as formulated for maximum intake
    - Feeding management is critical
    - Minimize sorting
  - Focus on ration fermentability during the fresh period

- Nonnutritional management
  - Minimize stressors and potential impact on physiology and variation in DMI

- Put cow- and herd-level monitoring systems in place to help identify need for management changes

---

Major strategies for application of DCAD for close-up dry cows

- Focus on feeding low K (and Na) forages and feeds to close-up dry cows
  - *Calculated DCAD ~ +10 mEq/100 g of DM*
  - *Urine pH ~ 8.3 to 8.5*

- Feeding low K forages along with partial use of anionic supplement in close-up ration or one-group dry cow ration
  - *Calculated DCAD ~ 0 mEq/100 g of DM*
  - *Urine pH ~ 7.5*

- Feeding low K forages along with full use of anionic supplement in close-up ration or one-group dry cow ration
  - *Calculated DCAD ~ -10 to -15 mEq/100 g of DM*
  - *Urine pH ~ 5.5 to 6.0 – need to monitor weekly and adjust DCAD supplementation if out of range*
- Need to also supplement Mg (dietary target ~ 0.45%) during close-up
- Recommend supplementing Ca (0.9 to 1.0% if low K only; 1.4 to 1.5% if full anionic diet)

U.S. trends in last 6 to 8 years

- Largely abandoned “steam up” concept advocated by 2001 Dairy NRC
- Controlled energy strategies for dry cows during both far-off and close-up periods (Drackley, 2007)
  - 0.59 to 0.62 Mcal/lb (1.30 to 1.36 Mcal/kg of NEL)
  - 12 to 16% starch
  - 40 to 50% forage NDF
- Appropriate for multiparous cows
- Too low energy/too bulky for primiparous cows?
- MP supply?? (RUP supplementation even more important)
- Diets need to deliver 15 to 18 Mcal/d of NEL (110 to 120% of ME requirements) during both far-off and close-up dry periods

Key components of transition cow management

- Nutritional management
  - Tight control of macrominerals in diet fed to cows as they approach calving
  - Controlling energy intakes both in far-off and close-up groups
  - Ensure cows consume diet as formulated for maximum intake
    - Feeding management is critical
    - Minimize sorting
  - Focus on ration fermentability during the fresh period
- Nonnutritional management
  - Minimize stressors and potential impact on physiology and variation in DMI
- Put cow- and herd-level monitoring systems in place to help identify need for management changes

Potential management/facility related stressors for transition cows

- Overcrowding (increased stocking density)
- Commingling of cows and heifers
- Excessive number of pen moves (group changes)
- Heat stress
- Overall cow comfort/hygiene

Stressors for transition cows

- Decrease dry matter intake and milk
- Increase body fat mobilization and wasting of muscle tissue
- Divert nutrients from milk to stress response/immune system
- Potential mechanism
  - Release of pro-inflammatory cytokines (TNFα, IL-1β, IL-6) and stress hormones (glucocorticoids, epinephrine, cortisol)

Drackley et al., 2005

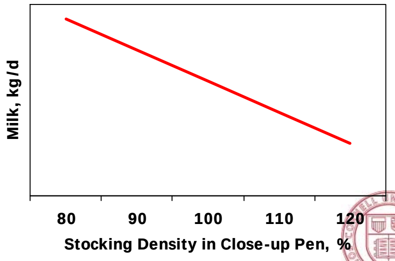
Stocking density

- Most attention by far
- Current recommendations (e.g., 0.75 m of feedbunk space per cow; 80% of headlocks) based upon observational work rather than randomized trials
- Observational studies have limited ability to determine optimal stocking density and relationships with other factors

Crowding in Close-up Pen Decreases Milk Production

- Primiparous and multiparous cows grouped together
  - 1600 cow facility, 2-row pens
- Primiparous cows
  - 2.95 kg/d increase in milk (1st 83 DIM) when stocked at 80 vs. 120% of stalls

- For each 10% increase in close-up stocking density above 80%, there was a 0.73 kg/d decrease in milk!



Cook et al., 2004

Commingling primiparous and multiparous cows

- Even fewer data than for stocking density
- Ospina et al. (2009) results suggest major opportunity in NE herds
  - Elevated NEFA in 45% of heifers sampled prepartum
- Higher responses of cortisol to ACTH challenge in primiparous compared to multiparous cows following introduction to a commingled environment
  - Gonzalez et al., 2003

Feeding Behavior of Heifers vs. Cows

Activity	Heifers	Cows
Prepartum total daily feeding time, min/d	213	187
Prepartum meal duration, min/d	27.2	24.2
Prepartum feeding rate, g DM/min	66.6	95.1
Postpartum feeding rate, g DM/min	78.8	106.7

Heifers need more time for access to feed; eat more slowly than cows

DeGroot and French, 2004

Crowding in Close-up Pen Decreases Milk Production (in some cows)

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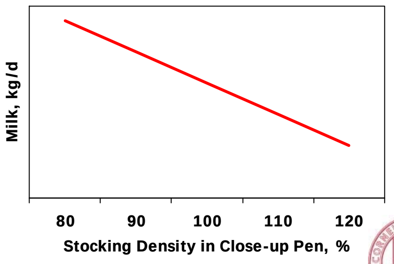
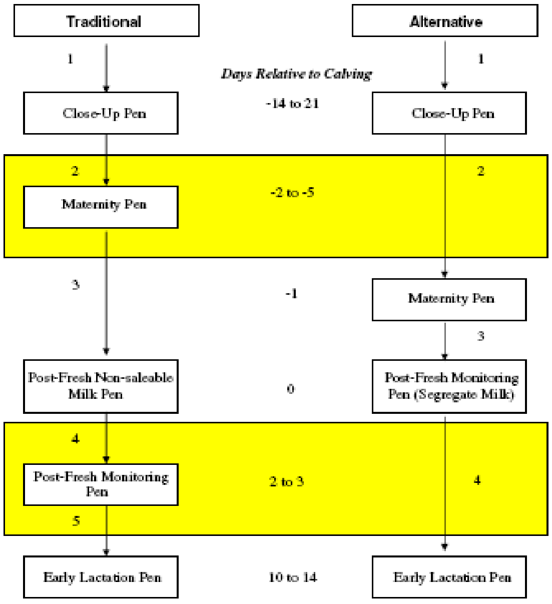
  - – 1600 cow facility, 2-row pens
- Primiparous cows
  - – 2.95 kg/d increase in milk (1st 83 DIM) when stocked at 80 vs. 120% of stalls

- For each 10% increase in close-up stocking density above 80%, there was a 0.73 kg/d decrease in milk!



Cook et al., 2004



Streamline approaches to grouping management of transition cows (Cook and Nordlund, 2004)

Time Spent in Maternity Pen

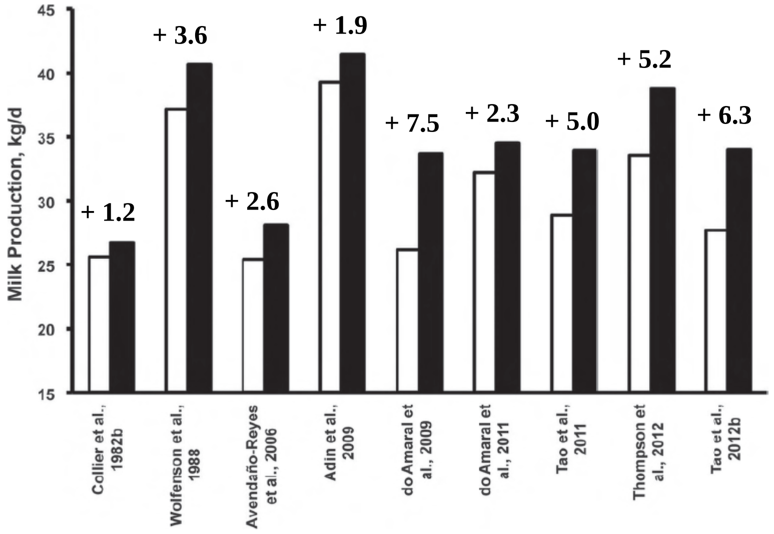
	<3 d	**≥ 3 d**	**Δ**
Herd 1 (4.5 d in pen)			
Calvings	112	182	
Culled by 60 d, %	3.6	9.3	2.6x
Herd 2 (5.9 d in pen)			
Calvings	34	129	
Culled by 85 d, %	2.9	9.3	3.1x
Subclinical ketosis, %	6.9	16.0	2.3x
Displaced abomasum, %	2.9	5.4	1.9x

Oetzel, 2003

Heat stress abatement during dry period

- Israeli study on evaporative cooling during entire dry period (Wolfenstein et al., 1988)
  - 24 C at 0700 h and 31 C at 1400 h
  - Cooled cows
    - Rectal temperatures 0.5 C lower than controls
    - Milk yield increased 3.6 kg/d during first 150 d
- Avendano-Reyes et al. (2006)
  - Study 1 – soaking cows without fans not effective in cooling
  - Study 2 – evaporative cooling for entire dry period increased milk yield (+ 2.5 kg/d) and milk fat (2.97 vs. 3.27%)

Cooling during the entire dry period increases subsequent milk production (differences in kg/d above bars)



Tao and Dahl. 2013. J. Dairy Sci 96 :4079–4093

Heat stress during the prepartum period decreases calf birth weight

Heat-stressed	Control	% reduction	Reference
36.6*	39.7	8	Collier et al. (1982b)
40.6*	43.2	8	Wolfsen et al. (1988)
33.7†	37.9	11	Avendano-Reyes et al. (2006)
40.8*	43.6	6	Adim et al. (2009)
31.0*	44.0	30	Do Amara et al. (2009)
39.5*	44.5	11	Do Amara et al. (2011)
41.6*	46.5	11	Tao et al. (2011)
36.5*	42.5	14	Tao et al. (2012b)

Tao and Dahl. 2013. J. Dairy Sci 96 :4079–4093

Key components of transition cow management

- Nutritional management
  - Tight control of macrominerals in diet fed to cows as they approach calving
  - Controlling energy intakes both in far-off and close-up groups
  - Ensure cows consume diet as formulated for maximum intake
    - Feeding management is critical
    - Minimize sorting
  - Focus on ration fermentability during the fresh period
- Nonnutritional management
  - Minimize stressors and potential impact on physiology and variation in DMI
- Put cow- and herd-level monitoring systems in place to help identify need for management changes

Types of monitoring

- Cow-level
  - Seeking to make a diagnosis/treatment decision on an individual animal
- Herd-level
  - Periodic (e.g., weekly) evaluation of a representative sample of cows in a sampling window of interest
  - Using as a barometer of the herd
  - Large epidemiological studies involving many herds have given us the ability to make inferences relative to associations of analytes with herd-level outcomes

Challenges with assessing herd-level metabolism and stress biology-related opportunities in transition cows

- Most of dairy industry works on averages

- Challenges related to energy/grouping mgt/nonnutritional factors cause increases in ***variation*** in DMI/performance/metabolism
  - Almost impossible to detect some of these on farms

- Potential tools for use in monitoring variation in transition cow management
  - Calcium (getting renewed attention)
  - NEFA (best marker for negative energy balance)
  - BHBA ("gold standard" blood ketone)
  - Haptoglobin (acute-phase response/systemic inflammation)
  - Fecal cortisol metabolites? (likely research tool rather than herd use)
  - Urine pH – (feeding management in herds feeding DCAD diets)
  - Rumination monitors? – other electronic monitoring?
  - Variation in early lactation milk yield / Transition Cow Index (TCI)

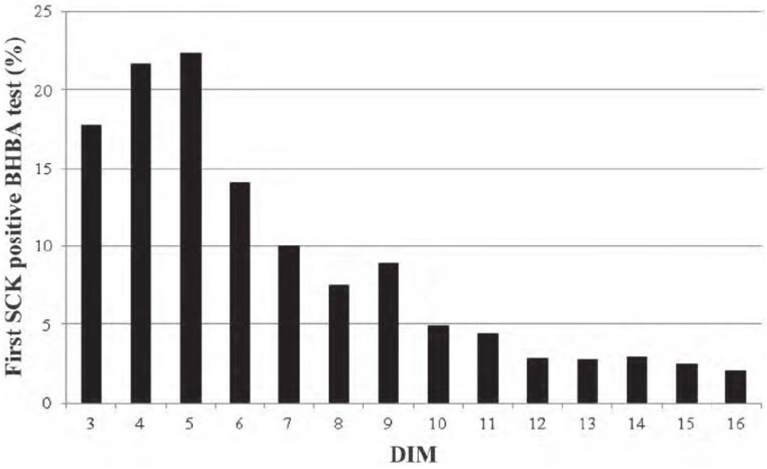
Herd-level impacts of elevated NEFA/BHB

Metabolite level	**Herd Alarm**	**Associated with:**
PRE-Partum NEFA ≥ 0.3 mEq/L	15%	+3.6% Disease incidence -1.2% Pregnancy rate - 529 lbs ME305 milk (both heifers and cows)
POST-Partum NEFA ≥ 0.6[a] - 0.7[b] mEq/L	15%	+1.7% Disease incidence[b] - 0.9% Pregnancy rate[a] Heifers: -640 lbs, Cows: **-** 1,272 lbs
BHB ≥ 10[a]-12[b*] mg/dL	15% *20%	+1.8% Disease incidence[b] -0.8% Pregnancy rate[b] Heifers: **-**1,179 lbs*, Cows: **-** 732 lbs[a]

***15% of 15 = 2-3 animals**

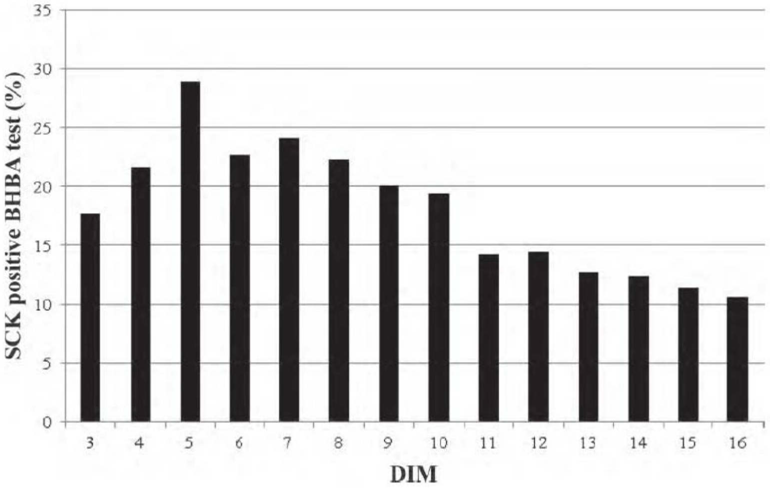
Ospina et al., 2010

Histogram of incidence of subclinical ketosis (SCK) in 1,717 Holstein dairy cows undergoing repeated testing for ketosis from 3 to 16 DIM. A positive test was defined as a blood BHBA concentration of 1.2 to 2.9 mmol/L



McArt et al., 2012. J. Dairy Sci. 95 :5056–5066

Histogram of prevalence of subclinical ketosis (SCK) in 1,717 Holstein dairy cows undergoing repeated testing for ketosis from 3 to 16 DIM. A positive test was defined as a blood BHBA concentration of 1.2 to 2.9 mmol/L



McArt et al., 2012. J. Dairy Sci. 95 :5056–5066

Approach for monitoring energy-related analytes in transition cows

- Sample size:
  - 15 to 20 cows
- Cows to sample
  - Pre-partum: 14 to 2 days before calving (NEFA only)
  - Post-partum: 3 to 14 DIM (NEFA and/or BHBA)
- Sample to take
  - Serum (red top tubes)
  - Don't shake, keep cool
  - Milk (ketones only)
- What to do with sample?
  - BHBA: Lab or Precision Xtra Meter (blood) or ketotest or infrared (milk)
  - NEFA: Lab
- What to do with results
  - Interpret % above cut-point
  - More than 15% above cut-point indicates herd-level problem

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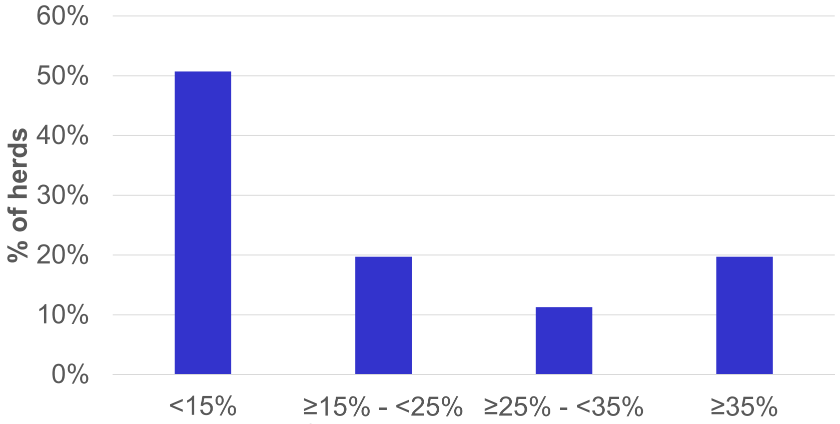
Prevalence of hyperketonemia between 3 and 14 DIM on 71 commercial dairy farms



Lawton et al., 2015 JAM

Top ten things to do for healthy and productive transition cows

- Manage macromineral nutrition/DCAD of dry cows, especially in the last 2 to 3 weeks before calving
- Control energy intake in both far-off and close-up cows – not too little, not too much
- Make sure supplying enough metabolizable protein before calving
- Get the feeding management right, every day
- Clean and comfortable housing and fresh water
- Manage social interactions/hierarchy
- Manage cold stress and heat stress
- High quality forage and fermentable diets for fresh cows
- Strategically use feed additives/nutritional tools
- Implement cow- and herd-level monitoring programs

Thanks!!

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Making Sense of Starch by NDF Interactions

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INTRODUCTION

Associative effects of feeds, nutrients, diets, and dry matter intake (DMI) influence the digestibility of nutrients in vivo. However, associative effects are largely ignored with commercial-lab in vitro or in situ digestibility measurements.

Presented in Table 1 are the findings of a survey, performed by the authors, of websites and sample reports from 4 major dairy feed testing labs in the USA for analyses related to starch and NDF digestibilities. Dairy nutritionists have a seemingly endless stream of assays, and calculations from these assays, available for characterizing feed ingredients and diets. The inclusion of biological assays, e.g. digestibility in rumen fluid, to go along with chemical assays, e.g. NDF, lignin, starch, etc., in the commercial feed analysis system has been a major step forward for the industry to characterize feed ingredients and diets according to their nutritive value.

However, when attempting to interpret and translate to the farm from the myriad of assays and calculations listed in Table 1, the inherent flaws of rumen in vitro and in situ measurements relative to in vivo digestibility results should be kept in mind. A partial list is as follows:

- Measurements relative to ingredient and nutrient composition and physical form of diet fed to donor or incubation cows (Cone et al., 1989; Mertens et al., 1996) rather than client farms where results will be used, e.g. effects of variable diet starch content and source on ruminal amylase activity and in vivo starch digestibility; effects on in vivo fiber digestibility of fluctuations in ruminal pH via production, buffering, absorption and passage of volatile fatty acids; effects of variation in rumen degradable protein on in vivo fiber and starch digestibility; etc.
- Measurements relative to DMI of donor or incubation cows rather than client farms with highly variable milk yield and hence DMI levels. Determination of digestion rates (k_d) allows this discrepancy to be partly corrected for by using rate of passage (k_p) assumptions. However, DMI may influence rumen pH (Shaver et al., 1986) and hence k_d; this effect would not be accounted for with kp assumptions in the $k_d/(k_d+k_p)$ calculations of digestibility.
- Fine grinding of incubation samples, to pass through a 1- to 2-mm screen, results in measurement of maximal rates and extents of NDF digestibility, while grinding incubation samples to pass through a 4- to 6-mm screen may mask the effects of test feed particle size on starch digestibility.
- Ruminal in vitro and in situ techniques ignore post-ruminal starch and NDF digestion. The proportion

Table 1. Survey of websites and sample reports from 4 major dairy feed testing labs in the USA for analyses related to starch and NDF digestibilities.

NDF; NDF_{OM}; Lignin; uNDF (Lignin × 2.4)
Starch; Prolamin; Ammonia; Particle Size; UW Feed Grain Evaluation; Processing Score
TMR-D; Rumen in vitro total tract NDFD (Combs-ivttNDFD)
Traditional (Goering – Van Soest) NDFD; Standardized (Combs – Goeser) NDFD
NDF k_d calculated from 24, 30, 48, 120-h NDFD (Combs – Goeser)
NDF k_d Mertens; NDF k_d Van Amburgh
24-h NDFD; calculated B_2/B_3 kd
30, 120, 240-h NDFD – forages; 12, 72, 120-h NDFD – byproducts
4, 8, 12, 24, 48, 72, 120, 240-h NDFD lag, pools & rates
120-h uNDF; 240-h uNDF
3-h, 7-h Rumen in vitro or in situ starch digestibility (ivRSD); k_d
Fecal Starch; Dietary Total Tract Starch Digestibility (TTSD)
Fermentrics™ (gas production system)
Calibrate™

of starch digested post-ruminally can be significant (Ferraretto et al., 2013).

Therefore, for the most part, the assays or calculations from these assays listed in Table 1 should be viewed as relative index values for comparison among feeds/diets or over time within feeds/diets, rather than as predictors of in vivo digestibility results. The obvious exceptions include: 1) determination of fecal starch concentrations to estimate in vivo total tract starch digestibility (TTSD) for diets (Fredin et al., 2014; Owens et al., 2015), and 2) determination of concentrations of fecal and diet undigested NDF (uNDF at 120 to 288 h) along with the nutrients of interest, in both fecal and diet samples, to determine in vivo total tract nutrient digestibility for diets (Schalla et al., 2012; Krizsan and Huhtanen, 2013). It is noted, however, that these results provide no information about site of digestion and pertain only to the diet fed rather than specific feed ingredients included within the diet.

In a field study of 32 high-producing commercial dairy herds in the Upper Midwest, Powel-Smith et al. (2015) used lignin and uNDF (240 h) as indigestible markers to determine in vivo TTSD and total tract NDF digestibility (TTNDFD) for diets. Measurements of ruminal in vitro starch digestibility (ivSD; 7 h) were unrelated ($R^2 = 0.00$) to TTSD. For TTNDFD, measurements of ruminal in vitro NDF digestibility (ivNDFD; 24 h) and uNDF were poorly ($R^2 = 0.13$ and 0.21, respectively) related.

Lopes et al. (2015), using in vivo TTNDF data from 21 treatment diets in 7 lactating dairy cow feeding trials conducted at the University of Wisconsin, evaluated uNDF (240 h) and the Combs rumen in vitro estimate of total tract NDF digestibility (ivttNDFD). Diet uNDF (240 h) was negatively related ($R^2 = 0.40$) to TTNDFD; each 1%-unit increase in uNDF (240 h) was associated with a 0.96%-unit decrease in TTNDFD. Mean values, however, were 15%-units greater for uNDF-predicted TTNDFD compared to the observed TTNDFD. The ivttNDFD calculations included diet uNDF (240 h), potentially-digestible NDF and NDF k_d determined using the in vitro procedure of Goeser and Combs (2009), assumed k_p, and assumed hindgut NDF digestion. The R^2 for the relationship between ivttNDFD and TTNDFD was 0.68 and mean values differed by only 1%-unit, showing promise for this approach.

The remainder of this paper will focus primarily on review and discussion of the effects of starch by NDF interactions and DMI on in vivo starch and NDF digestibilities.

CORN SILAGE

Substantially (10 to 15%-units) greater ivNDFD for brown midrib 3 mutation (bm_3) whole-plant corn silage (WPCS) hybrids associated with reduced lignin content compared to conventional hybrids is well established (Jung and Lauer, 2011; Jung et al., 2011). However, greater ivNDFD for bm_3 hybrids has sometimes, but not always, translated into greater in vivo NDF digestibility (Oba and Allen, 1999; Tine et al., 2001; Jung et al., 2011; Ferraretto and Shaver, 2015). Variable TTNDFD response to feeding bm_3 WPCS is influenced by the DMI response to the greater ivNDFD (Oba and Allen, 1999; Tine et al., 2001), while WPCS type (bm_3 versus near-isogenic or conventional WPCS hybrids) by dietary forage-NDF (Oba and Allen, 2000; Qiu et al., 2003), starch (Oba and Allen, 2000) and CP (Weiss and Wyatt, 2006) concentration or supplemental corn grain endosperm type (Taylor and Allen, 2005) interactions were undetected.

With approximately 10%-units greater ivNDFD for bm_3 compared to near-isogenic or conventional WPCS hybrids, DMI and TTNDFD responses were, respectively, 2.1 kg/d per cow and 1.8%-units (Oba and Allen, 1999), 0.8 to 1.4 kg/d per cow and non-significant (Oba and Allen, 2000), and 0.9 kg/d per cow and 2.5%-units (meta-analysis by Ferraretto and Shaver, 2015). Furthermore, Oba and Allen (1999) observed a negative linear relationship between DMI and TTNDFD responses for bm_3 WPCS, which was likely related to a faster passage rate through the rumen associated with greater DMI (NRC, 2001), with the regression indicating a zero TTNDFD response at a 3 kg/d per cow DMI response.

Tine et al. (2001) fed bm_3 WPCS TMR ad libitum or restricted to the DMI of the TMR containing near-isogenic WPCS to lactating dairy cows, while dry cows were fed bm_3 and near-isogenic WPCS TMR at maintenance intake levels. For dry cows, TTNDFD was 10%-units greater for the bm_3 diet, while for the lactating cows TTNDFD was 9%-units or 7%-units greater, respectively, for restricted-fed or ad libitum-fed cows compared to near-isogenic WPCS control diets. Averaged across treatments, TTNDFD was 67% in dry cows and 54% in lactating cows. Results from this study show a negative relationship between DMI and TTNDFD and TTNDFD response to bm_3 WPCS. While diet net energy for lactation (NE_L) concentrations were unaffected by treatment (*P* > 0.10), numerically diet NE_L content was 9% greater in dry cows, but only 2% greater in lactating cows, for bm_3 compared to near-isogenic WPCS diets. In Tine et al. (2001), DMI and milk yield were 2.4 and 3.1 kg/d per cow, respectively, greater for cows fed bm_3 WPCS compared to cows fed near-isogenic WPCS.

It is evident that the milk yield response to greater ivNDFD in bm$_3$ WPCS derives primarily through increases in DMI. Based on this research, the MILK2006 update of the MILK2000 WPCS hybrid evaluation model included discounts for estimating the NE$_L$ content of WPCS from predicted increases in DMI in response to greater ivNDFD, so that increases in estimated milk per ton in relationship to greater ivNDFD derive primarily through increases in DMI (Shaver, 2006; Shaver and Lauer, 2006). Prediction of DMI by NRC (2001), however, is not influenced by diet composition or forage ivNDFD.

From a meta-analysis, Ferraretto and Shaver (2015) reported 7%-unit and 2%-unit reductions in vivo for ruminal (RSD) and total tract (TTSD) starch digestibility, respectively, in bm$_3$ compared to near-isogenic or conventional WPCS hybrids. Compared to leafy hybrids, TTSD was 5%-units lower for bm$_3$ WPCS hybrids. Reduced starch digestibility for bm$_3$ WPCS hybrids could be due to greater kernel vitreousness (Fish, 2010; Glenn, 2013) and/or faster passage rate through the digestive tract associated with increased DMI (NRC, 2001; Ferraretto et al., 2013). Ferraretto et al. (2015a) reported 5%-units greater TTSD for lactating dairy cows fed an experimental floury-leafy WPCS hybrid compared to cows fed a bm$_3$ WPCS hybrid that appeared related to reduced kernel vitreousness and greater WPCS ruminal ivSD (7 h) and in situ (12 h) starch digestibility for the floury-leafy hybrid. However, ivNDFD (30 h), DMI and milk yield were 11%-units, 1.7 kg/d per cow and 2.2 kg/d per cow, respectively, greater for the bm$_3$ WPCS treatment. In agreement with previously discussed trials, TTNDFD was similar for the 2 diets despite the large ivNDFD difference between the WPCS treatments. Greater ivNDFD, DMI and milk yield for a bm$_3$ WPCS hybrid compared to an experimental floury-leafy WPCS hybrid has also been reported by Morrison et al. (2014).

These results underscore the importance of ivNDFD for WPCS hybrid selection from the standpoint of DMI and milk yield responses, and when attempting to incorporate parameters associated with greater starch digestibility into new WPCS hybrids. For example, improving starch digestibility of bm$_3$ hybrids through genetics appears to be a logical WPCS hybrid development strategy.

Ferraretto and Shaver (2012a), from a meta-analysis of WPCS trials with lactating dairy cows, reported the following: processing (1- to 3-mm roll gap) increased diet TTSD compared to 4- to 8-mm processed and unprocessed WPCS; processing increased TTSD for diets containing WPCS with 32 to 40% DM; processing increased diet TTSD when length of chop was set for 0.93 to 2.86 cm. Ferraretto and Shaver (2012b) and Vanderwerff et al. (2015) reported greater TTSD in lactating dairy cows fed Shredlage™ compared to conventional-processed WPCS. Clearly, physical form of WPCS affects starch digestibility. Grinding incubation samples for in vitro or in situ analysis through a common screen (e.g. 4- or 6-mm) may mask differences in particle size among WPCS that impact starch digestibility. Furthermore, incorporating measures of starch digestibility into WPCS hybrid selection is difficult because starch digestibility increases over time in storage (Ferraretto et al., 2015b).

DIETARY STARCH AND FORAGE NDF

Presented in Figure 1 (meta-analysis by Ferraretto et al., 2013) is the effect of dietary starch concentration on fiber digestibility. Increased dietary starch concentration reduced ruminal NDFD in vivo (*P* = 0.01) and TTNDFD (*P* = 0.001). The digestibility of dietary NDF decreased

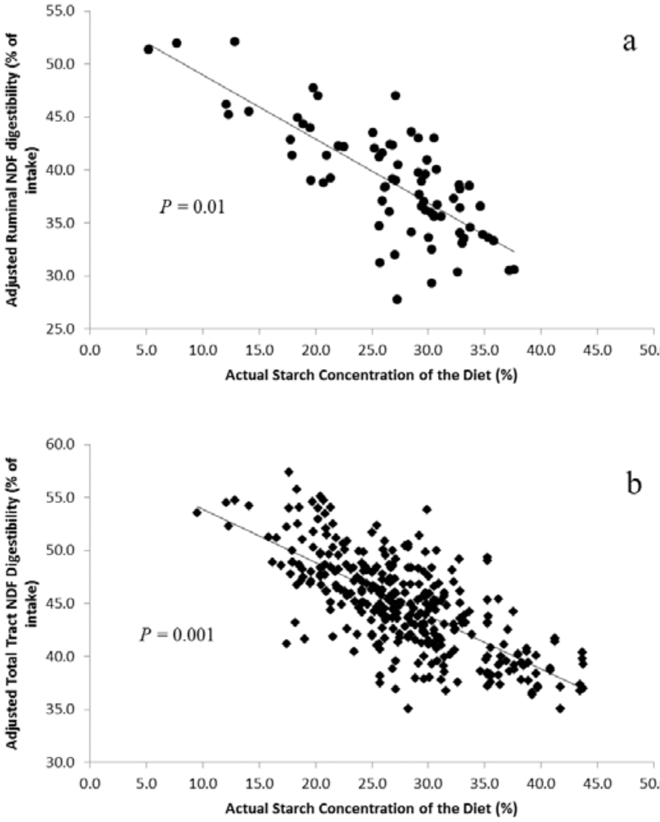

Figure 1. Effect of starch concentration of the diet on ruminal and total-tract digestibility of diet NDF adjusted for the random effect of trial. Ruminal digestibility data (Panel a) predicted from equation: y = 54.9746 + (-0.605 × starch concentration) + (0.063 ± 3.524); n = 70, RMSE = 3.55. Total-tract digestibility diet (Panel b) predicted from equation: y = 58.2843 + (-0.4817 × starch concentration) + (0.059 ± 3.191); n = 320, RMSE = 3.20. Ferraretto et al., 2013.

0.61%-units ruminally and 0.48%-units total-tract per %-unit increase in dietary starch content. Decreased fiber digestibility may be partially explained by a decrease in rumen pH as a consequence of greater amounts of starch (kg/d) being digested in the rumen as starch intake increases. Low rumen pH is known to affect microbial growth and bacterial adherence and thereby fiber digestion. Also, the inherently high fiber digestibility of non-forage fibrous by-products used to partially replace corn grain in reduced-starch diets may be partly responsible.

Weiss (2014; unpublished from 28th ADSA Discover Conf. in Starch for Ruminants) used the slope of Ferraretto et al. (2013) in Figure 1, or 0.5%-unit change in TTNDF for each 1%-unit change in dietary starch content, to calculate effects on dietary energy values. In the Weiss (2014) example, a 5%-unit increase in dietary starch content (e.g. 30% vs. 25%) reduced TTNDF 2.5%-units (46.5% to 44.0%), which resulted in a 5.3% increase in diet NEL content compared to a 6.5% increase had TTNDFD not been adversely affected by increased dietary starch content. Greater TTSD (>90%) than TTNDFD (<50%) tempers the negative impact on diet NEL content of reduced TTNDFD with greater dietary starch concentrations.

Effects of dietary forage NDF (FNDF) concentration on nutrient digestibilities were reported in the meta-analysis of Ferraretto et al. (2013). Fiber digestibility was unaffected by FNDF concentration in the diet either ruminally or total-tract. Similar results were reported by Zebeli et al. (2006). Furthermore, starch digestibility decreased only 0.17%-units per %-unit increase in dietary FNDF total-tract (*P* = 0.05), but not ruminally (Ferraretto et al., 2013). Thus, if dietary starch and total NDF concentrations are held constant, the primary effect of dietary FNDF was on DMI (*P* = 0.04) with a 0.17 kg/d per cow decrease in DMI per 1%-unit increase in dietary FNDF (Ferraretto et al., 2013). For example, a 3%-unit increase in dietary FNDF (25% vs. 22%, DM basis) would result in a 0.51 kg/d per cow decrease in DMI.

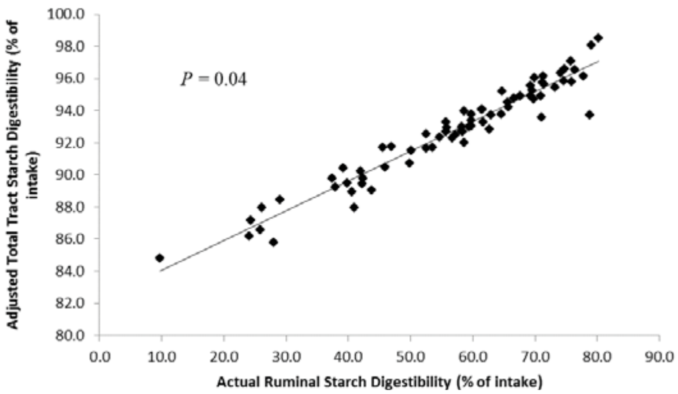

Figure 2. Relationship between ruminal and total-tract starch digestibility adjusted for the random effect of trial. Prediction equation: y = 82.224 + (0.185 × ruminal) + (-0.002 ± 0.772); n = 72, RMSE = 0.78. Ferraretto et al., 2013.

SITE OF STARCH DIGESTION

Relationships between ruminal, post-ruminal and total-tract starch digestibilities from the meta-analysis by Ferraretto et al. (2013) are presented in Figures 2 and 3. The RSD and TTSD were related positively (*P* = 0.04; Figure 2), with an increase of 0.19%-units total-tract per %-unit increase ruminally. Post-ruminal starch digestibility measured as percentage of flow to the duodenum was positively related to TTSD (*P* = 0.001; Figure 3). In feedstuffs with a high proportion of rumen-digested starch, e.g. corn silage or high-moisture corn, in vitro or in situ measurement of starch digestibility may be a useful predictor of TTSD if particle size differences among test feeds were not masked by grinding of the incubation samples to a similar particle size.

CONCLUSIONS

Generally, lab analyses related to starch and NDF digestibilities should be viewed as relative index values for comparison among feeds/diets or over time within feeds/diets, rather than as predictors of in vivo digestibility.

The milk yield response to greater ivNDFD in bm$_3$ WPCS derives primarily through greater DMI rather than diet TTNDFD or NE$_L$ content. Reduced RSD and TTSD in bm$_3$ compared to near-isogenic or conventional WPCS hybrids suggests potential for genetic improvement of bm$_3$ hybrids with a more floury-type endosperm.

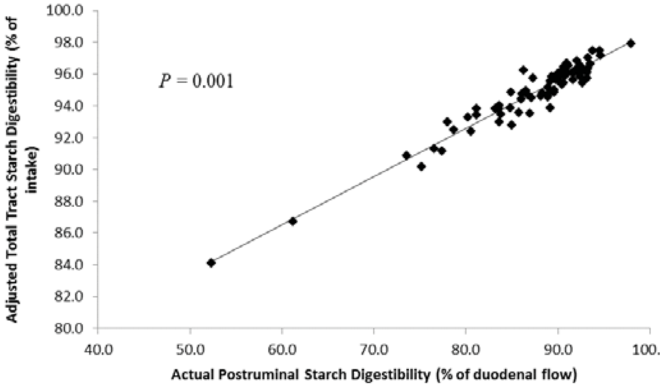

Figure 3. Relationship between postruminal starch digestibility as a percentage of duodenal flow and total-tract starch digestibility adjusted for the random effect of trial. Prediction equation: y = 68.287 + (0.304 × postruminal % of flow) + (0.013 ± 0.574); n = 72, RMSE = 0.58. Ferraretto et al., 2013.

Grinding incubation samples for in vitro or in situ analysis may mask differences in particle size among WPCS that impact starch digestibility, and incorporating measures of starch digestibility into WPCS hybrid selection is difficult because of ensiling effects on starch digestibility.

Increased concentrations of dietary starch decrease fiber digestibility. The negative effect, however, on calculated diet NE_L content is not large, and thus still favors higher starch diets. Comparisons among sites of starch digestion indicate that greater ruminal starch digestibility increases starch digestibility in the total tract. However, the proportion of starch digested post-ruminally can be high for some feedstuffs and diets, which would go undetected by rumen in vitro or in situ starch digestibility measurements.

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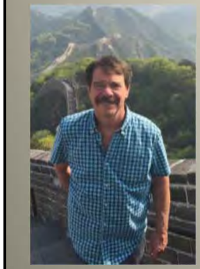
A Perspective on NDF & Starch Digestibility Measures



Randy Shaver & Luiz Ferraretto
Dairy Science Department

THE UNIVERSITY of WISCONSIN MADISON

UW Extension

DEPARTMENT OF DAIRY SCIENCE
University of Wisconsin-Madison

In Vitro

In Situ

Gas Production

In Vivo

In Vivo

Wisconsin Holstein sets 72,170 milk production record
2010: Tom & Gin Kestell & Sons, Waldo, WI

Ever-Green-View My 1326-ET
(EX-92 EX-MS)
4-05 365d 3x 72,168 3.9 2787 3.2 2286

WI AgSource DHIA Top 100

		RHA (lb)			
Stat	Cow #	Milk	Fat	Protein	Cheese
Average	486	31,297	1,154	961	3,150
Std. Deviation	500	1,622	90	57	203
Min	20	30,141	981	857	2,733
Max	3490	41,364	1,677	1,288	4,395

Sept. 2015

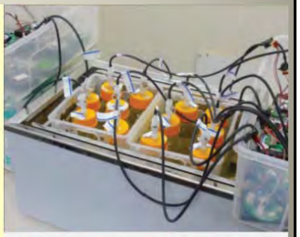
111 Herds >30,000 lb RHA which represents 2.5% of herds on test there

+30 WI Herds >30,000 lb RHA at NorthStar DHI

- Associative effects of feeds, nutrients, diets and DMI influence the digestibility of nutrients in vivo
    - Associative effects are largely ignored with in vitro or in situ digestibility measurements

In Vitro

In Situ



Gas Production

Survey of websites and reports of 4 major US dairy feed labs for analyses related to starch and NDF digestibilities

NDF; NDF_{OM}; Lignin; uNDF (Lignin × 2.4)

Starch; Prolamin; Ammonia; Particle Size; UW Feed Grain Evaluation; Corn Silage Processing Score

TMR-D; Rumen in vitro total tract NDFD (Combs-ivttNDFD)

Traditional (Goering – Van Soest) NDFD; Standardized (Combs – Goeser) NDFD

NDF k_d calculated from 24, 30, 48, 120-h NDFD (Combs – Goeser)

NDF k_d Mertens, MIR; NDF k_d Van Amburgh

24-h NDFD; calculated B_2/B_3 kd

30, 120, 240-h NDFD – forages; 12, 72, 120-h NDFD – byproducts

4, 8, 12, 24, 48, 72, 120, 240-h NDFD lag, pools & rates

120-h uNDF; 240-h uNDF

3-h, 7-h Rumen in vitro or in situ starch digestibility (ivRSD); k_d

Fecal Starch; Dietary Total Tract Starch Digestibility (TTSD)

Fermentrics™ (gas production system)

Calibrate™

Jones Index; (NDFd30 + starch)/NDFu30

Partial list of inherent flaws of rumen in vitro & in situ digestibility measures relative to in vivo

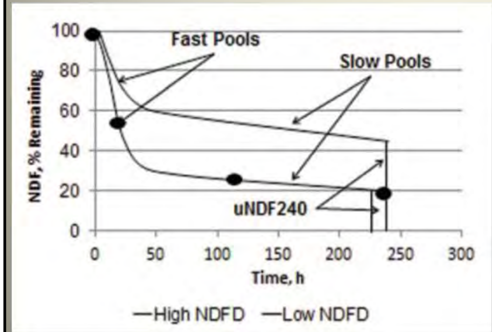
- Donor/incubation cow diet ingredient/nutrient content & physical form versus client farm(s)
    - e.g. Diet starch% & source affects amylase & cellulase activities; Rumen pH & fluctuation; RDP; etc.

- Ditto for DMI
    - $k_d/(k_d+k_p)$
    - k_p assumed; disagreement over use of k_p of DM or nutrient and determination methods for k_p (markers or fill/flux)
    - DMI & diet influence rumen pH and hence k_d

- Fine grinding of incubation samples
    - 1-2 mm screen for ivNDFD
        - Results in maximal rates and extents of NDF digestibility
    - 4-6 mm for ivStarchD
        - Masks particle size effects on starch digestibility

- Ignores post-ruminal NDF and starch digestion

A bit more on digestion kinetics



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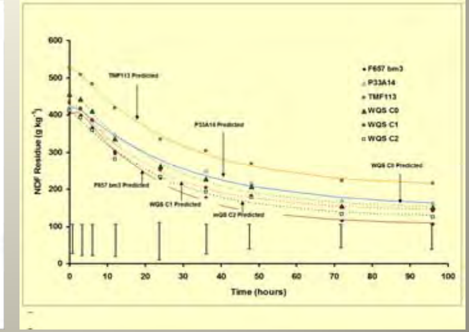
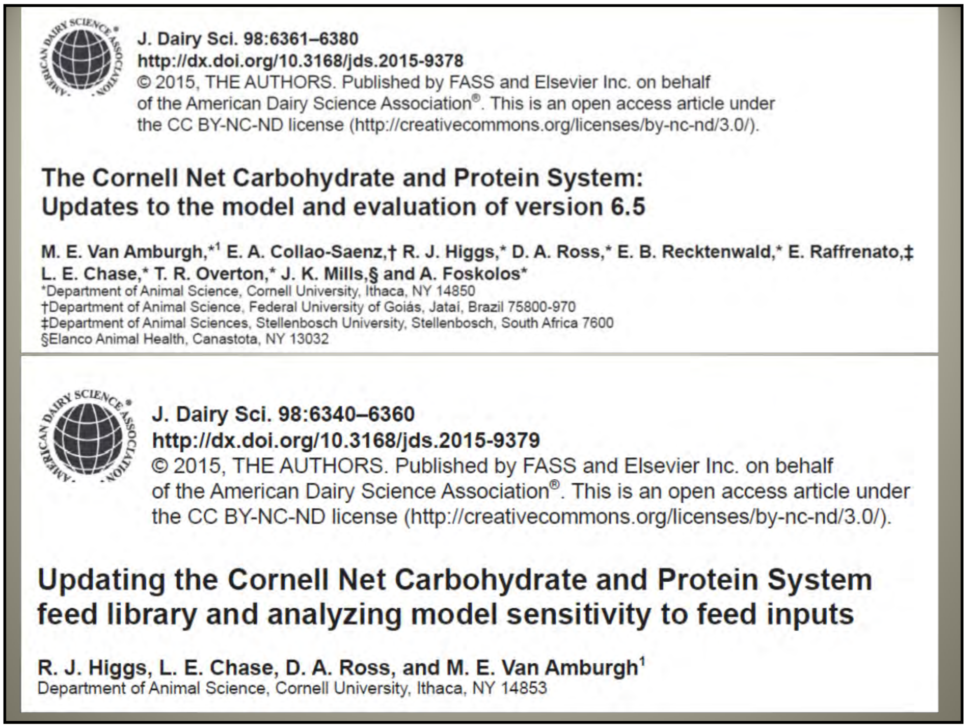


Jim Coors, UW Madison, Ben Justen's Thesis

For the most part, ruminal in vitro and in situ NDF digestibility measurements, should be viewed as relative index values for comparison among feeds/diets or over time within feeds/diets, rather than as predictors of in vivo digestibility



J. Dairy Sci. 98:6361–6380
http://dx.doi.org/10.3168/jds.2015-9378
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The Cornell Net Carbohydrate and Protein System: Updates to the model and evaluation of version 6.5

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J. Dairy Sci. 98:6340–6360
http://dx.doi.org/10.3168/jds.2015-9379
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Updating the Cornell Net Carbohydrate and Protein System feed library and analyzing model sensitivity to feed inputs

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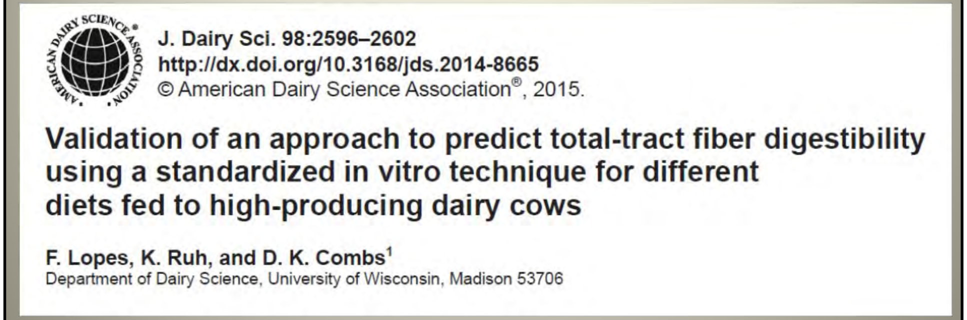
Department of Animal Science, Cornell University, Ithaca, NY 14853

In Vitro

In Situ

In Vivo

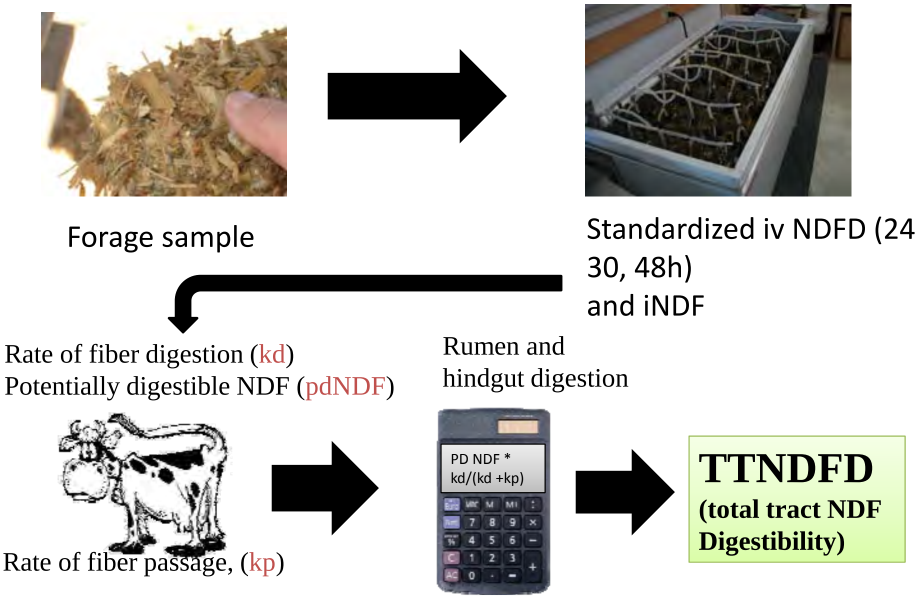


J. Dairy Sci. 98:2596–2602
http://dx.doi.org/10.3168/jds.2014-8665

Validation of an approach to predict total-tract fiber digestibility using a standardized in vitro technique for different diets fed to high-producing dairy cows

F. Lopes, K. Ruh, and D. K. Combs[1]
Department of Dairy Science, University of Wisconsin, Madison 53706

How is TTNDFD determined?



Forage sample

Standardized iv NDFD (24, 30, 48h)
and iNDF

Rate of fiber digestion (kd)
Potentially digestible NDF (pdNDF)

Rumen and
hindgut digestion

Rate of fiber passage, (kp)

PD NDF *
kd/(kd +kp)

TTNDFD
(total tract NDF Digestibility)

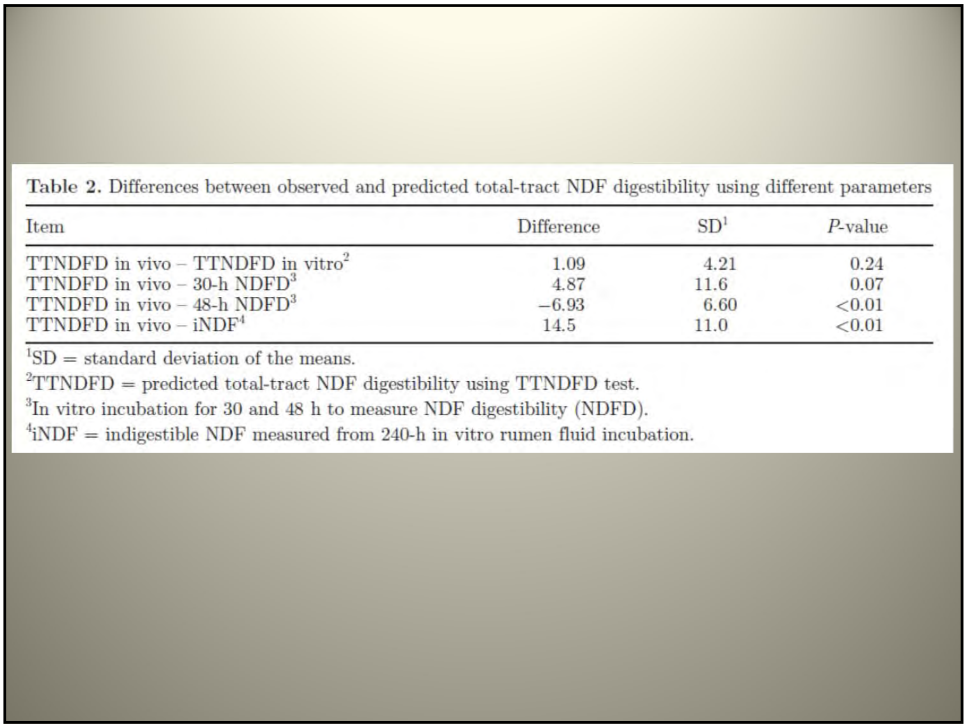


Table 2. Differences between observed and predicted total-tract NDF digestibility using different parameters

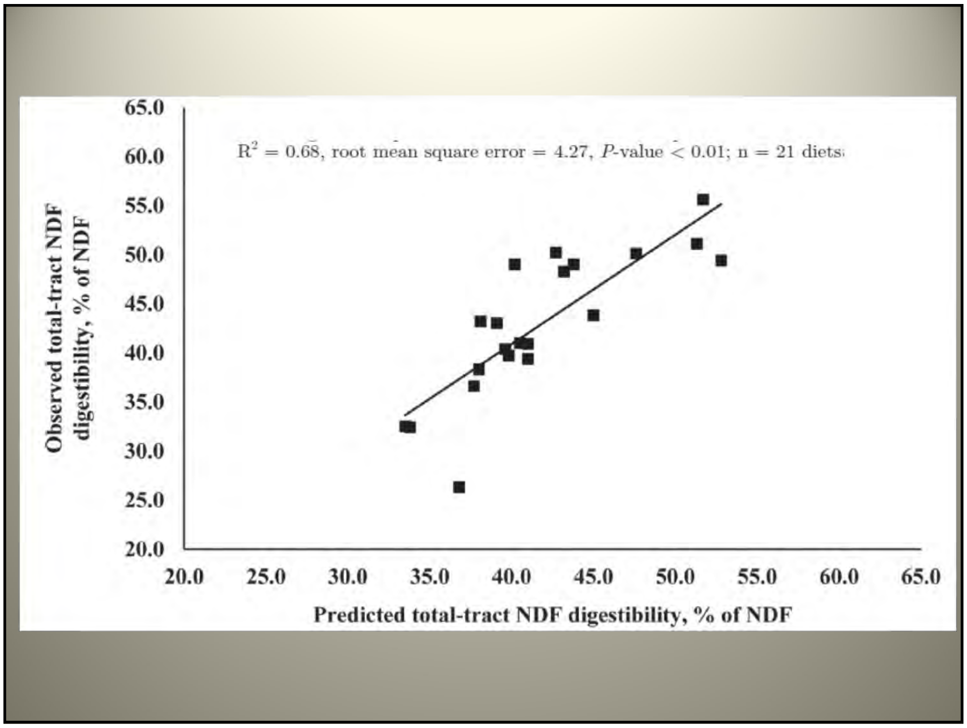
Item	Difference	SD[1]	*P*-value
TTNDFD in vivo – TTNDFD in vitro[2]	1.09	4.21	0.24
TTNDFD in vivo – 30-h NDFD[3]	4.87	11.6	0.07
TTNDFD in vivo – 48-h NDFD[3]	−6.93	6.60	<0.01
TTNDFD in vivo – iNDF[4]	14.5	11.0	<0.01

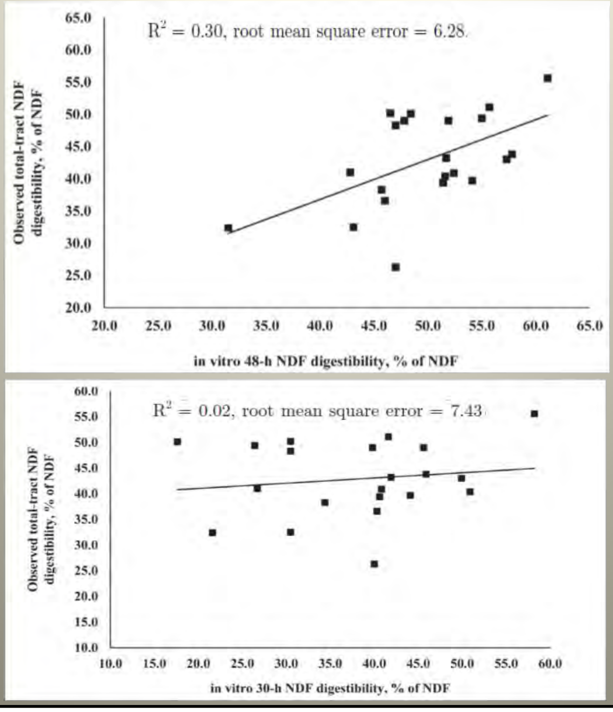
[1] SD = standard deviation of the means.

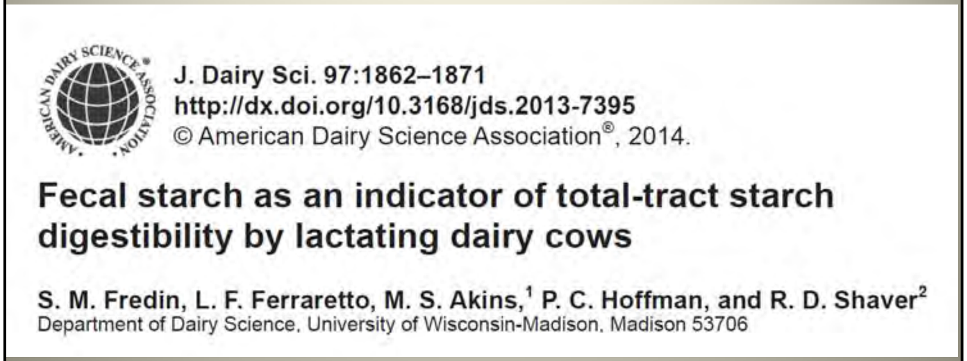
[2] TTNDFD = predicted total-tract NDF digestibility using TTNDFD test.

[3] In vitro incubation for 30 and 48 h to measure NDF digestibility (NDFD).

[4] iNDF = indigestible NDF measured from 240-h in vitro rumen fluid incubation.

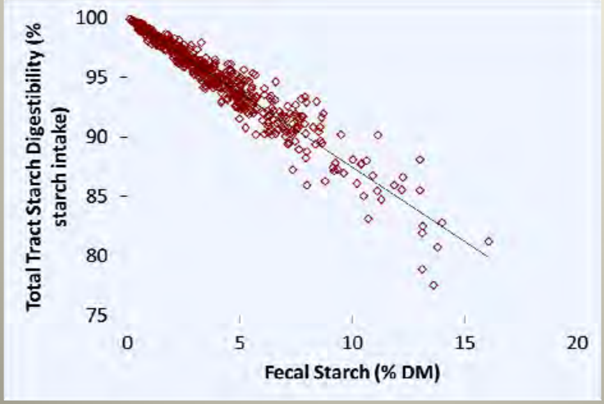





J. Dairy Sci. 97:1862–1871
http://dx.doi.org/10.3168/jds.2013-7395

Fecal starch as an indicator of total-tract starch digestibility by lactating dairy cows

S. M. Fredin, L. F. Ferraretto, M. S. Akins,[1] P. C. Hoffman, and R. D. Shaver[2]
Department of Dairy Science, University of Wisconsin-Madison, Madison 53706



$P < 0.001$

$R^2 = 0.94$

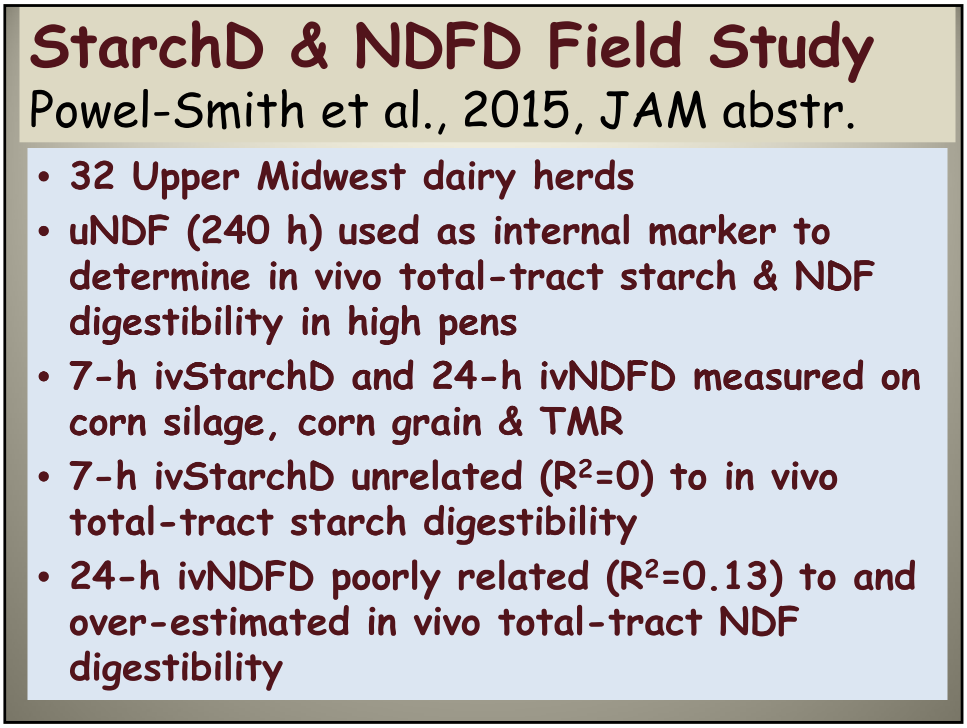
564 samples

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

Fredin et al., 2014, JDS

Utility of On-Farm Fecal Starch?

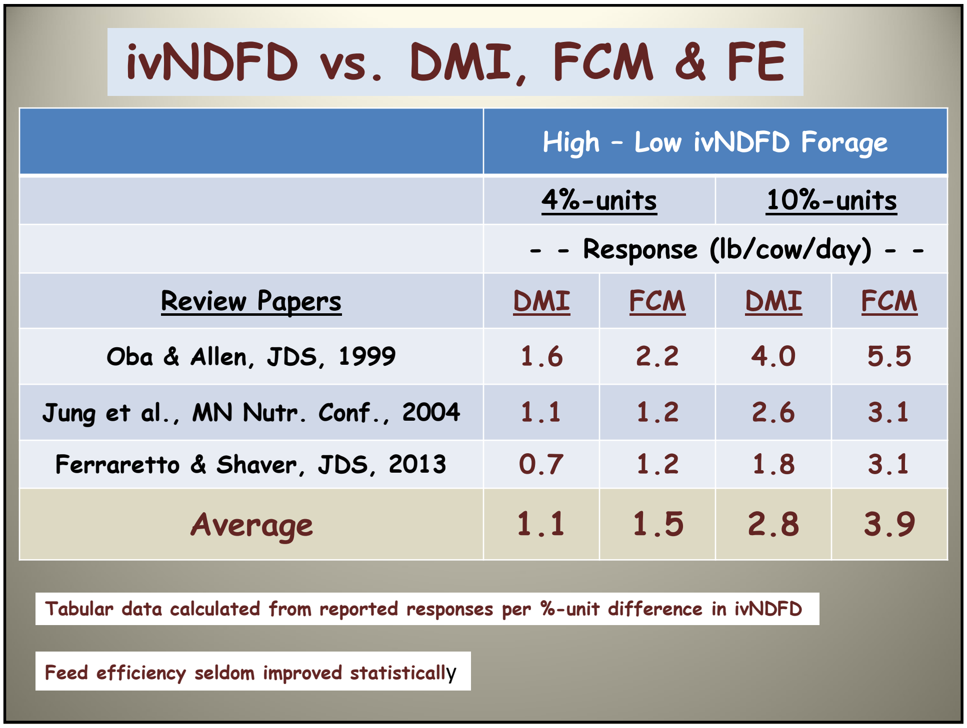
- Can be used to predict total tract starch digestibility from available equation or using uNDF
  - Monitor specific group over time
  - Reflects total diet, not specific feedstuffs!
  - Gives no indication of site of digestion
  - If <3% starch in feces no need to investigate feeds to improve starch digestion
  - If >3% should evaluate specific starchy feedstuffs



StarchD & NDFD Field Study

Powel-Smith et al., 2015, JAM abstr.

- 32 Upper Midwest dairy herds
- uNDF (240 h) used as internal marker to determine in vivo total-tract starch & NDF digestibility in high pens
- 7-h ivStarchD and 24-h ivNDFD measured on corn silage, corn grain & TMR
- 7-h ivStarchD unrelated (R^2=0) to in vivo total-tract starch digestibility
- 24-h ivNDFD poorly related (R^2=0.13) to and over-estimated in vivo total-tract NDF digestibility



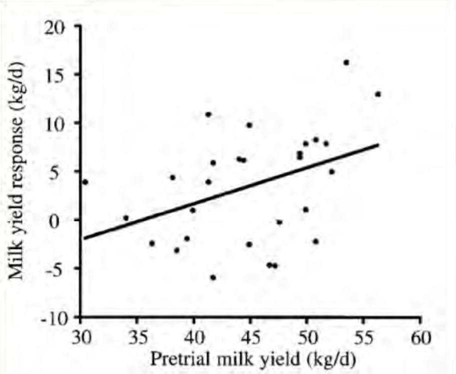
ivNDFD vs. DMI, FCM & FE

	High – Low ivNDFD Forage			
	4%-units		10%-units	
	- - Response (lb/cow/day) - -			
Review Papers	DMI	FCM	DMI	FCM
Oba & Allen, JDS, 1999	1.6	2.2	4.0	5.5
Jung et al., MN Nutr. Conf., 2004	1.1	1.2	2.6	3.1
Ferraretto & Shaver, JDS, 2013	0.7	1.2	1.8	3.1
Average	1.1	1.5	2.8	3.9

Tabular data calculated from reported responses per %-unit difference in ivNDFD

Feed efficiency seldom improved statistically

Response to ivNDFD vs. Level of Production

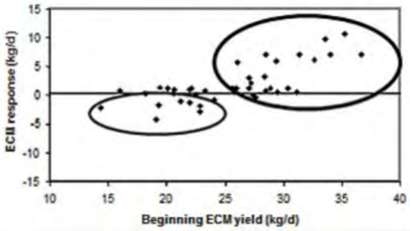


Effects of Brown Midrib 3 Mutation in Corn Silage on Dry Matter Intake and Productivity of High Yielding Dairy Cows

1999 J Dairy Sci 82:135–142

M. OBA and M. S. ALLEN[1]
Department of Animal Science,
Michigan State University, East Lansing 48824-1225

Figure 1. Difference in energy-corrected milk (ECM) response for cows fed high versus low NDF digestibility corn silage hybrids as it varies with milk production level (Ivan et al., 2004). Circles indicate that higher producing cows respond positively to higher NDF digestibility whereas lower producing cows do not respond, or respond negatively, to higher corn silage NDF digestibility.



Grant, Proc. 2015 4-State Nutr. & Mgmt. Conf., Dubuque, IA

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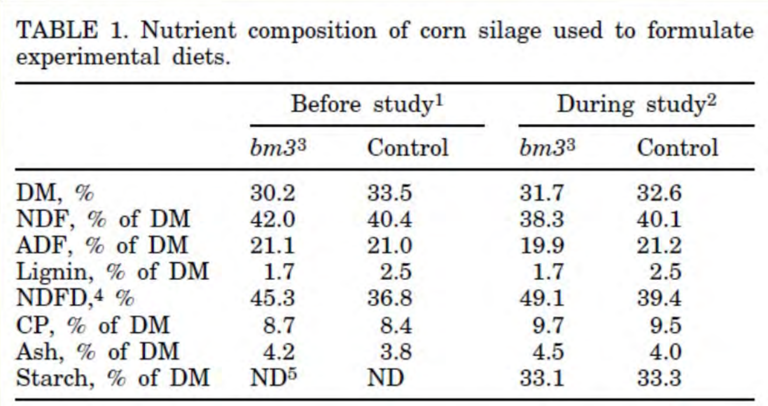


TABLE 1. Nutrient composition of corn silage used to formulate experimental diets.

	Before study[1]		During study[2]	
	bm3[3]	Control	*bm3*[3]	Control
DM, %	30.2	33.5	31.7	32.6
NDF, % of DM	42.0	40.4	38.3	40.1
ADF, % of DM	21.1	21.0	19.9	21.2
Lignin, % of DM	1.7	2.5	1.7	2.5
NDFD,[4] %	45.3	36.8	49.1	39.4
CP, % of DM	8.7	8.4	9.7	9.5
Ash, % of DM	4.2	3.8	4.5	4.0
Starch, % of DM	ND[5]	ND	33.1	33.3

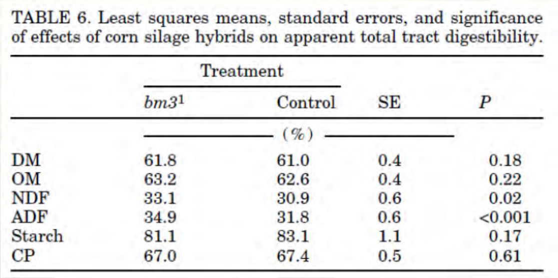
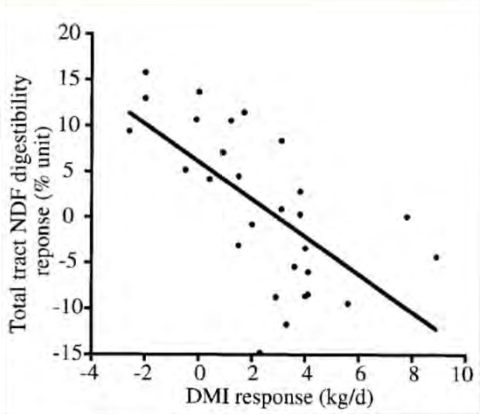


TABLE 6. Least squares means, standard errors, and significance of effects of corn silage hybrids on apparent total tract digestibility.

	Treatment			
	bm3[1]	Control	SE	*P*
	(%)			
DM	61.8	61.0	0.4	0.18
OM	63.2	62.6	0.4	0.22
NDF	33.1	30.9	0.6	0.02
ADF	34.9	31.8	0.6	<0.001
Starch	81.1	83.1	1.1	0.17
CP	67.0	67.4	0.5	0.61



Effects of Brown Midrib 3 Mutation in Corn Silage on Dry Matter Intake and Productivity of High Yielding Dairy Cows

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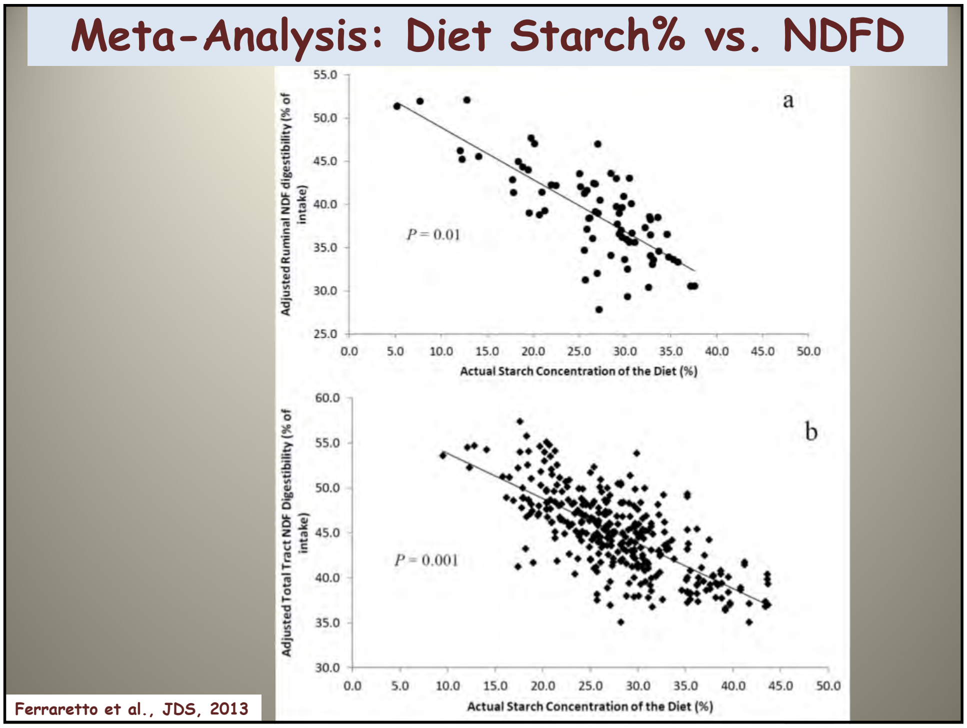
1999 J Dairy Sci 82:135–142

Energy content of bm$_3$ corn silage

Tine et al., 2001, JDS

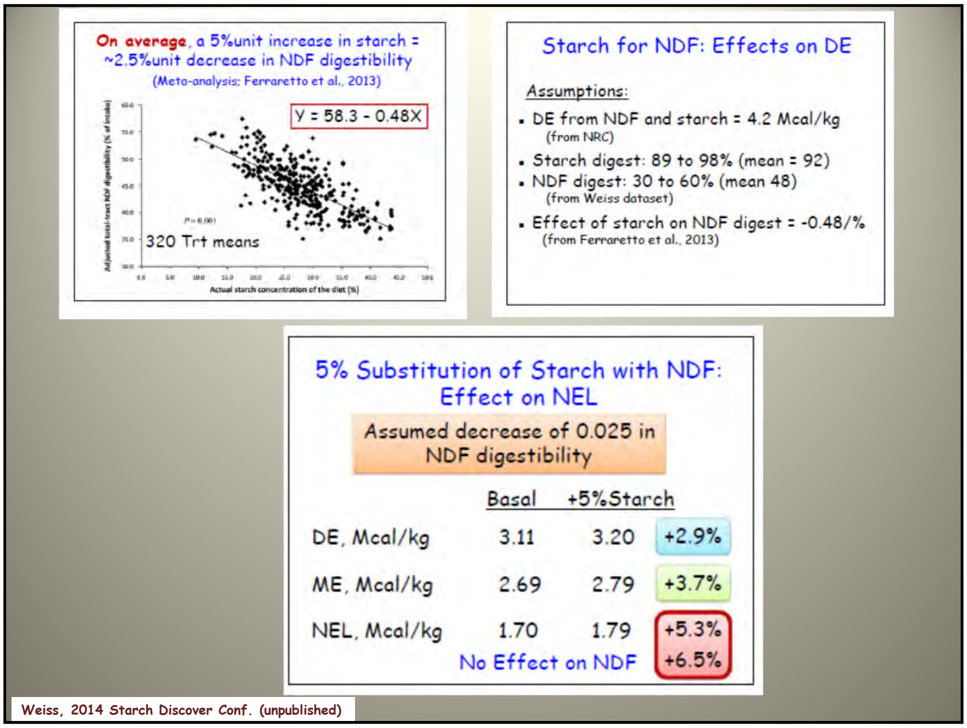
Item	Lactating 4x Maintenance		Dry Maintenance	
	Isogenic	bm$_3$	Isogenic	bm$_3$
TDN, %	---	---	72.1^{b}	74.8^{a}
DE, Mcal/kg	3.10	3.12	3.20^{b}	3.32^{a}
ME, Mcal/kg	2.58	2.68	2.62^{b}	2.77^{a}
NE$_L$, Mcal/kg	1.43	1.49	1.42	1.54

In Vivo



Meta-Analysis: Diet Starch% vs. NDFD

Ferraretto et al., JDS, 2013



On average, a 5%unit increase in starch = ~2.5%unit decrease in NDF digestibility
(Meta-analysis; Ferraretto et al., 2013)

Starch for NDF: Effects on DE

Assumptions:

- DE from NDF and starch = 4.2 Mcal/kg
  (from NRC)
- Starch digest: 89 to 98% (mean = 92)
- NDF digest: 30 to 60% (mean 48)
  (from Weiss dataset)
- Effect of starch on NDF digest = -0.48/%
  (from Ferraretto et al., 2013)

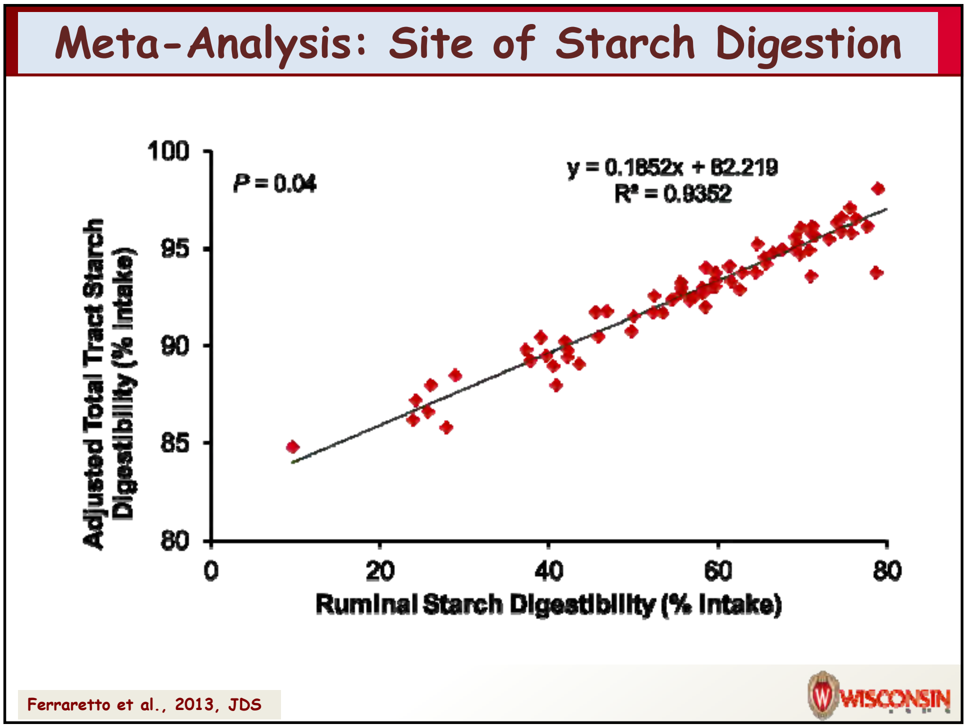
5% Substitution of Starch with NDF: Effect on NEL

Assumed decrease of 0.025 in NDF digestibility

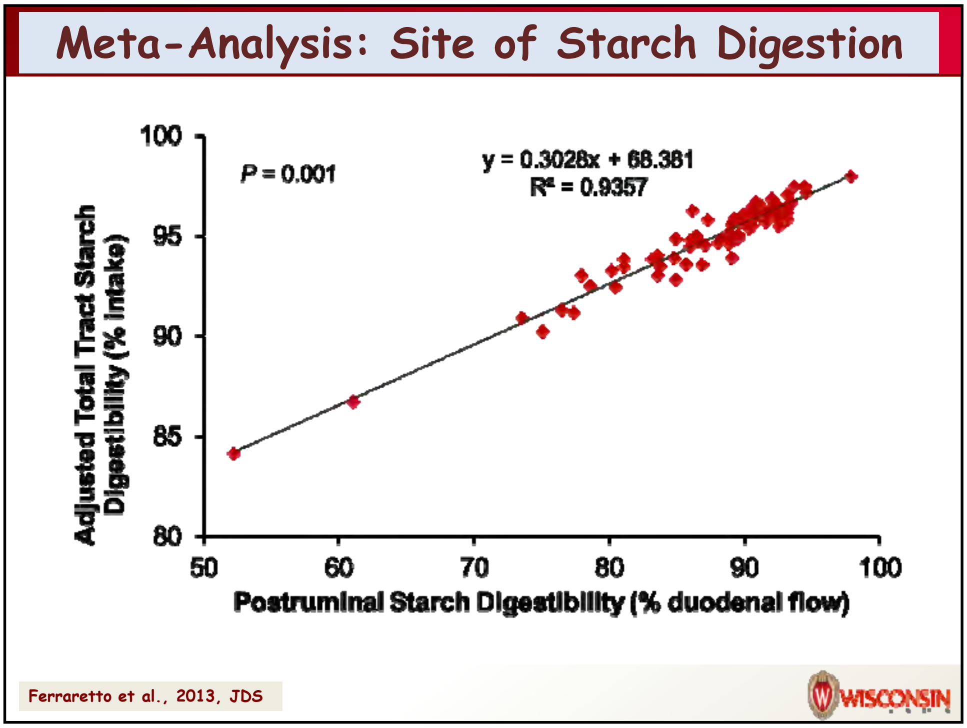
	Basal	+5%Starch	
DE, Mcal/kg	3.11	3.20	+2.9%
ME, Mcal/kg	2.69	2.79	+3.7%
NEL, Mcal/kg	1.70	1.79	+5.3%
		No Effect on NDF	+6.5%

Weiss, 2014 Starch Discover Conf. (unpublished)

Meta-Analysis: Site of Starch Digestion

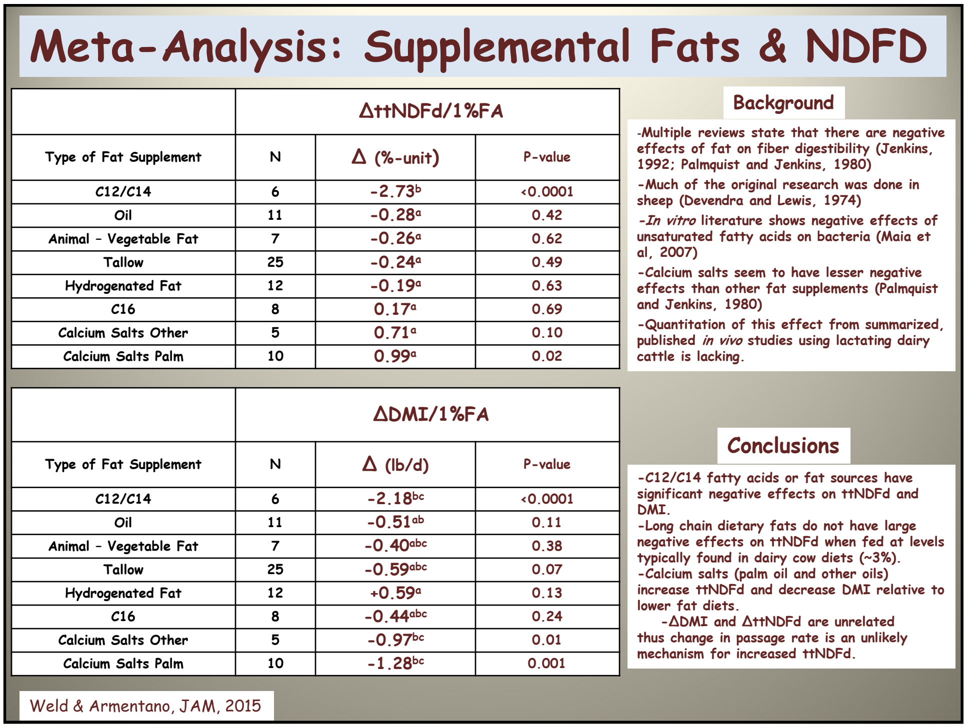


Ferraretto et al., 2013, JDS



Meta-Analysis: Site of Starch Digestion

Ferraretto et al., 2013, JDS



Meta-Analysis: Supplemental Fats & NDFD

	ΔttNDFd/1%FA		
Type of Fat Supplement	N	Δ (%-unit)	P-value
C12/C14	6	-2.73^{b}	<0.0001
Oil	11	-0.28^{a}	0.42
Animal - Vegetable Fat	7	-0.26^{a}	0.62
Tallow	25	-0.24^{a}	0.49
Hydrogenated Fat	12	-0.19^{a}	0.63
C16	8	0.17^{a}	0.69
Calcium Salts Other	5	0.71^{a}	0.10
Calcium Salts Palm	10	0.99^{a}	0.02

	ΔDMI/1%FA		
Type of Fat Supplement	N	Δ (lb/d)	P-value
C12/C14	6	-2.18^{bc}	<0.0001
Oil	11	-0.51^{ab}	0.11
Animal - Vegetable Fat	7	-0.40^{abc}	0.38
Tallow	25	-0.59^{abc}	0.07
Hydrogenated Fat	12	+0.59^{a}	0.13
C16	8	-0.44^{abc}	0.24
Calcium Salts Other	5	-0.97^{bc}	0.01
Calcium Salts Palm	10	-1.28^{bc}	0.001

Background

-Multiple reviews state that there are negative effects of fat on fiber digestibility (Jenkins, 1992; Palmquist and Jenkins, 1980)

-Much of the original research was done in sheep (Devendra and Lewis, 1974)

-*In vitro* literature shows negative effects of unsaturated fatty acids on bacteria (Maia et al, 2007)

-Calcium salts seem to have lesser negative effects than other fat supplements (Palmquist and Jenkins, 1980)

-Quantitation of this effect from summarized, published *in vivo* studies using lactating dairy cattle is lacking.

Conclusions

-C12/C14 fatty acids or fat sources have significant negative effects on ttNDFd and DMI.
-Long chain dietary fats do not have large negative effects on ttNDFd when fed at levels typically found in dairy cow diets (~3%).
-Calcium salts (palm oil and other oils) increase ttNDFd and decrease DMI relative to lower fat diets.
    -ΔDMI and ΔttNDFd are unrelated thus change in passage rate is an unlikely mechanism for increased ttNDFd.

Weld & Armentano, JAM, 2015

Summary & Conclusions

- There are associative effects on in vivo digestibility that go undetected with in vitro/in situ measures
- There are inherent flaws with in vitro/in situ measures relative to in vivo
- Nutrition models drive required analyses

Summary & Conclusions

- ivNDFD measures mostly unrelated to in vivo NDFD
- Milk yield response to greater ivNDFD derives mainly thru greater DMI
  - Logically DMI response to NDF/ivNDFD or uNDF should be included in intake prediction equations
- For diagnostics, fecal starch, uNDF to estimate in vivo digestibilities, & the Combs in vitro-TTNDF model look promising

Summary & Conclusions

- Greater diet starch content reduces fiber digestibility in vivo
  - The negative effect on diet NE_L is not large though and still favors higher starch diets
- Greater ruminal starch digestion related to greater total tract starch digestibility
  - Post-ruminal starch digestion can be high for some feeds & diet situations
    - ❖ Undetected by current in vitro/in situ StarchD measures
  - Sample grinding likely masks important particle size effects on in vitro/in situ StarchD measures

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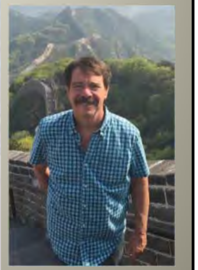
Visit UW Extension Dairy Cattle Nutrition Website

http://www.shaverlab.dysci.wisc.edu/



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