The Efficiency of Use of Nitrogen and Phosphorus in Lactating Dairy Cattle with Whole Farm Implications

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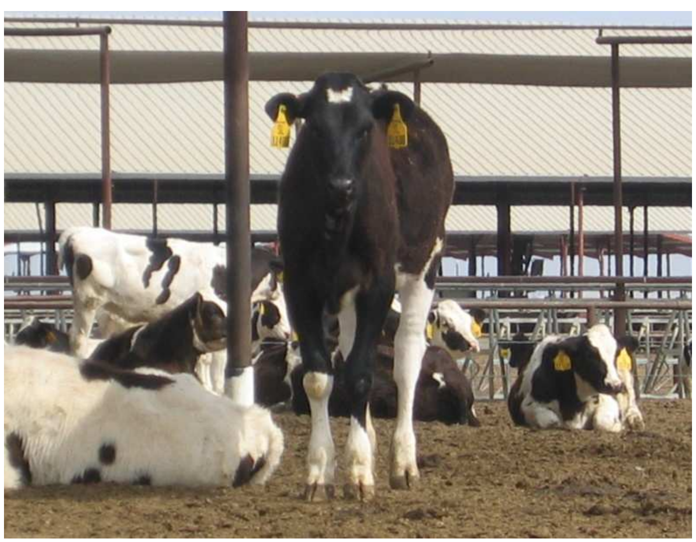


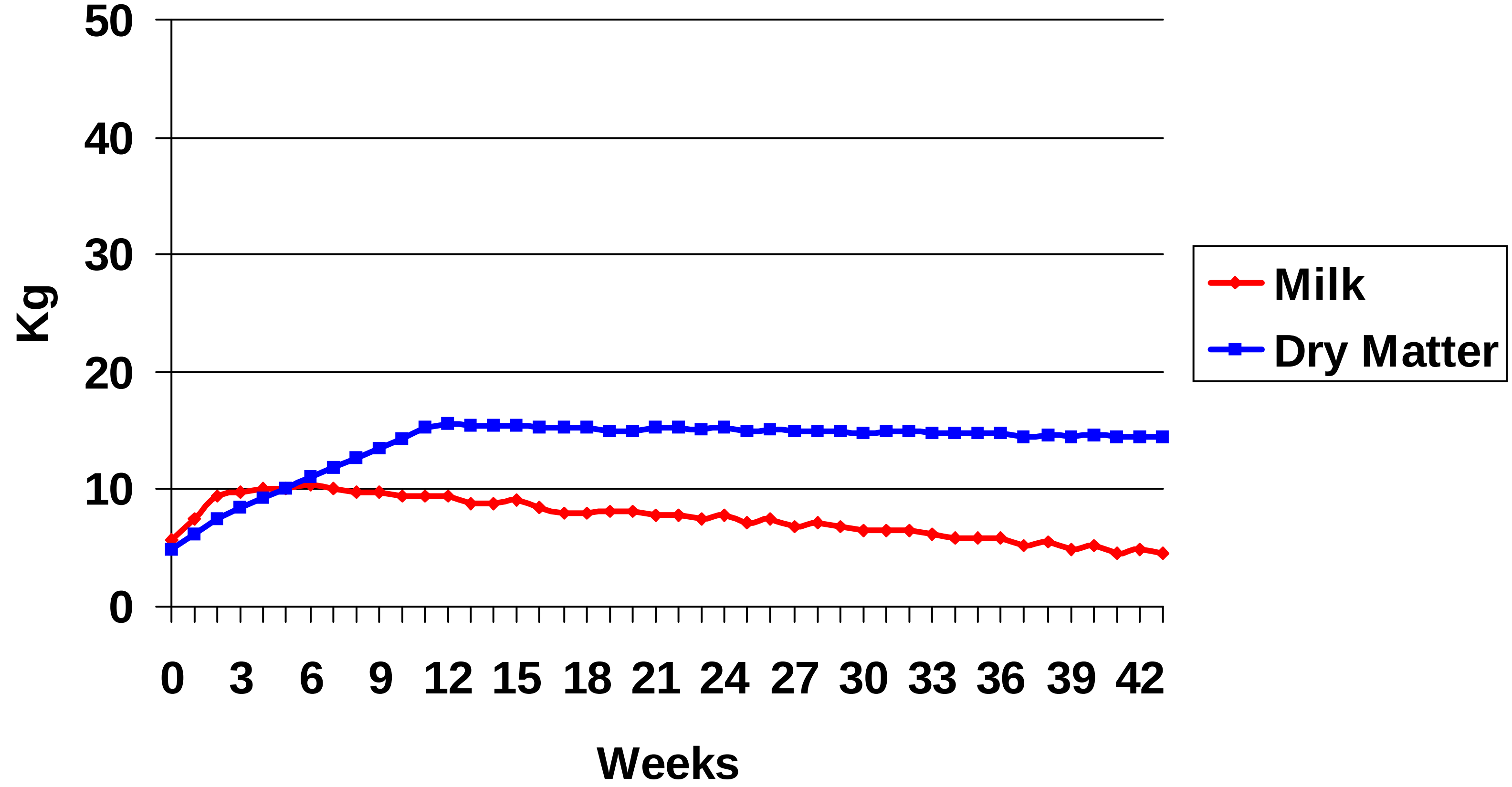
Objectives

- Briefly review production and productive efficiency and the implications to stress
- Review the efficiency of use of nitrogen and phosphorus in lactating cows with direct focus on the environment
- Briefly review management tools related to efficiency that can be employed by dairy farmers – some that might be disliked by the consumer
- Summarize the implications of improved efficiency of use and what it looks like on dairy farms

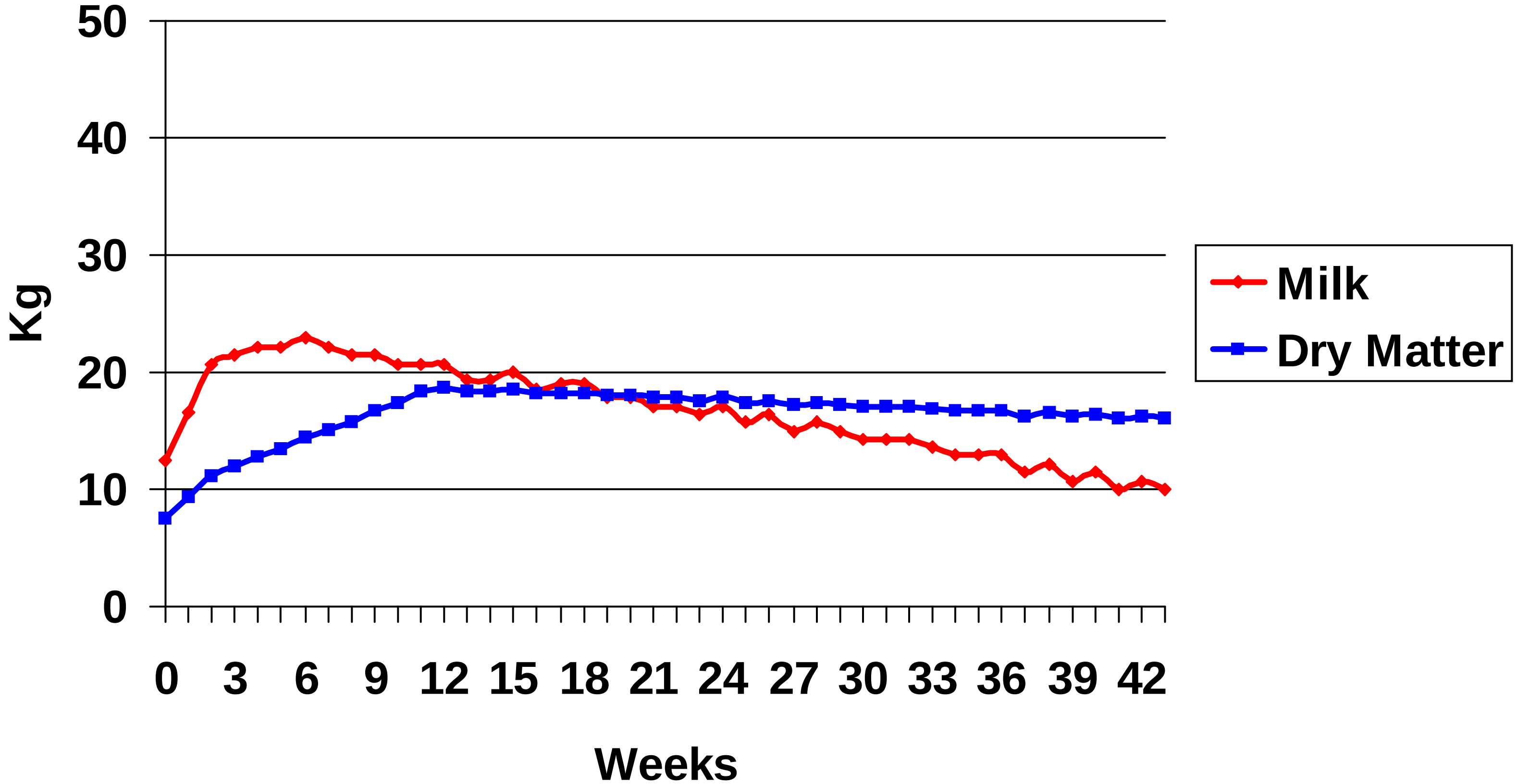
Productivity and Stress

- We have increased the productivity of dairy cows over the last 60 years
- Does that represent a stress or is it indicative of the absence of stress?
- Why is this an issue?

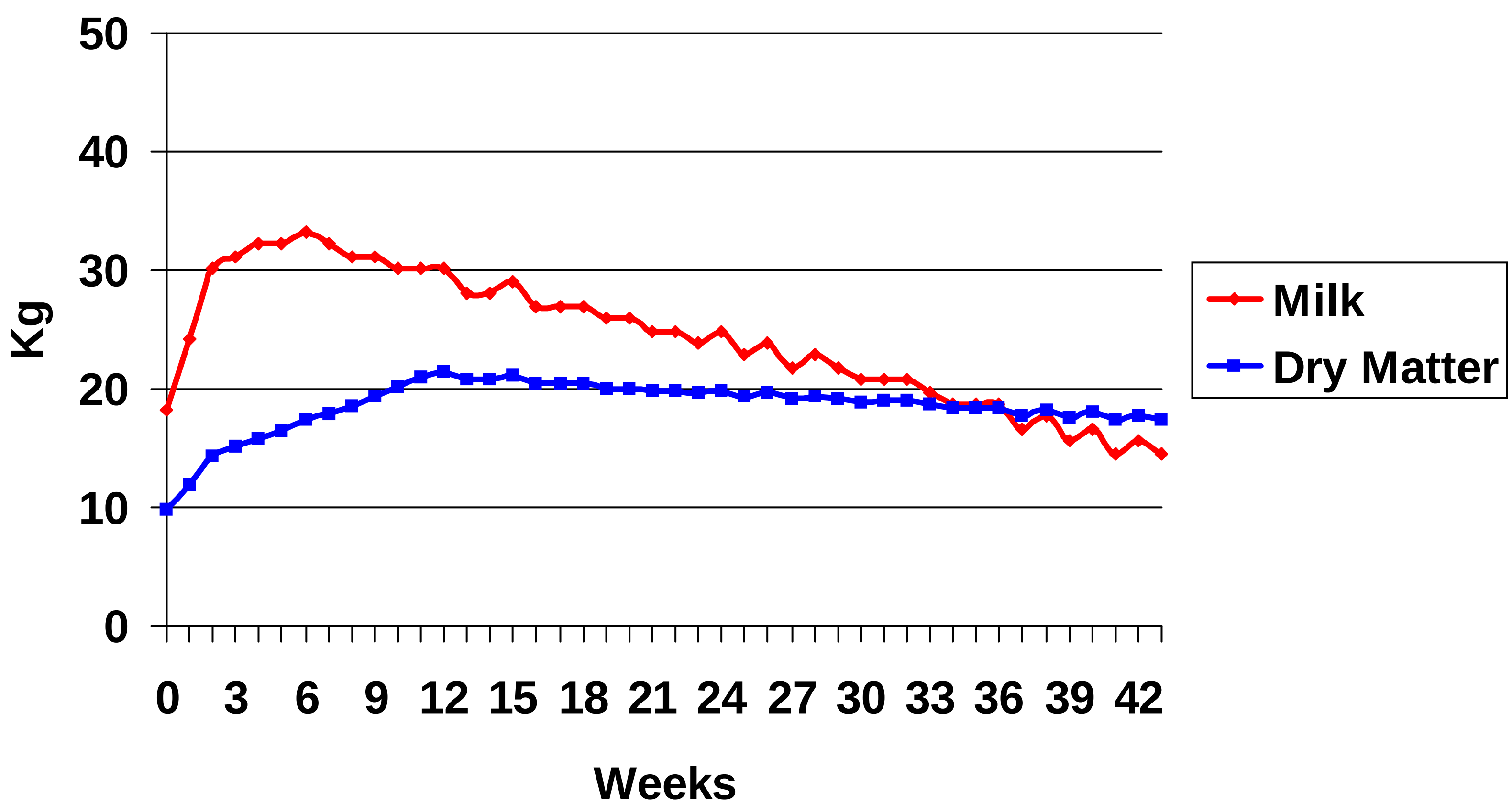
Average Milk Production ~1940



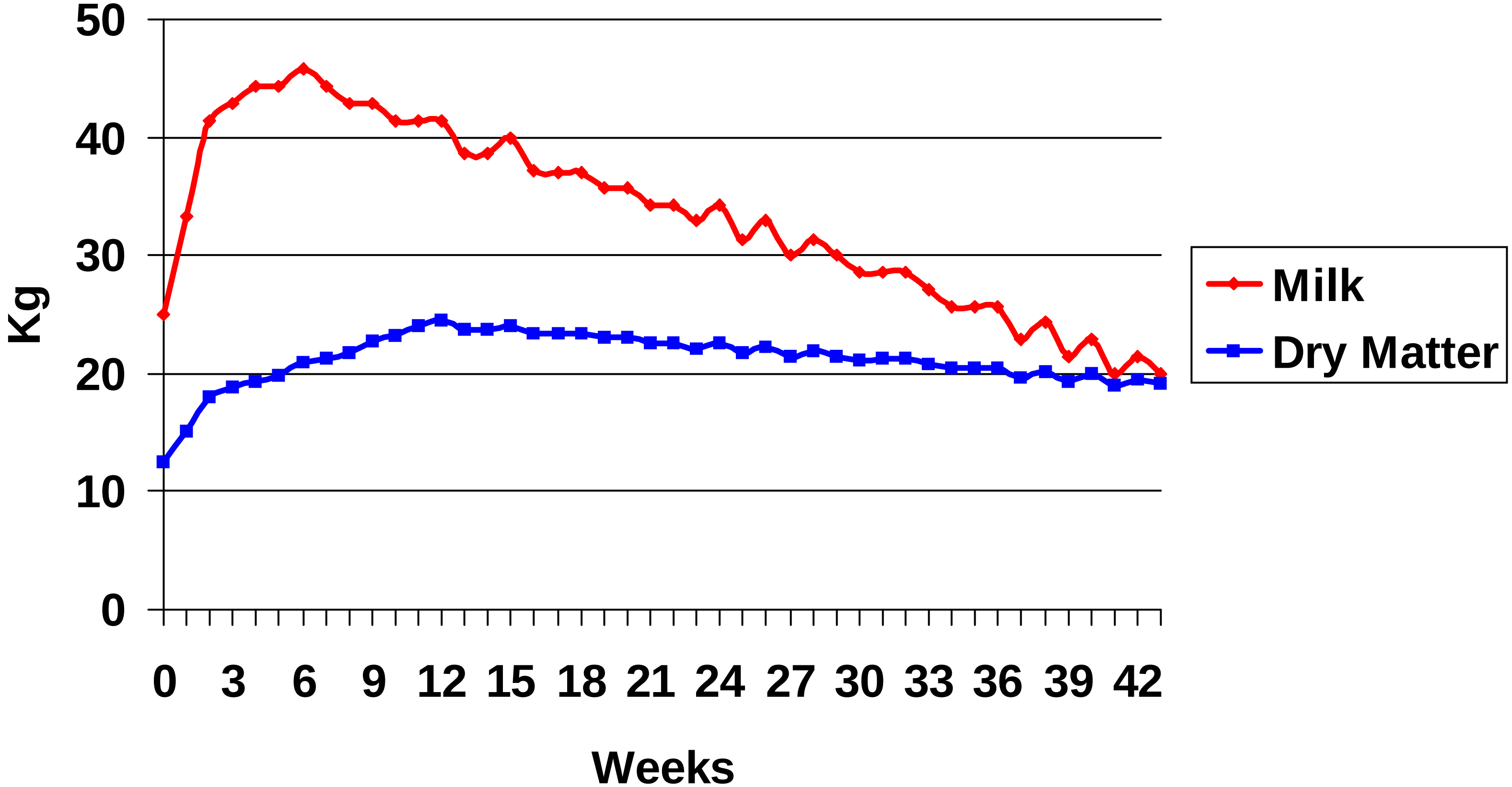
Average Milk Production ~1975



Average Milk Production ~1995



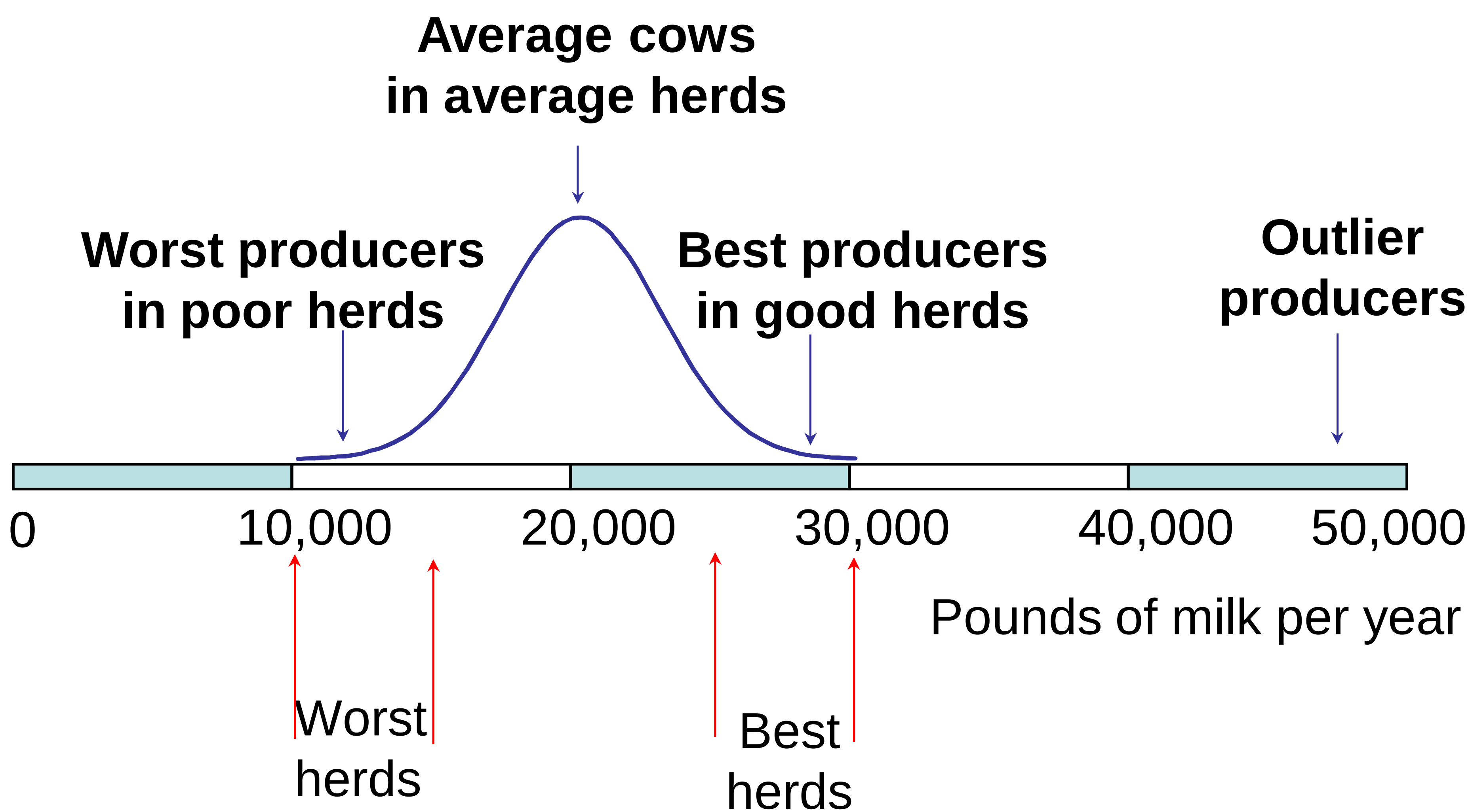
Average Milk Production ~2005



Comparison of Performance and Efficiency of Northeast Cows

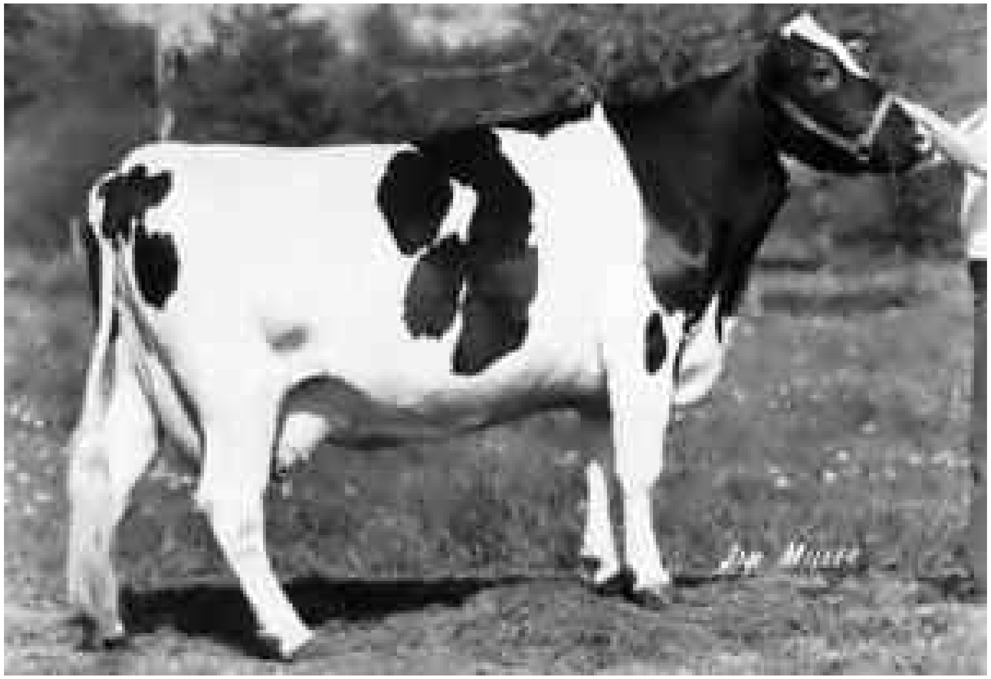
Variables	Year		
	1930	1965	1999
Performance and Inputs			
Milk yield, kg/d	6.4	17.7	30.9
Milk yield/feed intake, kg/kg	0.7	1.26	1.57
Use of net energy intake, %			
Maintenance	70	45	32
Milk synthesis	30	55	68
Animal Waste Products			
Fecal output/milk yield, kg/d	3.1	1.7	1.4
Urine output/milk yield, L/kg	3.1	1.1	0.6

Distribution of cow production



Genetics or environment? (management)

Collier et al. 2005



Breezewood Patsy Bar

Pontiac

Completed May 1974

2X 365 days 45,270 lbs

Muranda Oscar Lucinda-ET

Completed 1997

2x 365-day 67,914 lbs

Is High Production A Stress?

- When you remove stresses on dairy cows production increases.
- How can we then contend that high production is a stress?
- The absence of stress is required for high production

Sacramento, CA

Relationship Between Stress Production and Health

- Highly productive animals are healthy animals under minimal stress
- Increasing stress levels reduces production and health
- Likewise disease or reduced health is associated with reduced production and increased levels of stress

- **Review on welfare of dairy cattle**

“(It) may well be necessary to stop using genetic selection and some feeding methods to increase milk yield” (because these practices have resulted in stressed cows in which) “their normal biological functioning controls are overtaxed”

review by D.M. Broom, 1999
25th Int. Dairy Congress

- **Review on physiological limits of dairy cattle**

“Considerable doubts have often been expressed as to whether we are not pressing high production in our farm animals too far, thereby undermining their constitution and so shortening their life”

Sir John Hammond, 1952
Special Report to British Assoc. Adv. Science

Hammond disagreed and discussed the physiological basis for this.

Efficiency of Nutrient Use/Productive Functions

- **Animals differ very little in efficiency of nutrient use for milk synthesis**
- **Biochemical pathways to make milk are the same**
- **No relationship between genetic merit and partial efficiency of nutrient use for milk synthesis**
- **Nutrient partitioning is the major source of variation and that is part genetic and very much environment and management**

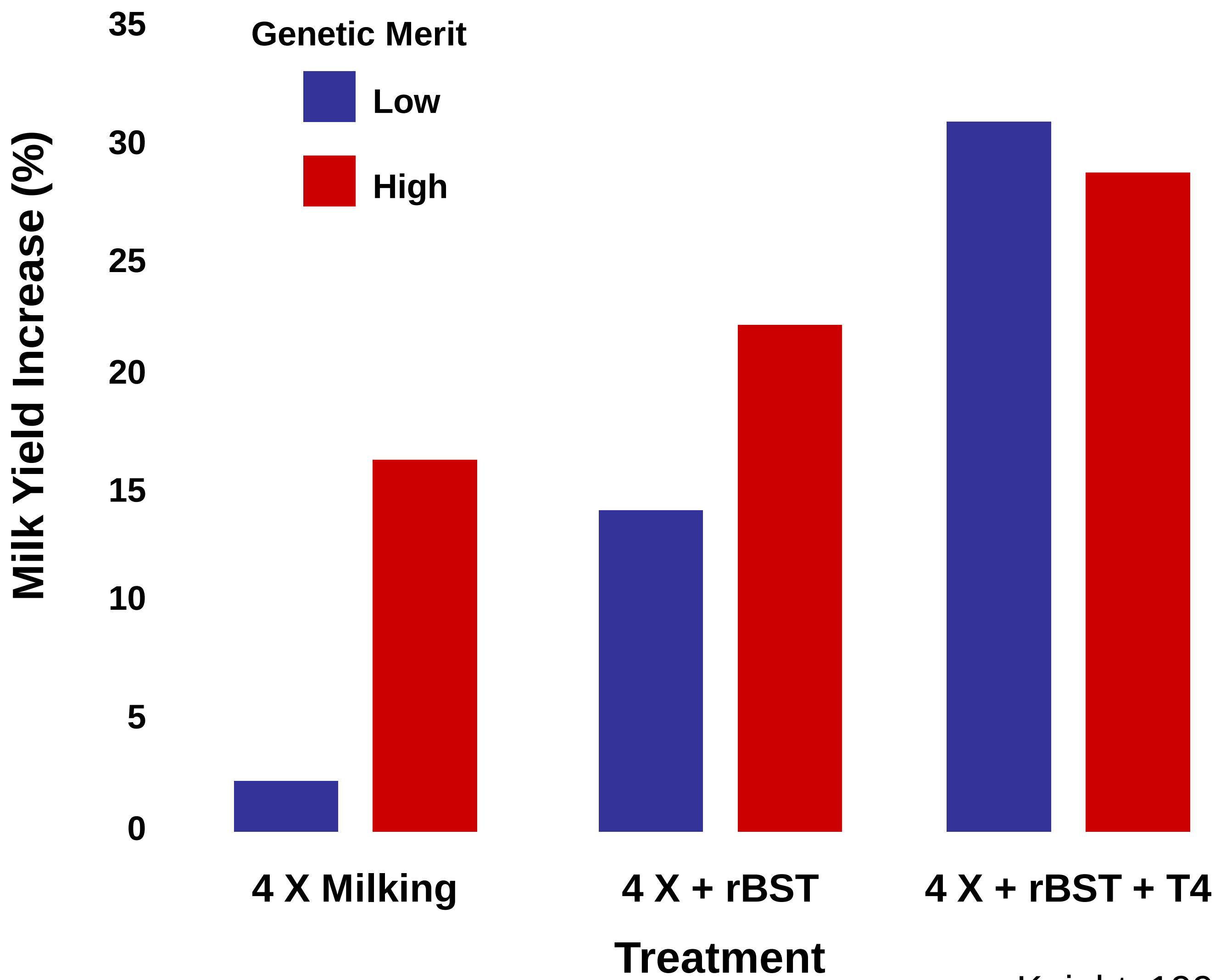
Example Of Animal Differences In Nutrient Partitioning

Variable[a]	Azalea	Bugle
Initial body weight (kg)	517	519
Intake of diet	- Equal -	
Liveweight change (kg)	+39.1	-51.8
Mean daily milk yield (kg 3.5% FCM)	12.3	26.3

[a]For first 67 days postpartum. Adapted from Swan (1976), based on unpublished data of Broster. Fat corrected milk (3.5%) calculated according to Tyrrell and Reid (1965).

Bauman

Milk yield response of high and low genetic merit cows to combinations of galactopoietic stimuli



Knight, 1999; Knight et al., 2004

Source of Variation and Prospects for Improvement

Efficiency component	Among-animal variation	Source of possible improvement	
		Selection	Management
Digestion and nutrient absorption	Low	Minor	Major
Nutrient use for maintenance and productive functions	Low	Minor	Major
Nutrient partitioning and intake	High	Major	Major

Bauman

Stress and Production

- Stress on dairy cattle is represented in the environmental component of milk yield heritability (0.75)
- Production level is not a stress
- Reducing stress by improving management will increase production
- Improving management skills through education is key to reducing stress on dairy cows
- Educating the end-user of milk about fundamental concepts of well managed cows is important

Effect of Nutrient Intake from Milk Replacer, expressed as intake over Maintenance on Milk Yield over 3 Lactations – Cornell Herd

Lactation	# of animals	Predicted difference in milk by each additional Mcal over maintenance	*P* value
1^{st}	792	578 lb	< 0.01
2^{nd}	451	744 lb	< 0.01
3^{rd}	181	1,215 lb	0.01
$1^{st} + 2^{nd}$	449	1,391 lb	< 0.01

Soberon et al. JDS 2009 (abstr.)

Nitrogen and Phosphorous in the Cow and Farm

Nitrogen Feeding and Ruminants

– Can utilize low quality protein sources and make protein from non-protein N
– Nitrogen in rumen not captured as microbial protein is potentially lost in urine as urea
– Bacterial cell wall is indigestible thus the higher the microbial protein production the greater the fecal losses.

Improving Nitrogen Efficiency

- We want to reduce N excretion
  - Environmental issues – ammonia volatilization
  - Feed protein is expensive (all feed is now expensive!)
- How do we do this?
  - Increase milk protein output
  - Reduce protein intake
    - Need to maintain milk output
  - Better meet the MP requirements of the cow with emphasis on amino acid requirements

Improving Efficiency of Use of Nitrogen on Farm to Reduce N Waste

- Opportunities exist – need refining
- On farm N efficiencies (milk N:feed N)

  25 to 32%
- Theoretical efficiency limit ~ 45% in lactating dairy cattle
- Practical limit is ~ 38% (although we have groups in herds doing this with more potential)
- Requires refinement of current ration formulation models – both MP balance and AA predictions
- Requires refinement of feeding management – reducing variation

We Are Working to Improve Efficiency of Use on Farm and Reduce N Waste

- Major routes of N excretion:
- Milk (25 to 40%)
- Feces
- Urine

} 75 to 60%

- Feces is relatively fixed ~200 to 250 g per day and is mostly endogenous protein, microbial cell wall and undigested feed

Improving Efficiency of Nitrogen Use

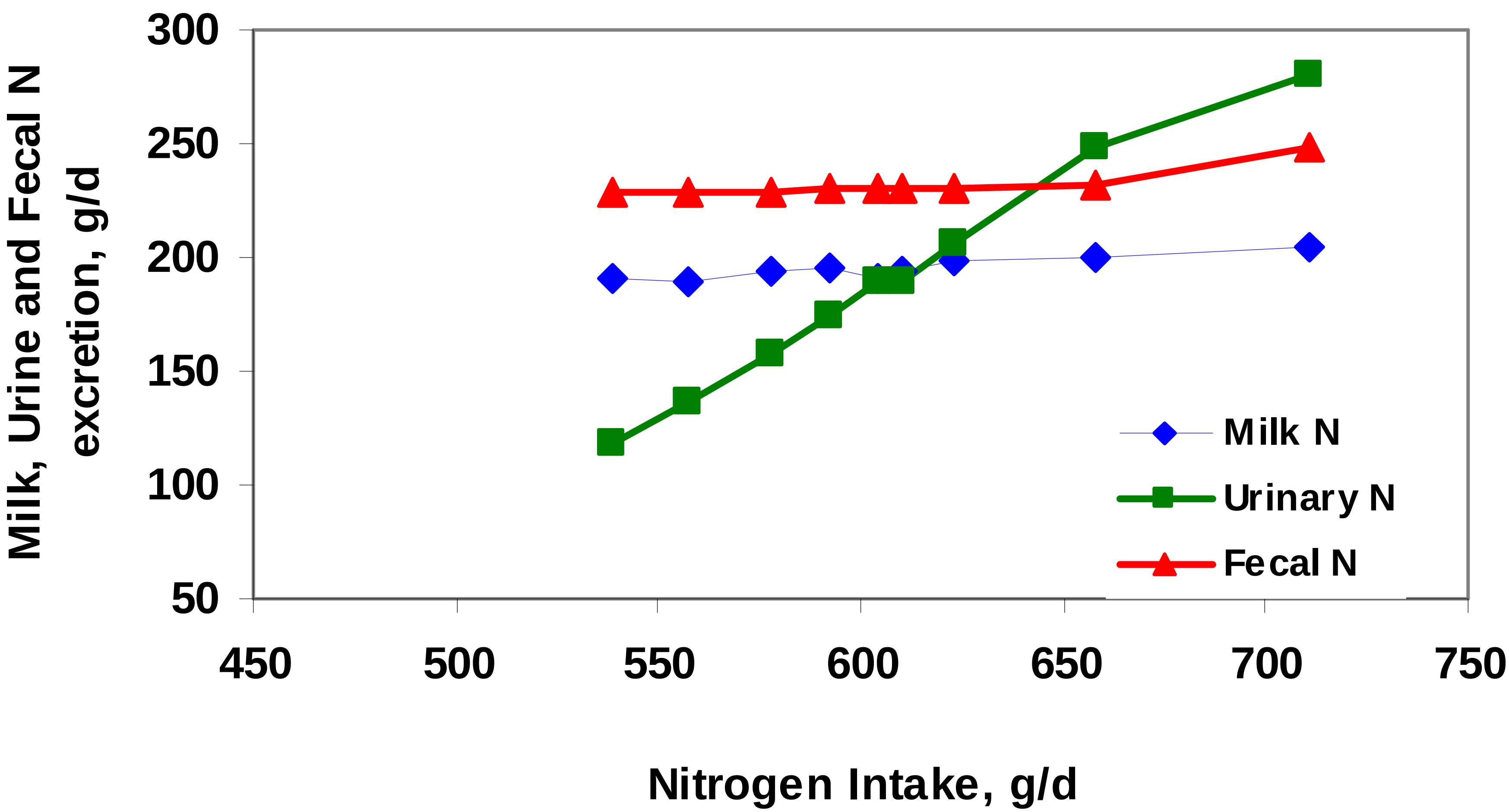
- Milk protein output is a function of energy supply and amino acid balance
- Urine N is variable and is a function of excess nitrogen intake and recycling
- Urine N is most volatile form – so reducing it will reduce the environmental impact and improve efficiency
- High levels indicate:
  - Overfeeding total protein
  - High rumen N balance relative to microbial demand

- Can use monitoring tools like milk urea nitrogen to evaluate independent of production responses

Urinary N is main form of excreted N
Fecal N is fairly constant

Reference	Intake N (g/d)	Fecal N (g/d)	Urinary N (g/d)
Kauffman and St-Pierre, 2001	429	178	93
	460	184	101
	572	198	190
Hristov and Ropp, 2003	658	208	233
	754	176	279

Nitrogen Excretion in Milk, Feces and Urine Based on N Intake in Lactating Dairy Cattle



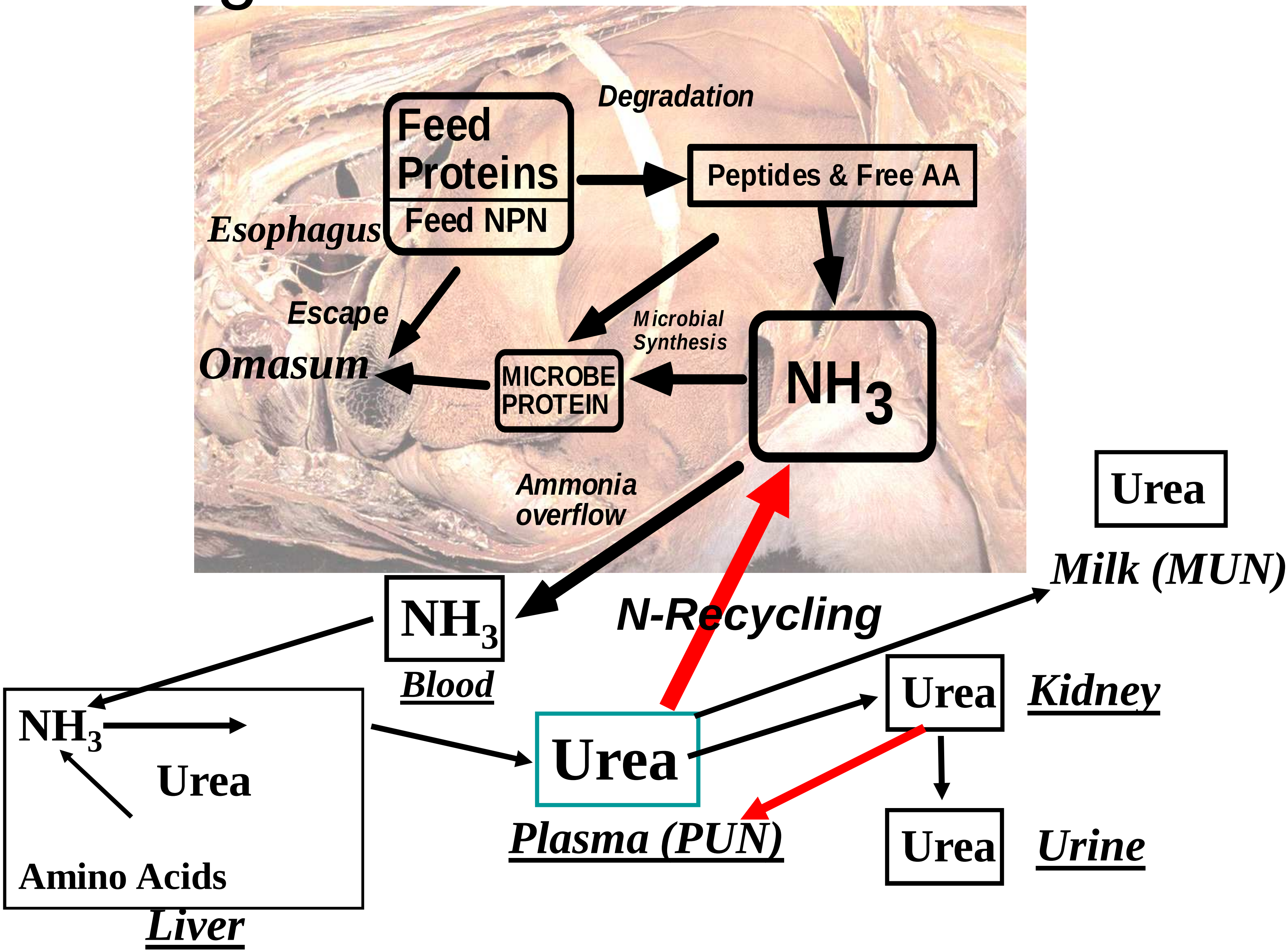
CNCPS v6.1 Nutrient Excretion – Manure and Manure Nitrogen

Excretion	
Fecal	44 kg
Urine	23 kg
TotalManure	67 kg
Fecal N	255 g
Urine N	227 g
Total Manure N	482 g
Productive N/Total N	30%
Productive N/Urinary N	0.91:1
Manure N/Total N	70%

Effect on Environmental Thinking on Nutrition Programs: CNCPS v6.1

- Added predictions for both CO_2 and CH_4 production per day and unit of milk output
- Express urinary and fecal nitrogen as a percent of intake nitrogen and milk nitrogen excretion
- Intent is to drive the concept of efficiency and not just production

Nitrogen Metabolism in the Cow



Nitrogen Metabolism

- **Cows convert 50 to 70% of intake N to urea N**
  - Appears to be an obligate function
- ~ 60% o**f the hepatic urea production is recycled to the gastrointestinal tract**
- **Approximately 30-80% of total microbial yield may originate from recycled N because of protozoal predation of bacteria**
- **Approximately 15-30% of intake N is recycled and used for microbial N production**

On Farm Herd Nutrition Tools to Improved N Utlization

- CNCPS/CPM Dairy
- NRC 2001 Dairy Cattle Model
- Spartan
- Amino Cow – Degussa
- Dalex
- Brill

All have strengths and weaknesses - all require further development for field application

Herd Level Examples of the Application of CNCPS v6.1

Example Herd A – 54 lb DMI, 92 lb Milk

% DM basis	CNCPS v6.1
CP	14.4
RDP	8.6
Sol CP	4.9 (34)
Rumen NH3, % req	134
Rumen peptides, % req	143
NDF	31.6
Lys:Met	3.29
ME allowable, lb	99
MP allowable, lb	90

Example Herd Ingredients – 54 lb DMI, 92 lb Milk

Ingredient	DM amount, lb
Corn silage	17
Grass haylage	12
Dry hay	3
Ground corn	13.3
Soybean Meal	4.0
Roasted soybean	1.6
Cane molasses	0.46
Sugar	0.70
Provaal	0.44
Urea	0.097
Meta smart	0.012
Min. & Vitamins	1.59
Total	54.2

Example herd B - 53 lb DMI, 89 lb milk

% DM basis	CNCPS v6.1 output
CP	15.0
RDP	8.1
Sol CP	4.9 (30)
Rumen NH3, % req	104
Rumen peptides, % req	110
NDF	31.5
Lys:Met	2.8
ME allowable, lb	94
MP allowable, lb	98

Example herd B - 53 lb DMI, 89 lb milk

Ingredient	DM amount, lb
Corn silage	19.5
Alfalfa hay	9.8
Wheat straw	1.0
Flaked corn	6.2
Ground corn	6.2
Soybean Meal	1.9
Amino Plus	2.9
Wheat midds	2.0
Citrus pulp	2.0
Sugar	0.50
Provaal	0.23
Energy Booster	0.35
Urea	0.13
Smartamine and Alimet	0.03
Min. & Vitamins	1.3

Herd C – High group (2 group system, no bST, 2x milk, no ionophore)

<u>Current stats</u>

DMI	50 lb
CP	15.8%
NDF	30.2%
Actual milk	84 lb
ME allowable	83.5 lb
MP allowable	91 lb
True protein	3.1%
Fat	3.7%
Met	2.3% MP
Lys	6.77% MP

Herd C – High group

Ration Fed				
			DM	AF
Ingredient	$/hd	%DM	lbs/day	lbs/day
2009 2nd Haylage-CNCPS-04051	0.42	44.4	5.98	13.49
Canola Meal Solvent-CNCPS-02006	0.53	90.2	3.28	3.64
Corn Grain Ground Medium-CNCPS-01040	0.75	88.0	8.83	10.04
2008 Corn Silage-CNCPS-03019	1.32	31.1	21.94	70.66
Citrus Pulp Dry-CNCPS-01031	0.54	88.6	4.07	4.59
Soybean Rolled Roasted-CNCPS-02028	0.24	93.2	1.09	1.17
Old SHF Lact-CNCPS-C071546	0.00	91.8	4.81	5.24

Concentrate mix contains Smartamine and Alimet

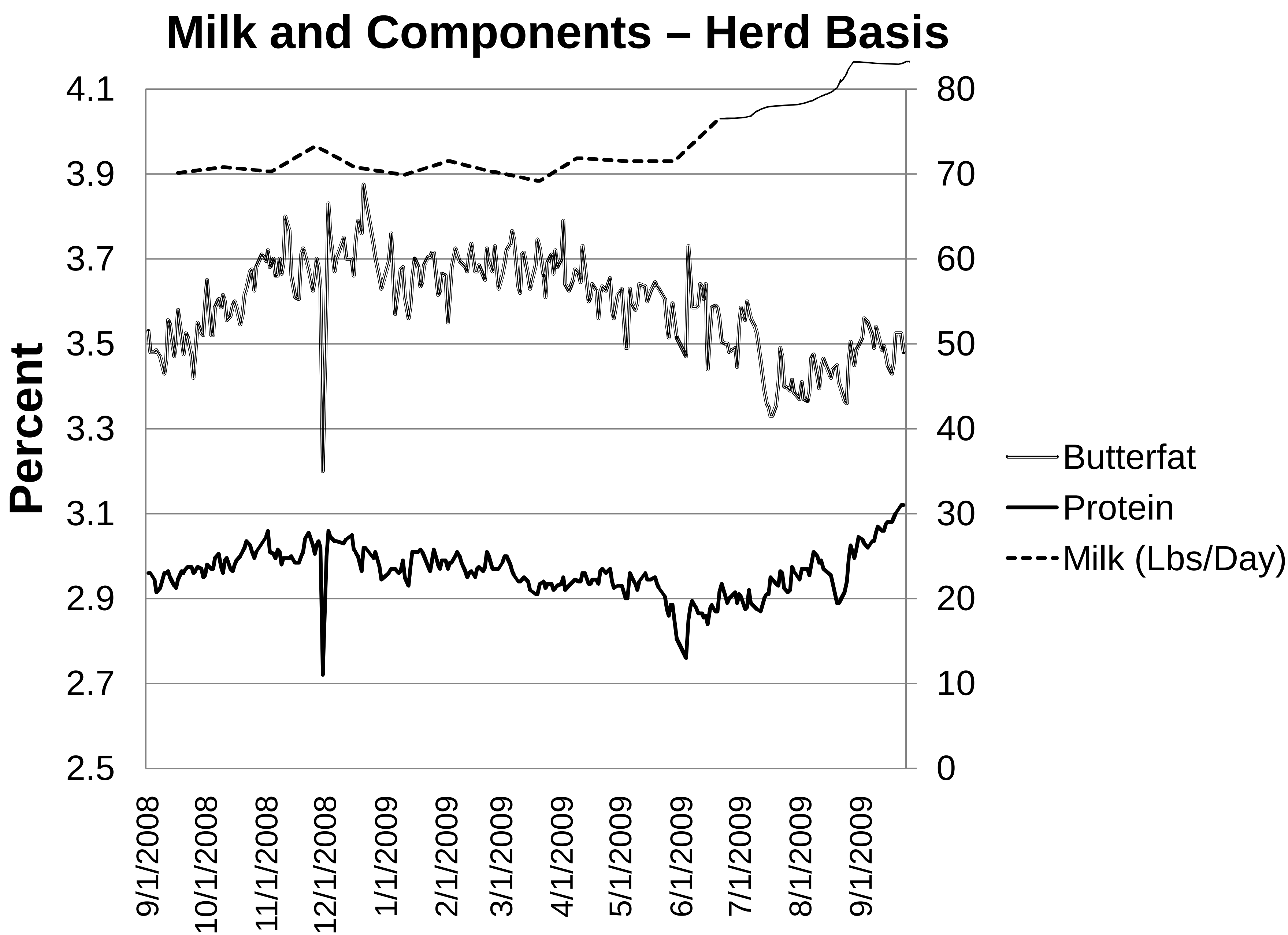
Herd C – High group

Nutrient Balances		
Nutrient	Balance	%Req
ME	-0.5 Mcal	99
MP	136 g	105
Rum. NH3-N	35 g	122
Rum. Pep-N	9 g	105
peNDF	-0.9 lbs	93
MP Lys	44.1 g	131.8
MP Met	20.3 g	148.5
Ca	46.64 g	169%
P	2.31 g	104%

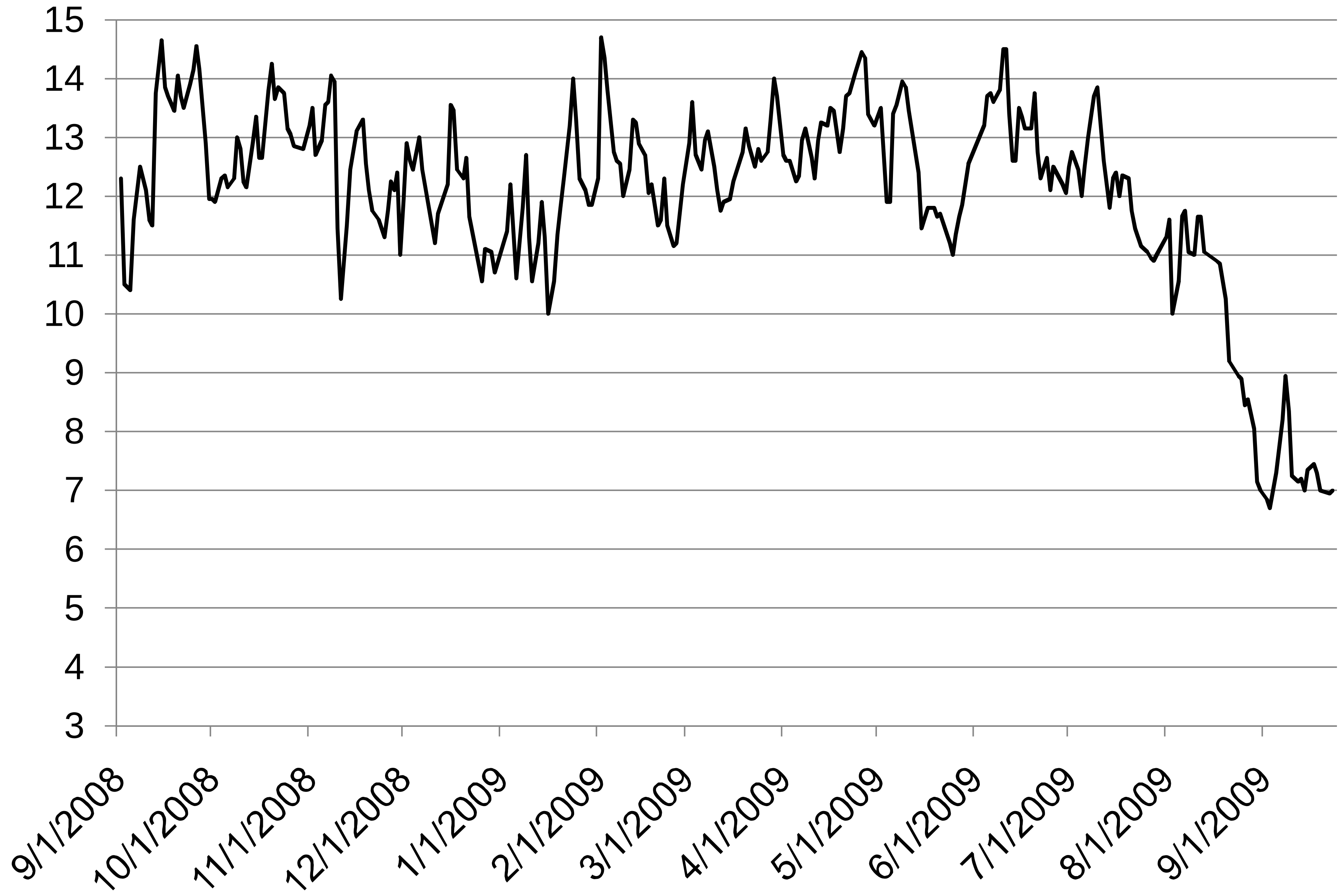
Lys	6.77 %MP
Met	2.30 %MP
Lys:Met	2.94

Herd C – High group

Fecal N	217 g
Urine N	154 g
Total Manure N	371 g
Productive N/Total N	35%
Productive N/Urinary N	1.30:1
Manure N/Total N	65%


Milk and Components – Herd Basis
Percent
4.1
3.9
3.7
3.5
3.3
3.1
2.9
2.7
2.5
80
70
60
50
40
30
20
10
0
9/1/2008
10/1/2008
11/1/2008
12/1/2008
1/1/2009
2/1/2009
3/1/2009
4/1/2009
5/1/2009
6/1/2009
7/1/2009
8/1/2009
9/1/2009
Butterfat
Protein
Milk (Lbs/Day)

Milk Urea Nitrogen – Bulk Tank



What is the impact on N excretion?

Our calculations indicate ~60 g N/cow/d less urinary excretion

1100 cows = ~26.5 tons N less in the environment

In 2009, that was $0.40/cow/d reduced feed costs

Herd Example - D
1050 cows – High group characterized

Nutrient Balances		
Nutrient	Balance	%Req
ME	3.5 Mcal	105
MP	64 g	102
NH3-N	33 g	117
Peptide-N	-15 g	93
peNDF	0.2 kg	103
Lys	45.4 g	125.6
Met	35.9 g	167.1
Ca	-8.64 g	89%
P	-2.97 g	96%
Mg	1.27 g	114%
K	52.71 g	120%

Total ME Avail.	74.61 Mcal/day
ME Milk Prod	56.0 kg/day
MP Milk Prod	54.0 kg/day
MUN (mg/dl)	11.1
Urea Cost	0.07 Mcal
Rumen pH	6.43
Milk:Feed	1.99
IOFC ($/Head)	8.61
IOPurFC ($/Head)	10.91

Excretion	
Fecal	49 kg
Urine	20 kg
TotalManure	69 kg
Fecal N	245 g
Urine N	196 g
Total Manure N	441 g
Productive N/Total N	38%
Productive N/Urinary N	1.33:1
Manure N/Total N	62%
Fecal P	54.2 g
Urine P	1.4 g
Total Manure P	55.6 g
Productive P/Total P	43%
Manure P/Total P	57%
CH4 (Mcal)	6.67
CH4 (L)	728.22

Diet Concentrations	
NFC	41.5 %DM
CHO Ferm.	41.2 %DM
	57.7 %CHO
NDF Ferm.	9.4 %DM
	30.5 %NDF
Starch Ferm.	21.9 %DM
	76.2 %Starch
Sol. Fiber Ferm.	6.3 %DM
	84.8 %Sol Fiber
Sugar Ferm.	3.6 %DM
	67.3 %Sugar
Sugar (A4)	5.4 %DM
Starch (B1)	28.7 %DM
Sol Fiber (B2)	7.4 %DM
Ferm. Fiber (B3)	21.2 %DM
Lig * 2.4 (C)	6.7 %DM
NDF	30.90 %DM
Forage NDF	78.46 %NDF
Forage NDF	0.94 %FBW
EE	5.1 %DM
LCFA	4.1 %DM
CP	15.85 %DM
RDP	8.08 %DM
Lys	6.74 %MP
Met	2.71 %MP
Lys:Met	2.49 %MP
TDN	71.6 %DM
ME	2.75 Mcal/kg
NEl	1.77 Mcal/kg
Forage	60.1 %DM
DM	44.7 %DM
DCAD1	138 meq/kg
DCAD2	97 meq/kg
Monensin	0.00 mg/hd
Monensin	0.00 ppm

1,542 lb BW

~100 DIM

59.5 lb DMI

15.8% CP

60% Forage

120 lb milk/d

Milk:Feed (Feed efficiency): 1.99

Herd Example - Herd D

NDF, %DM: 30.9

Starch, % DM: 28.7

Sugar, % DM: 5.4

Ether extract, % DM: 5.1

%Forage: 60.1

Forage NDF, %BW: 0.94

Diet Concentrations	
DM	44.7 %DM
Forage	60.0 %DM
CP	15.85 %DM
RDP	8.14 %DM
NDF	30.89 %DM
Forage NDF	78.46 %NDF
Forage NDF	0.94 %FBW
EE	5.2 %DM
LCFA	4.1 %DM
Lys	6.90 %MP
Met	2.39 %MP
Lys:Met	2.89
TDN	68.0 %DM
ME	1.17 Mcal/lb
NEl	0.76 Mcal/lb
Sugar (A4)	5.4 %DM
Starch (B1)	28.7 %DM
Sol Fiber (B2)	7.4 %DM
Ferm. Fiber (B3)	24.2 %DM
Lig * 2.4 (C)	6.7 %DM
NFC	41.5 %DM
CHO Ferm.	42.2 %DM
	59.1 %CHO
NDF Ferm.	10.4 %DM
	33.7 %NDF
Starch Ferm.	21.9 %DM

Herd Example - Herd D

Excretion	
Fecal	49 kg
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Fecal N	245 g
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Fecal P	54.2 g
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Total Manure P	55.6 g
Productive P/Total P	43%
Manure P/Total P	57%
CH_4 (Mcal)	6.67
CH_4 (L)	728.22

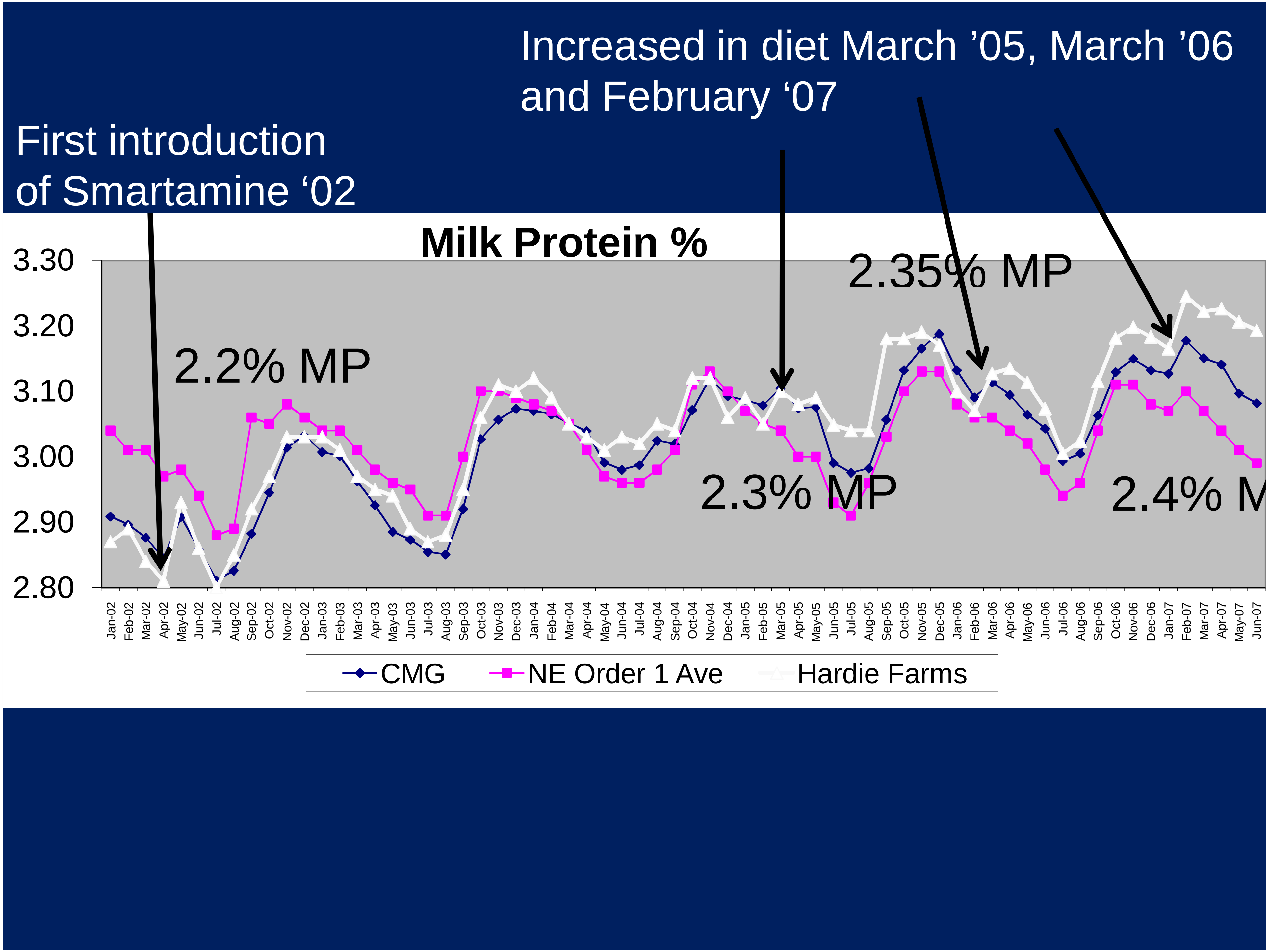
Productive N : N Intake – 38%!

Remember – most farms are 25 to 30%

High groups should be >30%

Productive N: Urinary N – 1.33:1

Most farms are 0.6 to 0.8:1


First introduction
of Smartamine '02
Increased in diet March '05, March '06
and February '07
Milk Protein %
2.2% MP
2.3% MP
2.35% MP
2.4% M
3.30
3.20
3.10
3.00
2.90
2.80
Jan-02
Jun-07
CMG
NE Order 1 Ave
Hardie Farms

- Conclusions

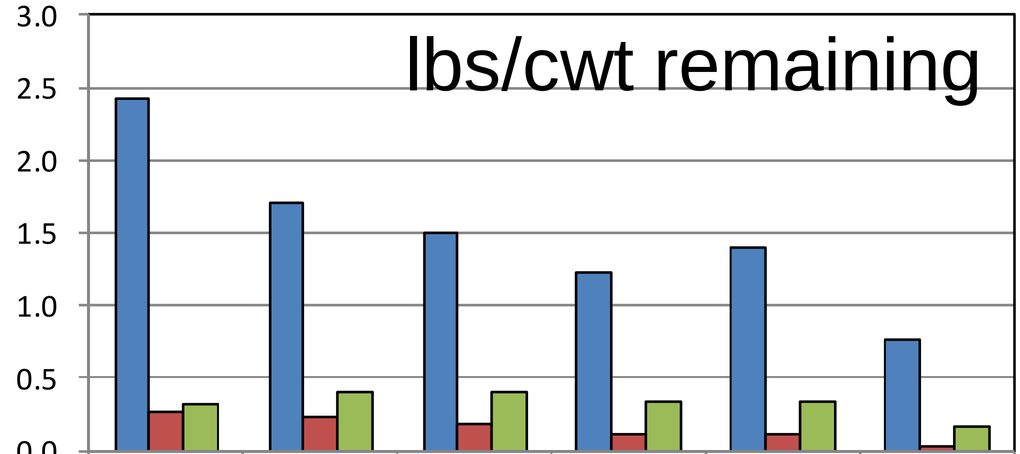
There is capacity to improve our nutrition formulation systems to improve N efficiency

the cow can help solve some of the problems

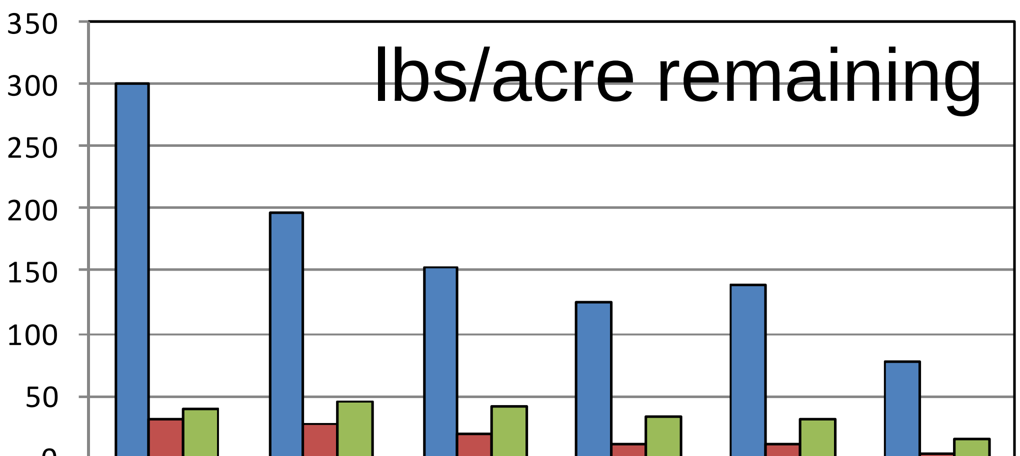
We have the opportunity to lower protein intakes to reduce the environmental impact of dairy farms

The ability to formulate for amino acids is getting better especially for Met and Lys

We need to further update the models to reflect our new knowledge of protein and amino acid metabolism



	2004	2005	2006	2007	2008	2009
Nitrogen	2.43	1.71	1.5	1.22	1.4	0.77
Phosphorus	0.26	0.23	0.19	0.12	0.11	0.03
Potassium	0.32	0.4	0.41	0.34	0.33	0.16



	2004	2005	2006	2007	2008	2009
Nitrogen	301	196	152	125	138	77
Phosphorus	32	27	20	12	11	3
Potassium	40	46	42	34	32	16

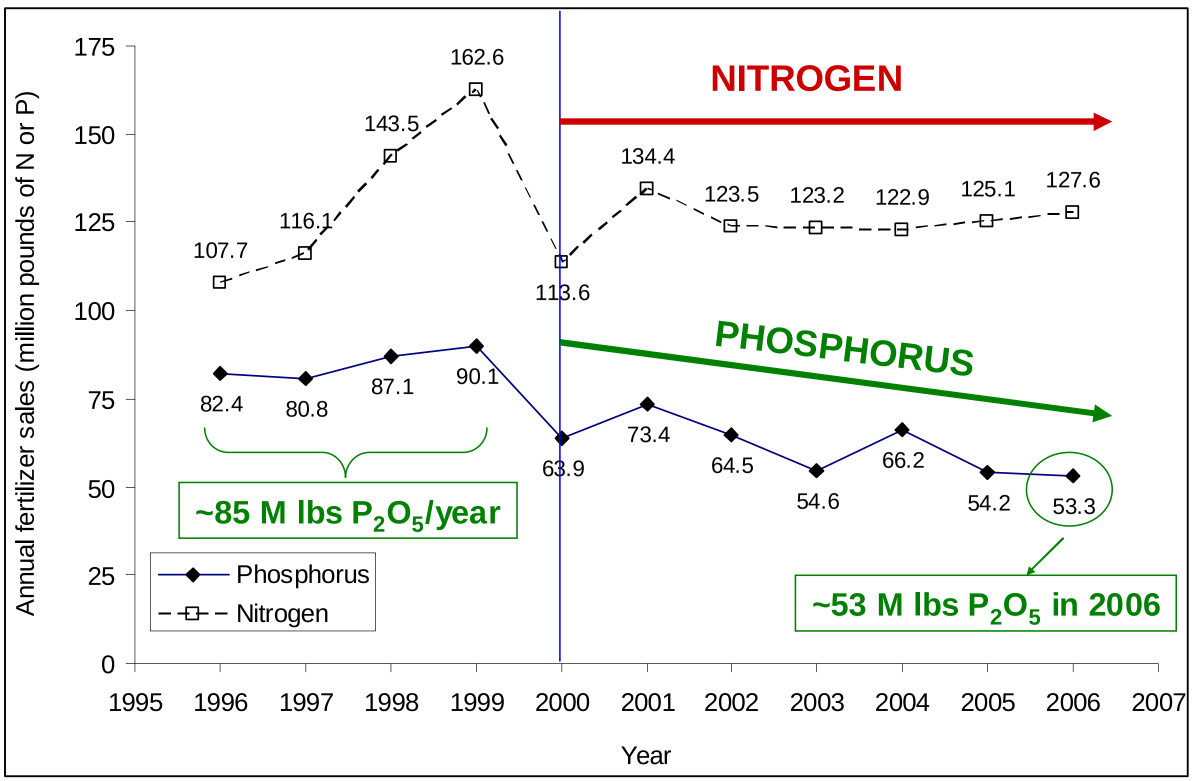
A 550 cow dairy in Central NY

Whole-farm N, P and K nutrient balances

Improvements are reflected in changes at the farm level!!

Good News for NYS!!

Phosphorus: 165 million lbs P_2O_5 savings since 2000!



Summary

- High production is really the outcome of improved partitioning of nutrients by the cow and the absence of stress

- We have the capability of greatly reducing the impact of the dairy industry on the environment by focusing on feeding and management of the cow – this has been lost on policy makers and funding agencies

Summary

- Within a production management strategy, there will undoubtedly be varying approaches to reduce the environmental impact

- Technologies currently available are needed now and will be in the future if the industry is to meet at least 2 out of 3 of consumer demands – means we have a great educational challenge that can’t be met through traditional food marketing

What about bST

- Capper and Bauman have assembled a LCA model to evaluate the effects of bST application to reduce environmental impact

- Based on a 10 lb increase in milk yield due to repartitioning of energy and protein for milk yield – results in greater energy and protein efficiency

bST and the Environment

- 8.3% reduction in CH_4 emission per unit of milk
- 9.37% reduction in N_20 emission per unit of milk
- Overall, an 8.5% reduction in GWP per unit of milk produced

Capper et al.

Reproductive Efficiency

- Garnsworthy (2004) evaluated fertility practices as related to methane and ammonia emissions from cattle

- Evaluated effect of three pregnancy rates 19, 26 and 43% on emissions with 26% representing 1995 rates

- Analysis concluded that achieving 26% versus 19% pregnancy rate would reduce methane output by 10% and ammonia by ~9% - primarily through dilution of maintenance relationships (optimizing milk yield)

Consumer and Societal Expectations

- Affordable food prices
- Environmentally friendly
- Hormone and antibiotic “free”
- Safe food
- Humanely treated animals
- Local food

  (New Oxford American Dictionary - new word for 2007 – Locavore)

Consumer and Societal Expectations and Producer Needs

- Consumer demands and producer needs are at times mutually exclusive
- Consumers are somewhat uninformed primarily due to advertising and marketing approaches that distance them from actual production practices (e.g. where does Ben and Jerry’s get their milk from)

Urea Nitrogen Kinetics in Cattle and Sheep

	N intake, g/d	Digestible N, g/d	Urea-N synthesis, g/d	Urea-N to gut, g/d
Dairy cattle	450	301	262 (87%)	171 (57%)
Steers	64	33.1	35.4 (107%)	28.1 (85%)
Sheep	17.1	11.5	16.3 (142%)	9.9 (86%)

Lapierre and Lobley, 2001