What is the CNCPS? The model and the cow

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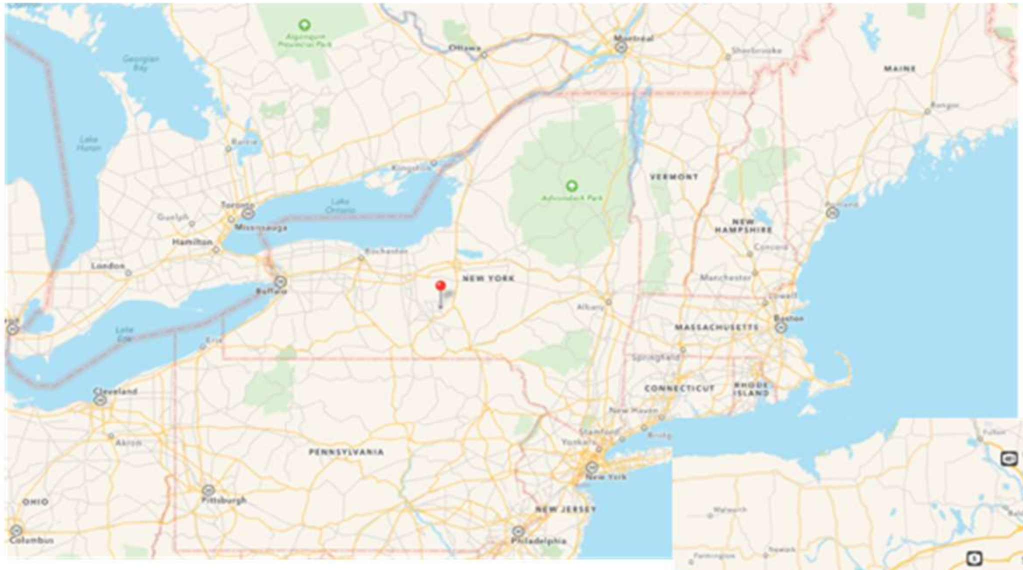
President AMTS

AMTS

First: Some questions

- Which feed is better at making milk?
  - Maize silage or wheat straw?
  - Whole maize grain or fine-ground barley?
  - Rapeseed or rumen protected rapeseed?
- Which feed is less expensive?
  - Per ton? Per kg of potential milk?
- How do we know these answers?
  - Feeding trials, experience, company literature, guessing….
- Need to use a feeding system (mathematical model) to predict future performance on hypothetical diets.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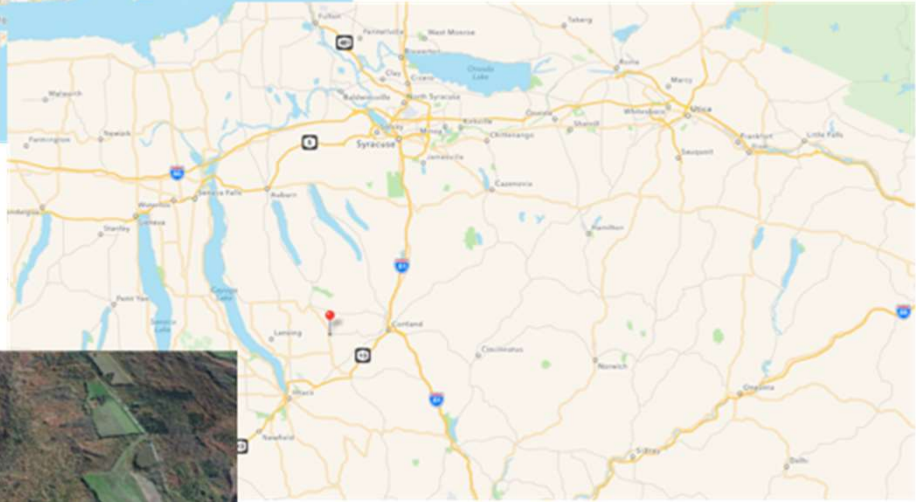
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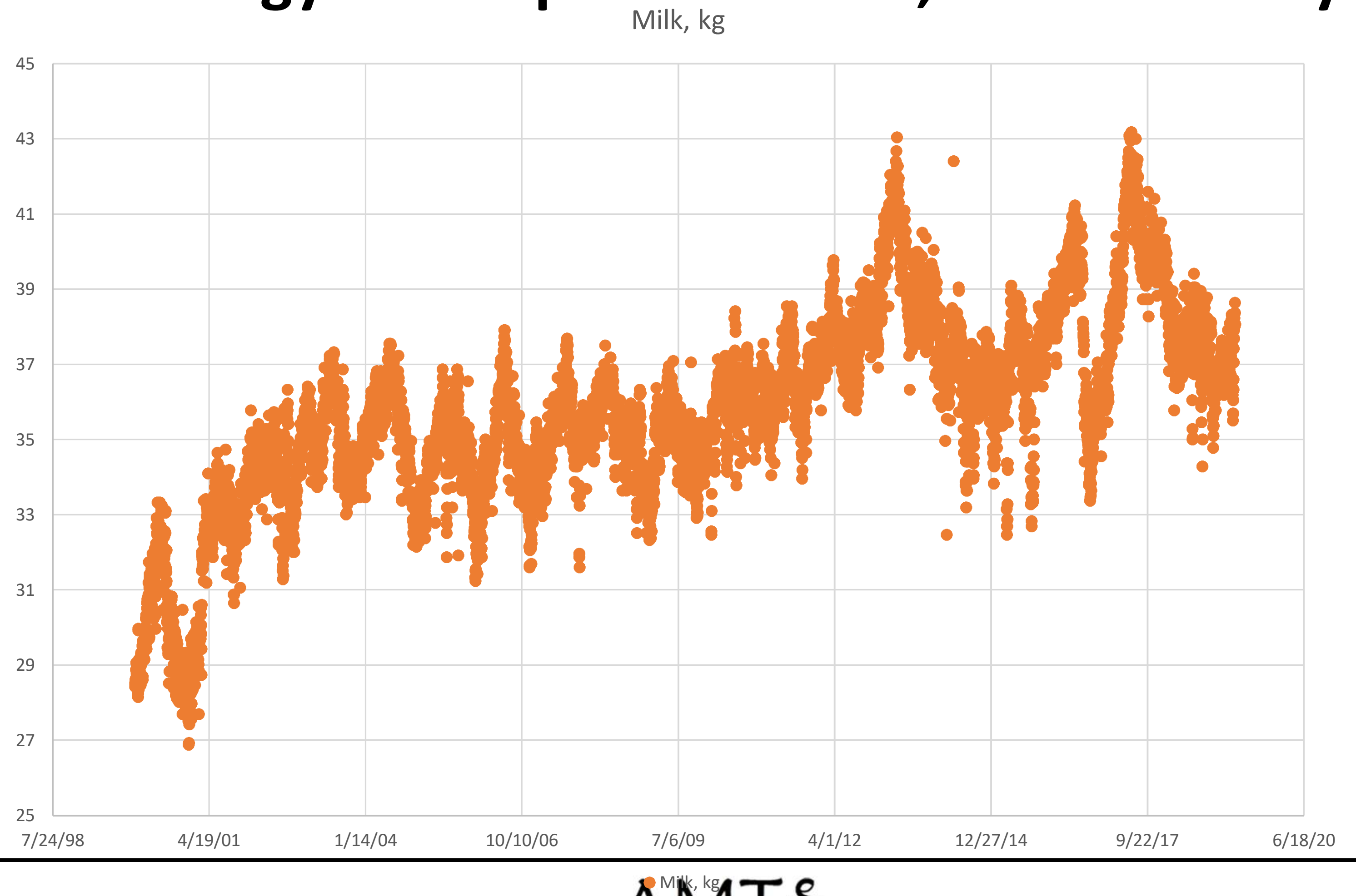
Long term strategy and implementation, 800 cow dairy in NYS



CNCPS Releases through the years

- CNCPS v1: 1991
- v2 1993
- v3 1994
- v4 2000
- v5 2003
- v6 2006
- v6.1 2009
- v6.5 2013
- v6.55 2015
- v7: 2018?

AMTS started in 2005 in collaboration with Cornell to commercialize the biological model

- CPM was a commercial application only for dairy cattle
  - CPM as a spreadsheet for several years
  - CPM v1 1994ish
  - CPM v2 never released
  - CPM v3 2006
  - 2009: CPM officially disbanded

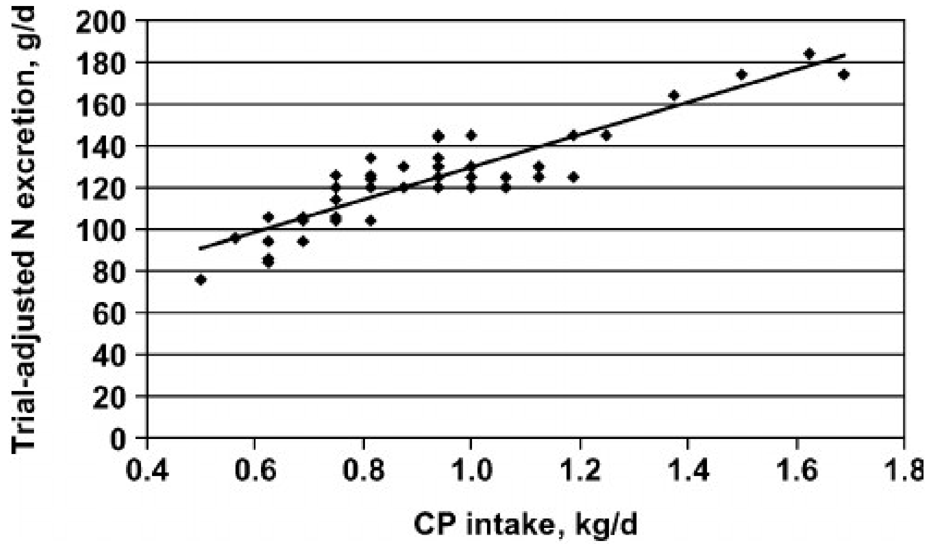
How?

- **Communication is key**
- **The Model is critical**
  - **used not only for formulation but also for doing ‘what-if’ scenarios**
- **A commitment to continuously improve**
  - **recognition that a change today may take 3-12 months to fully see the impact**
  - **recognition that marginal income, and income over feed costs, is critical versus ‘least cost’**
  - **recognition that you can not short-change good nutrition**

What is a mathematical nutrition model?

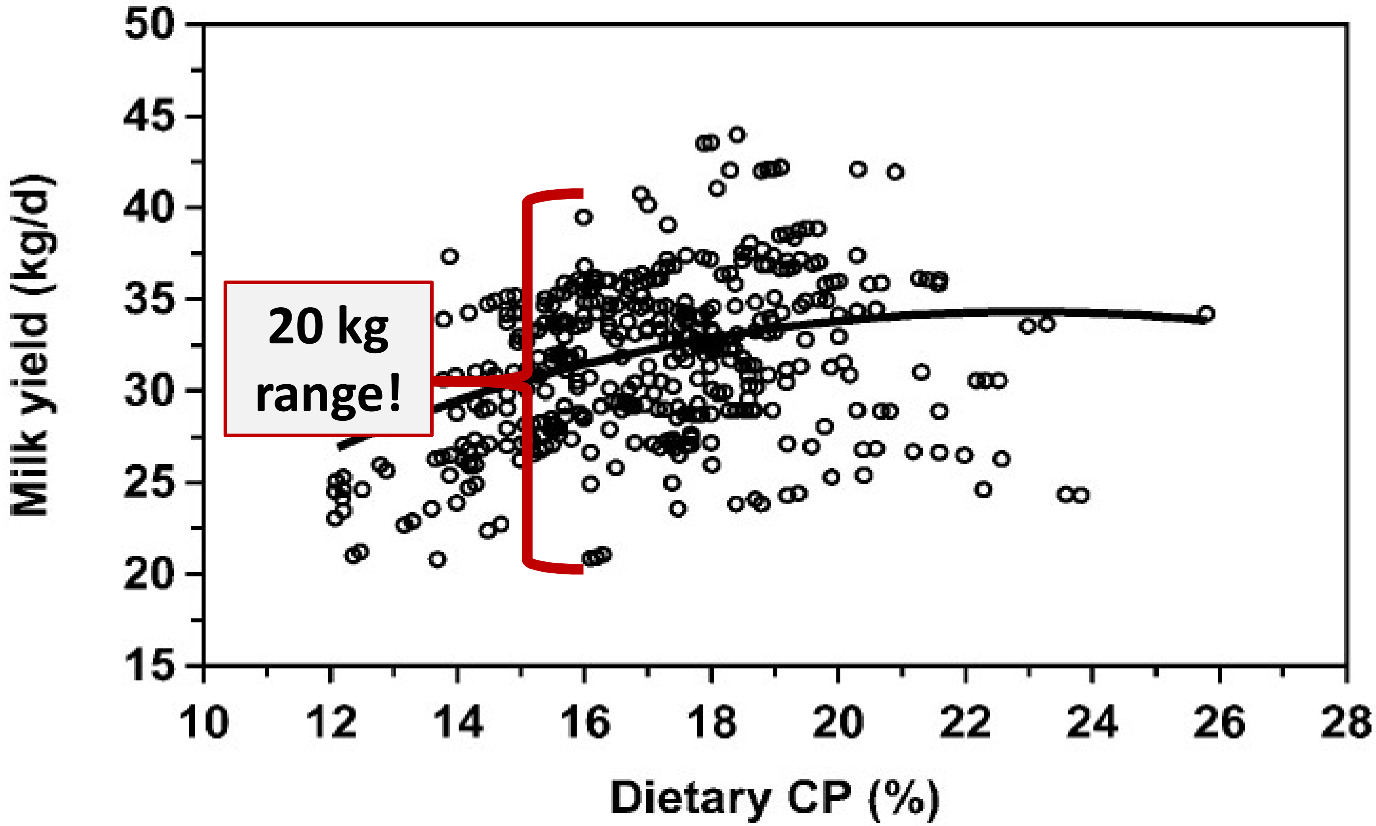
- Description of a complex biologic system (the cow) using mathematical terms and principals.
- Usually used to predict an outcome
- Example:
  - Empirical approach (regression)
  - Equation of line:
    - N excretion = (CP x 78.39) + 51.4
    - SE: 10.8 g/d = approx. 8% error.
  - This is a very simple model for N excretion
- Can we use CP to predict milk yield?

$$Y = aX_1 + bX_2 + c + \varepsilon$$

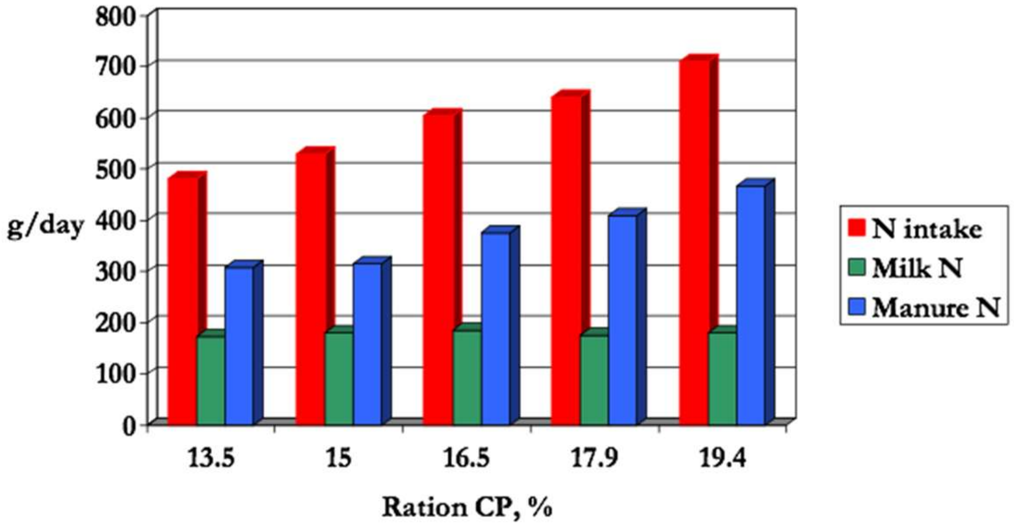


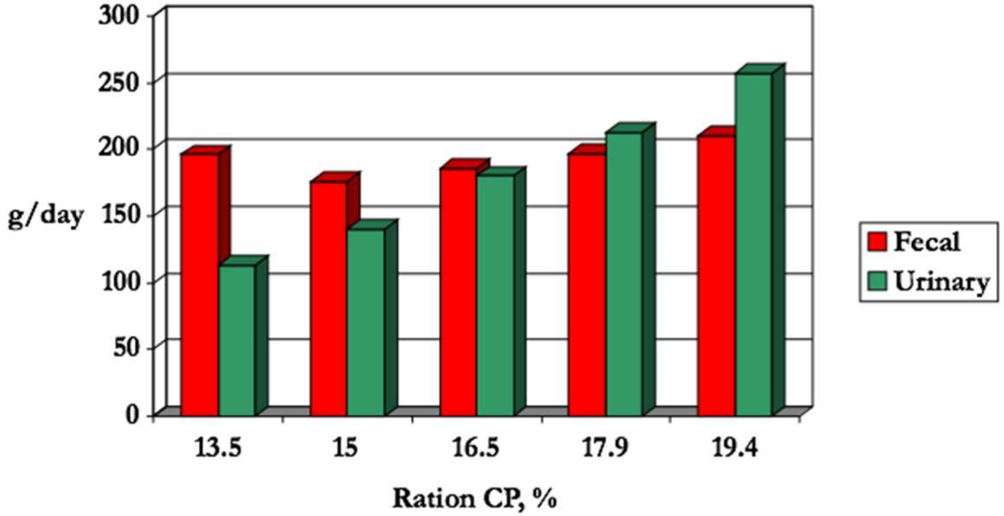
Dietary CP % vs. milk yield

- Line is curvilinear
- There is a lot of spread around the line.
- Maybe something else is driving milk yield.
- How do we account for multiple drivers?



N Intake and Excretion from Rations Varying in CP Levels



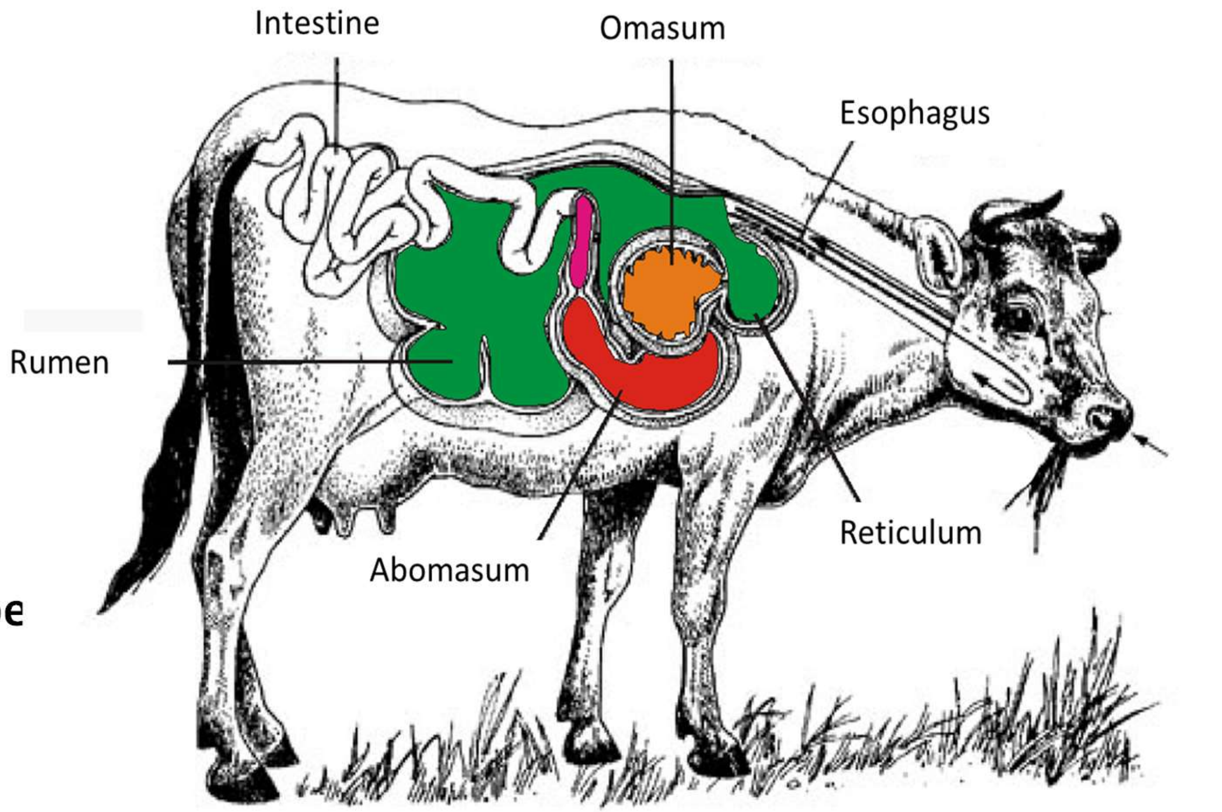


tom@agmodelsystems.com

- Source: Olmos Colmenero & Broderick, 2006

Back to Basics: The ruminant animal

- **Dynamic digestion process**
  - **Heterogenous diets**
  - **Fermentation chamber**
  - **Selective retention of particles**
- **Bacterial fermentation**
  - **Growth and outflow**
  - **Nitrogen cycling**
  - **40-60% of AA from microbes**
- **Multiple physiologic needs**
  - **Maintenance, growth, lactation, pregnancy, reserves gain/loss happe at same time**
- **Need an accounting system!**



Cornell Net Carbohydrate and Protein System

- A mathematical model accounting for supply and requirements
- Focused around energy, protein and amino acid balance

Requirements

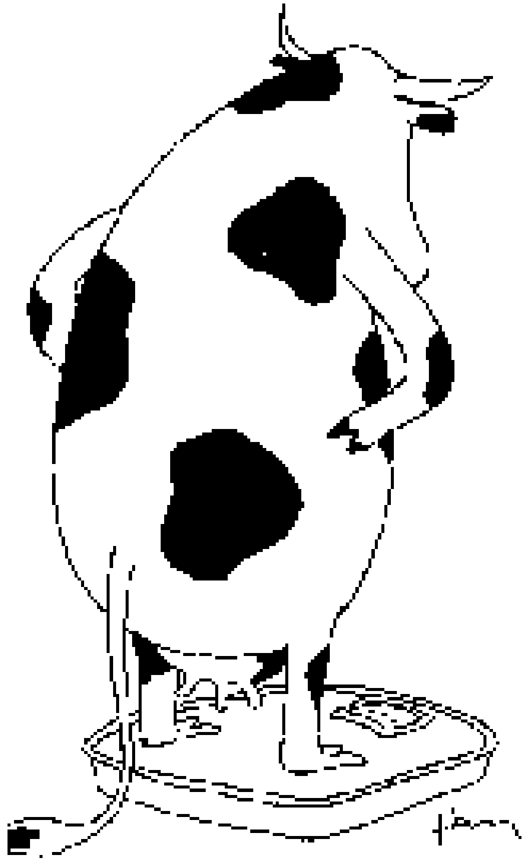
- Generally use empirical equations
- Maintenance, pregnancy Lactation, growth, reserves
- Animal characteristics are most important
- Adjustments made for environment and activity

Supply

- Mechanistic equations
- Rumen sub-model (microbes) and intestinal digestibility drive supply
- Feed characteristics are most important
- Diet associated effects are taken into account

Single most important animal input?

- **BODY WEIGHT. Used to predict:**
  - **Predicted feed intake**
  - **Maintenance energy requirements**
    - **basal**
    - **adjustments for activity**
  - **Protein maintenance requirements**
    - **scurf**
    - **urinary**
  - **Passage rates**
  - **Growth requirements**
  - **Pregnancy requirements**
  - **Reserve requirements**

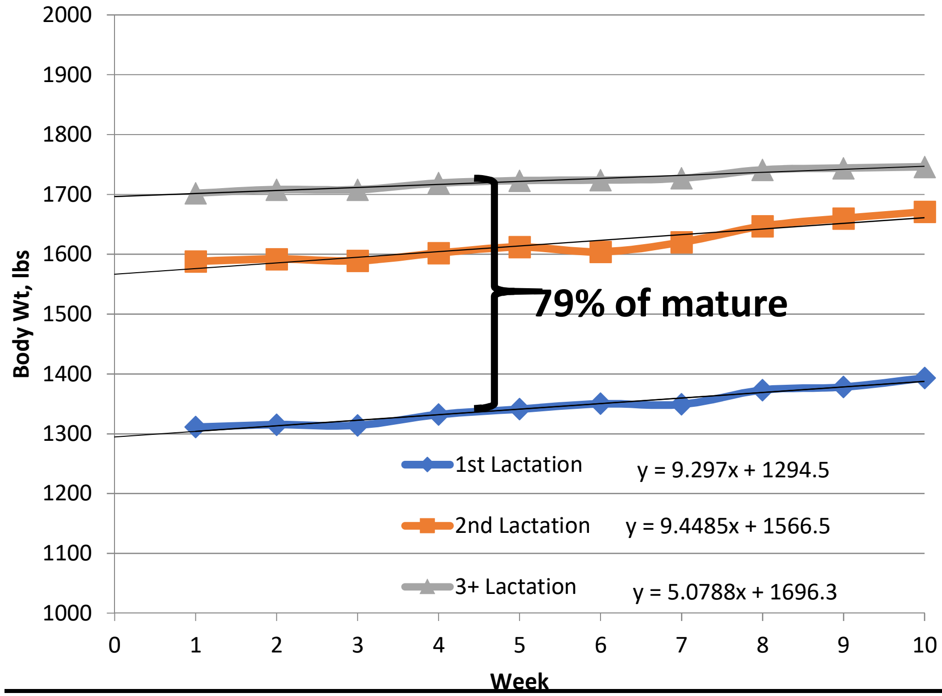


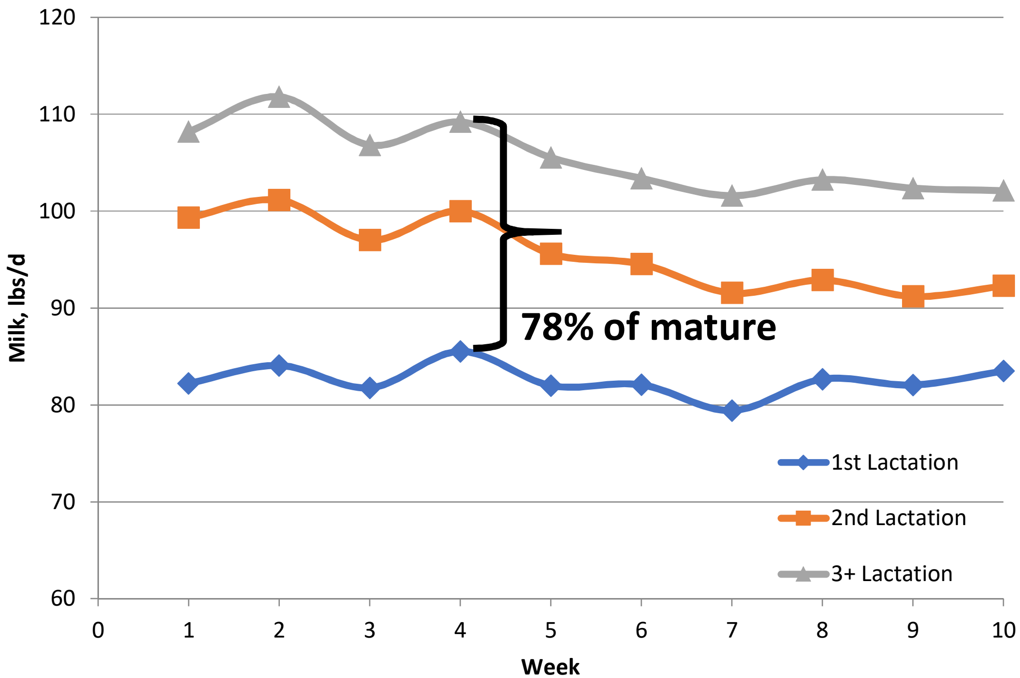
Cows are (still) getting bigger

- **Cornell Research Farm**
  - **1993 – mature body weight = 668 ± 67 kg**
  - **2016 – mature body weight = 776 ± 74 kg**
- **That is an approximately 1% per year increase**

- Fessenden and Van Amburgh, 2016

Direct relationship between calving weight and milk production





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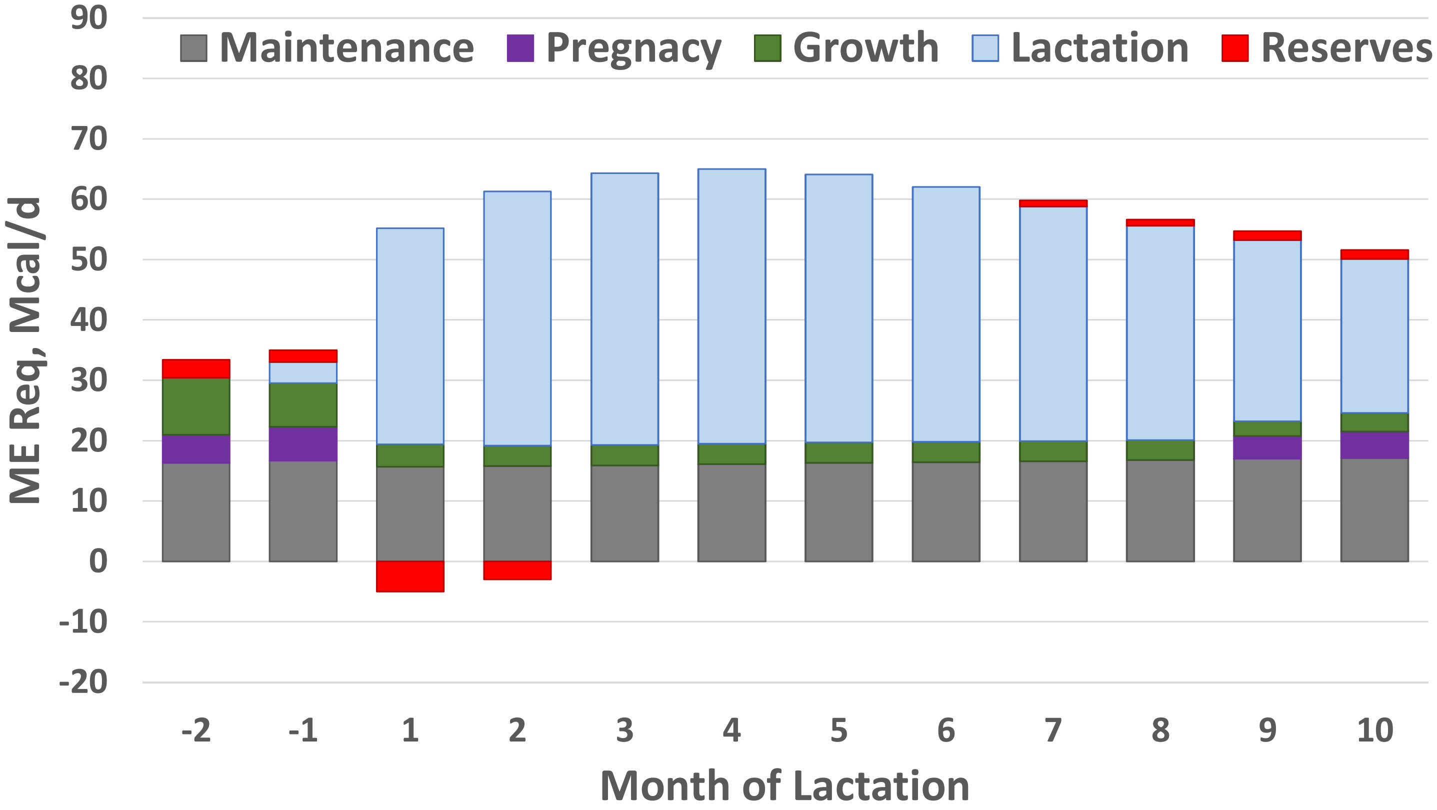
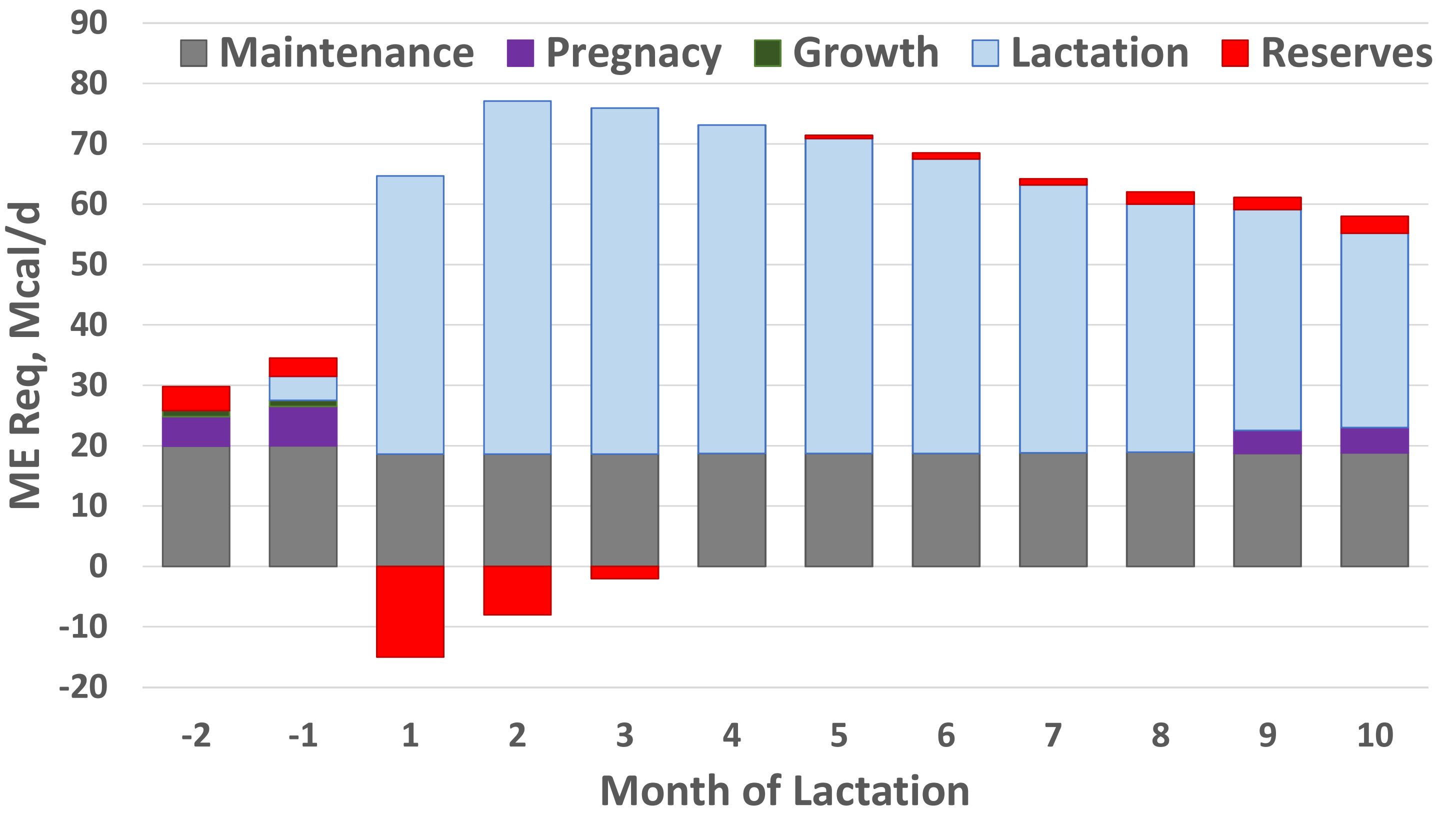
Requirements for Energy –1st Lactation

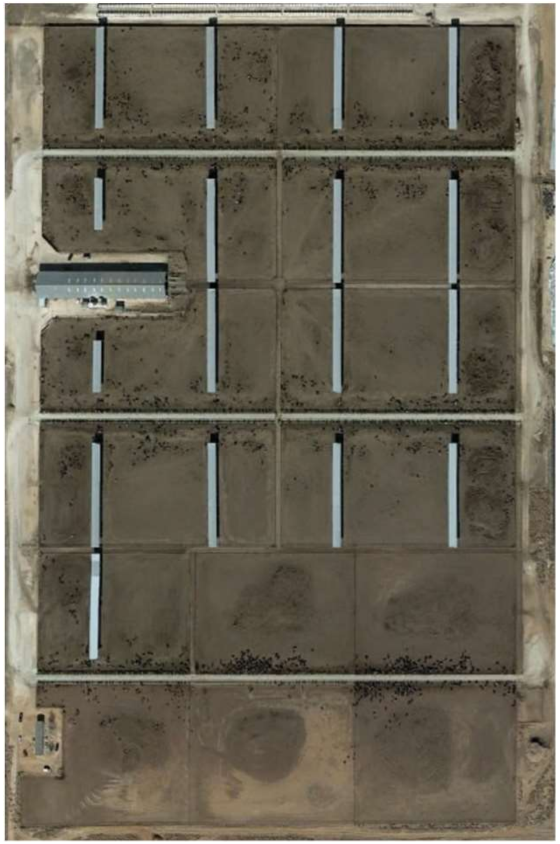


Requirements for Energy –Mature Cows



Distances?

4200 cow dairy

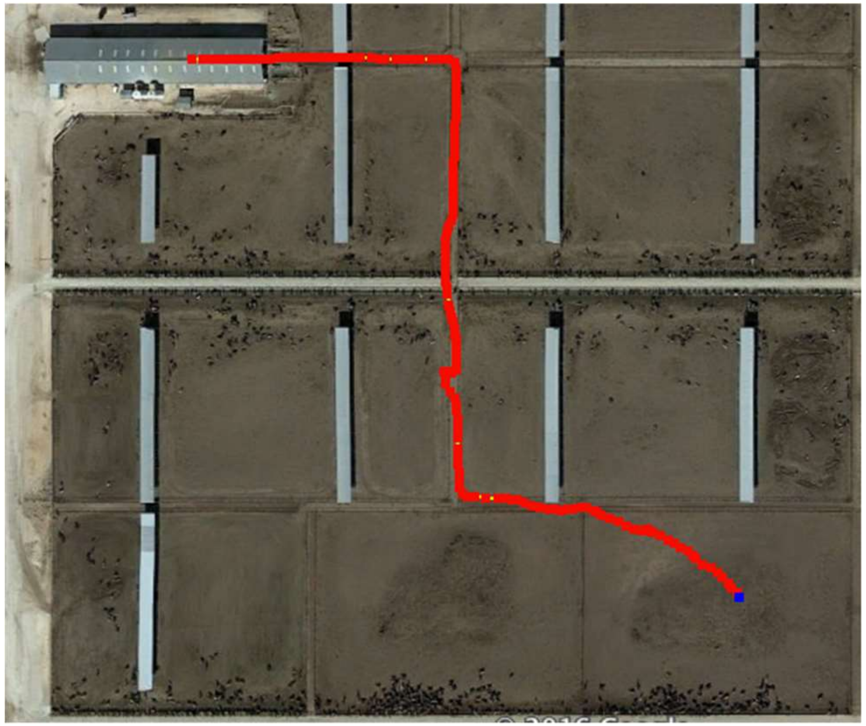


Note: all of these pictures and distances in these few slides are from Google Earth and using their path function to determine distance.

Late lactation cows

- Parlor to center of lot is
  - 500 m

- Milking 2x per day is
  - 4 x 500
    - 2,000 m walking to/from parlor



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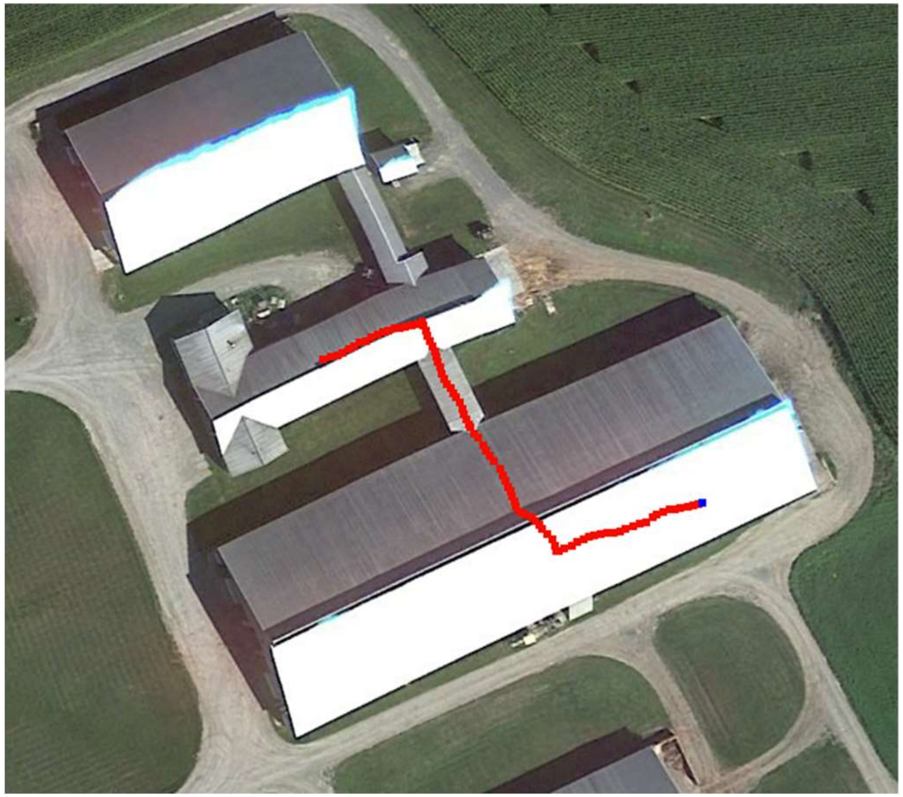
750 cow dairy

- **Parlor to center of farthest pen is:**
  - **100 m**
  - **3x milking so**
    - **100 x 6 =**
      - **600 m walking per day to/from parlor**

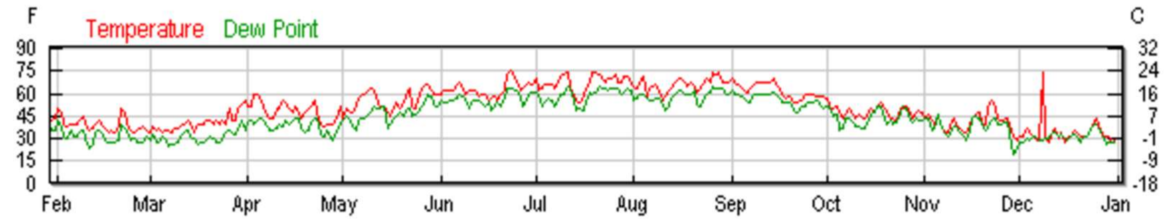


Why is this important?

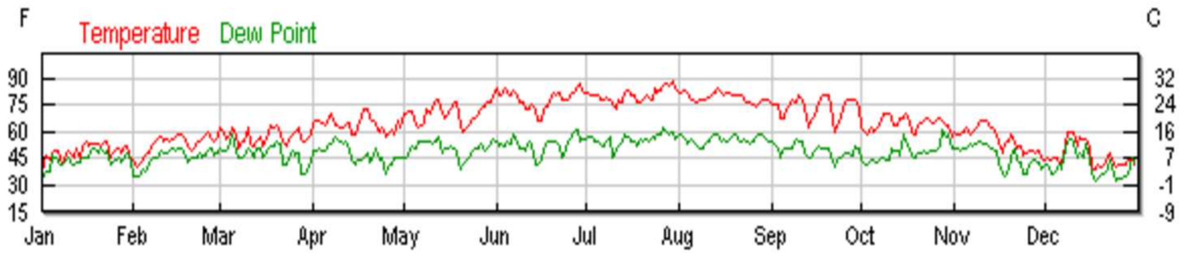
- Aussie researchers put cows on treadmills
  - For every 1 km flat distance walked, energy requirements increase the equivalent of about 500 ml milk
    - Or 1 mile = about 1.54 lbs of milk
  - Sloped walking (>3% slope) about 5x greater!
- Now, we can also use this to our advantage
  - Fresh and high cows as close to milking center as possible
  - Late lactation cows furthest to help us control BCS
    - Fat cows even further

Environment Adjustments

- **Temperature and Humidity**
  - **Bremen, Germany**

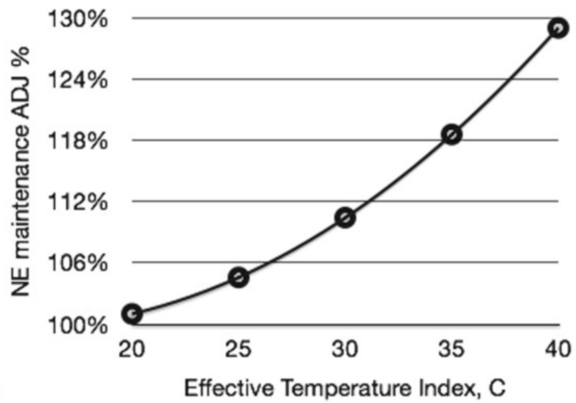


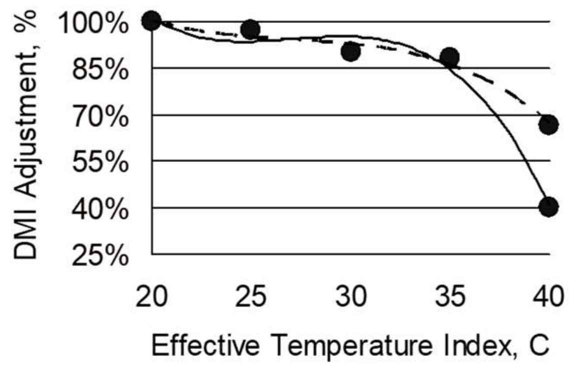
  - **Central Valley California**



  - **Use the conditions that the cows feel**

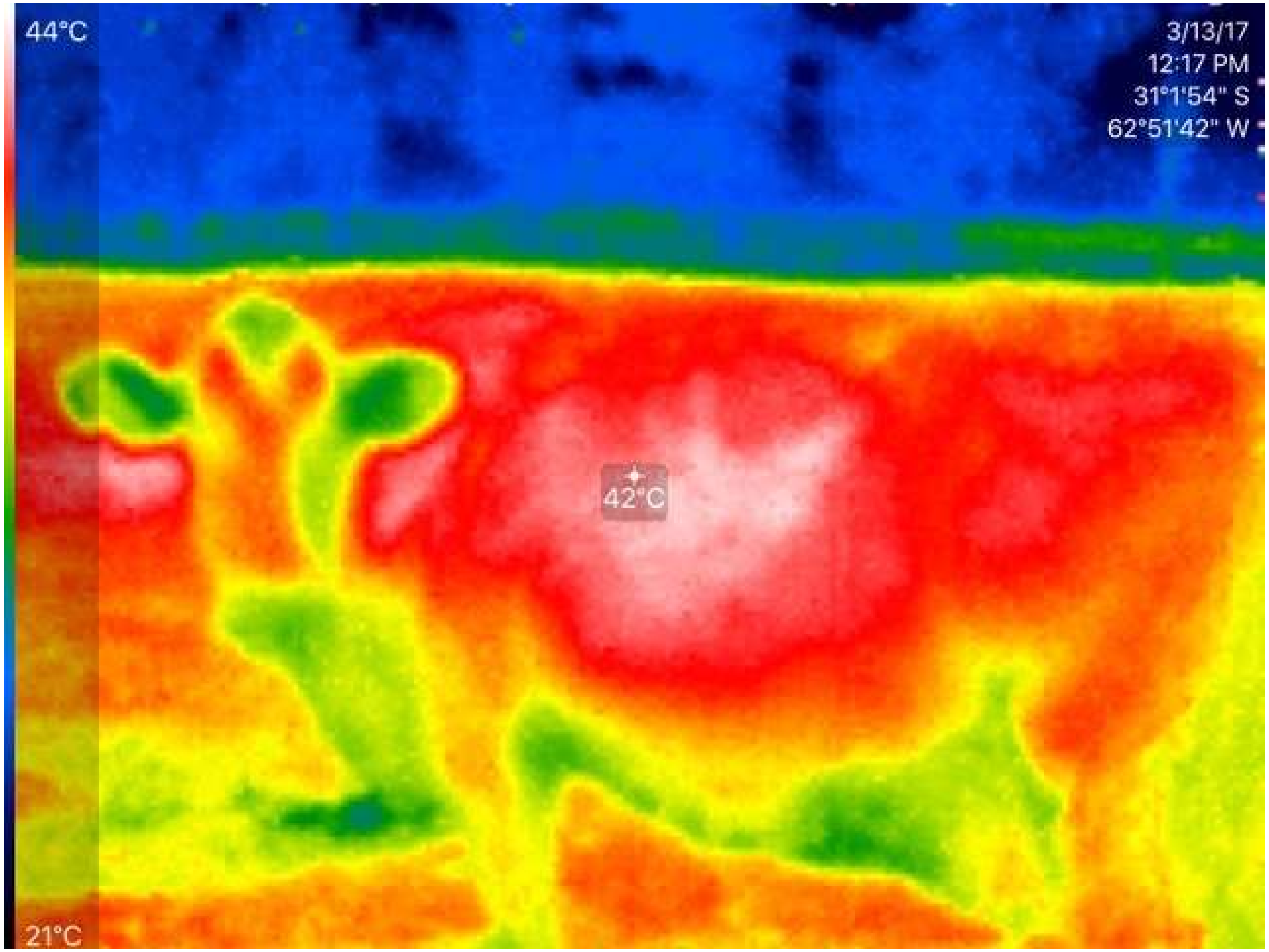
Heat Stress





Maintenance Adjustments

	Deg C	0°C		-10°C		-20°C	
	Coat Condition	**Clean**	**Heavily Covered**	**Clean**	**Heavily Covered**	**Clean**	**Heavily Covered**
Dry cow	**0 Wind**	100%	100%	100%	104%	101%	137%
	20 kph Wind	100%	100%	100%	120%	121%	155%
100 kg Heifer	**0 Wind**	162%	262%	197%	326%	236%	390%
	20 kph Wind	236%	295%	292%	367%	349%	438%

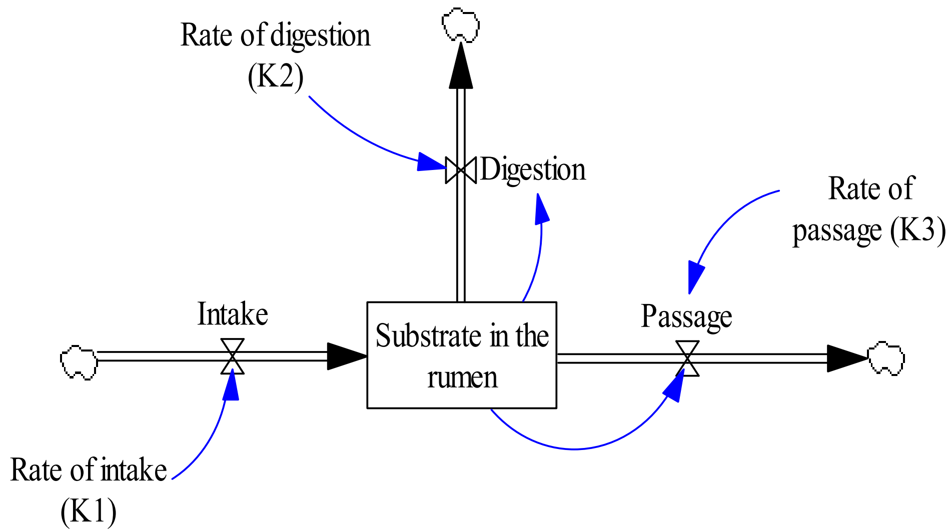

44°C
3/13/17
12:17 PM
31°1'54" S
62°51'42" W
42°C
21°C

Cattle inputs – Key numbers in the CNCPS

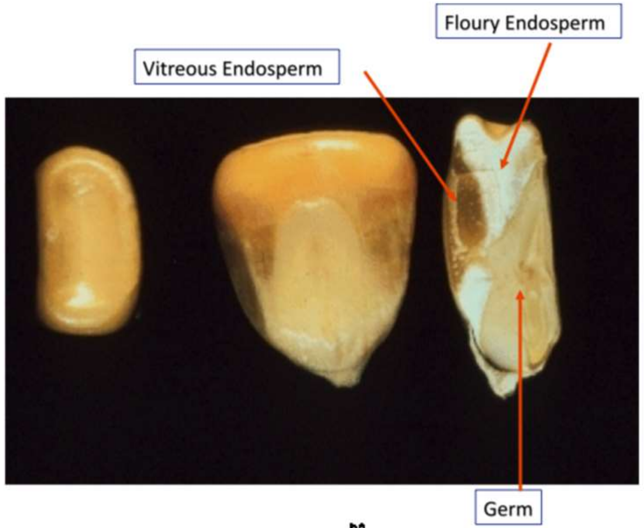
- **Lactating cows**
  - **Body weight is very important!**
  - **21 days in milk: Intake equation picks up**
  - **191 days pregnant: Fetal requirements begin**
  - **Average daily gain always <u>frame growth</u>, not reserves gain.**
    - **Mature cows (3+ lactation) should not have an ADG.**
    - **Reserves change should be reflected in BCS change**
- **Dry Cows**
  - **260 days pregnant: Fetal and mammogenesis requirements really take off.**
  - **MP requirements are quite high in the last month of dry period**
  - **Dry cows can be very heavy**
    - **Conceptus will be almost 2 x the weight of the new calf.**

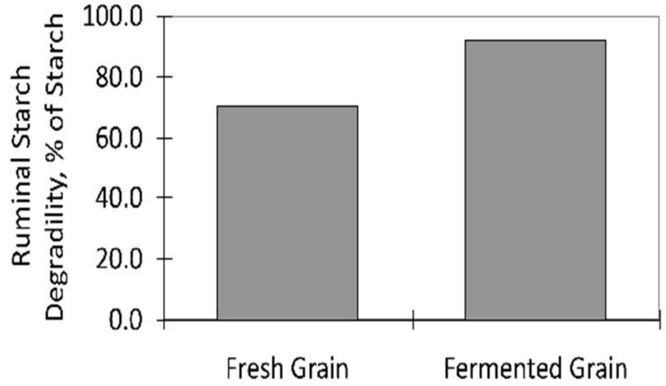
Rumen Submodel

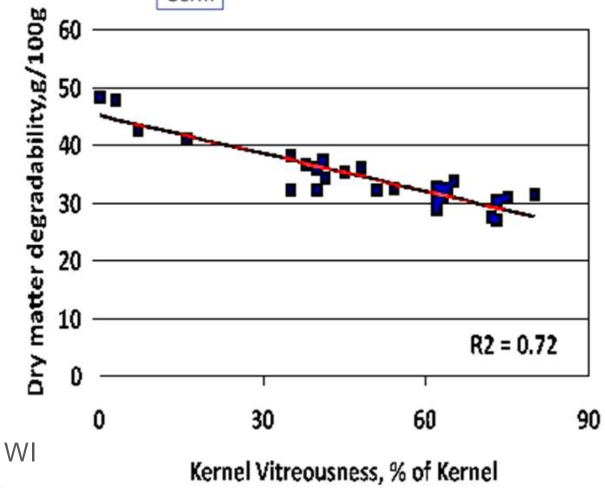
- **Digestibility = kd/(kd+kp)**
  - **Rate of degradation (kd):**
    - **specific to the feed fraction**
  - **Rate of passage (kp):**
    - **specific to the animal**
- **Equation used to calculate disappearance of given substrate**
  - **Microbial growth rate is calculated from CHO kd**
- **Metabolizable Energy (ME):**
  - **Calculated from digested nutrients**
- **Metabolizable Protein (MP):**
  - **Microbial protein & Undegr. Protein**

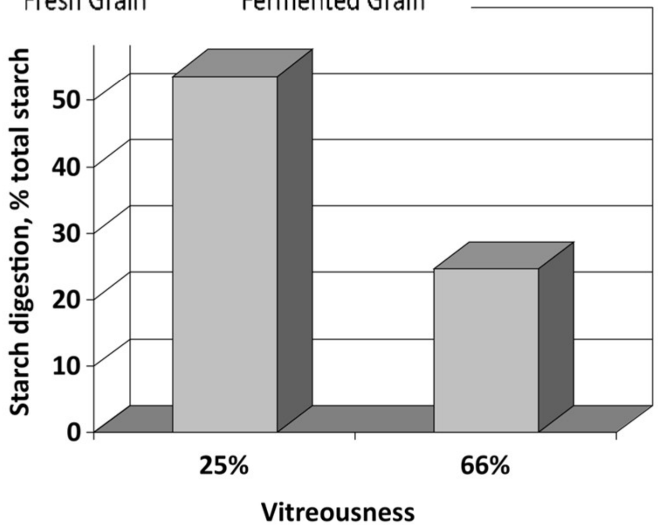


Starch Quality



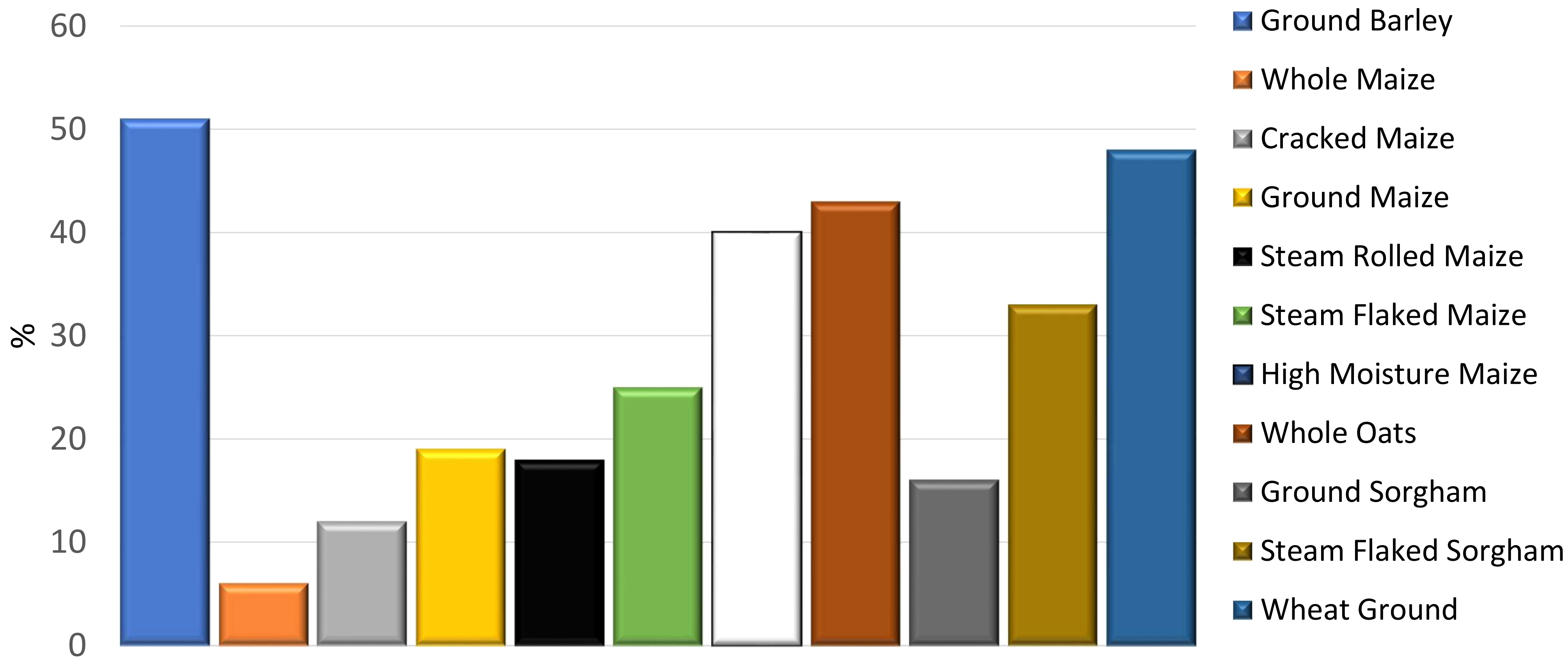






Adapted from P. Hoffman, Univ. of WI

Rumen Degraded Starch, % DM

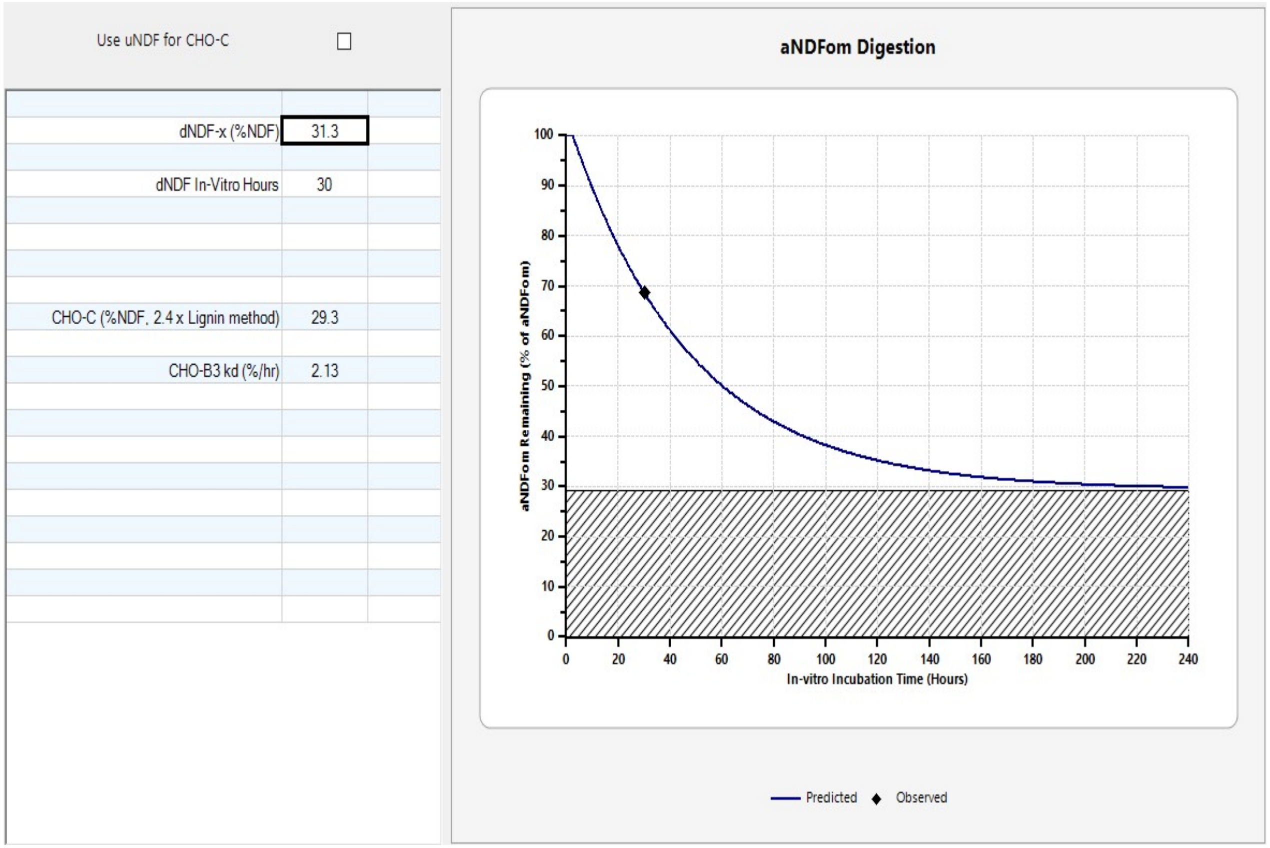


So let's look at a few examples

Pool	kd	kp	% Degraded in rumen
Sugar	40%	12%	76.9%
Good maize starch	15%	6%	71.4%
Poor maize starch	7%	6%	53.8%
CHO B3	4%	2%	66.7%
CHO C	0%	2%	0%

NDF digestibility: most models

- **Whole-crop silage from UK**
- **Traditional single time point:**
- **Used 30 h NDFd:**
  - **31.3 % of NDF**
- **Lignin 2.4 as estimation of iNDF:**
  - **29.3 % of NDF**
- **Kd: 2.13 %/h**

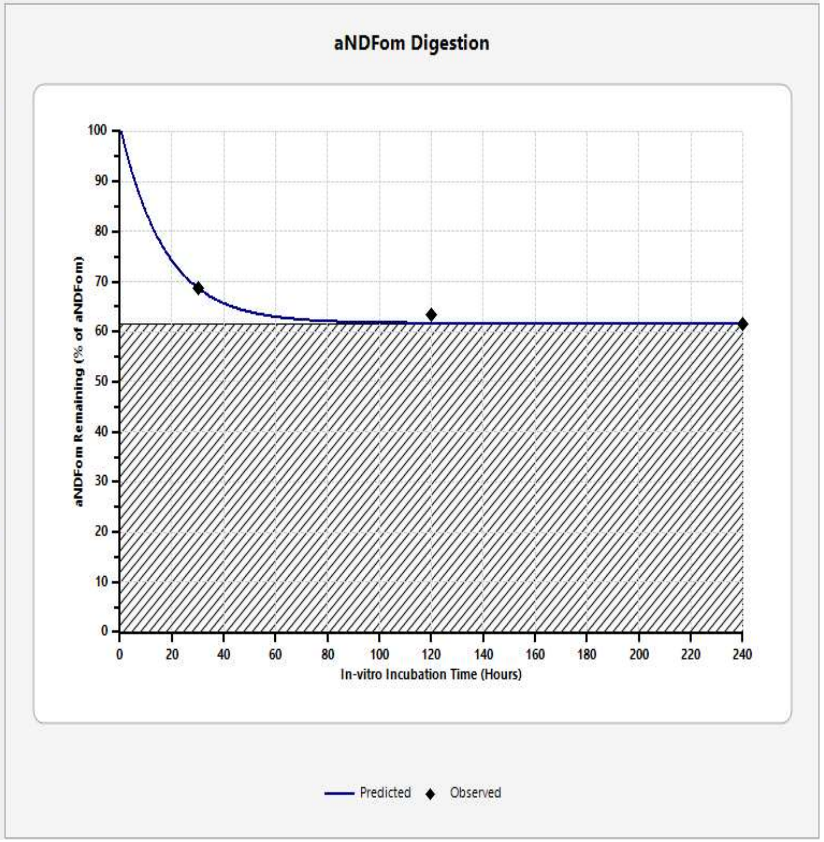


NDF digestibility: new CNCPS method

- **Same UK forage**
- **3 time point**
  - **30h: 31.3 %**
  - **120h: 36.5 %**
  - **240h: 38.4 %**
- **Measured uNDF**
  - **61.6 % of NDF**
- **Kd: 5.7 %/h**

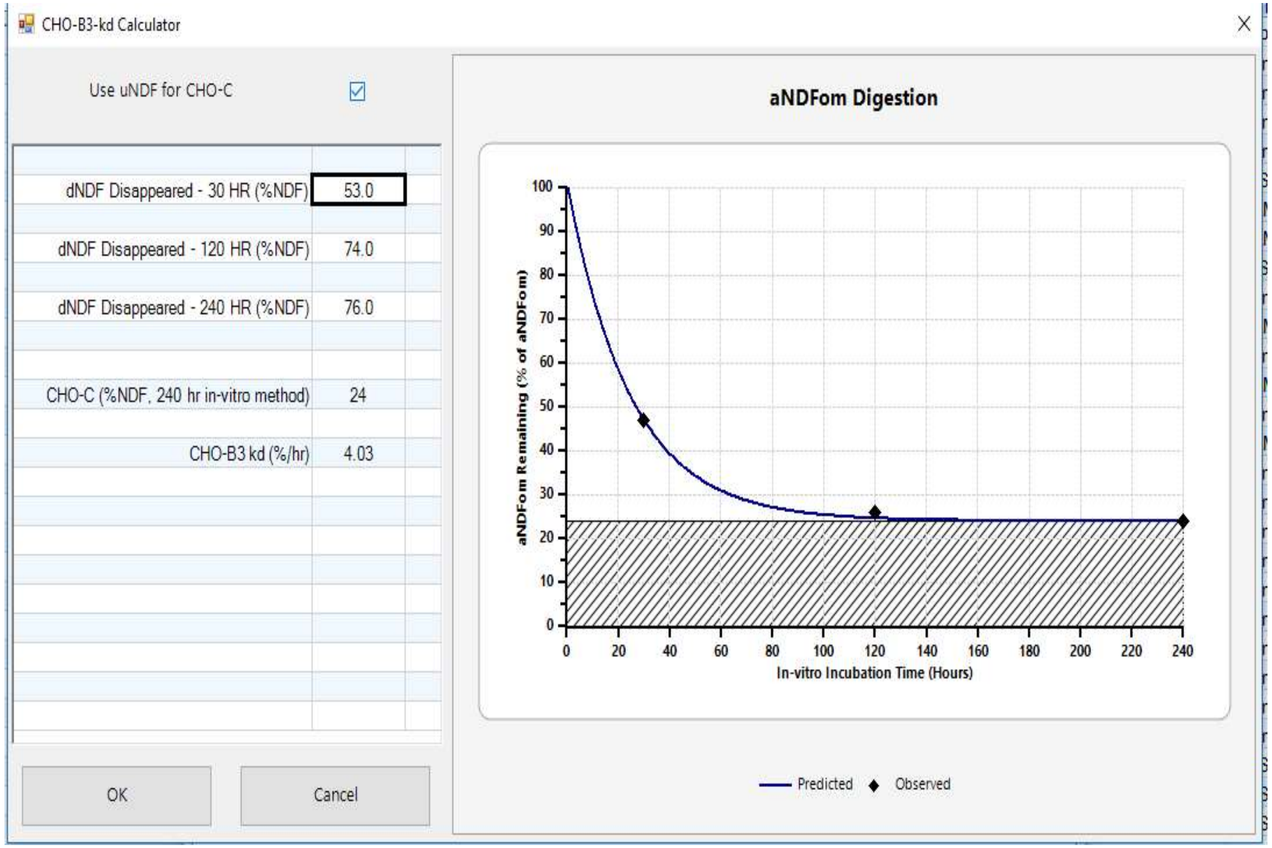
Use uNDF for CHO-C ☑

dNDF Disappeared - 30 HR (%NDF)	31.3
dNDF Disappeared - 120 HR (%NDF)	36.5
dNDF Disappeared - 240 HR (%NDF)	38.4
CHO-C (%NDF, 240 hr in-vitro method)	61.6
CHO-B3 kd (%/hr)	5.7



NDF digestibility in the CNCPS

- In vitro digestibility
  - 30, 120, and 240 h of incubation in rumen fluid
- Allows us to 'see' degradation characteristics
- NIR estimations for these numbers are quite good
- Available only through US-linked laboratories and EuroFinn at this point



CNCPS Feed Fractions

Protein Fractions				Carbohydrate Fractions		
Label	Lab Measure	Relative kd		Label	Lab Measure	Relative kd
PRT A1	Ammonia	Fast		CHO A1-A3	VFA	Moderate
PRT A2	Sol. True Prot.	Med-Fast		CHO A4	Sugars	Fast
PRT B1	By difference	Moderate		CHO B1	Starch	Med-Fast
PRT B2	NDIP-ADIP	Slow		CHO B2	Sol. Fiber	Moderate
PRT C	ADIP	Undegradable		CHO B3	Digestible NDF	Slow
				CHO C	uNDF	undegradable

Feed analysis: Do we really need all this info?

DAIRYLAND
Laboratories, Inc.

217 E. Main St.
Arcadia, WI 54612
Telephone: 608-323-2123
Fax: 608-323-2184
Email: info@dairylandlabs.com

Report Date: 3/28/2017
Sample No.: 001-1703-675360

To: Agrofeed Kft-NIR
Vadas 7
6086, Hungary,

Account No.: 7707 (0)
Sampled By: Agrofeed Kft-NIR Spe
Sampled For: SZIRMA-TERM KFT

Product: silo kukorica Tejelo
Description2: Kosa Levente

Test Mode: N3
Feed Type: Corn Silage

		Dry Basis	Average	Normal Range
Summary				
Moisture		63.79%		
Dry Matter		36.21%		
pH		3.75		
Results				
Crude Protein	%DM	8.15	7.82	5.72 - 9.92
AD-ICP	%DM	0.26	0.69	0.35 - 1.03
ND-ICP w/SS	%DM	0.76	0.96	0.55 - 1.97
Protein Sol.	%CP	69.82	37.50	16.33 - 58.68
Ammonia-CP	%CP	12.02	6.07	1.23 - 10.90
Ammonia-CP	%DM	0.98	0.54	0.13 - 0.94
ADF	%DM	22.04	24.66	17.06 - 32.26
aNDF	%DM	35.69	41.00	30.08 - 51.92
aNDFom	%DM	34.83	40.10	29.71 - 50.76
Lignin (Sulfuric Acid)	%DM	2.60	3.67	2.23 - 5.11
Lignin	%NDFom	7.46	8.01	5.30 - 10.72
Lignin input (uNDF/2.4)	%DM	4.06	4.42	2.55 - 6.30
NDFD 30	%NDFom	61.50	53.87	43.57 - 64.17
NDFD 120	%NDFom	68.73	71.54	62.62 - 80.34
NDFD240	%NDFom	72.04	73.90	65.70 - 83.20
uNDFom30	%DM	13.41	18.20	13.30 - 23.30
uNDFom120	%DM	10.89	11.45	7.02 - 15.78
uNDFom240	%DM	9.74	10.50	6.00 - 14.90
Starch	%DM	38.41	31.84	18.46 - 45.22
IVSD7-o	%Starch	84.84	73.81	42.52 - 84.67
Fat (EE)	%DM	4.38	3.17	2.15 - 4.19
TFA (fat)	%DM	2.99	2.22	1.18 - 3.26
Ash	%DM	4.51	3.80	1.42 - 6.18
Calcium	%DM	0.18	0.24	0.12 - 0.36
Phosphorus	%DM	0.24	0.24	0.18 - 0.30
Magnesium	%DM	0.14	0.20	0.12 - 0.28
Potassium	%DM	1.05	1.05	0.63 - 1.47
Sulfur	%DM	0.11	0.11	0.09 - 0.13
Sugar (ESC)	%DM	0.31	1.72	0.02 - 4.67
Sugar (WSC)	%DM	0.30	3.76	2.18 - 6.51
Lactic Acid	%DM	4.16	2.90	0.01 - 5.98
Acetic Acid	%DM	3.30	1.04	0.01 - 2.39
Propionic Acid	%DM	0.61	0.17	0.01 - 0.49
Silage Acids	%DM	8.07	3.95	0.01 - 7.87
Lactic:Acetic ratio		1:1		

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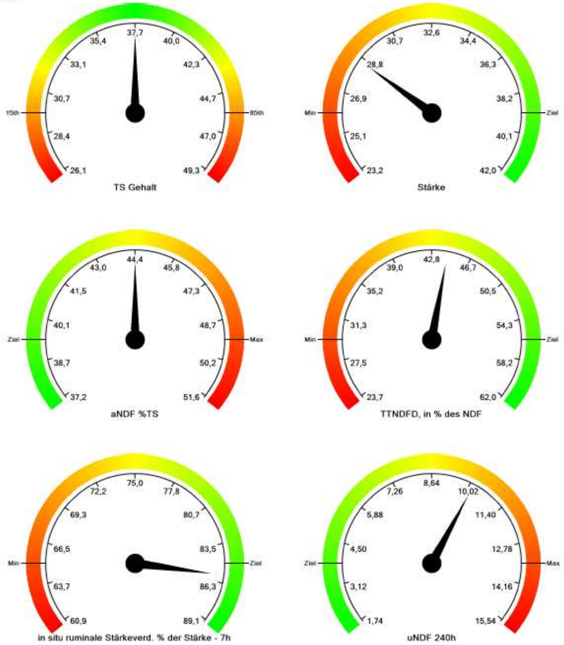
DAIRYLAND Laboratories, Inc.
PAGE 1
REFERENCE: 161451
03/28/2017

Visueller Futteranalyse Report

Lab # 10201145 22.08.2017
Sample ID Maissilage 2017 links Wand
Betrieb Hansen, Plau
Fütterungs-berater Hauke Hansen



Das Maximum entspricht dem 85. Perzentil und das Minimum dem 15. Perzentil.
Das Ziel kann je nach Anforderung das Minimun oder Maximun sein oder auch mittig liegen (grün).

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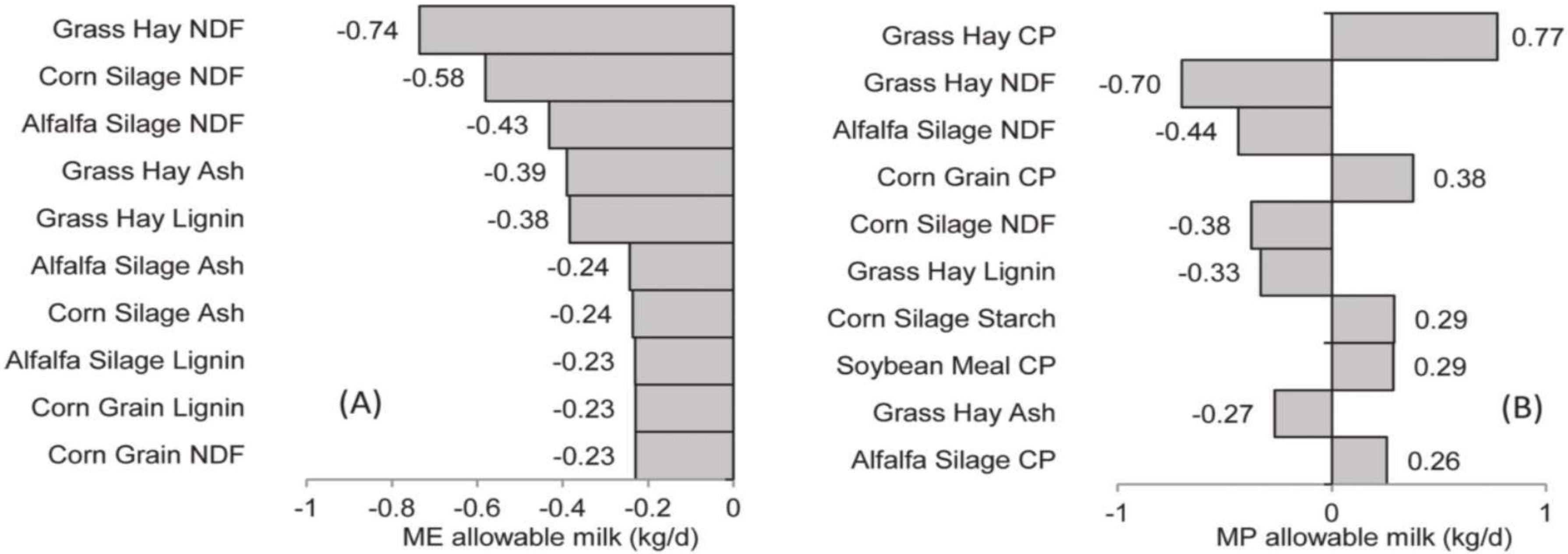
Dry Matter

Sensitivity analysis utilizing Monte Carlo sampling techniques proved that moisture content of silages is directly related to income over feed costs (IOFC)

Sample description	Dry matter	NDF
Maize Silage 1	36.9	33.5
Maize Silage 2	33.5	41.3
Maize Silage 3	35.6	38.3
Mazie Silage 4	38.9	39.9
Maize Silage 5	39.7	37.3
Maize Silage 6	29.9	39.5
Maize Silage 7	27.8	50.2
Mean	**34.6**	**40.0**
Standard Deviation	4.5	5.1
Coefficent of Variation	12.9%	12.8%
N required	77	101
Sample every	**4**	**3**
assume fed for 365 days		

Feed analysis: Composition

- **Which measurements of composition are most important?**
- **Evaluated ME and MP sensitivity to 1 SD increase in amount of nutrient**

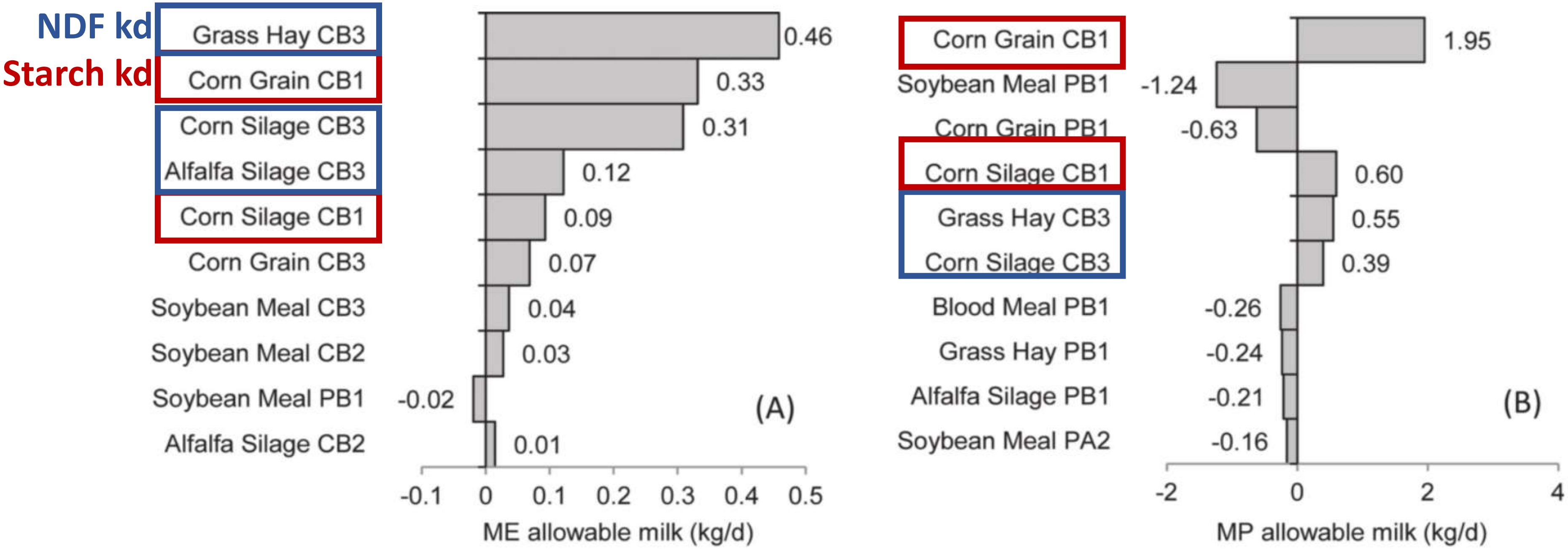


AMTS

- Higgs et al., 2015

Feed analysis: Digestibility

- **Which measurements of digestibility are most important?**
- **Evaluated ME and MP sensitivity to 1 SD increase in digestion of nutrient**



Feed analysis: Ranking of what is important

Corn Silage	Haycrop
aNDFom	aNDFom
Starch	aNDFom dig (3 time point)
aNDFom dig. (3 time point)	CP
Starch dig. (7h 4mm, or lab kd)	Ammonia CPE
CP	Sol. Protein
TFA (or EE)	NDICP
Ash	ADICP
VFA	ESC (or WSC)
ESC (or WSC)	Ash
ADICP	TFA (or EE)
NDICP	VFA
Sol. Protein	

Feed analysis: Which ones to use?

Summary

Moisture	63.79%
Dry Matter	36.21%
pH	3.75

Results

Crude Protein	%DM	8.15
AD-ICP	%DM	0.26
ND-ICP w/SS	%DM	0.76
Protein Sol.	%CP	69.82
Ammonia-CP	%CP	12.02
Ammonia-CP	%DM	0.98
ADF	%DM	22.04
aNDF	%DM	35.69
aNDFom	%DM	34.83
Lignin (Sulfuric Acid)	%DM	2.60
Lignin	%NDFom	7.46
Lignin input (uNDF/2.4)	%DM	4.06
NDFD 30	%NDFom	61.50
NDFD 120	%NDFom	68.73
NDFD240	%NDFom	72.04
uNDFom30	%DM	13.41
uNDFom120	%DM	10.89
uNDFom240	%DM	9.74
Starch	%DM	38.41

Starch	%DM	38.41
IVSD7-o	%Starch	84.84
Fat (EE)	%DM	4.38
TFA (fat)	%DM	2.99
Ash	%DM	4.51
Calcium	%DM	0.18
Phosphorus	%DM	0.24
Magnesium	%DM	0.14
Potassium	%DM	1.05
Sulfur	%DM	0.11
Sugar (ESC)	%DM	0.31
Sugar (WSC)	%DM	0.30
Lactic Acid	%DM	4.16
Acetic Acid	%DM	3.30
Propionic Acid	%DM	0.61
Silage Acids	%DM	8.07
Lactic:Acetic ratio		1:1

Ration | Ration Shots (Empty) | Opt. Feed Constraints | Optimizer | Adv. Optimizer | Batch Report | Feeding Sheet | Reports | Notes | Reports 2 | Pal. Opt.

Recipe: High diet active

Cattle: Lact Cow Barns.Pen 5 Old cows

Feed		kg/day (DM)		kg/day (AF)	%DM
Corn silage 2016	8.12	8.12	28.31	28.31	29.856
Alfalfa silage 2017 2nd	3.78	3.78	12.40	12.40	13.900
Cow Grass 2nd 2017	2.49	2.49	9.07	9.07	9.167
HMEC 2016	4.043	4.043	6.307	6.307	14.858
chocolate	1.793	1.793	2.068	2.068	6.591
Corn meal	1.192	0.000	1.354	0.000	0.000
EZ Protein June 19 2017	5.7819	5.7819	6.3852	6.3852	21.248
flakes n steep	N/A	1.1920	N/A	1.4569	4.381
Click to add...					
Total	27.2109	27.2109	65.8943	65.9960	100.000
Predicted DMI (CNCPS)	27.371	27.3711			
Inputted/Predicted DMI (%)	99.415	99.415			
Predicted DMI (NRC)	30.122	30.122			
Drinking Water Intake (AF)	[illegible]	[illegible]			

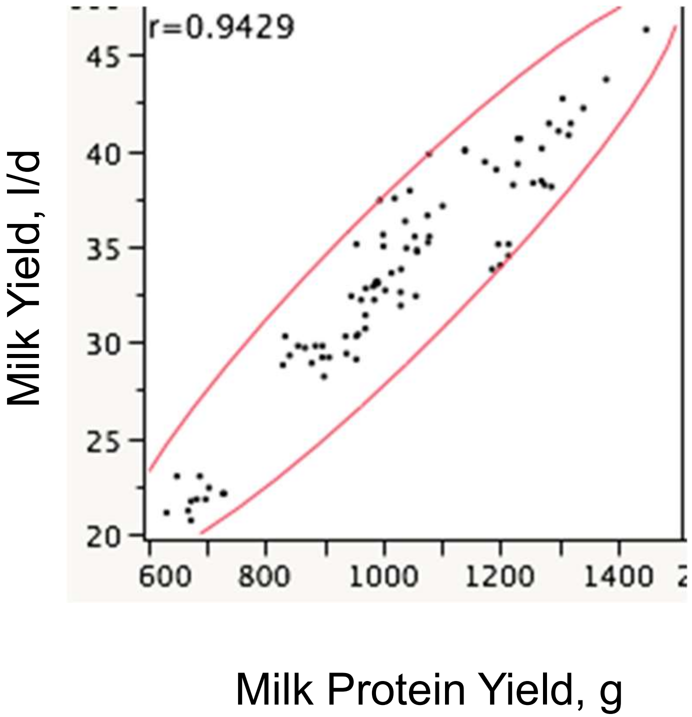
Ration Outputs | AA Supp. Tool | CNCPS | Min/Vit | Additives | Amino Acids | Met E & P | P & E | PRT Pools | CHO Pools | CHO F

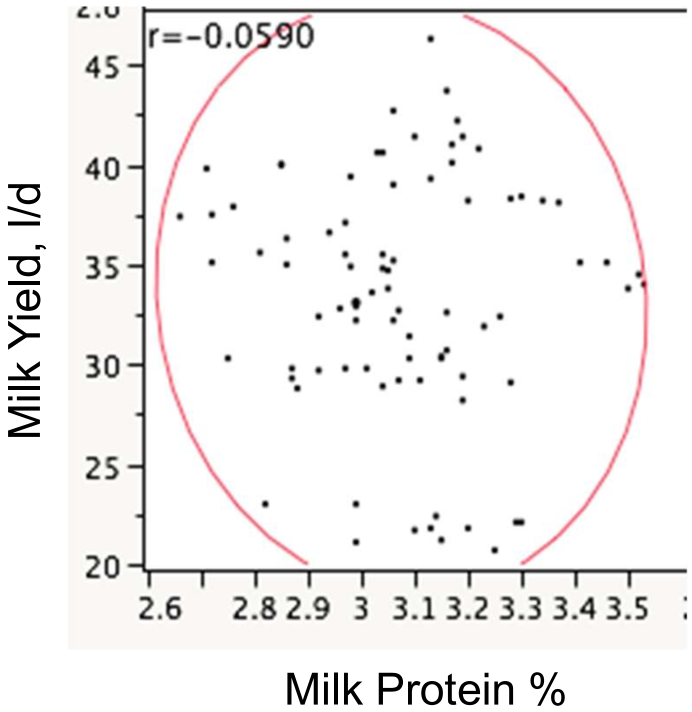
		Safe Min	Min	Snap. Value	Value
Dry Matter Intake (kg/day)		29.48	29.48	27.21	27.21
IOFC		0.00	0.00	7.24	7.20
Cost/hd	?	0.00	0.00	6.34	6.55
Forage (%DM)	?	53.00	53.00	52.92	52.92
Forage NDF (%BW)	?	0.00	0.98	0.79	0.79
DM (%)		20.00	20.00	41.29	41.23
ME Allowable Milk (kg/day)		48.93	48.93	48.28	48.78
MP Allowable Milk (kg/day)		48.93	48.93	48.20	49.81
ME (%Rqd)	?	100.00	103.00	100.43	101.20
MP (%Rqd)	?	100.00	100.00	100.29	102.68
MP Supply (g)	?	500.00	500.00	3,147.69	3,211.64
Rumen NH3 (%Rqd)		120.00	130.00	159.82	152.56
NFC (%DM)	?	0.00	0.00	40.93	40.86
peNDF (%DM)	?	18.50	18.50	19.76	19.90
Lactic (%DM)	?	0.00	0.00	2.97	3.02
Sugar (%DM)	?	0.00	0.00	3.97	4.00
Starch (%DM)	?	0.00	22.00	28.19	28.04
Fermentable CHO (%CHO)	?	0.00	40.00	60.89	62.12
Ferm. Starch (%DM)	?	21.50	21.50	20.80	21.56

Amino Acid Composition, g/100 g

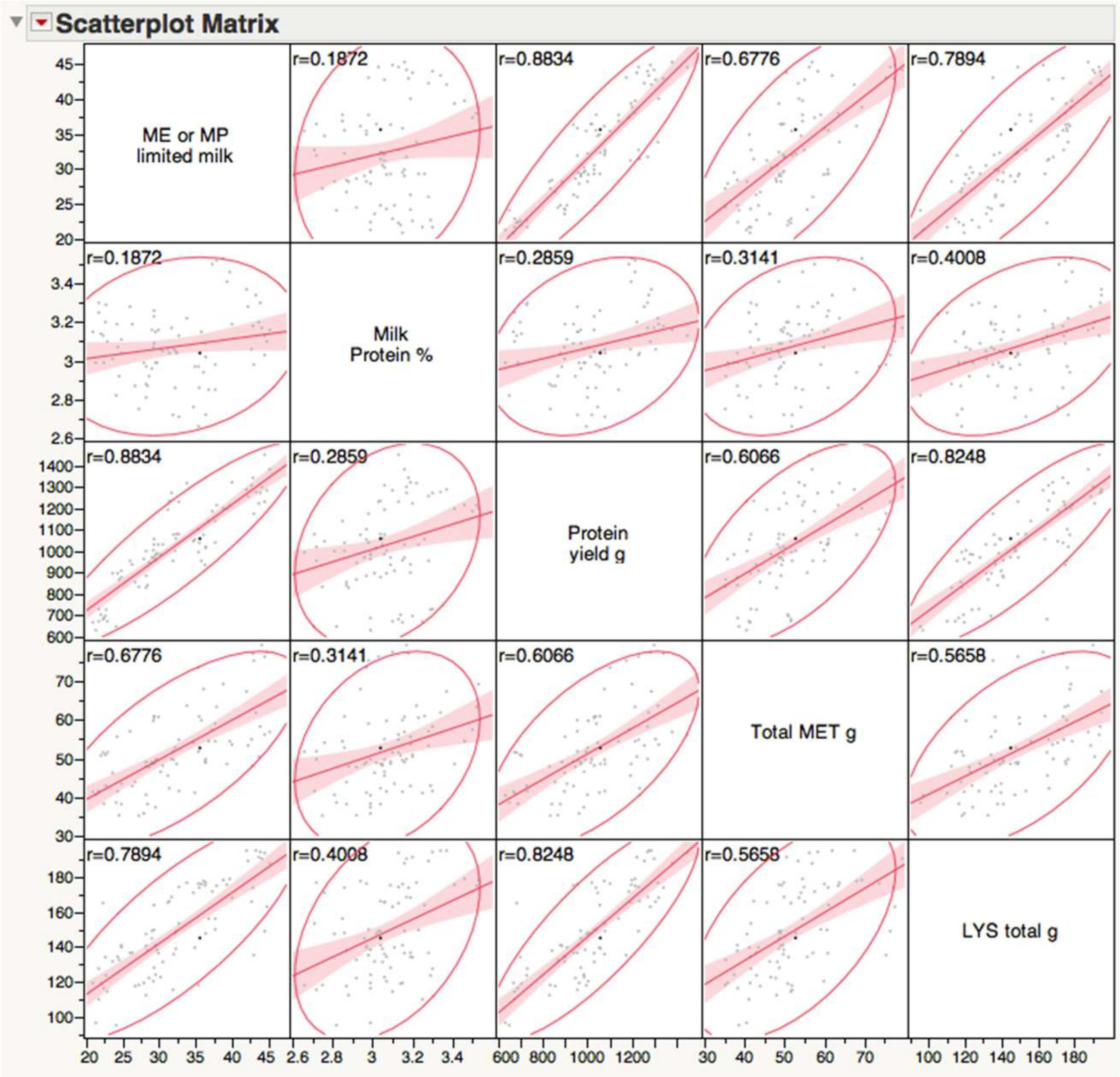
Amino Acid	Tissue	Milk	Microbes
MET	1.82	2.71	2.68
LYS	6.29	7.62	8.2
HIS	2.45	2.74	2.69
PHE	3.65	4.75	5.16
TRP	1.18	1.51	1.63
THR	3.83	3.72	5.59
LEU	6.96	9.18	7.51
ILE	2.94	5.79	5.88
VAL	4.28	5.89	6.16
ARG	6.65	3.4	6.96

Milk Protein and Yield



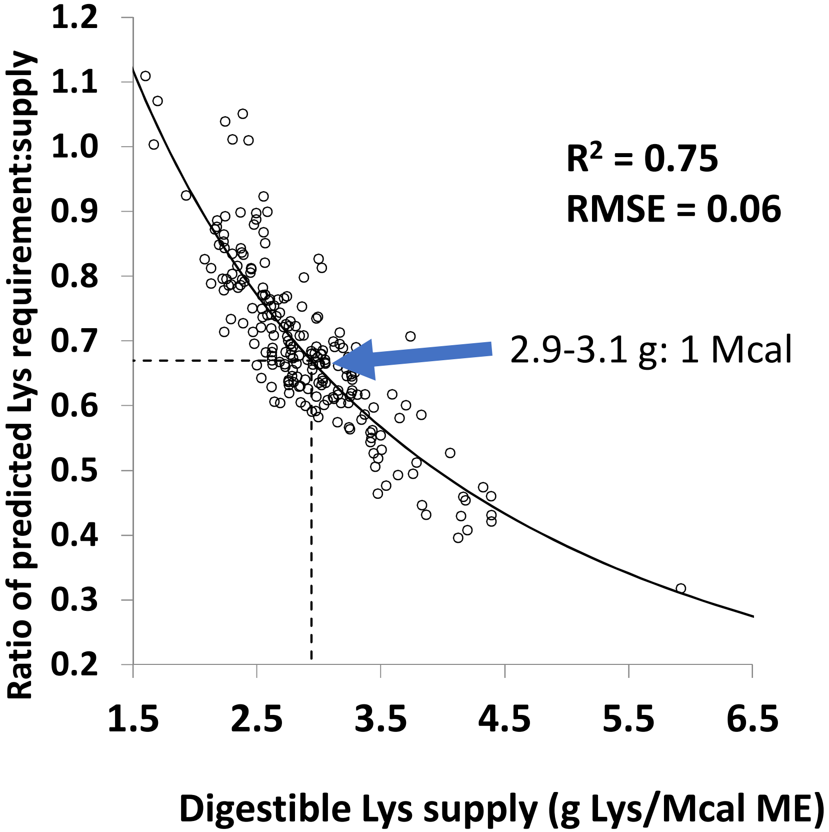


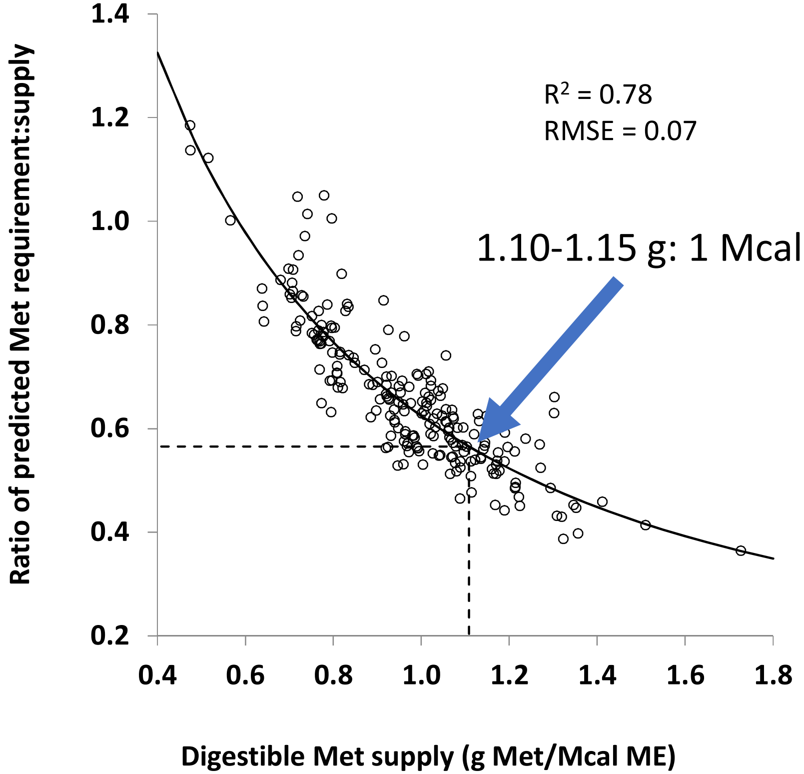
Also dependent upon Energy Availability



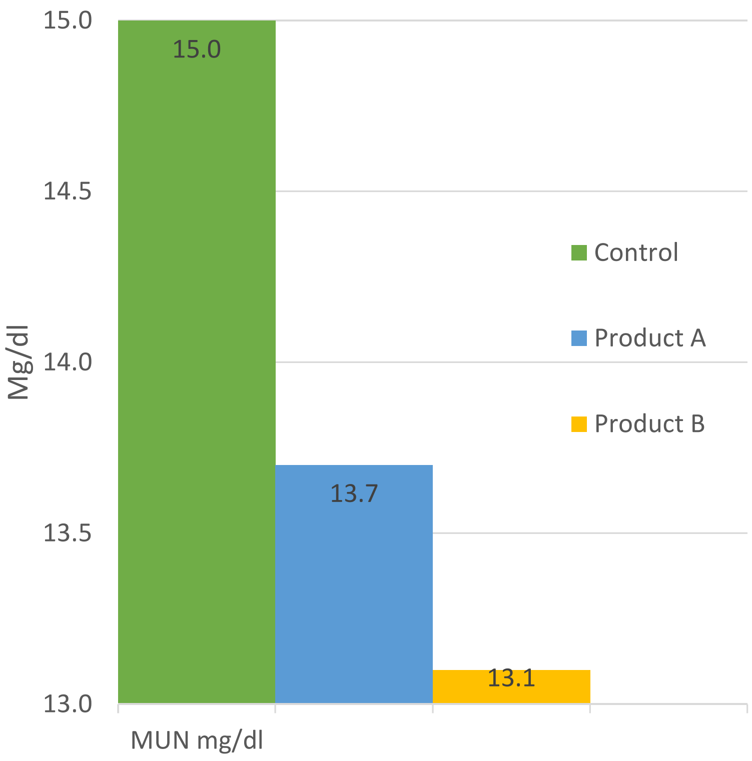
Scatterplot Matrix
ME or MP limited milk
Milk Protein %
Protein yield g
Total MET g
LYS total g
r=0.1872
r=0.8834
r=0.6776
r=0.7894
r=0.2859
r=0.3141
r=0.4008
r=0.6066
r=0.8248
r=0.5658

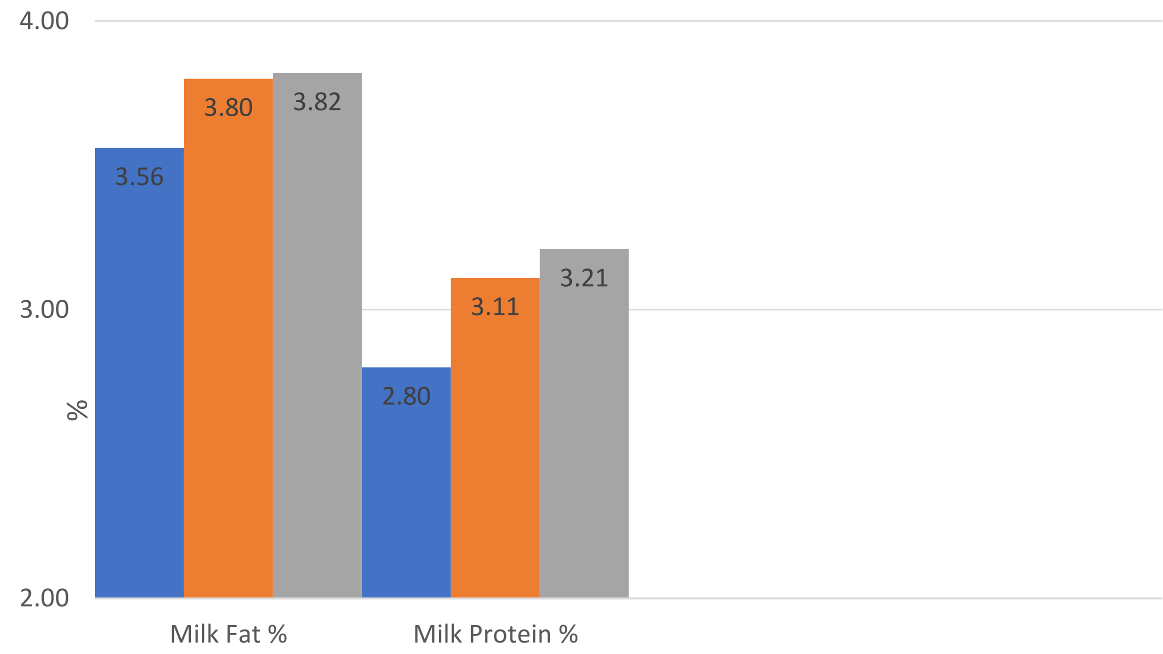
AA use expressed relative to energy





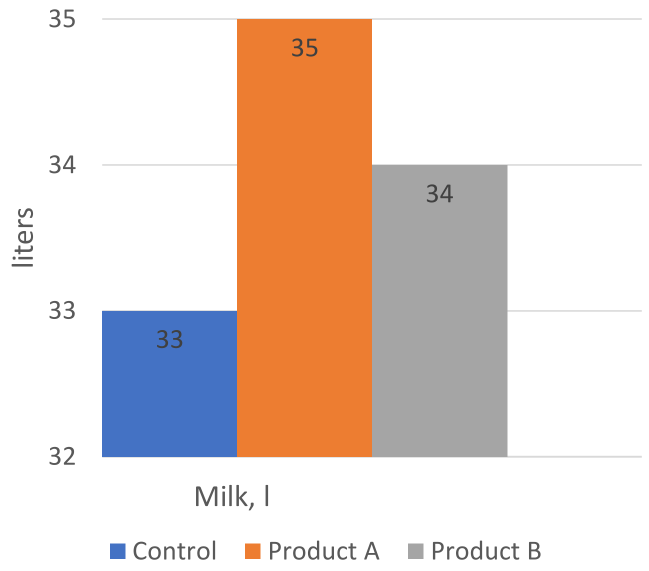
Two Products/Different Responses

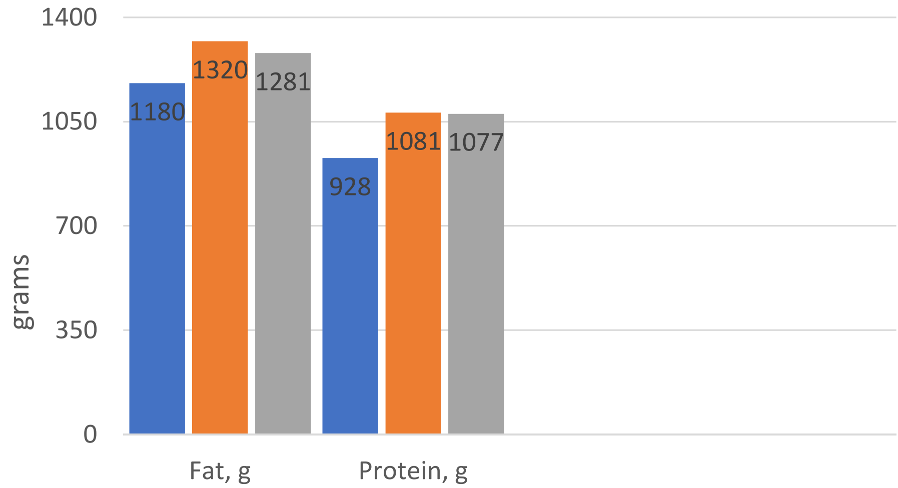




AMTS

Product Comparison





AMTS

Time to change thinking

- Amino Acids for years were thought of, and marketed as, additives.

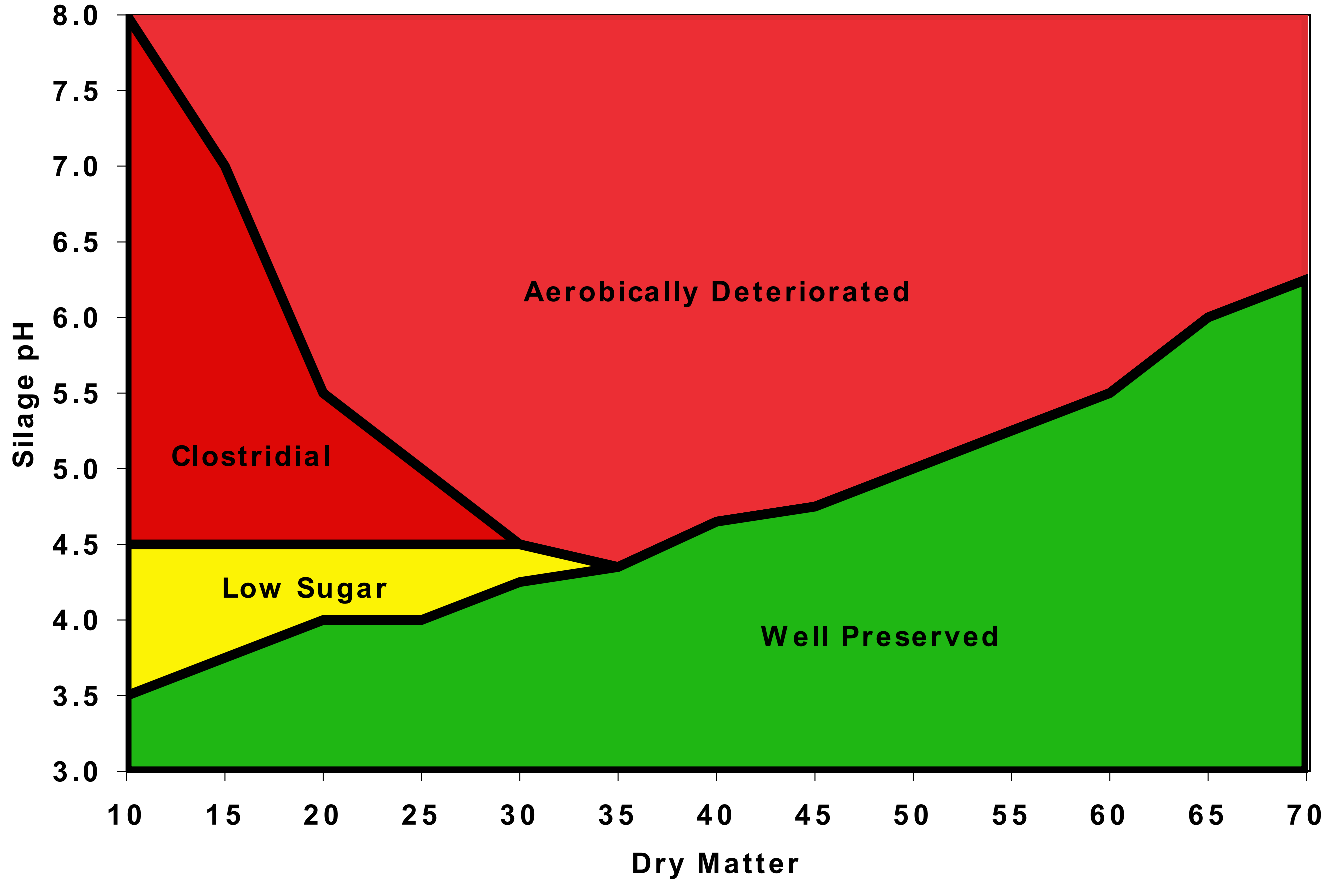
- This is NOT true. They are essential nutrients. Look at all the new data on MET and its impact on
  - Production
  - Immune function
  - Reproduction

  - Decisions should be based on the lost cost per gram of metabolizable AA

Successful implementation of the model

- **Step 0: think like a microbial nutritionist first!**
- **Step 1: good inputs**
  - **bodyweight critical in all nutrition programs**
- **Step 2: maximize fermentable CHO intake**
- **Step 3: maintain peNDF to keep rumen health**
- **Step 4: adequate RDP supply/sources to support microbial growth**
- **Step 5: supplement the animal to achieve desired ME, MP, AA, fatty acid, Min/Vit levels to meet requirements.**

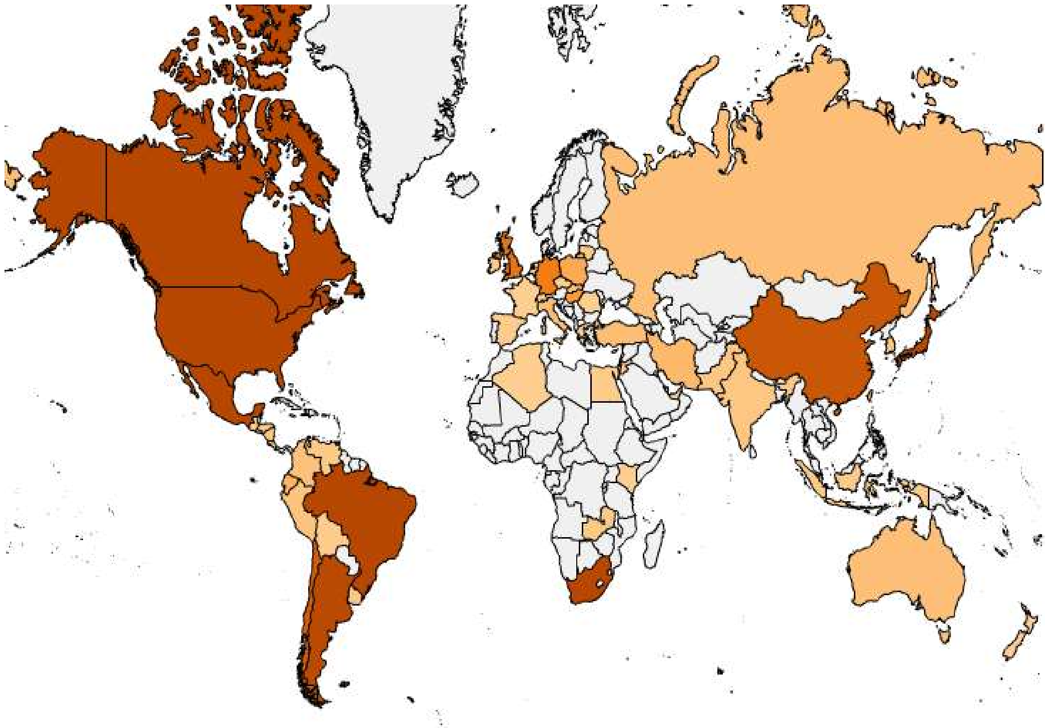
The best formulated diet can fail



Is the CNCPS a US-only model?

- CNCPS equations based on:
  - Many breeds of cattle (not only Holstein)
  - Req. equations use beef and sheep data
  - Passage rate system from NORFOR
  - Modeling principles by German, Dutch, Danish, UK, French and Swiss researchers
- CNCPS evaluated in:
  - Irish pasture cows (in progress)
  - Italian water buffalo
  - Nelore cattle (Brazil)
  - Mexican dairy farms
  - Vietnamese small-holders
  - Indian browsing
  - Many other systems

- AMTS users in 40+ countries



Thank you

- **Additional Resources:**
  - **Website: www.agmodelsystems.com (FREE 30-day trial)**
  - **Blog: www.agmodelsystems.com/blog**
  - **Educational webinars: www.agmodelsystems.com/webinars**