Holsteins Behaving Like Jerseys and Thoughts on the Capacity of Dairy Cattle to Make Milk Components

Mike Van Amburgh, Alexandra Benoit, Andrew LaPierre and Dave Barbano

Depts. of Animal Science and Food Science

mev1@cornell.edu

CORNELL UNIVERSITY
FOUNDED A.D. 1865

Primary factors affecting milk components

- Genetics
- Nutrition
- Environment and management

Input from Paul Van Raden at USDA and Chad Dechow, Penn State

Genetics

- Genetic selection is greatly accelerated with the advent of genomic selection

- In addition, reproductive technologies have reduced the lag time when genetic materials can be secured from animals greatly reducing the generation interval and speeding up rate of change

- Selection pressure on milk fat is several times greater than for milk protein, primarily because of marker assisted selection and the identification of a specific gene DGAT-1 which is strongly associated with milk fat synthesis

- Milk protein is more complex and tightly tied to lactose synthesis and energy sensing by the cow (liver and mammary gland) so more difficult to move

What are the limits? Two world record holders as examples

Selz-Pralle Aftershock 3918

PTA Milk = 228 kg
EBV Milk = 456 kg

35,467 kg + 34,601 kg=**70,068 kg**
Lower bound = **46,003 kg**

Ever-Green-View My Gold - ET

PTA Milk = 216 kg
EBV Milk = 431 kg

35,154 kg + 34,627 kg = **69,781 kg**
Lower bound = **46,170 kg**

Chad Dechow, 2019

Perspective

- Based on evaluations by J. Cole and C. Dechow, the genetic capacity for milk yield for Holsteins is approximately 75,000 lb
  - There are cows on commercial farms in Central NY in high performing herds that are peaking in milk yield between

    196 to 214 lb/d (>44,000 lb/lactation)

- My perspective is that many cows in a herd have this capacity.

- Leads to the question, what are we doing, and when, that either detracts from or fails to “turn on” that ability and when is that communicated to the animal?

General observations

- Nothing is new for a cow producing 44,000 lb

- Everything that we know is more relevant for this cow

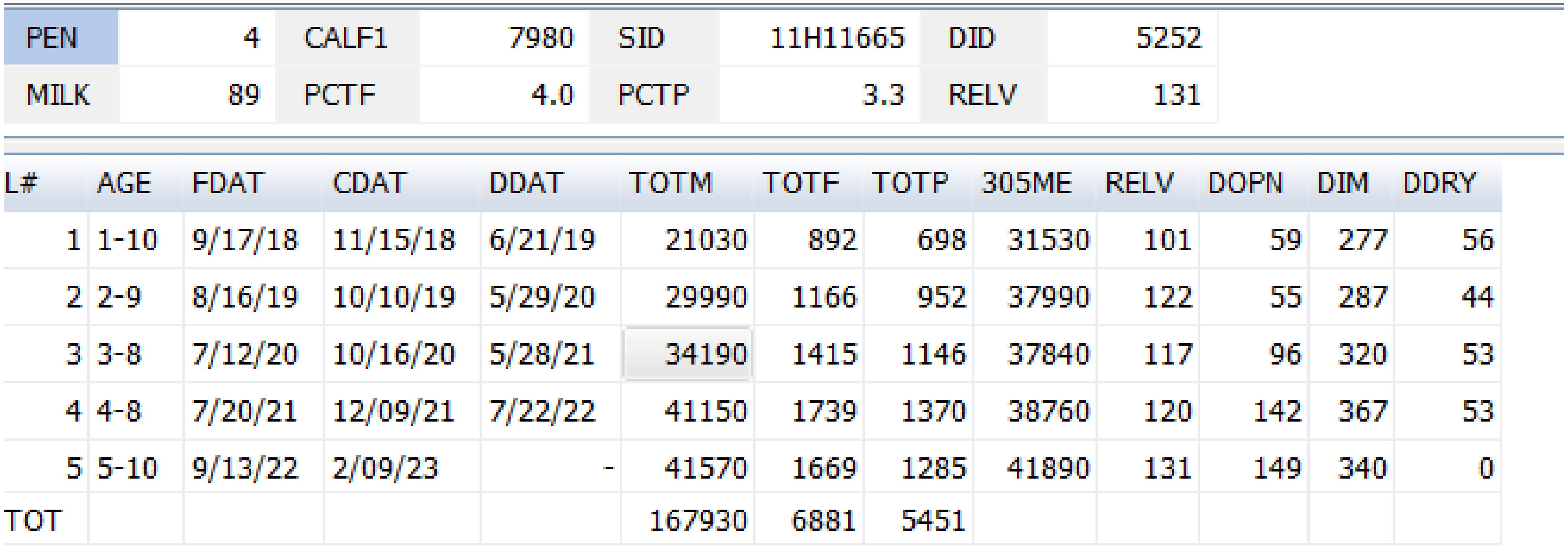
  - Think of a Fiat 500 (76 hp) vs a Ferrari SF90 Stradale (986 hp) (happy at 60 km/h vs 0 to 100 km/h in 2.5 sec – capable of 340 km/h)

- Meeting all requirements is important for cows to achieve these outcomes

- Formulating for metabolizable protein, digestible amino acids, fatty acids and carbohydrates – focus on milk components not just volume

Cow 6028 4th lactation record

- 41,150 lb milk, 1,739 lb fat, 1,370 lb protein in 367 days of lactation
- She averaged 103 lb/d for the lactation

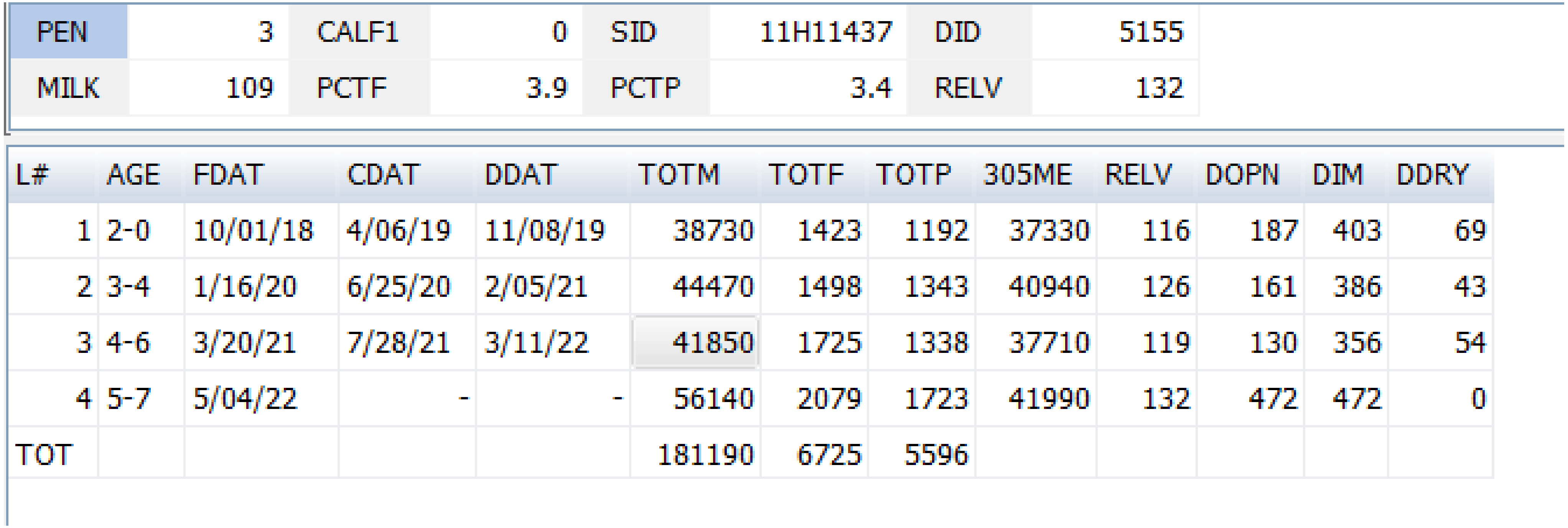


PEN	4	CALF1	7980	SID	11H11665	DID	5252
MILK	89	PCTF	4.0	PCTP	3.3	RELV	131

L#	AGE	FDAT	CDAT	DDAT	TOTM	TOTF	TOTP	305ME	RELV	DOPN	DIM	DDRY
1	1-10	9/17/18	11/15/18	6/21/19	21030	892	698	31530	101	59	277	56
2	2-9	8/16/19	10/10/19	5/29/20	29990	1166	952	37990	122	55	287	44
3	3-8	7/12/20	10/16/20	5/28/21	34190	1415	1146	37840	117	96	320	53
4	4-8	7/20/21	12/09/21	7/22/22	41150	1739	1370	38760	120	142	367	53
5	5-10	9/13/22	2/09/23	-	41570	1669	1285	41890	131	149	340	0
TOT					167930	6881	5451					

Cow 5973 3rd lactation record

- 41,849 lb milk, 1,724 lb fat, 1,338 lb protein in 356 days of lactation
- Averaged 117.4 lb milk per day

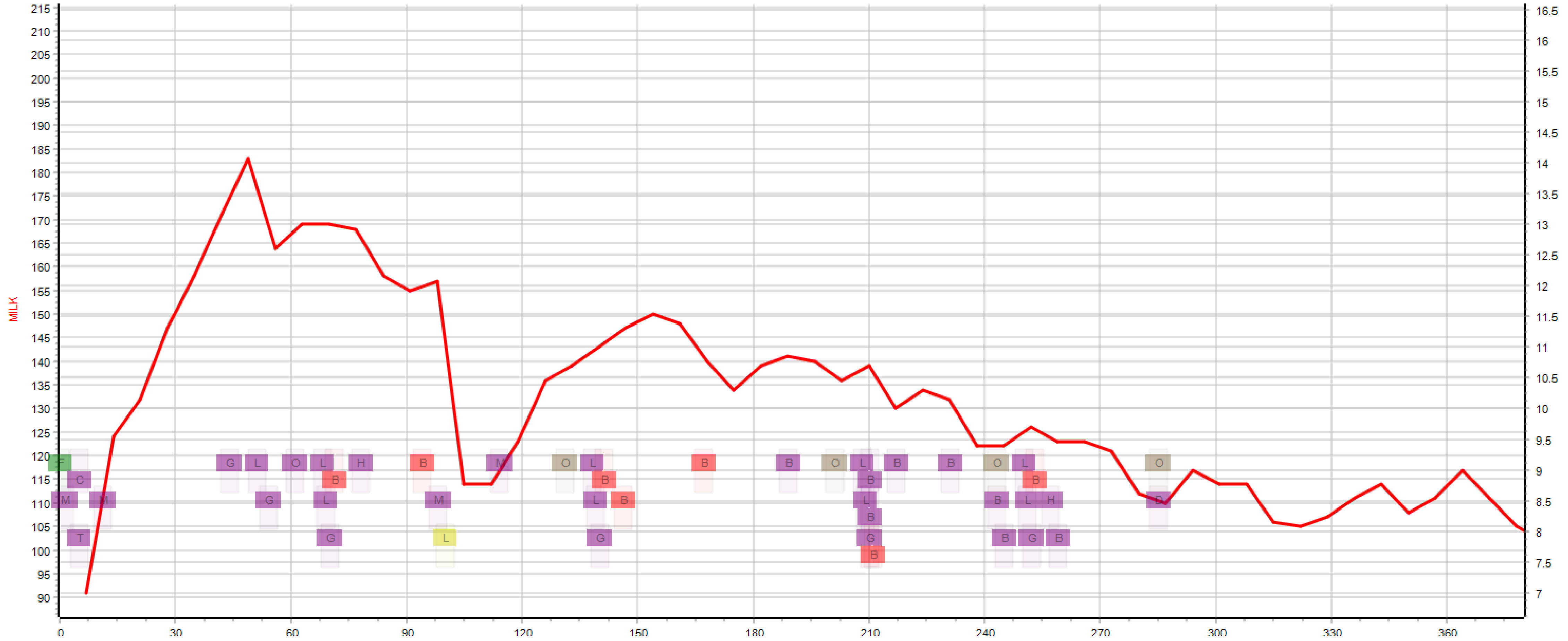


PEN	3	CALF1	0	SID	11H11437	DID	5155
MILK	109	PCTF	3.9	PCTP	3.4	RELV	132

L#	AGE	FDAT	CDAT	DDAT	TOTM	TOTF	TOTP	305ME	RELV	DOPN	DIM	DDRY
1	2-0	10/01/18	4/06/19	11/08/19	38730	1423	1192	37330	116	187	403	69
2	3-4	1/16/20	6/25/20	2/05/21	44470	1498	1343	40940	126	161	386	43
3	4-6	3/20/21	7/28/21	3/11/22	41850	1725	1338	37710	119	130	356	54
4	5-7	5/04/22	-	-	56140	2079	1723	41990	132	472	472	0
TOT					181190	6725	5596					

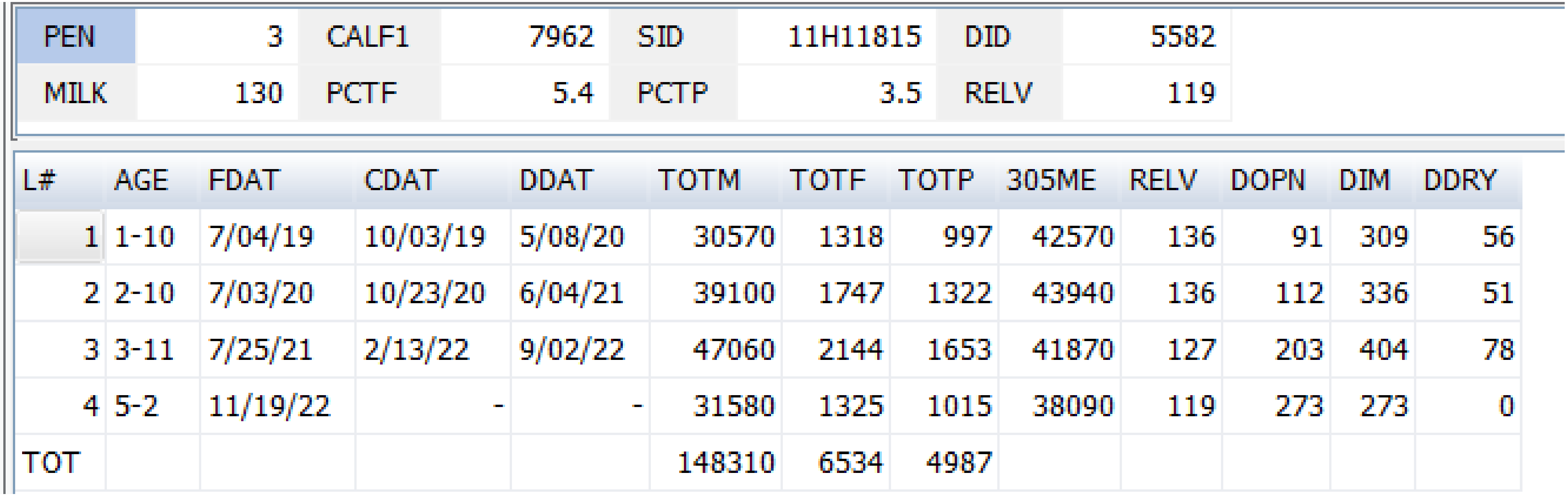
Cow 5973

- Peaked at 183 lb milk per day



Cow 6389 3rd lactation

- 47,060 lb milk, 2,144 lb fat, 1,653 lb protein
- Averaged 117 lb/d 404-day lactation

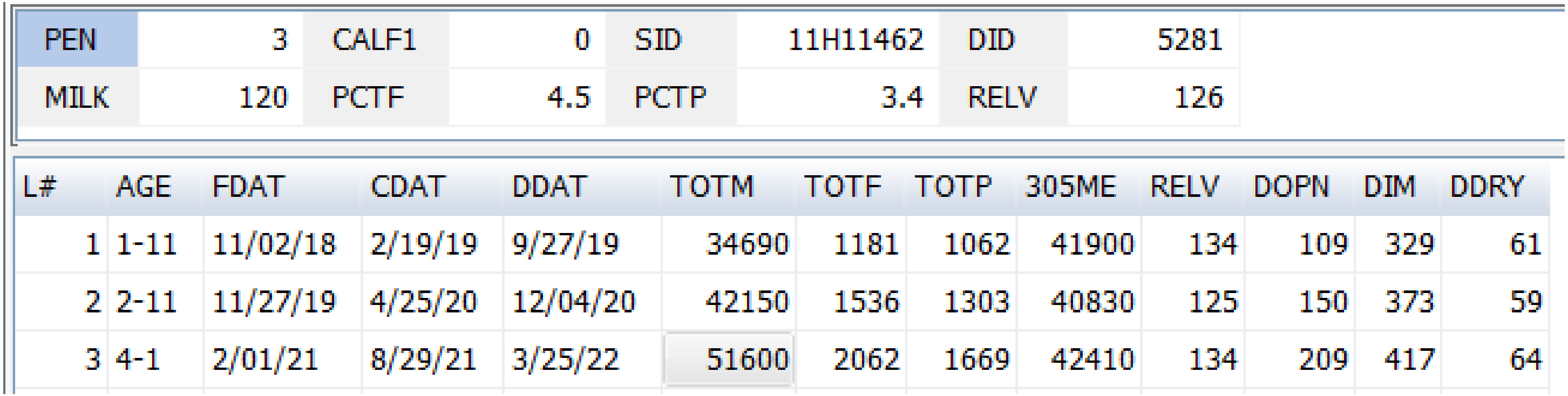


PEN	3	CALF1	7962	SID	11H11815	DID	5582
MILK	130	PCTF	5.4	PCTP	3.5	RELV	119

L#	AGE	FDAT	CDAT	DDAT	TOTM	TOTF	TOTP	305ME	RELV	DOPN	DIM	DDRY
1	1-10	7/04/19	10/03/19	5/08/20	30570	1318	997	42570	136	91	309	56
2	2-10	7/03/20	10/23/20	6/04/21	39100	1747	1322	43940	136	112	336	51
3	3-11	7/25/21	2/13/22	9/02/22	47060	2144	1653	41870	127	203	404	78
4	5-2	11/19/22	-	-	31580	1325	1015	38090	119	273	273	0
TOT					148310	6534	4987					

Cow 4291
3rd lactation

- 51,600 lb milk, 2,063 lb fat, 1,668 lb protein
- 124 lb milk per day – 4% Fat, 3.23% protein
- 417 day lactation



PEN	3	CALF1	0	SID	11H11462	DID	5281
MILK	120	PCTF	4.5	PCTP	3.4	RELV	126

L#	AGE	FDAT	CDAT	DDAT	TOTM	TOTF	TOTP	305ME	RELV	DOPN	DIM	DDRY
1	1-11	11/02/18	2/19/19	9/27/19	34690	1181	1062	41900	134	109	329	61
2	2-11	11/27/19	4/25/20	12/04/20	42150	1536	1303	40830	125	150	373	59
3	4-1	2/01/21	8/29/21	3/25/22	51600	2062	1669	42410	134	209	417	64

NMPF-3-O

Average Milk Composition of Holstein and Jersey Cattle – published 1998

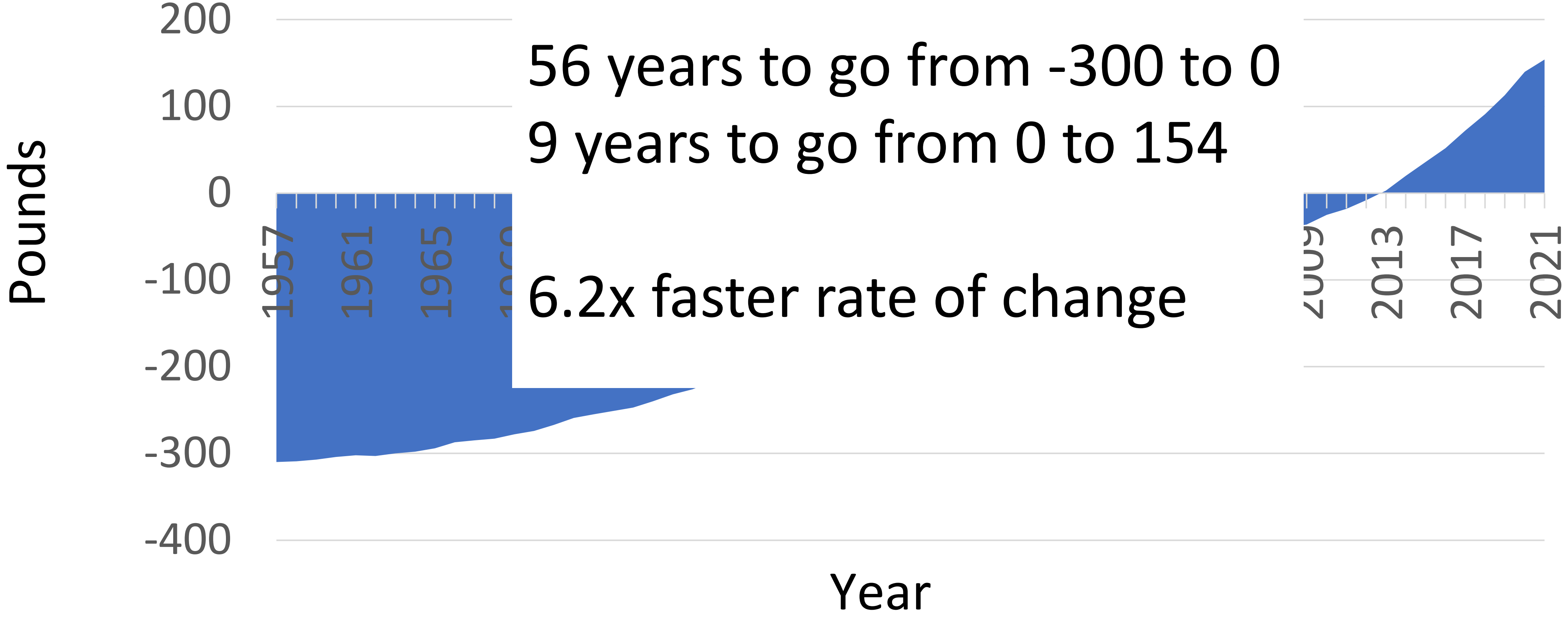
Milk component	Holstein	Jersey
Fat, %	3.7	5.1
Protein, %	3.1	3.7
Lactose, %	4.9	5.0

- To increase milk fat percent and yield, the best way is to feed diets to increase those fatty acids called "**de novo**" and "**mixed**" and they represent fatty acids from 4 carbons to 16 carbons

- Through some research studies and our nutritional modeling work, we have been able to increase milk fat by almost **10%** (from 4.2% to 4.7%) and milk protein by **8%** (from 3.1% to 3.35%) while maintaining milk yield

Dr. Stallings, Virginia Tech
https://www.thecattlesite.com/articles/685/nutrition-changes-milk-composition

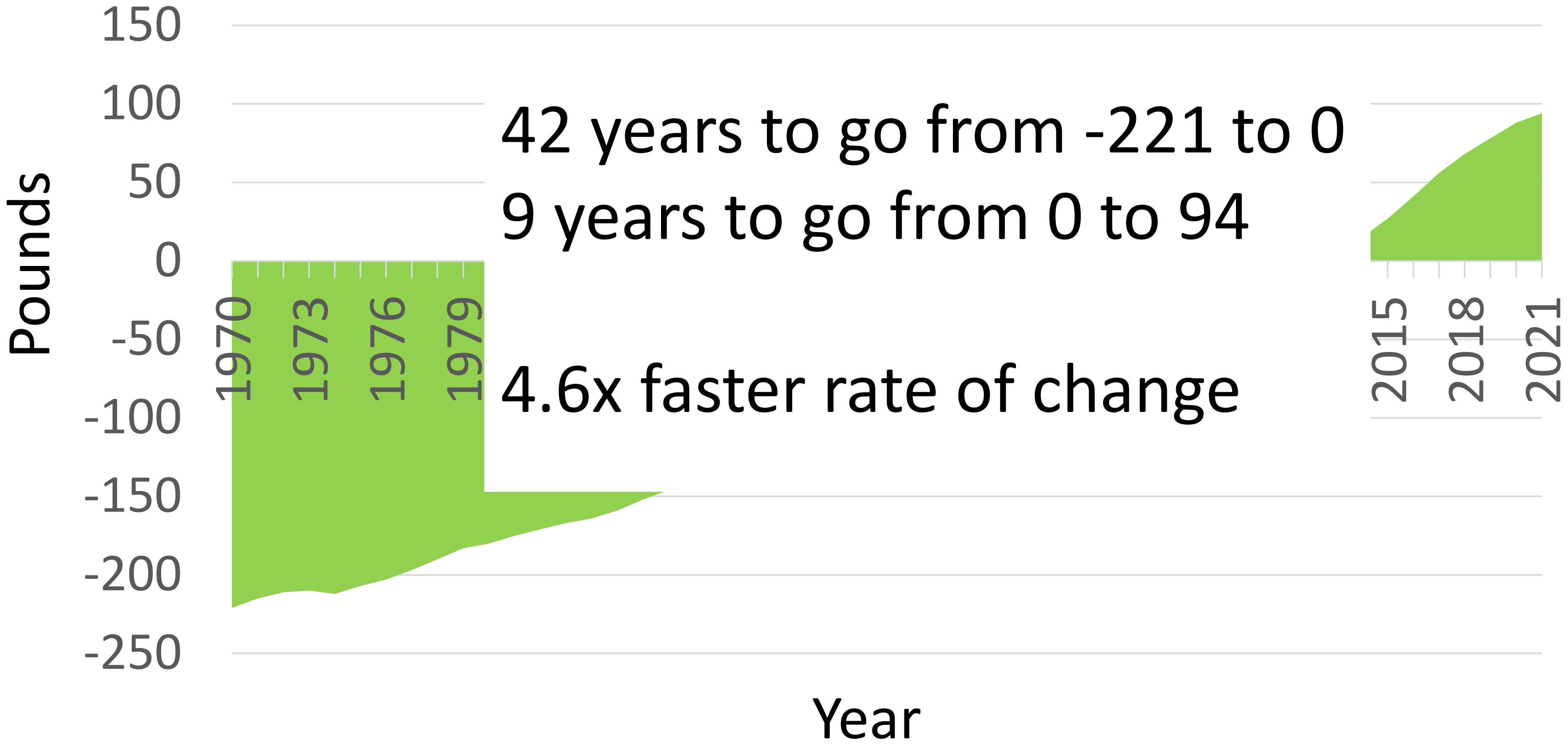
Sire Breeding Value for Fat 1957-2021



56 years to go from -300 to 0
9 years to go from 0 to 154

6.2x faster rate of change

Sire Protein Breeding Values over 51 years



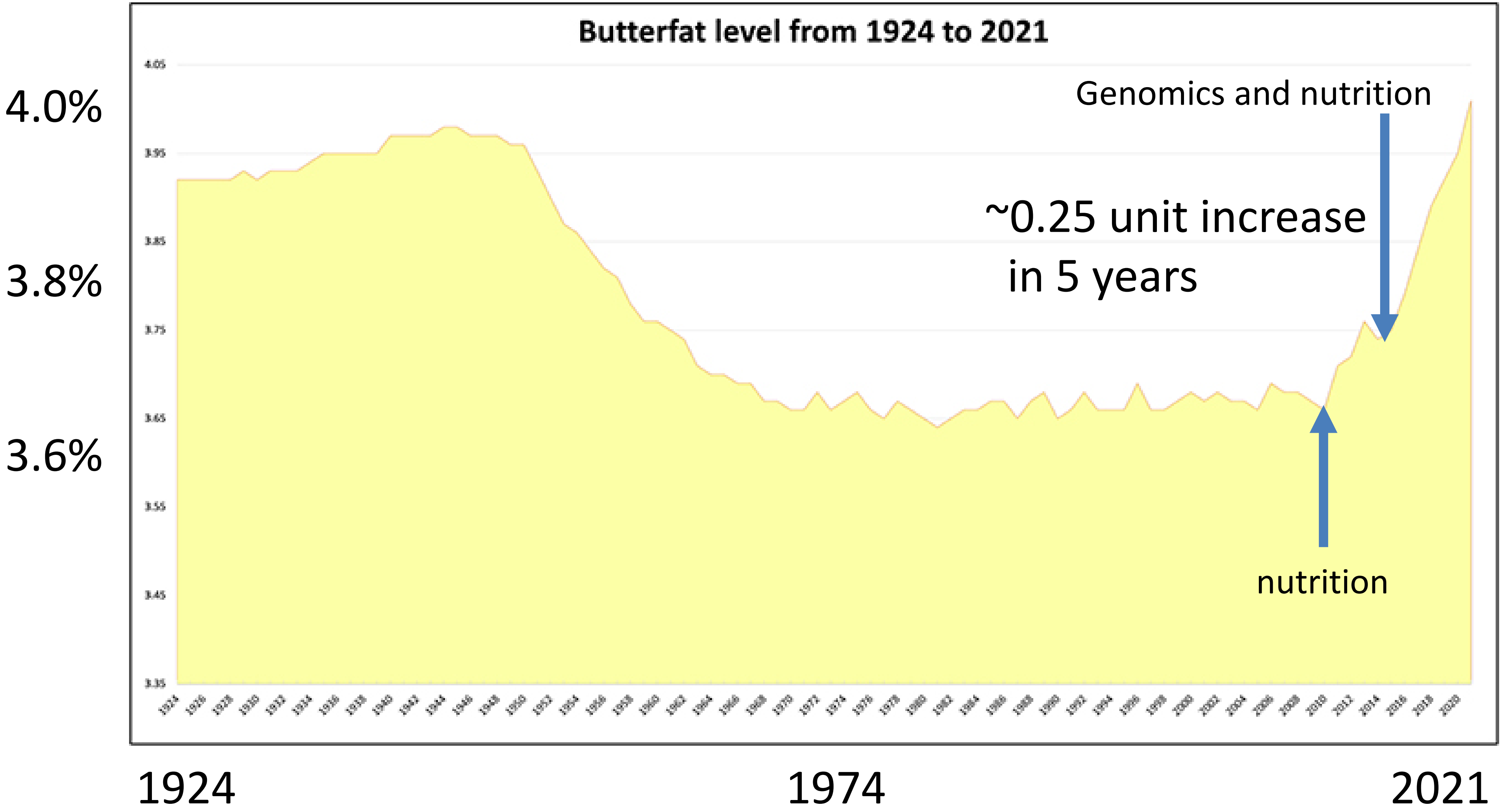
42 years to go from -221 to 0

9 years to go from 0 to 94

4.6x faster rate of change

Dechow, 2023; https://webconnect.uscdcb.com/#/summary-stats/genetic-trend

U.S. butterfat percentage has increased since 2015



Genomics and nutrition

~0.25 unit increase
in 5 years

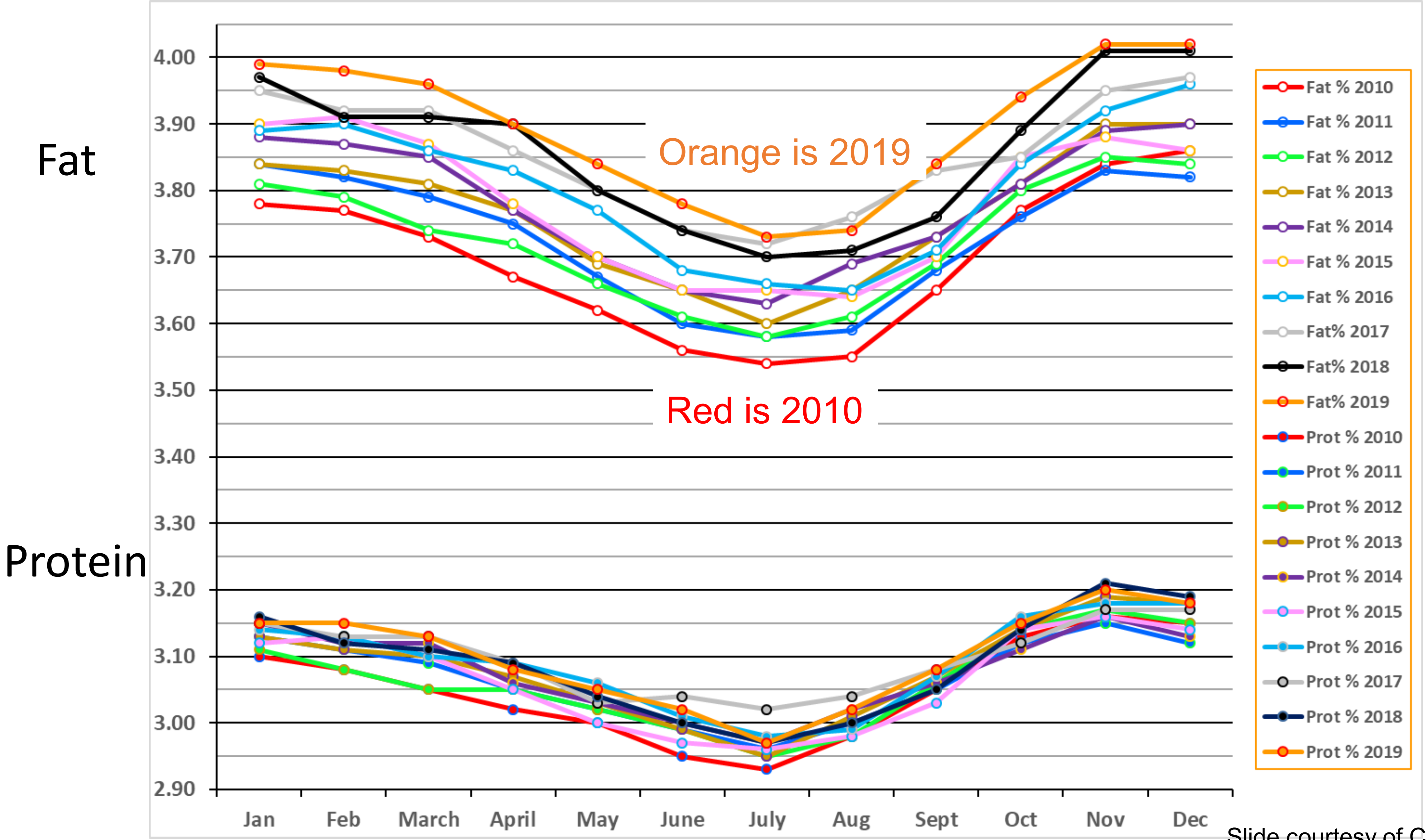
nutrition

Data: USDA

Graphic:
Hoard’s
Dairyman

Dr. Paul VanRaden USDA

Northeast U.S. FMMO 1 Milk Fat and Protein % -- 2010 to 2019

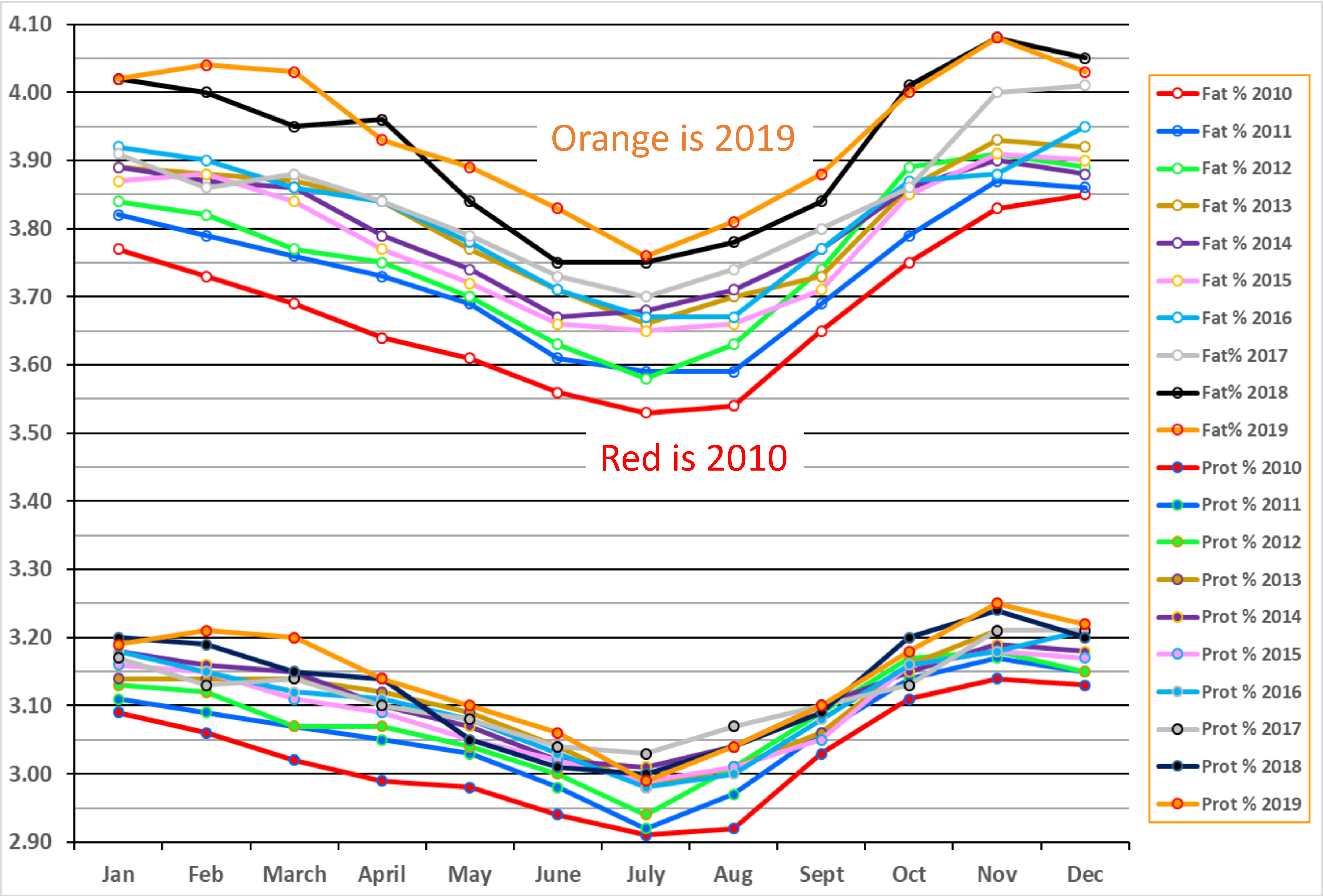


Slide courtesy of Clay Zimmerman

Upper Midwest U.S. FMMO 30 Milk Fat and Protein % - 2010 to 2019

Fat

Protein



Source: Zimmerman, Balchem Corporation - 2020

Nutrition

- Milk Yield and Milk Protein Synthesis
- Are **energy** driven events
  - Relies on an adequate supply of amino acids from both rumen function and dietary sources
  - Driven by propionate production in the rumen
    - Propionate is converted to glucose in the liver – which in turn stimulates insulin secretion
  - Insulin secretion stimulates protein synthesis in the mammary gland
  - Energy intake and amino acids stimulate insulin like growth factor – I (IGF-I) secretion from the liver
  - Protein supply per se is not an activator of milk protein output but can modulate some of the signaling – IGF-I, mTOR, elongation factors (methionine, leucine and others)

Nutrition: Milk fat

- Milk fat is a combination of de novo fatty acids (C4 to C14), mixed fatty acids (C16+C16:1) and preformed fatty acids (C18 to C22)
- Milk fat is synthesized by the mammary gland from acetate and butyrate for de novo fatty acid synthesis (C4 to C14 carbon length FA)
- De novo milk fat synthesis is dependent on acetate availability, amino acid availability and energy from glucose for ATP and reducing equivalents – we are learning how to best modify nutrient supply to enhance de novo fatty acids
- The gland can elongate C14 to C16 to make mixed and needs to for fluidity (melting point) so the fat melts at body temperature and the same requirements for de novo are needed for mixed fatty acids
- Mixed and preformed can come from the diet, or from mobilized tissue (adipose tissue mobilized when cows are in early lactation).
- Milk fat can be depressed or decreased by feeding too many unsaturated fatty acids, which then are modified by bacteria and create reductions in milk fat production which lowers milk fat content. The milk fat levels from 1970-2012 are partially due to diet induced milk fat depression, along with genetics.

Fat supplementation on milk fat yield

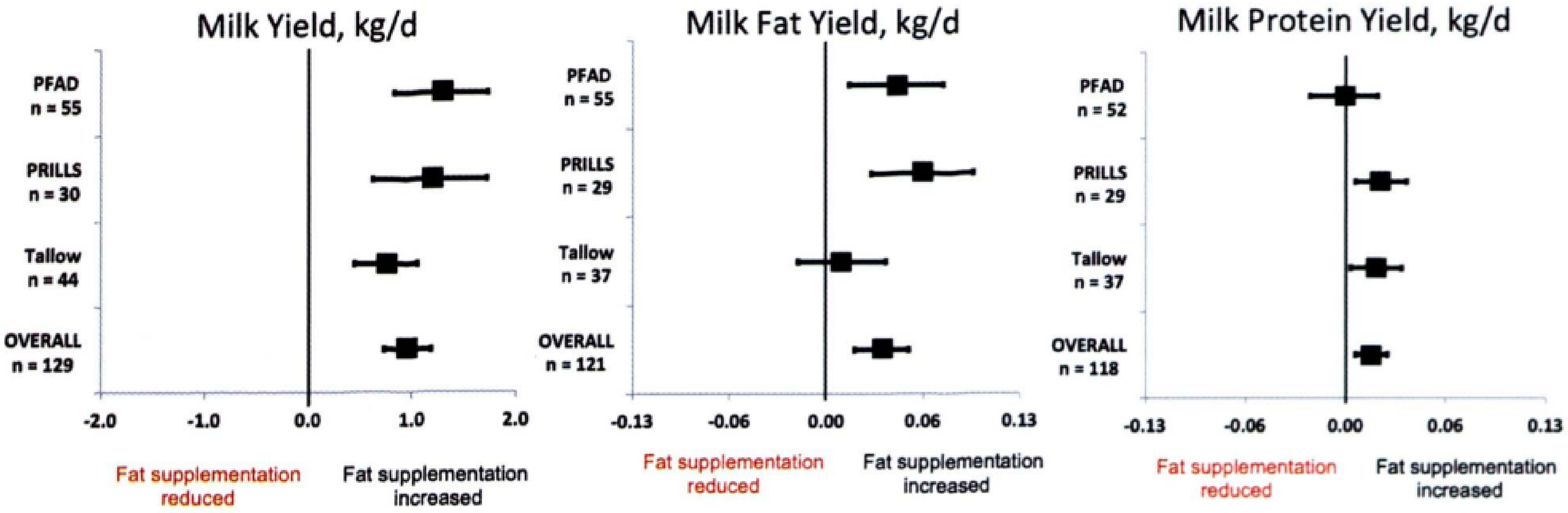


Figure 1. Effect of commercially available FA supplements on yield of milk, milk fat, and milk protein (Boerman JP, Lock AL. Feed intake and production responses of lactating dairy cows when commercially available fat supplements are included in diets: a meta-analysis. *J Dairy Sci* 2014; 97 (E-Suppl. 1):319). All data reported in peer-reviewed journals in which FA supplements were included at ≤ 3% diet DM compared to control with no added FA supplement. All studies had to have measurements of variance reported. **PFAD** – calcium salts of palm FA distillate (~ 50% 16:0, ~ 50% unsaturated 18-carbon FA); **PRILLS** – saturated FA prills (> 80% saturated FA [16:0 and/or 18:0]); **Tallow** – animal fat labeled as tallow (~ 50% 16:0 and 18:0, ~ 45% 18:1). Data analyzed using Comprehensive Meta-Analysis (CMA) version 2.0 (Biostat, Englewood, NJ), calculating difference between FA supplemented and control diets using a random effects model.

Lock and de Souza, Proc. Cornell Nutr. Conf. 2015

Effects of insulin on milk protein

- Hyperinsulinemic-Euglycemic clamps (lots of glucose and then insulin to match to keep them at normal physiological levels of glucose)

  - Insulin and glucose alone
    - **15% increase in milk protein yield** (Mackle et al., 1999)
  - Insulin and glucose w/ abomasal infusion of casein
    - **28% increase** in milk protein yield (Griinari et al., 1997)
  - Insulin and glucose w/ abomasal infusion of BCAA & casein
    - **25% increase** in milk protein yield (Mackle et al., 1999)

Modification of milk composition due to diet formulation

With the increase in genetic capability for milk component dietary requirements for nutrients are slowly increasing

Nutritionally, we are learning how to better meet the nutrient requirements of lactating dairy cattle to allow them to produce milk fat and protein consistent with their genetic capability

When we refine the diets to better meet the requirements for amino acids, fatty acids and various carbohydrates, we observe increases in milk fat and protein yield – in some cases allowing Holstein cattle to produce components consistent with Jersey cattle

Amino Acids and De Novo FA Synthesis

- Lys increased enzymes related to de novo FA synthesis (ACS, ACC, FAS) through upregulation of FABP and SREBP1 (Li et al., 2019)
    - Further increased when supplemented with palmitic acid and oleic acid

- Additionally, Met and Leu increase expression of SREBP1– important regulator of enzymes for milk FA synthesis (Li et al., 2019).

- Arg increased de novo and mixed FA synthesis and expression of ACC, SCD, DGAT1 (Ding et al., 2022)

Fatty Acid Synthetase (FAS)

- FAS synthesizes de novo FA by elongating FA carbon chain

- Active sites with AA essential for function and transfer of intermediates during elongation of de novo FA
  - His, Lys, Ser, Cys (Smith et al., 2003; Wettstein-Knowles et al., 2005)

- FAS expression decreased in His- and Lys-deficient human liver cell medium (Dudek and Semenkovich, 1995)
  - This was reversible when His and Lys were reintroduced

- Expression of FAS increased by adding both NEAA and EAA compared each treatment individually (Fukuda and Iritani, 1986)
  - FAS complex likely has requirement for both types of AA

Dose titration of Rumensin – nothing to do with amino acids, except the diets were formulated using the latest information on diet formulation related to AA levels from CNCPS v7 and everything we thought we knew about making a “modern diet”

Prior to this diet, the cows were producing 93 lb, 4.1% fat and 3.1% true protein at about 120 DIM

Benoit et al., ADSA abstr. 2022

Dietary ingredient	**Dry matter inclusion, lb**
Corn silage	19.5
Haylage - MML	10.8
Corn ground fine	10.0
SBM	3.8
SoyPass	3.2
Citrus Pulp	2.5
Wheat midds	2.5
Dextrose	0.88
Blood meal	0.55
Bergafat 100	0.33
Energy Booster 100	0.33
Sodium bicarb	0.22
Rumen protected methionine	0.066
Rumen protected lysine	0.066
Levucell SC	0.022
Vitamins and Minerals	0.904
Total	55.65

Formulated dietary feed chemistry

DM, %	45.1
CP, %	15.75
Sol CP, %CP	31.5
aNDFom, %	31.6
WSC/Sugar, %	4.92
Starch, %	26.33
EE, %	4.4
ME, mcal/lb	1.204
ME, Mcal @25.3 kg DMI	67.1
Forage, % DMI	54.3
Forage, %BW	0.93
Methionine, g/Mcal ME	1.19
Lysine, g/Mcal ME	3.03
Methionine, g	80
Lysine, g (methionine x 2.7)	216

Diet formulation characteristics

- 54% forage diet – formulated to achieve the lowest uNDF for the highest aNDFom digestible pool for the available forages

- Dry ground corn from the farm – moderate starch

- Sugar added to enhance rumen fermentation, increase microbial flow (bacteria and protozoa) and fiber digestion - older data from Hoover indicating that 5-7% sugar in TMR diets is beneficial for component yields

- Rumen protected methionine and lysine formulated at 1.19 grams methionine/Mcal ME and lysine set at 2.7 times the methionine – these values are many grams higher than previously fed

- Utilized a blend of fatty acids, higher in Palmitic (0.432 lb), Stearic (0.144 lb) and Oleic (0.02 lb) – moderate in RUFAL – in previous research achieving 1.5:1 palmitic:oleic enhanced milk protein synthesis likely through insulin signaling

DIET/INTAKE RELATED INFORMATION – METHIONINE AND LYSINE LEVELS

Cows consumed approximately 71-72 mcals per day

Methionine @ 1.19g/Mcal = 1.19* 71.5 = **85 g**

Lysine @ 2.7 times Met = 85g * 2.7 = **229 g**

These levels are what we consider the true requirement to be based
on the last 10 years of research

Meeting the requirements should improve energetic efficiency

Dose titration of Rumensin

	Treatment					
Item	0	11g	14.5g	18g	SEM	P-Value
Days in milk	190	168	193	184	7.2	----
DMI, lb/d	59.29	59.29	59.07	61.05	0.44	0.08
Milk Yield, lb/d	82.65	86.84	85.07	85.07	0.88	< 0.05
ECM, lb/d,	101.16	103.15	103.37	102.93	0.88	0.40
ECM:Feed	1.73	1.74	1.76	1.69	0.01	< 0.05
BCS	2.9	3.1	3.0	2.9	0.2	0.70
BW, lb	1521	1519	1530	1525	6	0.55
PUN, mg/dL	9.2	9.1	9.2	8.9	0.15	0.50

Benoit et al., ADSA abstr.

Dose titration of rumen modifier

	Treatment					
Item	0	11g	14.5g	18g	SEM	P-Value
Milk						0.20
Milk						0.50
Milk						0.21
Milk protein, kg	1.29	1.34	1.31	1.32	0.01	0.09
Milk lactose, %	4.62	4.65	4.63	4.62	0.01	< 0.05
Milk lactose, kg	1.80	1.86	1.83	1.83	0.02	0.17
Milk solids, %	13.8	13.8	13.9	13.8	0.04	0.39
Milk solids, kg	5.33	5.47	5.44	5.43	0.05	0.25
MUN, mg/dL	8.92	10.20	9.65	9.56	0.12	< 0.01

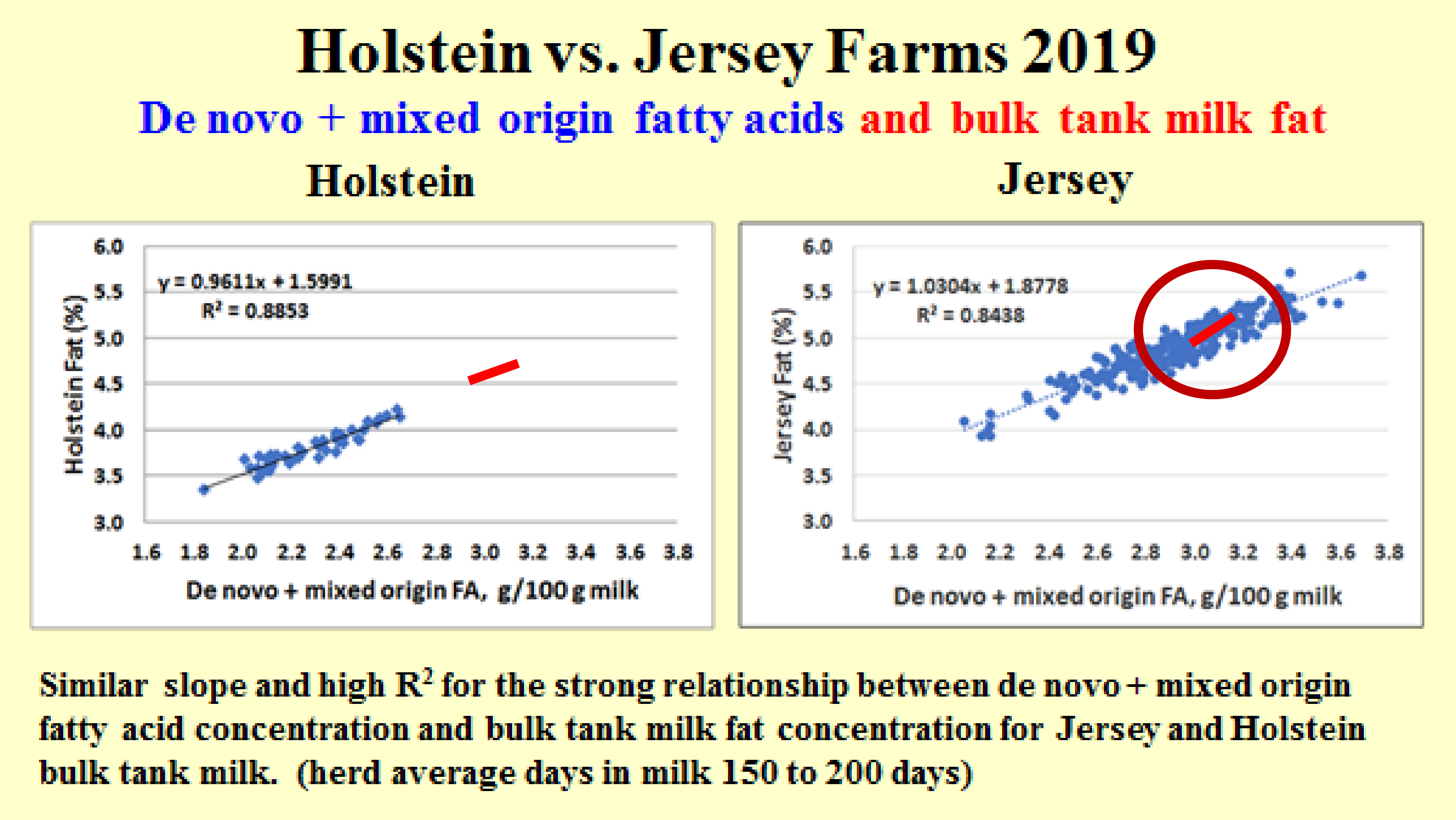
Cows were yielding 6.96 lb components at 190 DIM

Benoit et al., ADSA abstr.

Dose titration of Rumensin

	Treatment					
Item	0	11g	14.5g	18g	SEM	P-Value
De novo, g/100g	1.131	1.157	1.168	1.156	0.01	0.03
De novo, kg	0.44	0.45	0.46	0.46	0.005	0.32
Mixed, g/100g	1.856	1.881	1.918	1.897	0.02	0.02
Mixed, kg	0.73	0.74	0.75	0.75	0.009	0.39
Preformed, g/100g	1.34	1.33	1.38	1.85	0.02	0.23
Preformed, kg	0.52	0.52	0.54	0.53	0.007	0.29
Fatty acid chain length	14.6	14.5	14.5	14.5	0.01	0.83
Double bond proportion	0.23	0.23	0.23	0.23	0.002	0.42
C16:0, %	1.81	1.80	1.85	1.84	0.02	0.17
C16:0, kg	0.70	0.71	0.72	0.72	0.009	0.37
C18:0, %	0.36	0.36	0.38	0.36	0.005	0.08
C18:0, kg	0.14	0.14	0.15	0.14	0.002	0.15
C18:1, %	0.79	0.78	0.80	0.79	0.009	0.30
C18:1, kg	0.30	0.31	0.31	0.31	0.003	0.53

Milk de novo and mixed fatty acids from this study compared to Jersey milk components



Holstein vs. Jersey Farms 2019

De novo + mixed origin fatty acids and bulk tank milk fat

Holstein **Jersey**

Similar slope and high R^2 for the strong relationship between de novo + mixed origin fatty acid concentration and bulk tank milk fat concentration for Jersey and Holstein bulk tank milk. (herd average days in milk 150 to 200 days)

Barbano et al. Proc Cornell Nutr. Conf. 2019

FEED COSTS, MILK PRICE AND RETURN

Feed	$/ton AF	% DM	$/ton DM	% of diet	$/lb DM
No R Mix	540	90.5	597	20.9	0.062
11 g/ton Mix	542	90.7	598	20.9	0.062
14.5 g/ton Mix	554	90.5	612	20.9	0.064
18 g/ton Mix	555	90.4	614	20.9	0.064
Soybean meal	338	87.5	386	6.81	0.013
Corn meal	158	85.4	185	18	0.017
Haylage	60	39.5	152	19.4	0.015
Corn silage	50	29.			

Diet	$/lb DM	DMI	$/cow/d
0 g/ton	0.137	59.4	8.12
11 g/ton	0.137	59.1	8.08
14.5 g/ton	0.138	58.9	8.15
18 g/ton	0.138	61	8.45
Cov	0.137	56.8	7.78

	0 g/ton	11 g/ton	14.5 g/ton	18 g/ton
Milk, lb	86.2	88	87.3	87.2
Fat, %	4.60	4.67	4.72	4.67
Protein, %	3.35	3.38	3.37	3.39
Other solids, %	5.7	5.7	5.7	5.7
Milk $/cwt	24.50	24.75	24.78	24.80
Milk income $/cow	21.12	21.78	21.64	21.63
IOFC $/cow	13.00	13.70	13.49	13.18

Pay price	$/lb
Fat	1.58
Protein	4.82
OS	0.19

Observations from the study

- Milk components can be greatly enhanced even in mid-lactation if requirements for various nutrients are met
- Data demonstrate that meeting the amino acid requirements enhance energetic efficiency more than nitrogen efficiency
- Holstein cattle can produce milk fat like Jersey cattle if fed an appropriate diet – meeting the requirements
- These cows are more environmentally efficient because they are producing more components per unit of intake reducing the intensity of greenhouse gas emissions

Effect of Rumen Protected Methionine and Lysine on Energy Corrected Milk Yield (and don't forget about Histidine…)

- 144 cows assigned to a replicated pen study
- Three levels of rumen protected Methionine
- Lysine was held constant at 3.2 g metabolizable AA per Mcal ME
- Histidine was similar to the highest Methionine level

- Methionine was fed at 0, 1.05 and 1.19 g metabolizable Met per Mcal ME

- 14-day covariate, 84-day treatment; 75% multiparous, 25% primiparous cattle per pen

Danese et al. unpublished

144 cows, replicated pen, 16 cows/pen	Diet, g Metabolizable Met/Mcal ME				
Parameter	0.86	1.05	1.19	SEM	P value
Body Weight, lb	1538	1554	1545	7.3	0.30
Dry Matter Intake, lb	58.2	58.4	57.5	0.7	0.59
Milk Yield, lb	98.3	99.8	98.7	0.8	0.38
ECM, lb	107.6^{a}	110.6^{b}	111.1^{b}	1.0	0.02
ECM to DMI	1.87	1.88	1.92	0.017	0.21
Milk True Protein,% g/100g Milk	3.09^{a}	3.24^{b}	3.34^{c}	0.010	< 0.01
Milk True Protein, lb	3.04^{a}	3.22^{b}	3.29^{b}	0.011	< 0.01
Milk Fat, %	4.21^{a}	4.25^{a}	4.36^{b}	0.026	< 0.01
Milk Fat, lb	4.14	4.23	4.28	0.023	0.16
MUN, mg/dL	11.20	11.44	11.09	0.120	0.12

Lysine formulated at 3.2 g/ Mcal ME for all treatments

Danese et al. unpublished

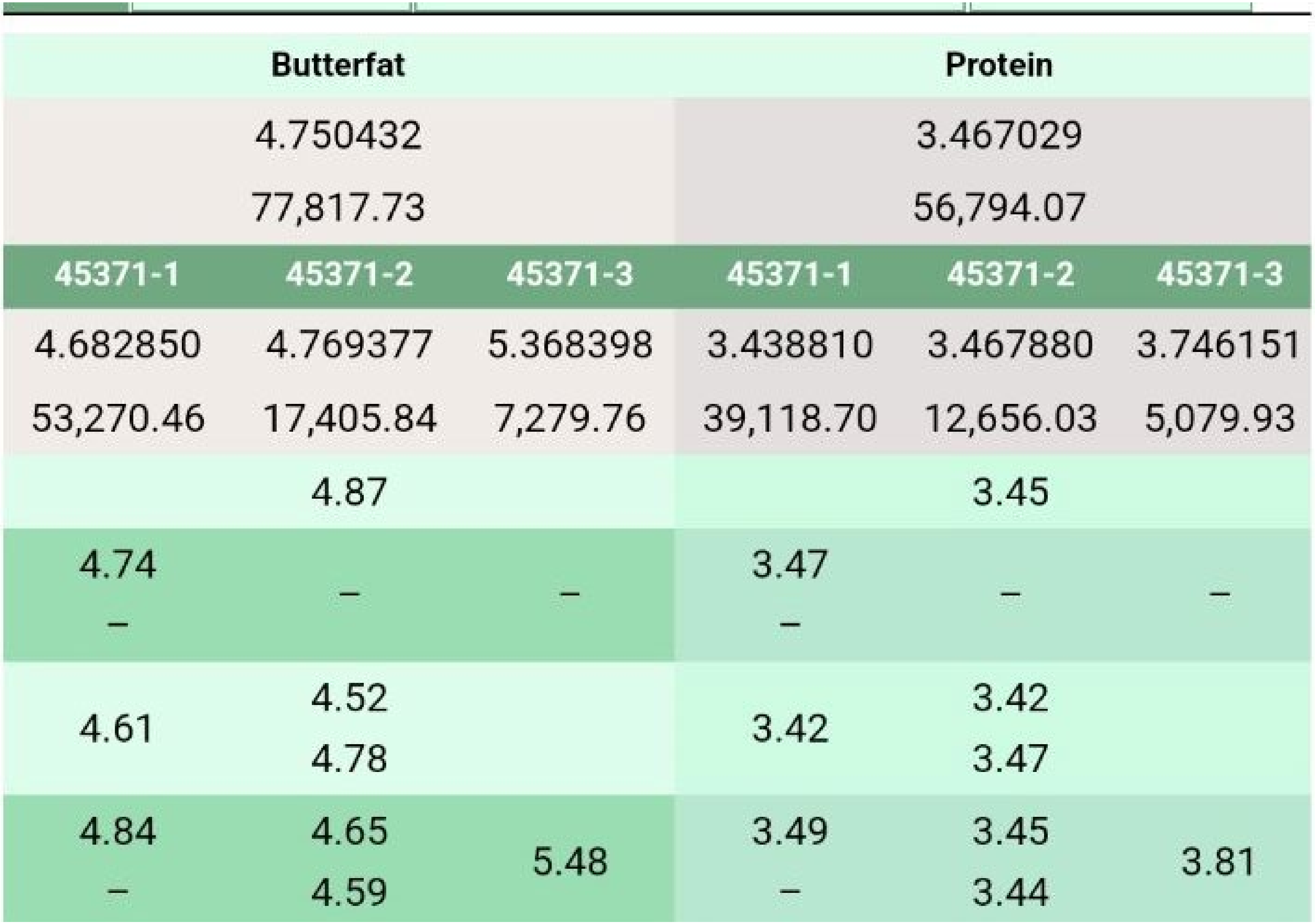
Diet, g Metabolizable Met/Mcal ME

Milk Fat, g/100g Milk	**0.86**	**1.05**	**1.19**	**SEM**	**P value**
De novo	1.14^{a}	1.17^{b}	1.20^{b}	0.010	< 0.01
Mixed	1.65^{x}	1.67^{xy}	1.70^{y}	0.015	0.07
Preformed	1.16	1.15	1.19	0.013	0.20
Milk Fat, % Milk Fat					
De novo	28.79^{a}	29.33^{b}	29.34^{b}	0.088	< 0.01
Mixed	41.83	41.61	41.56	0.148	0.40
Preformed	29.33	29.08	29.07	0.166	0.43

Danese et al. unpublished

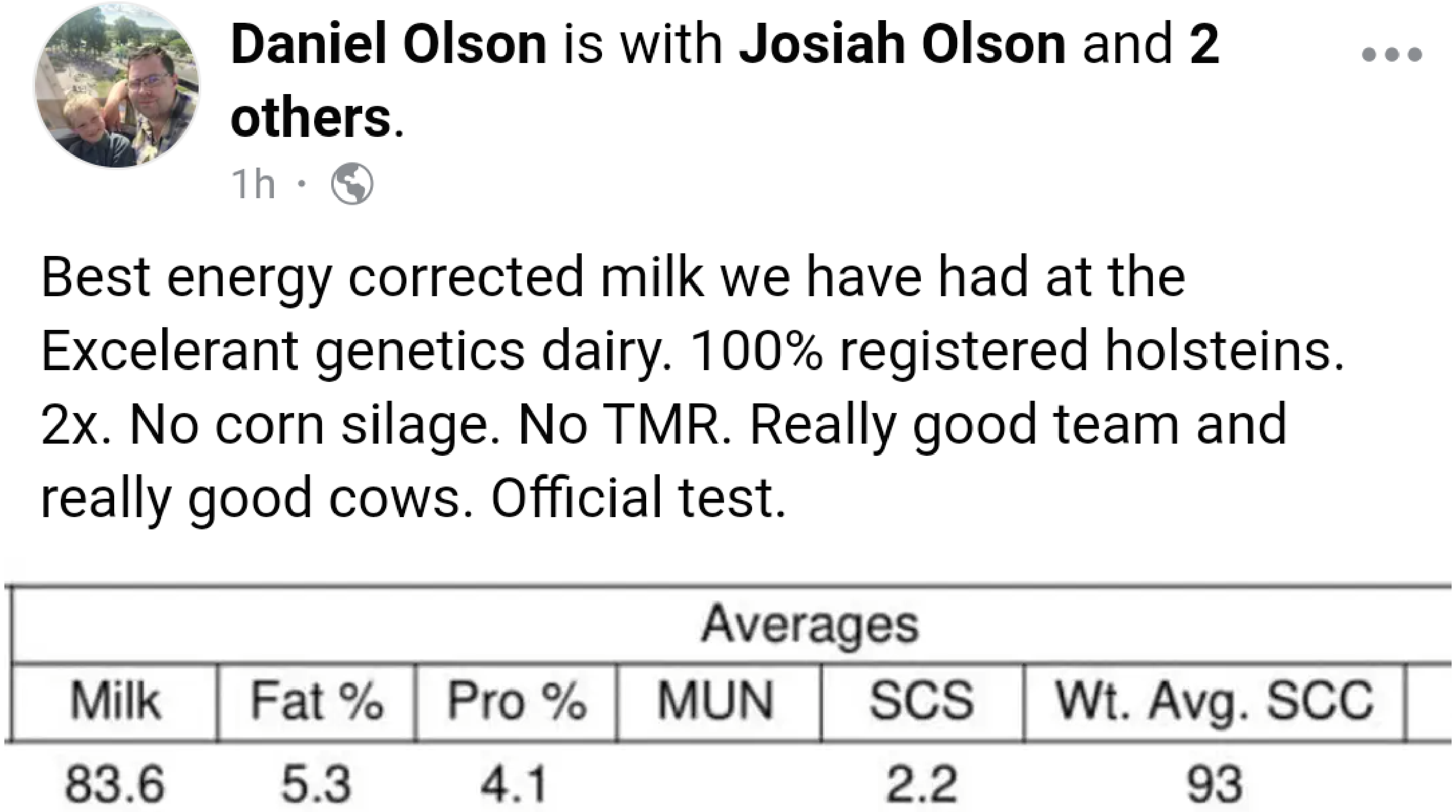
Two herds in Southern PA – both between 100 and 150 cows with diets formulated using similar dietary metrics as the previous study – these values represent the whole herd - these are Holstein cattle. Milk fat in both herds was about 4.2% before dietary interventions. Milk protein was approximately 3.1% prior to diet change.

Herd 1		**Herd 2**	
Milk yield, lb	90	Milk yield, lb	91
Milk fat, %	4.64	Milk fat, %	4.76
Milk true protein, %	3.48	Milk true protein, %	3.46
Milk fat yield, lb	4.12	Milk fat yield, lb	4.30
Milk protein yield, lb	3.12	Milk protein yield, lb	3.13



Butterfat			Protein		
4.750432			3.467029		
77,817.73			56,794.07		
45371-1	**45371-2**	**45371-3**	**45371-1**	**45371-2**	**45371-3**
4.682850	4.769377	5.368398	3.438810	3.467880	3.746151
53,270.46	17,405.84	7,279.76	39,118.70	12,656.03	5,079.93
	4.87			3.45	
4.74 –	–	–	3.47 –	–	–
4.61	4.52 4.78		3.42	3.42 3.47	
4.84 –	4.65 4.59	5.48	3.49 –	3.45 3.44	3.81

Excelerant Genetics – Dan Olsen



Daniel Olson is with **Josiah Olson** and **2 others**.

1h ·

Best energy corrected milk we have had at the Excelerant genetics dairy. 100% registered holsteins. 2x. No corn silage. No TMR. Really good team and really good cows. Official test.

Averages					
Milk	Fat %	Pro %	MUN	SCS	Wt. Avg. SCC
83.6	5.3	4.1		2.2	93

Summary

- The genetic selection for increased milk components is moving rapidly due to genomics and short generation intervals
- Nutrition is starting to recognize this and allow for the phenotypic expression of this capability
- Fat yield is moving much faster than protein and that is partly by selection and more about meeting specific requirements
- Incentives for milk protein have not been as favorable, thus attempts to enhance it are moderate
- Anything that improves cow comfort, lying time and overall welfare will allow for enhanced component yield

Thank you for your attention!

Open for questions.