Prediction of total milk fat of dairy cows: A multimodel approach

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Why we care about milk fat?

- Source of energy, fatty acids, and bioactive lipids.
- Quality of dairy products
- Milk payment system
- Majority of milk value is determined by milk protein and fat
- Human health

Milk Fat

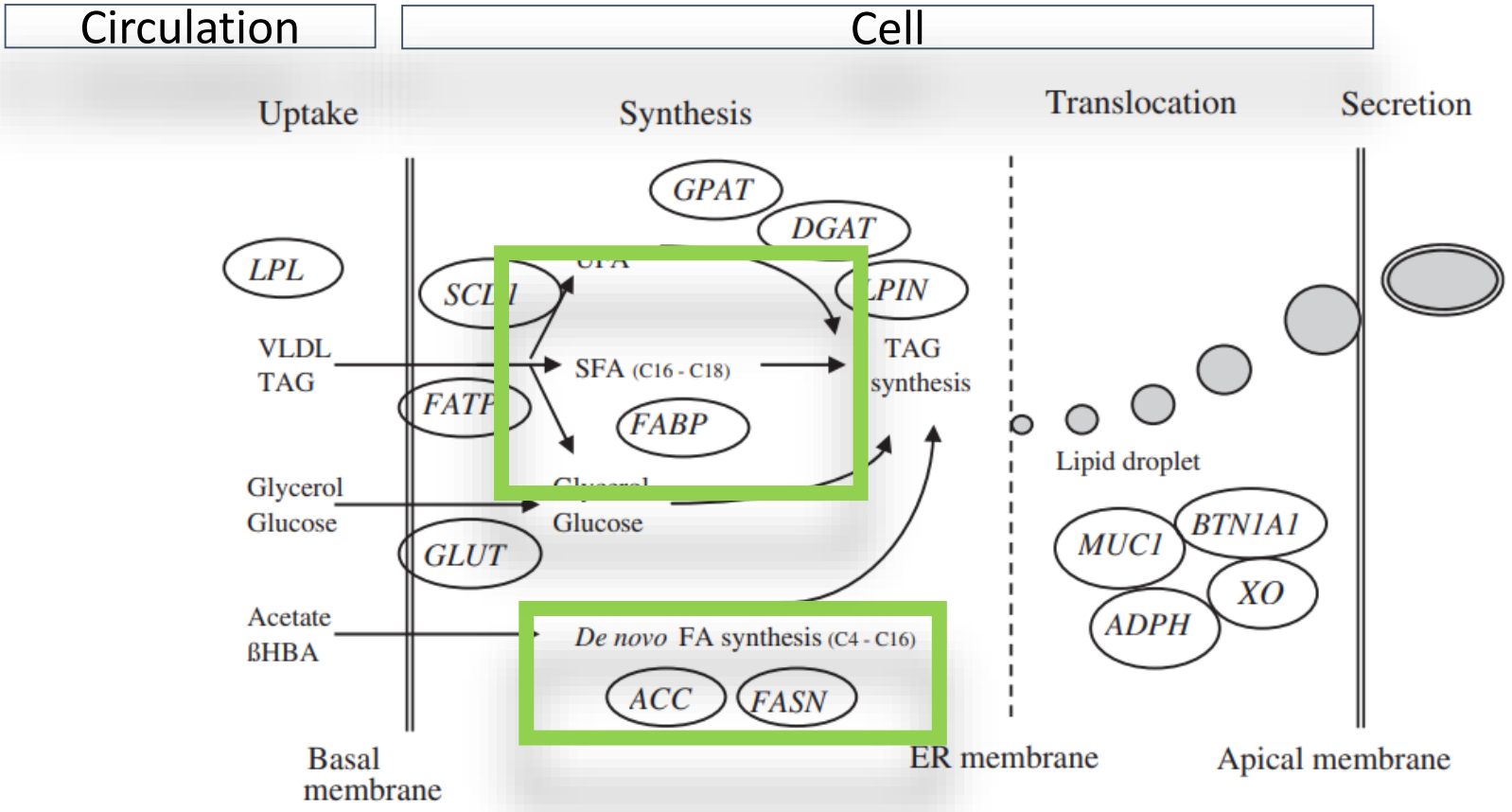


Figure 1. Milk fat synthesis

Harvatine et al. 2009, which was adapted from McGuire and Bauman (2002).

Milk Fat

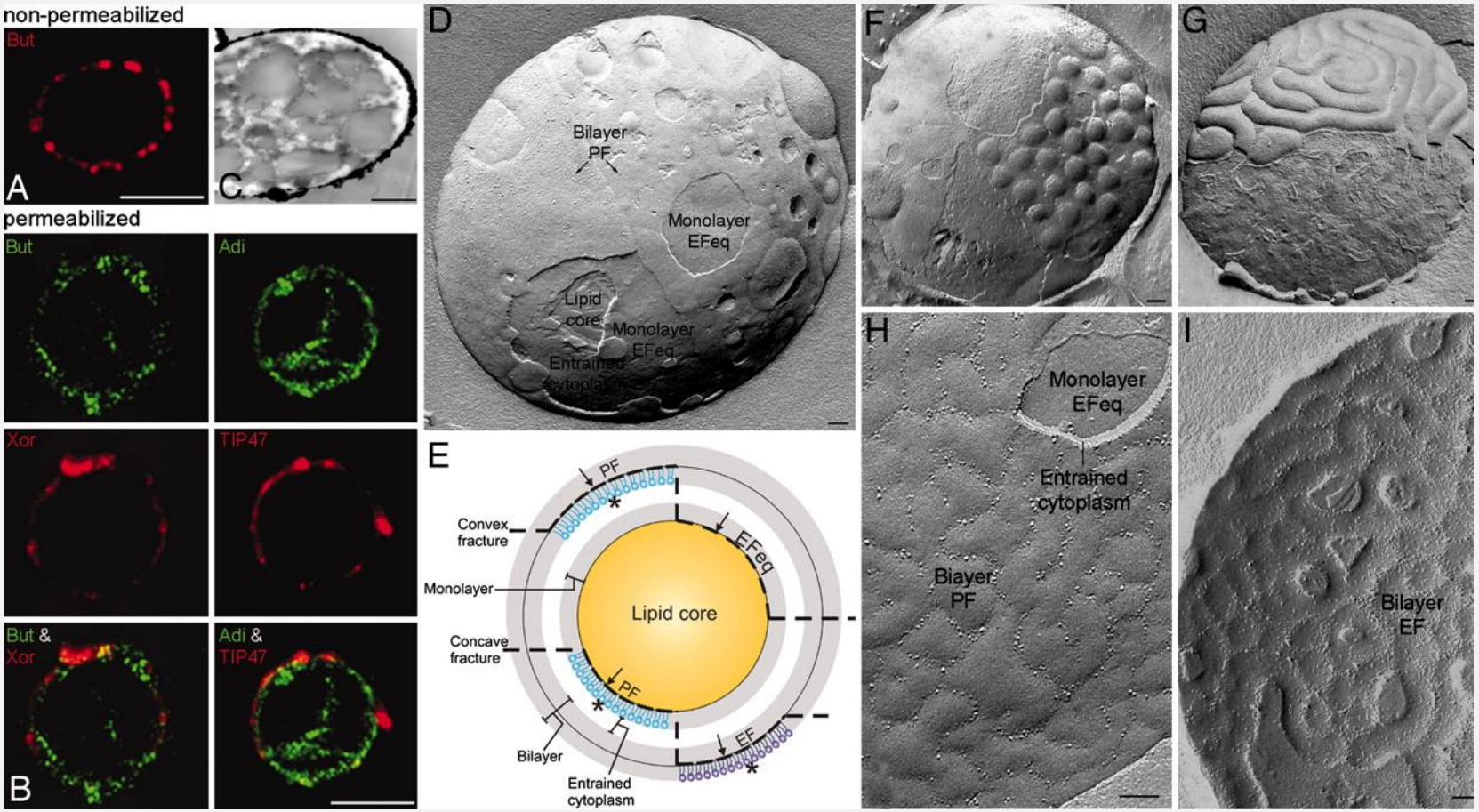
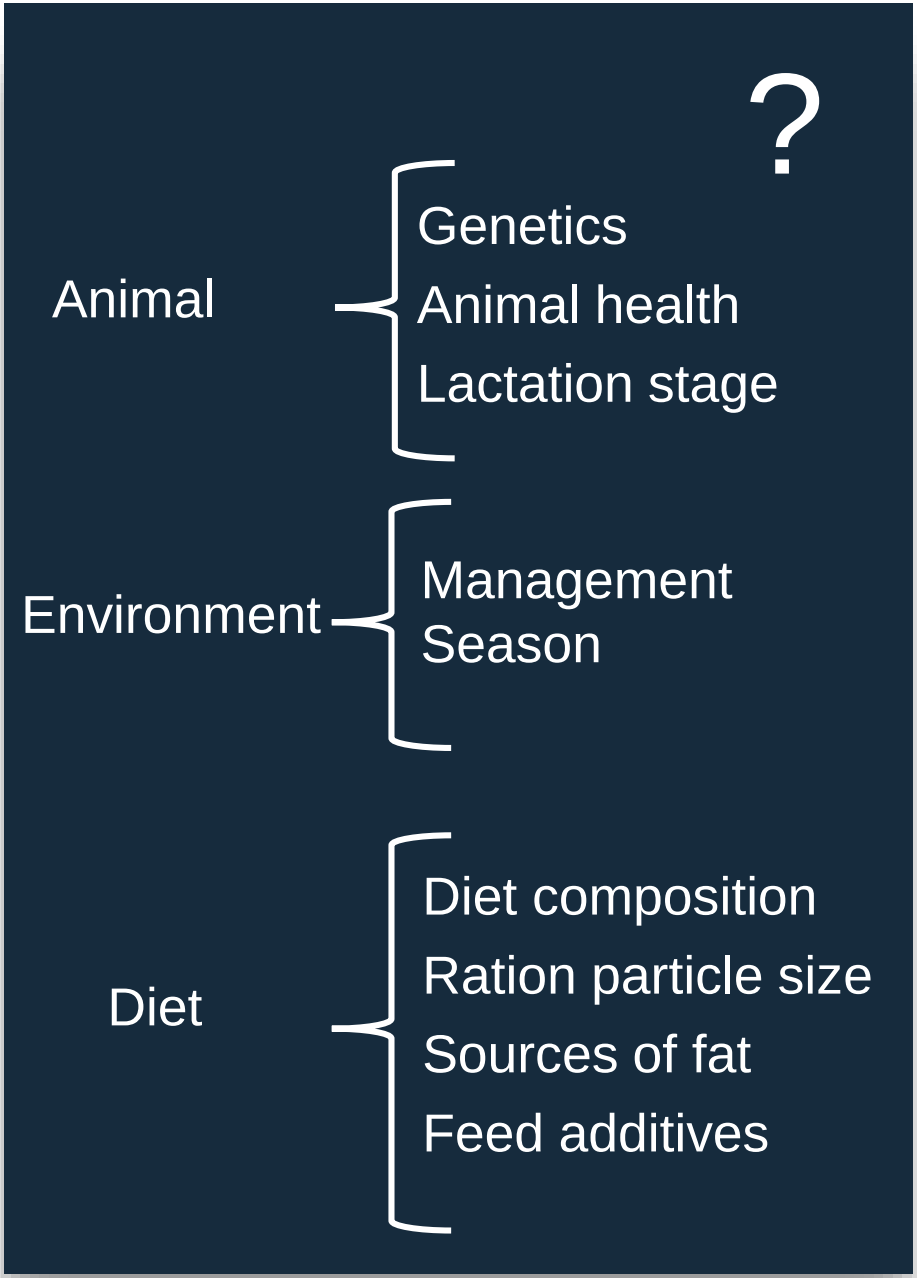


Figure 1. Proteins and structure of the milk fat globule envelope.
Robenek et al. Proceedings of the National Academy of Sciences of the United States of America 103 27 (2006): 10385-10390 .



The Problem

Predicting total milk fat has been challenging.

High unexplained variation among and within herds.

Hypothesis

Dietary intakes of specific nutrients, diet composition, and animal characteristics were the primary drivers of total milk fat yield and could be used to predict milk fat responses to diet.

Objective

To develop prediction models for estimating total milk fat yield from:

- Fat-free dry matter intake (DMI),
- Intakes of specific nutrients (individual FAs and AAs),
- Diet composition,
- Characteristics of dairy cows.

Materials and Methods

Data collected by the National Animal Nutrition Program (https://animalnutrition.org/)

Data collection

Inclusion criteria

- Descriptions of all treatments
- Milk fat and milk production
- Dry matter intake (DMI)
- Feed ingredients or diet composition
- Days in milk (DIM) and BW
- Number of animals

Database

- 158 studies (658 treatment means)
- 2,843 animals

Calculations

Dry matter intake (DMI) and diet composition

- Fat-free DMI (kg/d)
- Individual FA intakes (g/d)
- Individual AA intakes (g/d)
- NRC (2001) feed library
- CNCPS v6.5 feed library
- Individual intakes of digestible FA:

Daley et al. (2018)

- Absorbed amounts of each AA:

Fleming et al. (2019)

Materials and Methods

Table 1. Summary of the database used for estimating the milk fat model (n = 158 studies, 658 treatment means)

Variable	n	Mean	SD
Animal performance			
Milk yield, kg/d	658	32.4	6.9
Milk fat, %	658	3.56	0.42
Milk fat, g/d	658	1143	236
Milk protein, %	654	3.09	0.21
Milk lactose, %	348	4.78	0.16
BW, kg	658	604	47
Days in milk, d	658	136	56

Variable	n	Mean	SD
Diet composition, % of DM			
Crude fat	658	4.2	1.3
Fatty acids (FA)	658	3.4	1.3
Forage	658	50.8	10.3
Starch	658	27.5	7.0
Crude protein (CP)	658	16.7	2.4
Rumen degradable protein	658	11.5	1.7

Variable	n	Mean	SD
Intakes			
Dry matter intake (DMI), kg/d	658	21.4	3.4
Fat-free DMI, kg/d	658	20.6	3.2
Digestible energy (DE) intake, Mcal/d	658	66.5	11.1
Fat-free DE intake, Mcal/d	658	61.5	10.1
FA intake, g/d	658	731	310

Materials and Methods

Table 1. Summary of the database used for estimating the milk fat model (n = 158 studies, 658 treatment means)

Variable	n	Mean	SD
Individual Intakes of FA, g/d			
C12:0	658	12	9
C14:0	658	9	7
C16:0	658	146	95
C16:1	658	7	8
C18:0	658	36	47
C18:1 cis	658	162	101
C18:1 trans	658	5	7
C18:2	658	268	111
C18:3	658	67	28
Other FA	658	24	17
C18:1 cis + C18:2 + C18:3	658	497	188

Variable	n	Mean	SD
Individual intakes of absorbed AA, g/d			
Arg	658	113	24
His	658	51	11
Ile	658	124	23
Leu	658	193	43
Lys	658	162	29
Met	658	49	10
Phe	658	123	24
Thr	658	112	20
Thp	658	28	5
Val	658	133	25

Materials and Methods

- Individual intakes of digestible FA (g/d)

  C12:0, C14:0, C16:0, C16:1, C18:0, C18:1cis, C18:1trans C18:2, C18:3

- Absorbed AA (g/d)

  Arg, His, Ile, Leu, Lys, Met, Phe, Thr, Trp, Val

- Fat-free dry matter intake (kg/d)

Fat-free DMI = DMI – FA intake

- Dietary composition, % of DM

  Starch, forage, and

  rumen-degradable protein (RDP)

- BW (kg) and days in milk (DIM, d)

Candidate predictor variables

Materials and Methods

- ✓ R (version 3.5.1)
- ✓ Outliers 3 SD from the mean
- ✓ Multimodel inference using MuMIn package (pdredge)
- ✓ Mixed models (lme4 package) included the study as the random effects
- ✓ Data were weighted using the square root of the number of animals represented in each treatment

Model

$$Y_{ij} = \beta_0 + s_i + \beta_{ij} \times X_{ij} + e_{ij},$$

Where:

Yij is the dependent variable,
β_0 is the intercept,
s_i represent the random effect of study,
β_{ij} represent the regression coefficient of Y on X,
X_{ij} represent the value of the predictor variables,
e_{ij} the residual error.

Materials and Methods

Multimodel Inference Framework

Package 'MuMIn'

April 9, 2019

Type Package
Title Multi-Model Inference
Version 1.43.6
Date 2019-04-08
Encoding UTF-8
Author Kamil Bartoń
Maintainer Kamil Bartoń <kamil.barton@go2.pl>
Description Tools for performing model selection and model averaging. Automated
model selection through subsetting the maximum model, with optional
constraints for model inclusion. Model parameter and prediction
averaging based on model weights derived from information criteria

Potential candidate variables → **Global Model** → **Set of candidate models** → **Model selection** → **Evaluation**

✓ The best models were selected on the basis of Akaike's information criterion with correction for small sample size (AICc).

✓ Variance inflation factor (VIF).

✓ Repeated cross evaluation (repeated 500 times, 15% testing and 85% training).

✓ Finals models were evaluated using root mean square error (RMSE) and concordance correlation coefficient (CCC).

Results

- Total 10,240 candidate models
- Best models VIF < 3

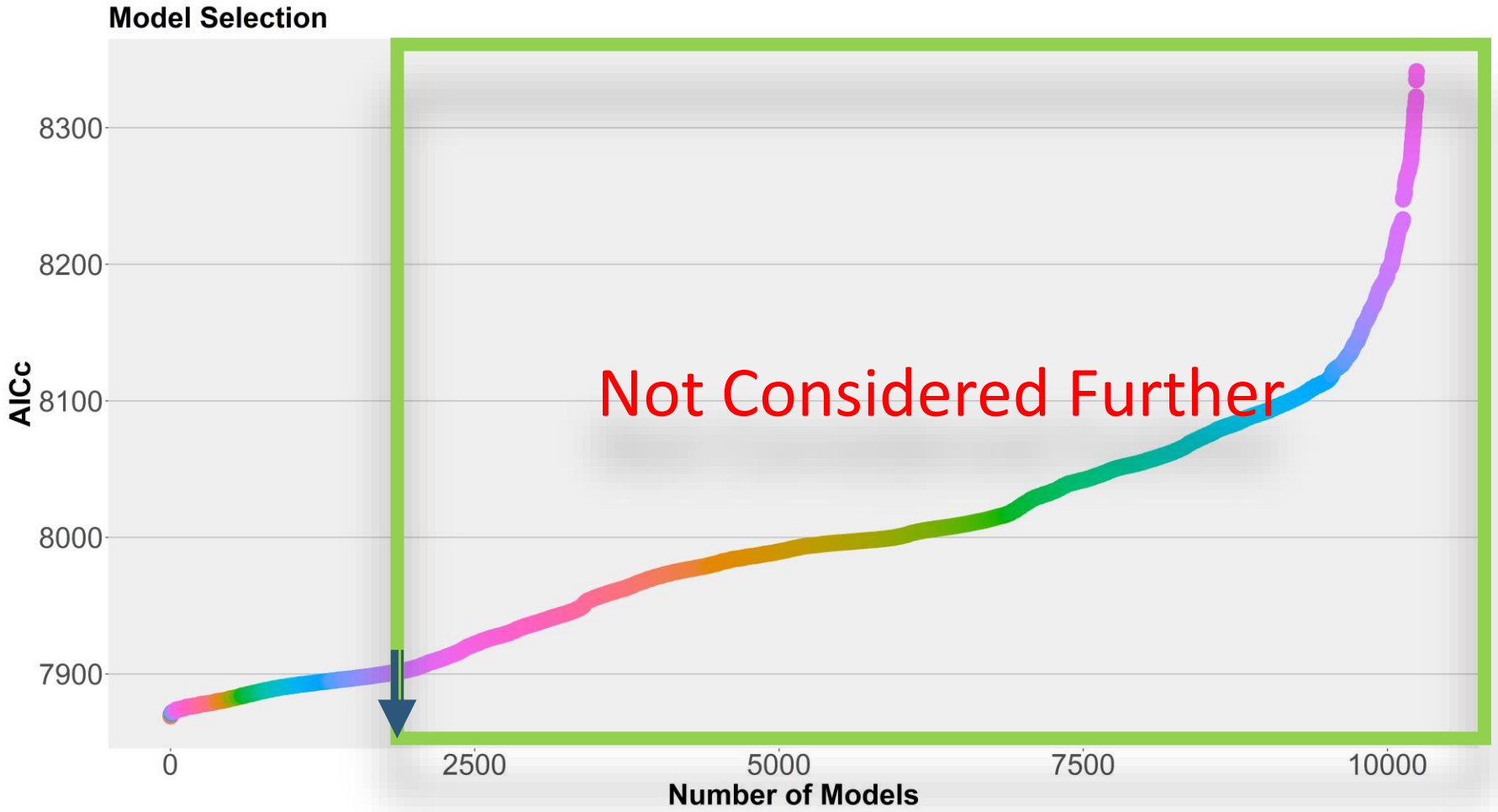


Figure 2. AICc of candidate models

Range of slope values
Best 2000 models

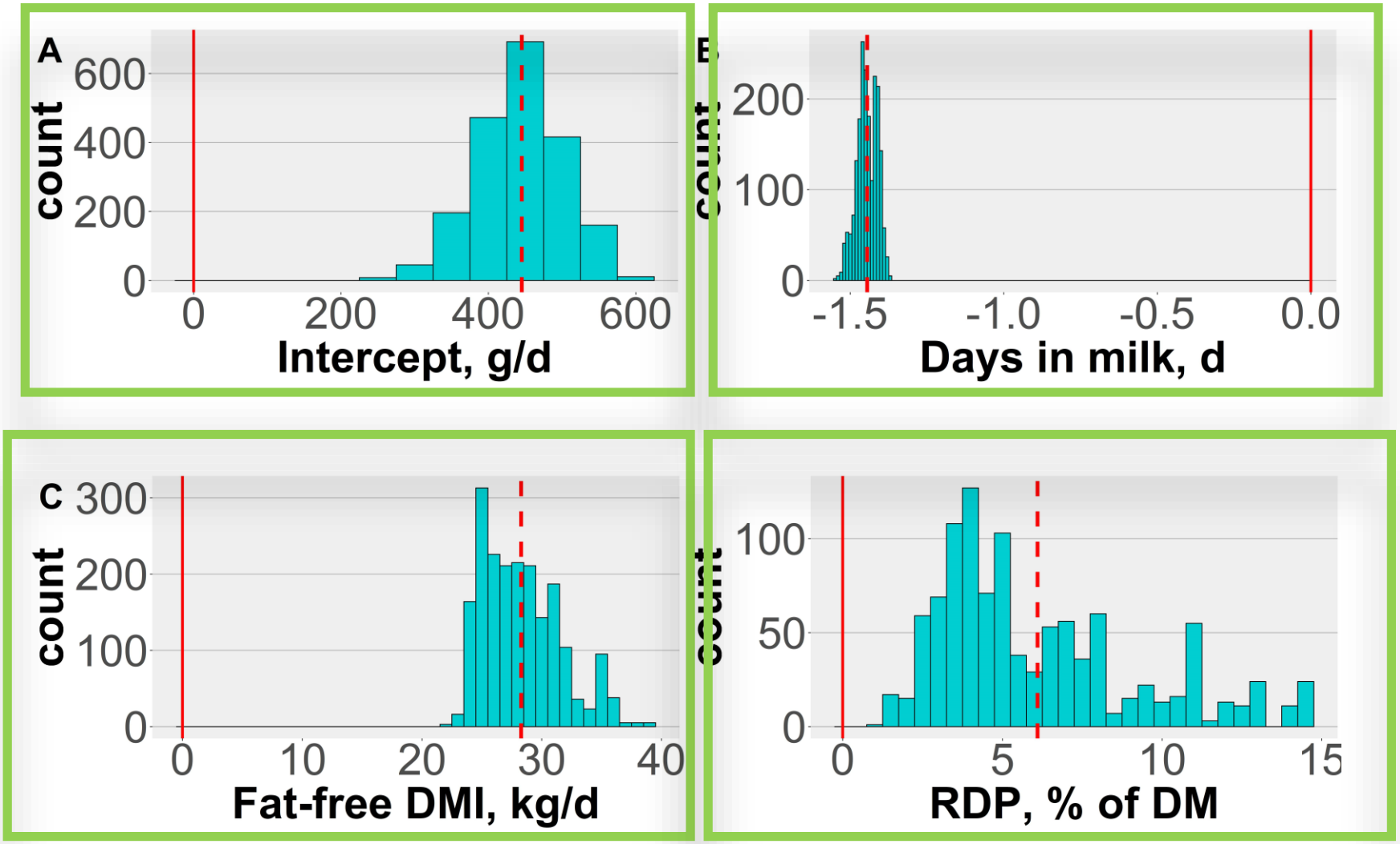


Figure 3. Slopes of candidate variables from the set of 2000 best models

Range of slope values
Best 2000 models

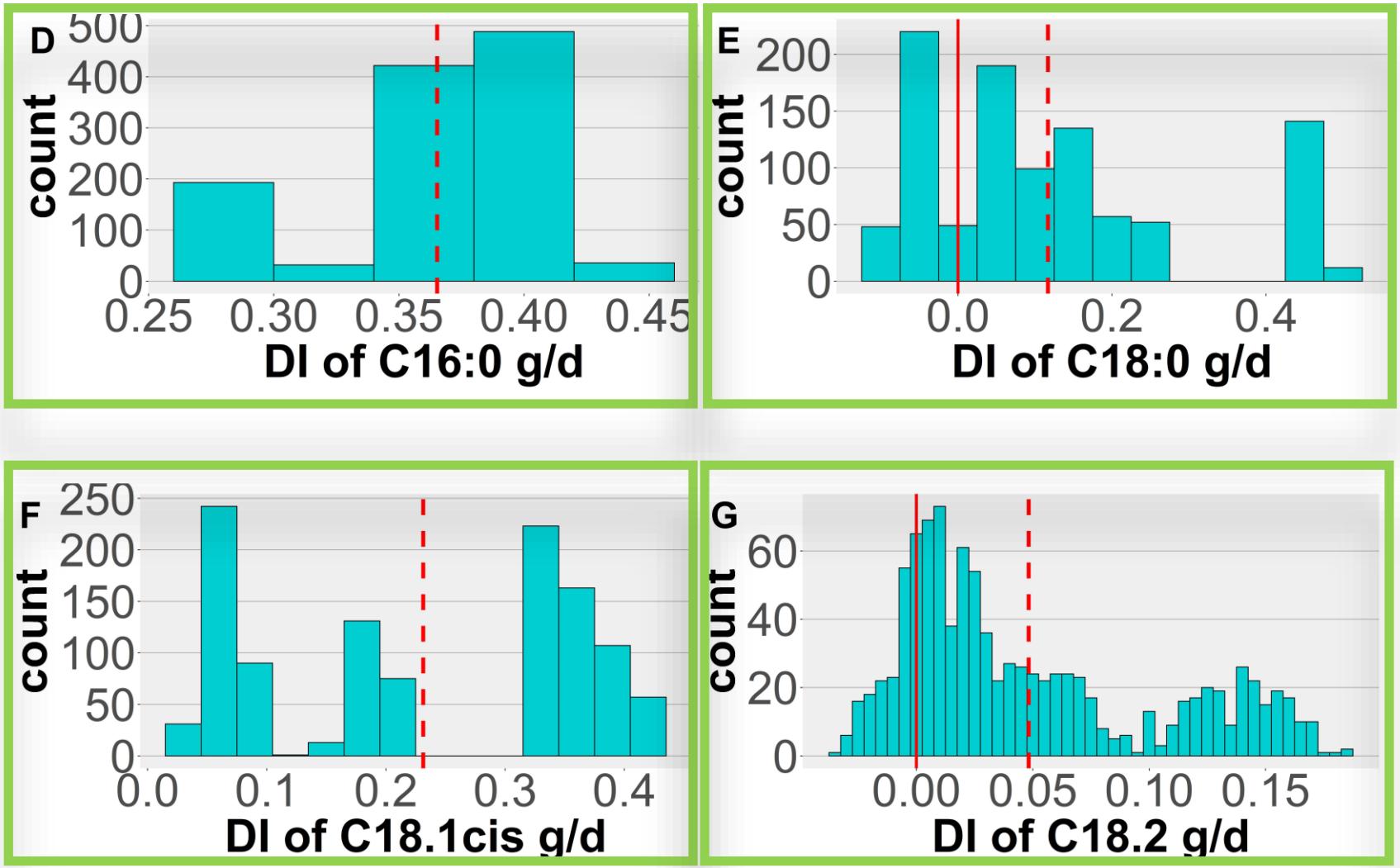


Figure 3. Slopes of candidate variables from the set of 2000 best models. DI = Digestible intake.

Range of slope values
Best 2000 models

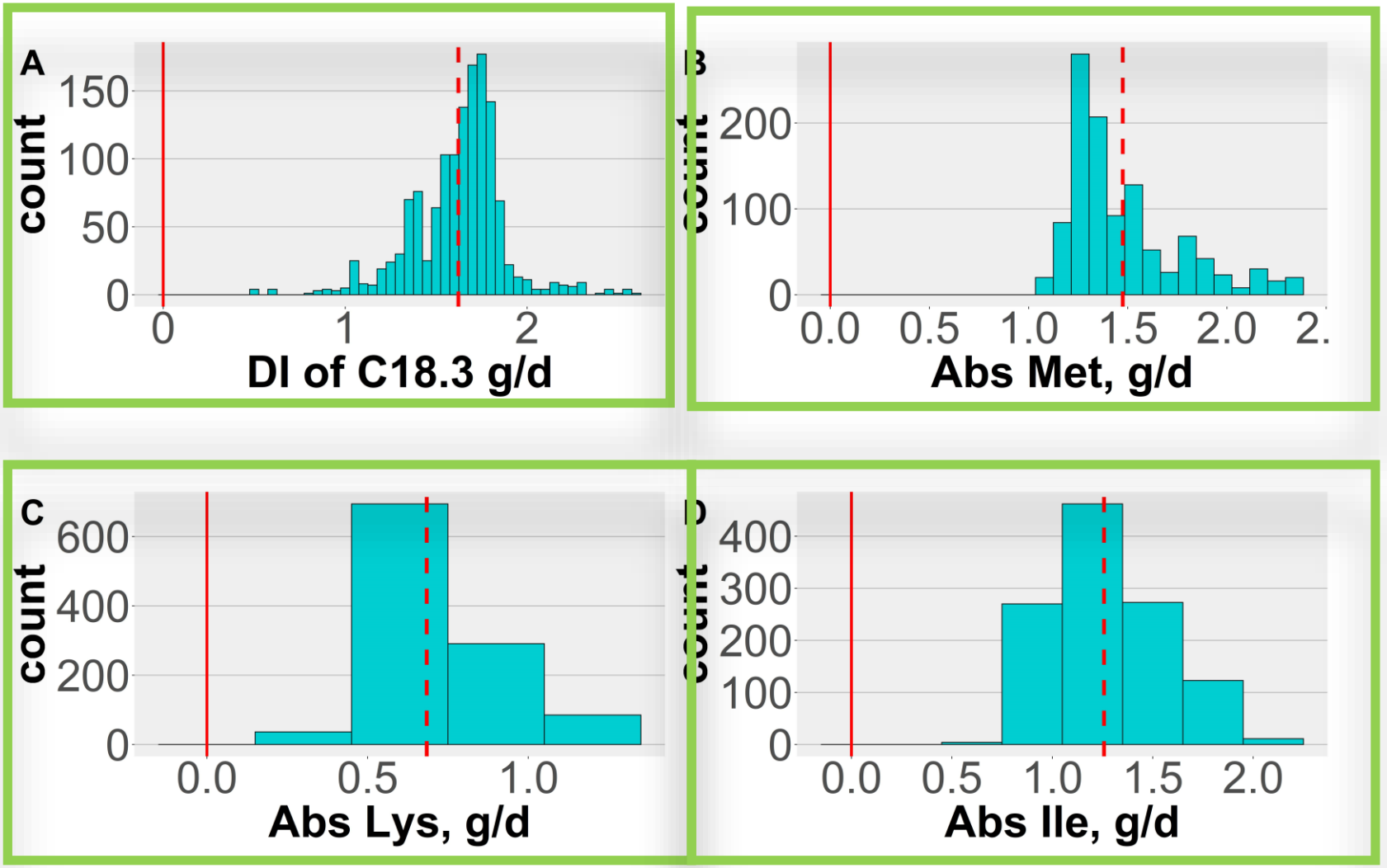


Figure 3. Slopes of candidate variables from the set of 2000 best models
DI = Digestible intake. Abs= absorbed.

Results

- ✓ High variation for effects of digestible C12:0 and C14:0.
- ✓ Consistent positive effect of intake of digestible 16:0.
- ✓ High variation for effects of digestible of C18:0, C18:1cis, and C18:2.
- ✓ Consistent positive effect of intakes of absorbed Met, Ile, and Lys.

Results

Table 3. Best four models for estimating the milk fat yield (g/d) of dairy cows

	Model 1		Model 2		Model 3		Model 4	
Predictors	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Intercept	446.9	57.1	407.1	70.6	452.9	57.1	522.4	64.2
Abs Ile, g/d	0.98	0.43	0.76	0.49	1.45	0.36	0.86	0.45
Abs Lys, g/d	0.53	0.28	0.48	0.28			0.44	0.29
Abs Met, g/d	1.23	0.53	1.25	0.53	1.34	0.53	1.13	0.54
DIM, d	-1.41	0.12	-1.40	0.12	-1.42	0.12	-1.44	0.12
Fat-free DMI, kg/d	23.64	3.06	24.89	3.32	24.52	3.03	29.35	3.11
DI of C16:0, g/d	0.40	0.07	0.41	0.07	0.40	0.07	0.40	0.07
DI of C18:3, g/d	1.81	0.35	1.83	0.35	1.80	0.35		
RDP, % DM			3.89	4.07				
Starch, % DM							-2.36	0.98
Model evaluation								
AIC_C	7869		7870		7870		7888	
CCC	0.806		0.806		0.806		0.802	
RMSE, %	14.11		14.10		14.09		14.23	

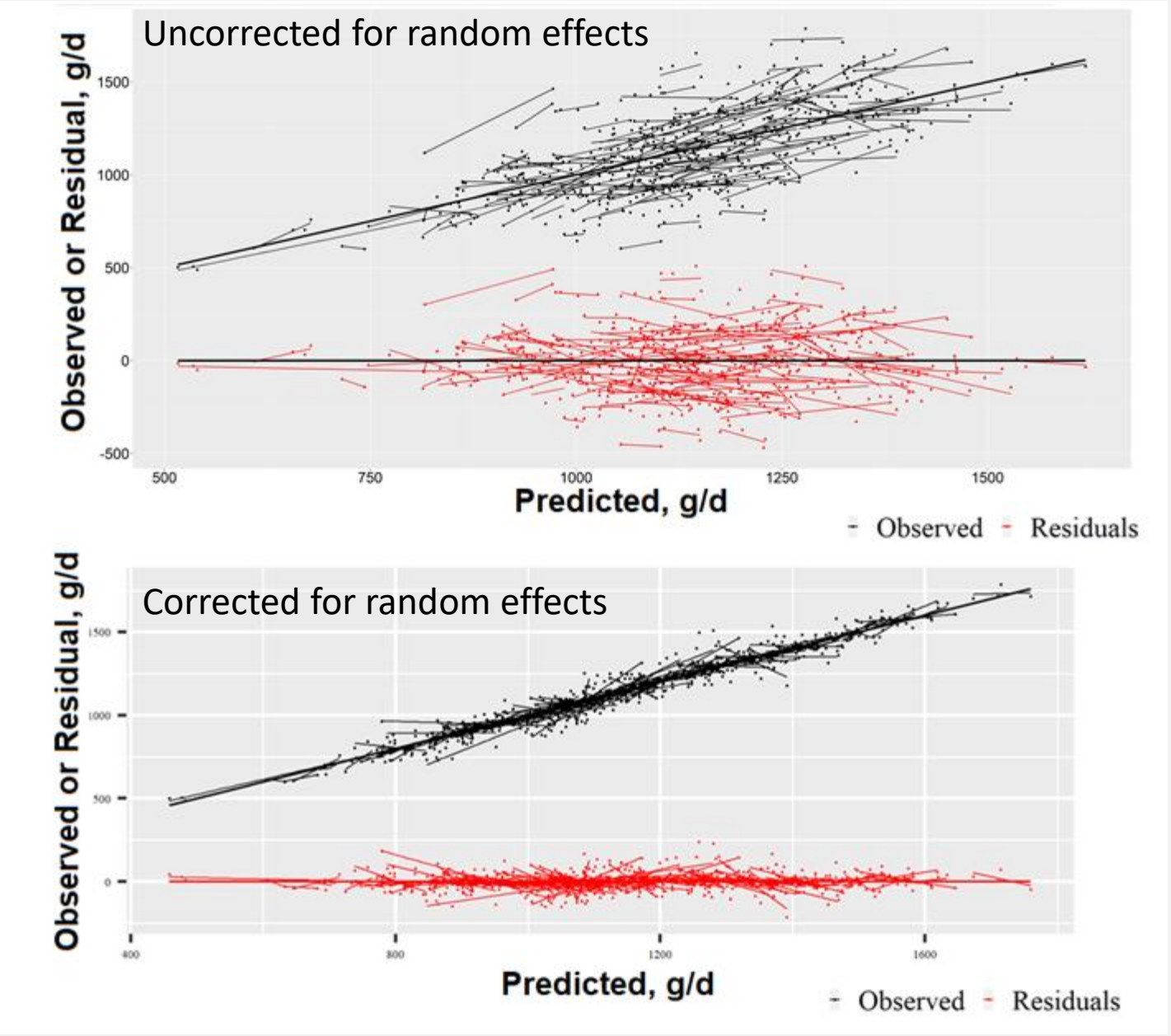


Figure 5. Model 3: Observed vs. predicted and residuals vs. predicted for milk fat yield (g/d).

n = 658 treatment means.

Conclusion

- Intake of digestible C16:0 positively affected the milk fat yield.
- Intake of digestible C18:3 positively affected the milk fat yield of cows fed about 67 ± 28 g/d.
- Models containing intake of absorbed Met, Ile, and Lys had a better fit in comparison to other candidate models.
- The models developed can be used as a practical tool for predicting milk fat production of cows.

Photo: DD Silva, 2018. Parana State, Brazil

National Animal Nutrition Program

Leveraging Resources, Linking Researchers

THANK YOU

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