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Derivation of the metabolic status in dairy cows - prediction of ruminal daily pH mean

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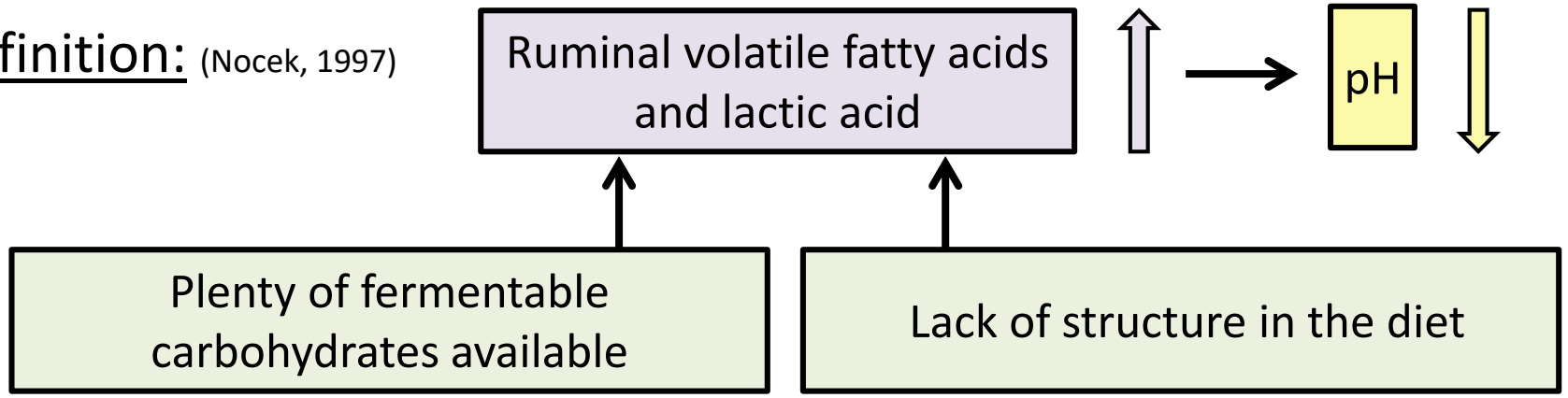
Introduction

Metabolism disorder in dairy cows: Subacute ruminal acidosis (SARA)

> *"It may […] be appropriate to suggest that SARA is the most important nutritional disease of dairy cattle."* (Enemark, 2008)

Definition: (Nocek, 1997)



Adequate ruminant nutrition (!)

Present indicators for SARA

- Daily mean pH <6.2 and time pH <5.8 >5.2 h per day (Zebeli et al., 2008)
- Fat-to-Protein ratio <1.0 (Enemark et al., 2002; KTBL, 2016)
- pH <5.5 using rumenocentesis (Nordlund et al., 1995; Garett et al., 1999)

Introduction

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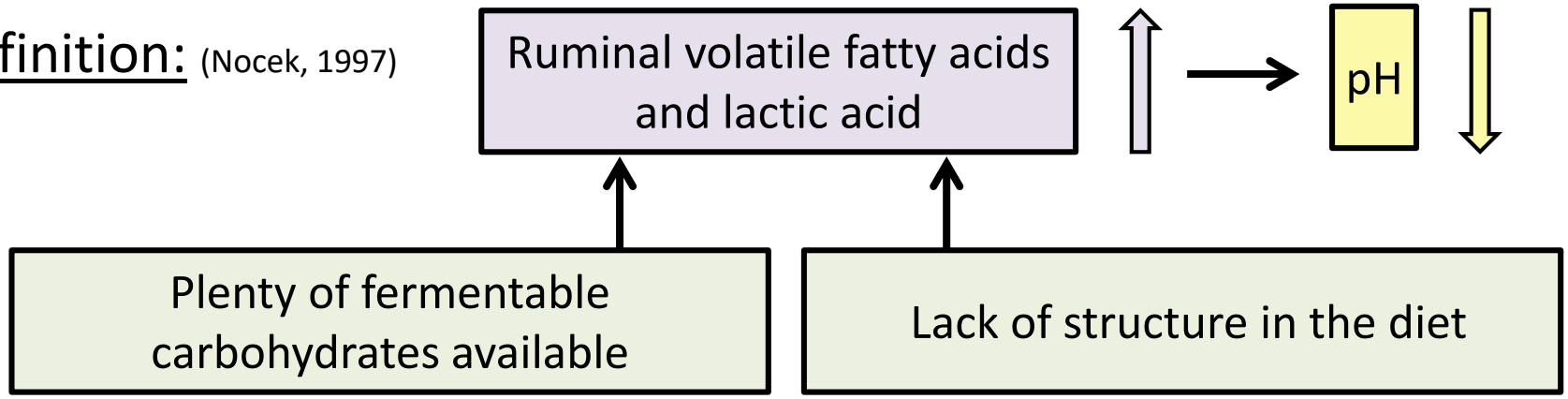


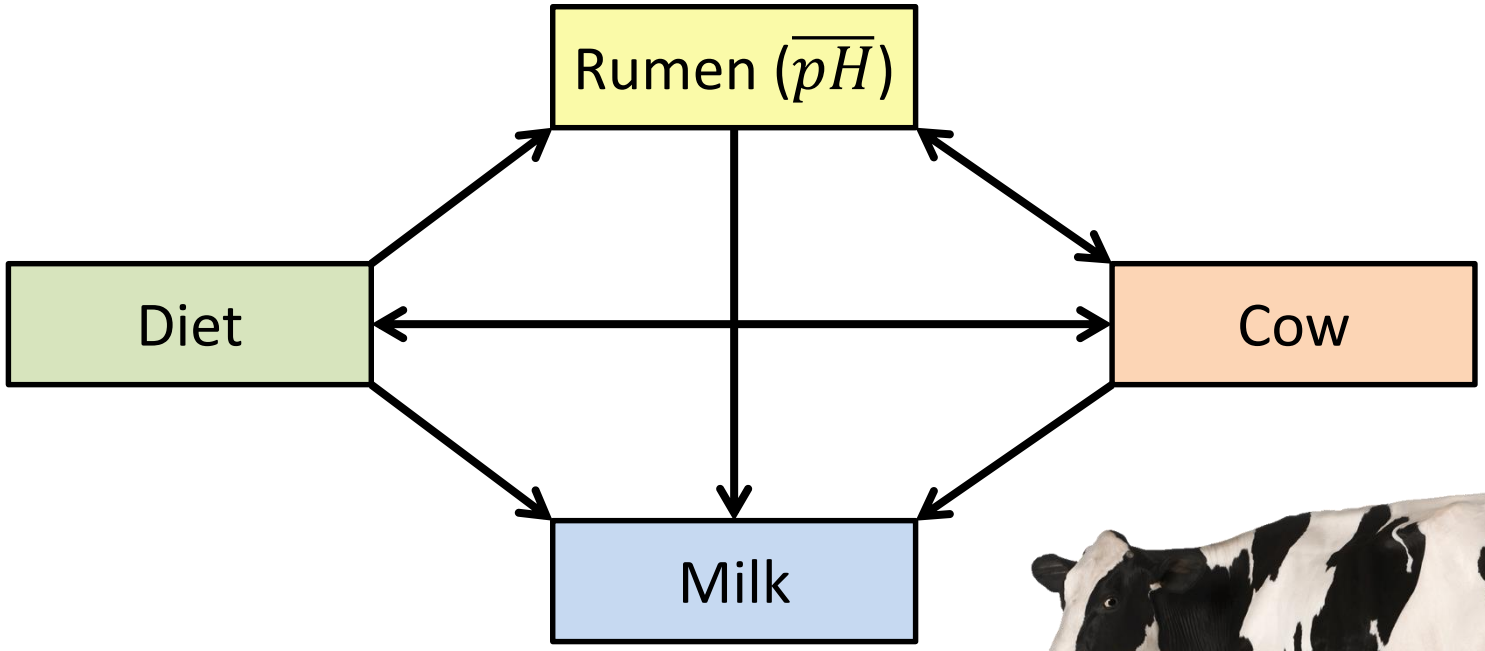
Adequate ruminant nutrition (!)

The phenotype of SARA is not clearly defined yet

→ Main reason: Subacute = No clinical signs

Objective

Modeling of the daily mean ruminal pH ($\overline{pH}$) using meta-analytical methods



[1]

Objective

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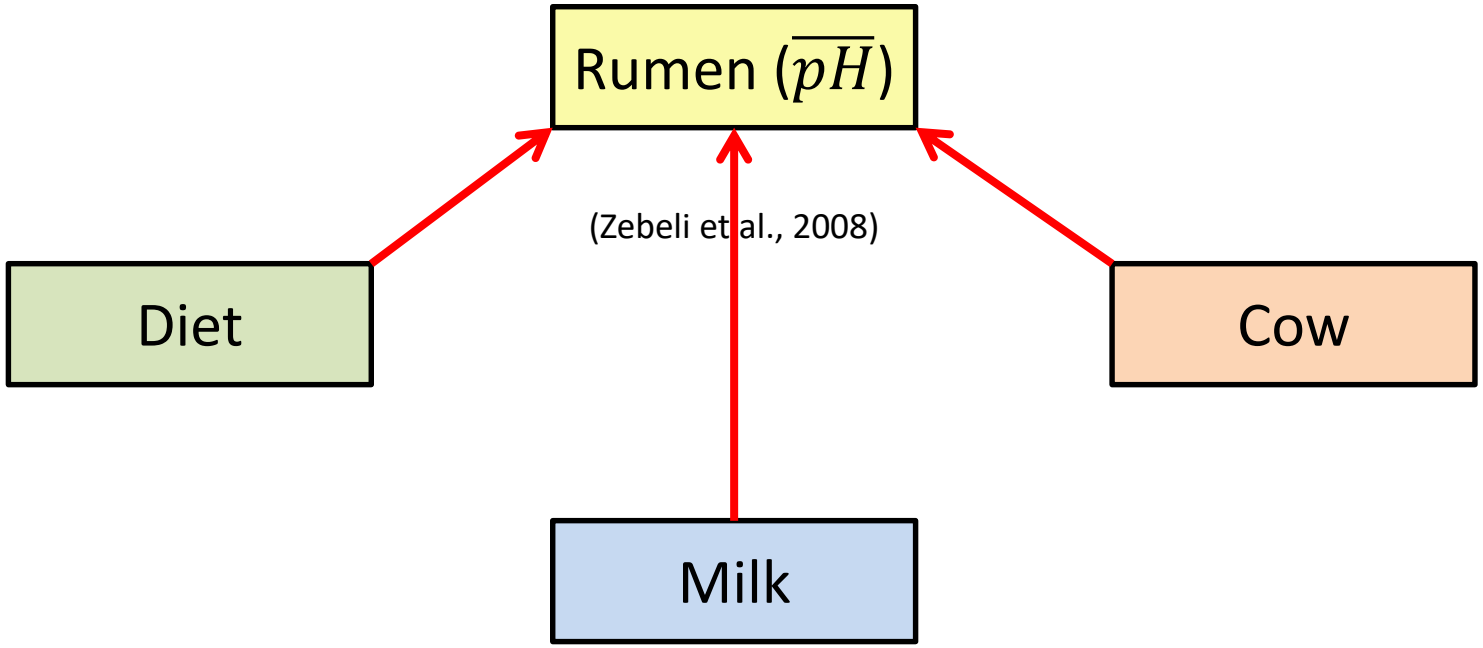
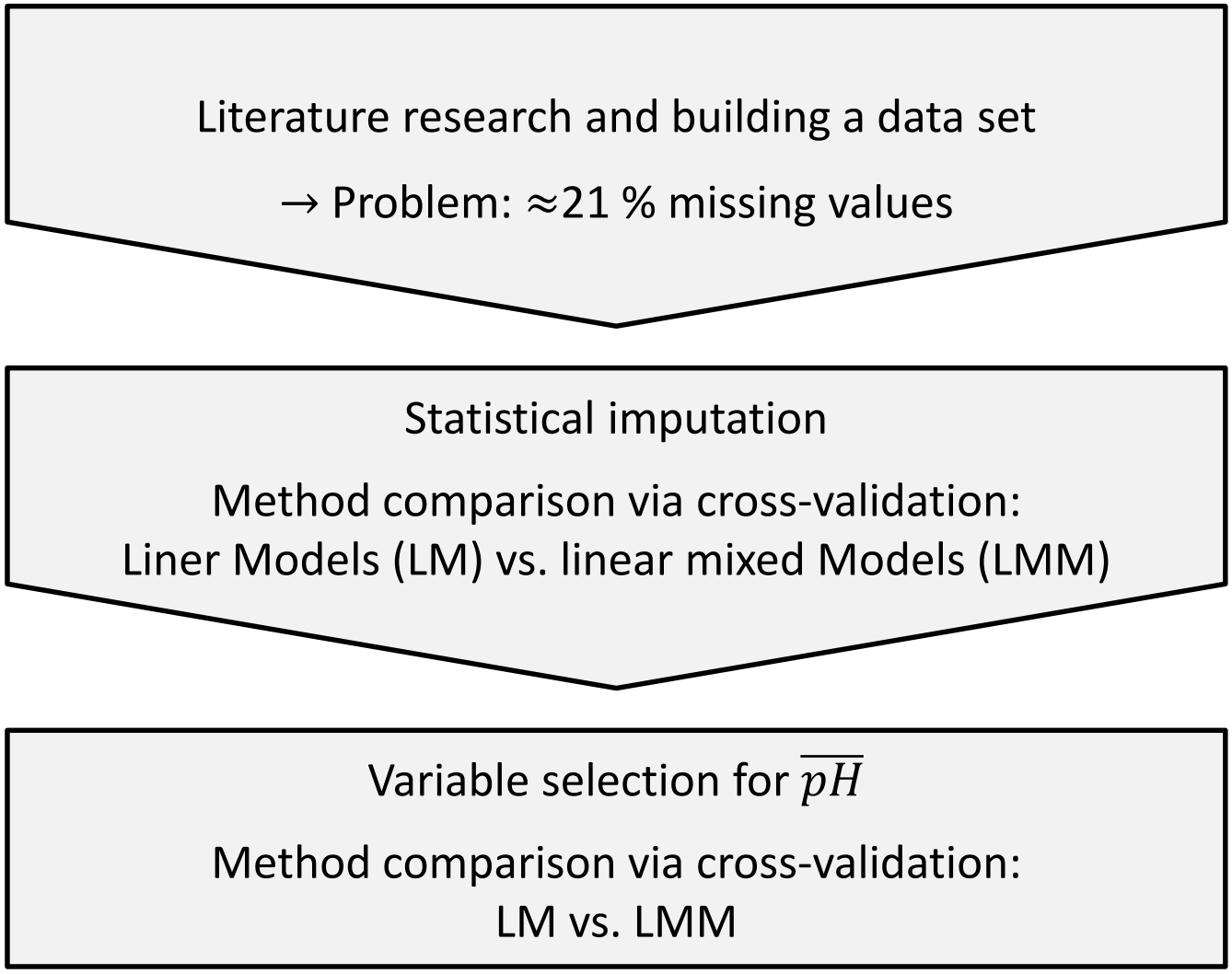


- Predictors: Milk- and diet-specific parameters
  - Focus on parameters that are available in agricultural practice
- Analysis and validation of present indicators

Materials and Methods

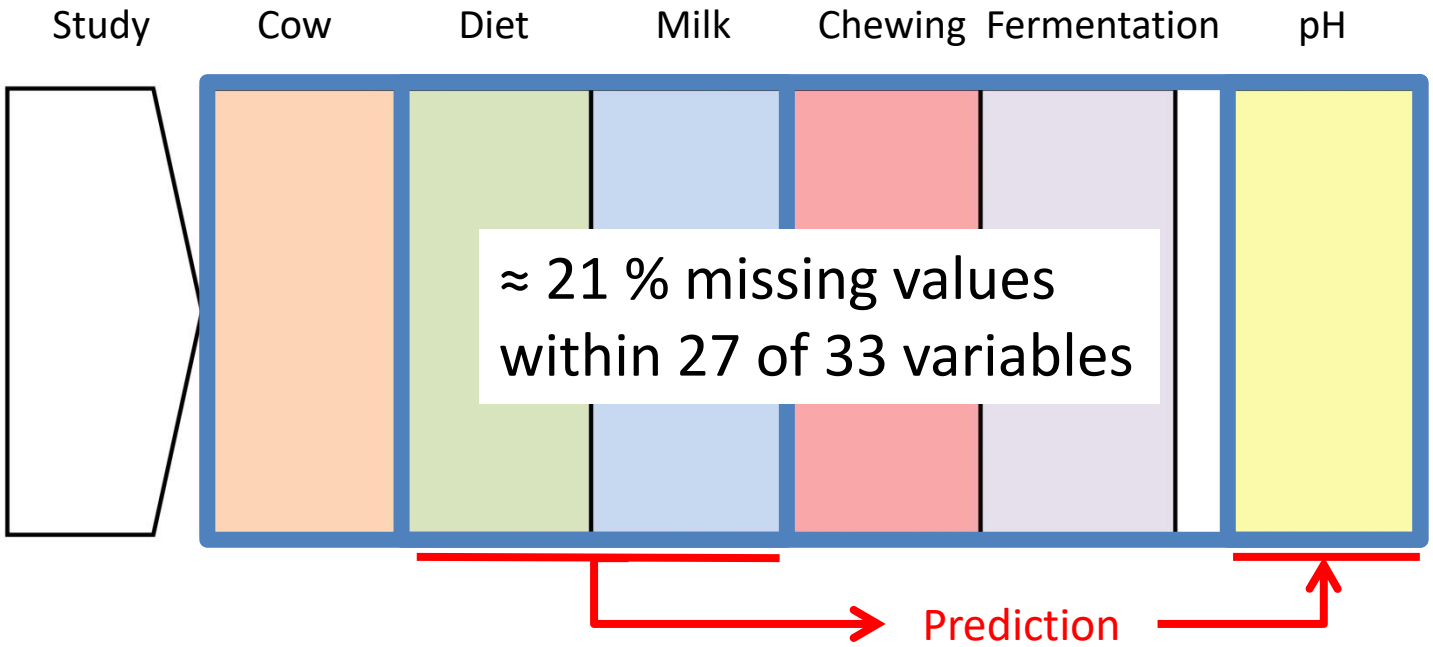
Workflow



Materials and Methods

Step I: Data

- Selection criteria for studies
  - Continuous pH measurement in the ventral sac of the rumen
  - Measurement >24 h in cannulated lactating Holstein cows
- Hierarchical data structure with group level “study”
  - n = 39 studies, k = 141 treatment means (Σ = 279 cows)



Materials and Methods

Meta-regression for Step II and III:

- LM: linear and quadratic effects

$$y_i = \beta_0 + \beta_1 x_{i,1} + \beta_2 x_{i,2} + \beta_2 x_{i,2}^2 + \ldots + e_i$$

- LMM: linear and quadratic effects, study as random effect

$$y_{ij} = \beta_0 + \beta_1 x_{ij,1} + \beta_2 x_{ij,2} + \beta_2 x_{ij,2}^2 + \ldots + study_j + e_{ij}$$

- Weighted least squares estimation
  - Weighting by the reciprocal standard error (Inverse variance method) (Borenstein et al., 2009; Schwarzer et al., 2015)
- Model comparison via leave-one-study-out cross-validation on the correlation between observed and predicted values $r(y, \hat{y})$ (Prediction with LMM only on the fixed effect part)

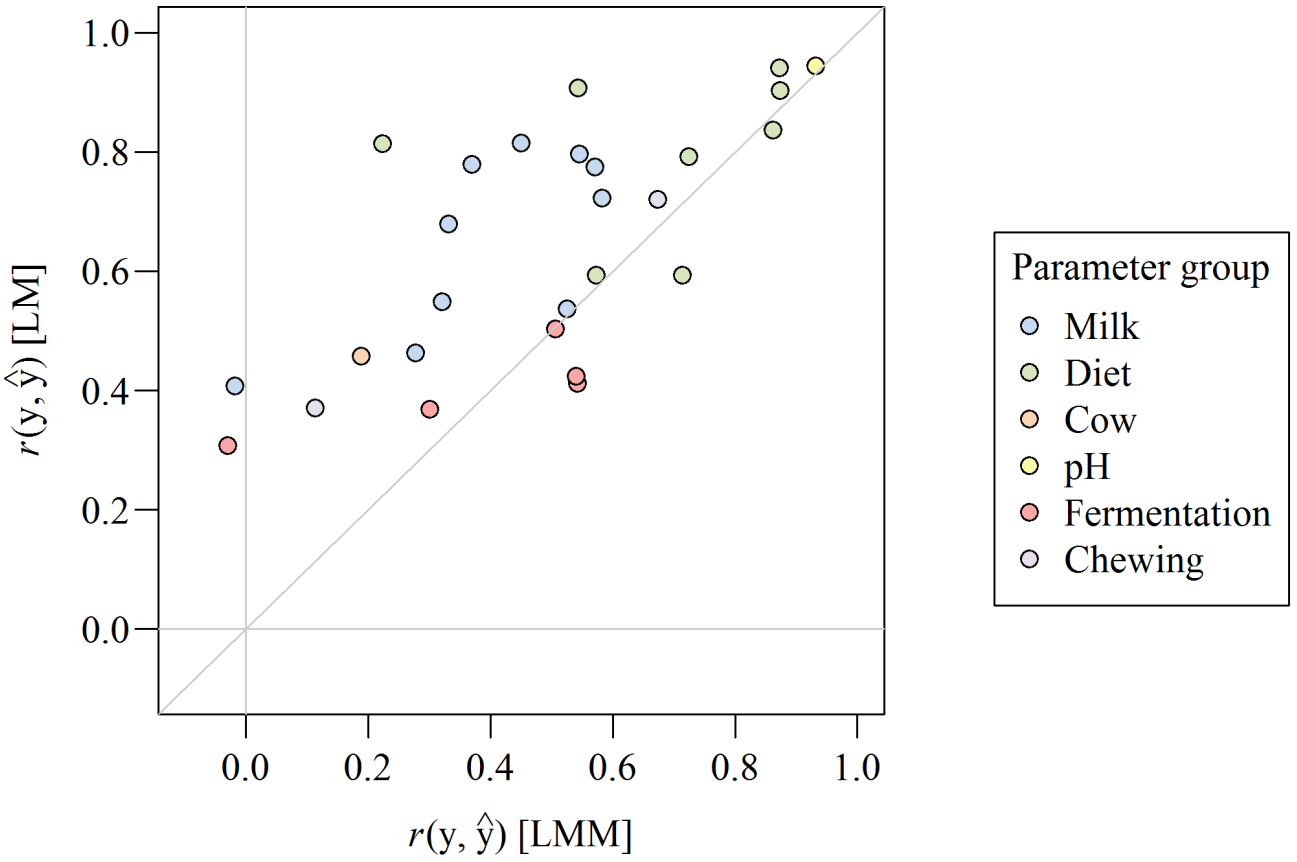
Materials and Methods

Step II: Statistical imputation

- Multiple Imputation by Chained Equations (MICE) (Azur et al., 2011)
  - Each variable with missing values is modeled by other variables of the same dataset
    - Developed algorithm for variable selection with a stepwise forward selection using the Bayesian information criterion (BIC)
    - Considering linear effects
  - Series of regression models in an iterative process
- Within statistical imputation all variable groups were used

Materials and Methods

Step II: Statistical imputation, Method comparison via $r(y, \hat{y})$



- Imputation performance of LM better than of LMM

  → Further analysis on the data base which was imputed by LM

Materials and Methods

Step III: Variable selection for $\overline{pH}$

- Developed algorithm for variable selection with a stepwise forward selection using the BIC
- Considering linear and quadratic effects
- Separate variable selection for $\overline{pH}$ on parameters of

Milk | Diet | Milk & Diet

Results and Discussion

Variable selection for $\overline{pH}$

	Linear models			Linear mixed models		
Predictors	**LM1**	**LM2**	**LM3**	**LMM1**	**LMM2**	**LMM3**
Protein						
FPR						
Lactose						
Lactose^2						
NEL						
EE						
ADF						
peNDF>8						
(peNDF>8)						
NFC						

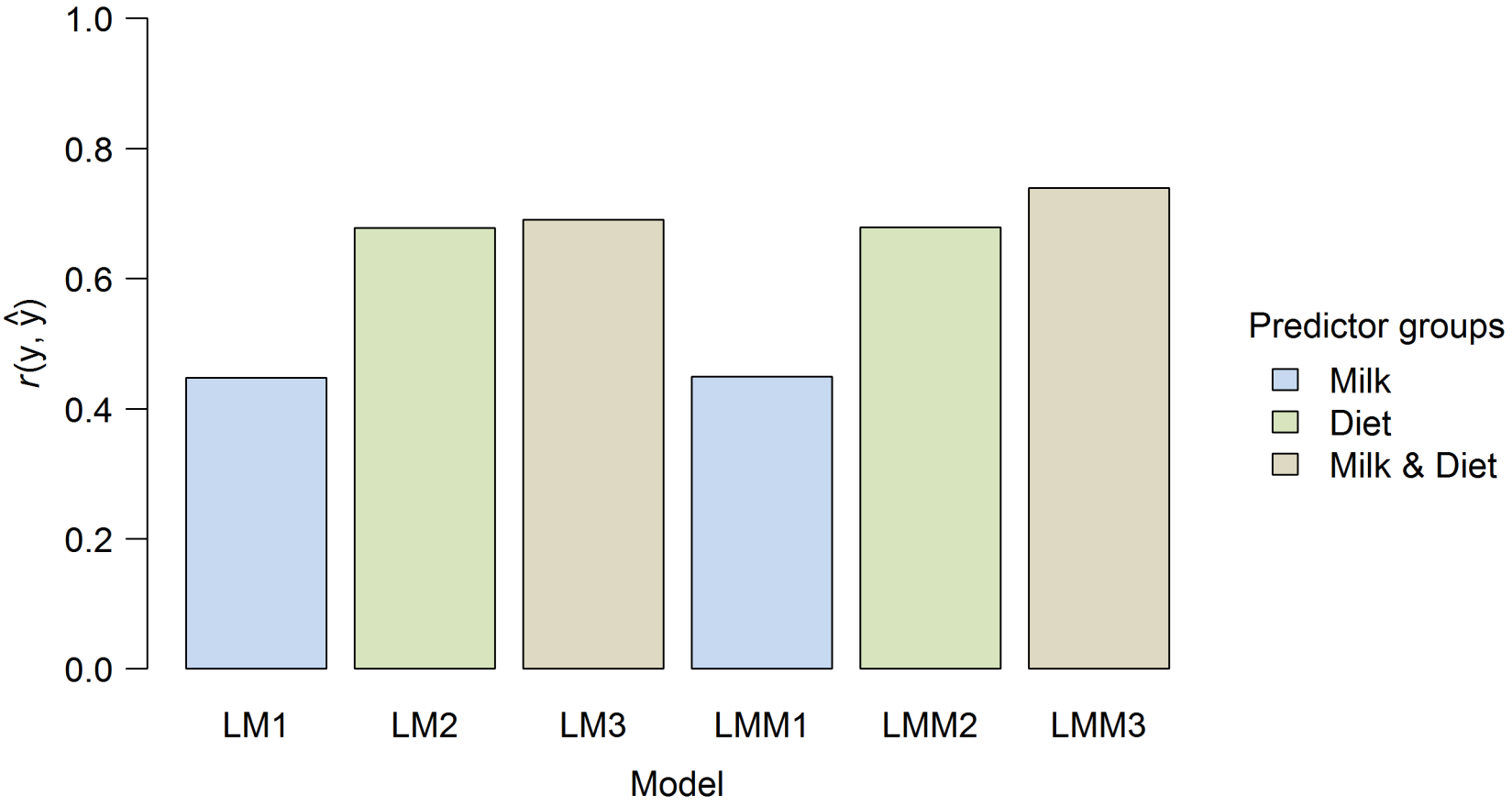
Predictor groups
- Milk
- Diet
- Milk & Diet

NEL = Net energy lactation, **EE** = Ether extract, **ADF** = Acid detergent fiber,
peNDF>8 = physically effective neutral detergent fiber >8mm, **NFC** = Non fiber carbohydrates

Results and Discussion

Variable selection for $\overline{pH}$

- Results of cross-validation $r(y, \hat{y})$



Conclusion

- Statistical imputation is a useful tool for meta-analytical data
- The explorative variable selection detected known associations
- Moderate predictability of ruminal $\overline{pH}$
- Additional consideration of milk parameters improves the modeling of $\overline{pH}$
- Clear signs for **protein** and **lactose** as indicators

Outlook

- Investigation of the influence of location for pH measurement
  - ventral sac of the rumen vs. reticulum
- Validation on data which were collected on 100 cows equipped with boluses on practical farms

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Thank you for your attention!

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Appendix

Variable selection for $\overline{pH}$

	Linear models			Linear mixed models		
Predictors	**LM1**	**LM2**	**LM3**	**LMM1**	**LMM2**	**LMM3**
Intercept	10.172	2.353	43.936	9.993	3.873	10.123
Protein	-0.389		-0.431	-0.457		-0.460
FPR				0.453		
Lactose	-0.615		-15.253	-0.639		-0.529
Lactose^2			1.565			
NEL		0.290			0.249	
EE		0.086			0.078	
ADF		0.027	0.027			
peNDF>8		0.077			0.063	0.049
(peNDF>8)^2		-0.002			-0.001	-0.001
NFC					-0.015	-0.015

Predictor groups
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- Diet
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NEL = Net energy lactation, **EE** = Ether extract, **ADF** = Acid detergent fiber,
peNDF>8 = physically effective neutral detergent fiber >8mm, **NFC** = Non fiber carbohydrates