KU LEUVEN

75th EAAP Annual Meeting
Florence – Italy

In-line milk analysis
How accurate can we get?

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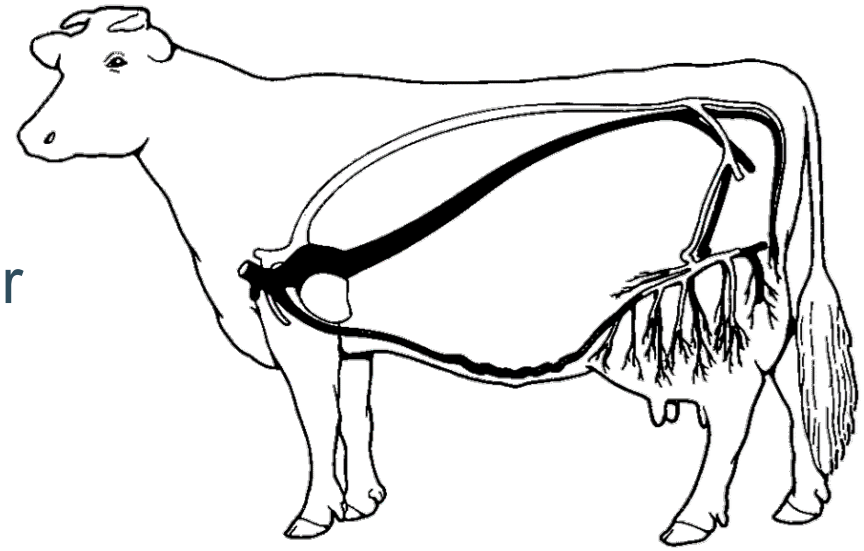
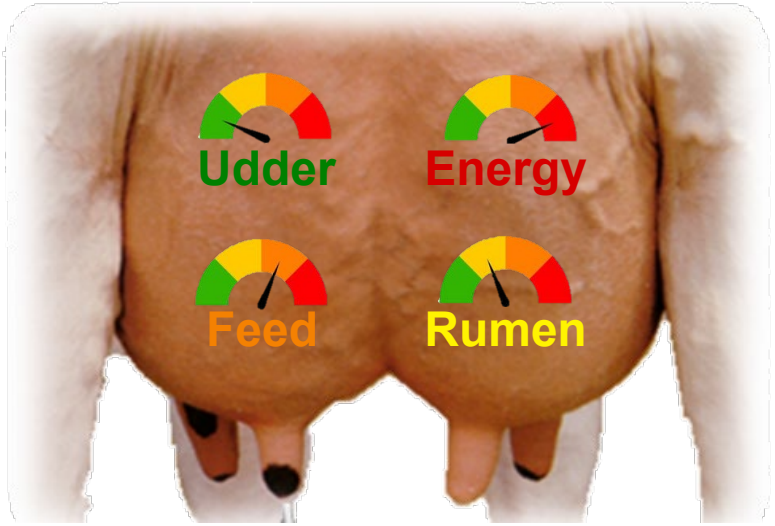
Division Animal and Human Health Engineering
Livestock Technology research group

Livestock Technology

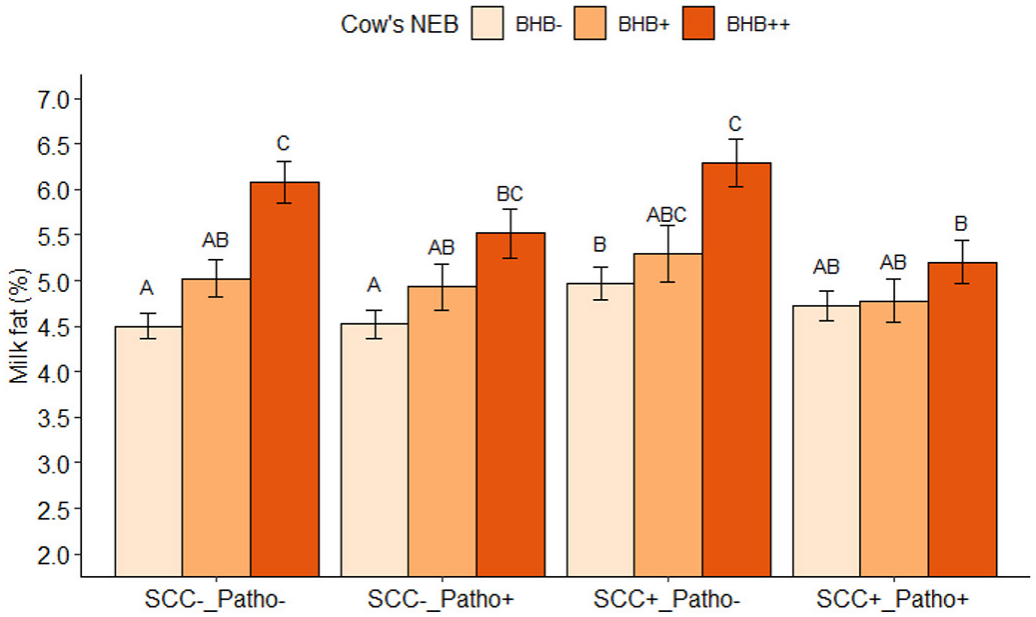
Cow health monitoring

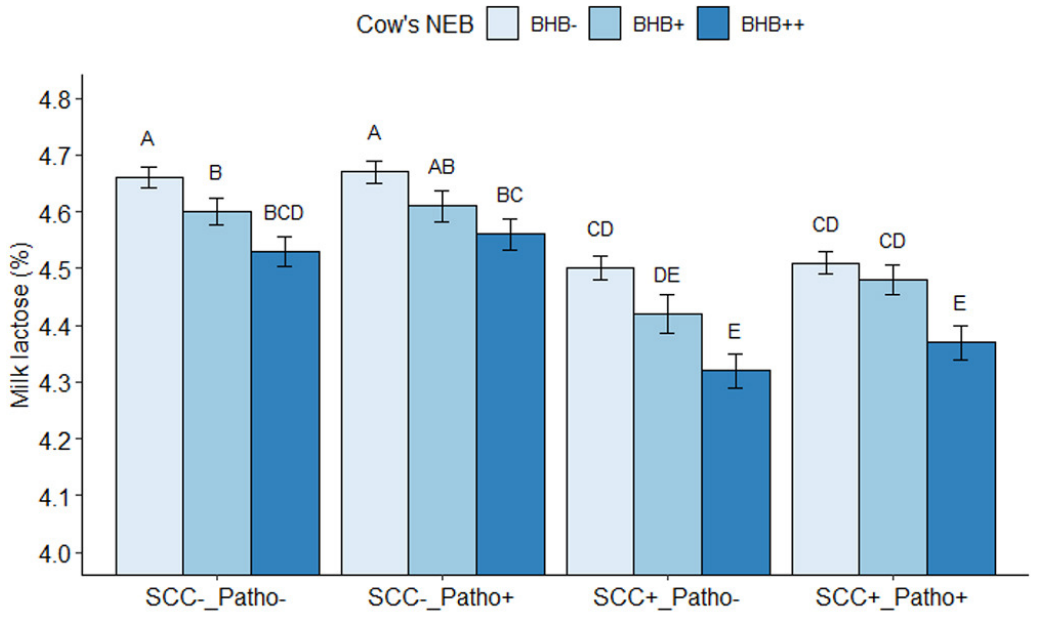


- 1L milk = 500L blood circulating through udder
- Mastitis:
  - Increase in milk sodium and chlorine
  - Decrease in lactose and potassium
- Negative energy balance:
  - Increase in milk fat (long-chain FA)
  - Decrease in protein
  - Increase in ketones
- Rumen acidosis: drop in milk fat (short-chain FA)
- Nutrition: balance between milk urea and protein



Quarter milk composition



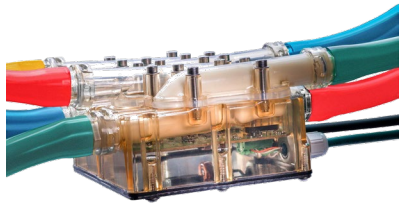


SCC−: <100 000 cells/mL; SCC+: ≥100 000 cells/mL
Patho−: Absence milk pathogens; Patho+: Presence milk pathogens
BHB−: <0.15 mM; BHB+: 0.15 – 0.19 mM; BHB++: >0.19 mM

Hamon et al. (2024). Decreased lactose percentage in milk associated with quarter health disorder and hyperketolactia, a proxy for negative energy balance, in dairy cows. J. Dairy Sci. 107:5041-5053.

On-farm milk sensors

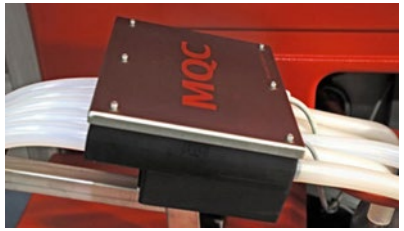
Real-time / ~~destructive~~ / ~~consumables~~



GEA Dairymilk M6850

Boumatic / SAC Gemini

Afimilk Afilab



Lely MQC II

DeLaval V300

Allflex SenseHub Milkplus

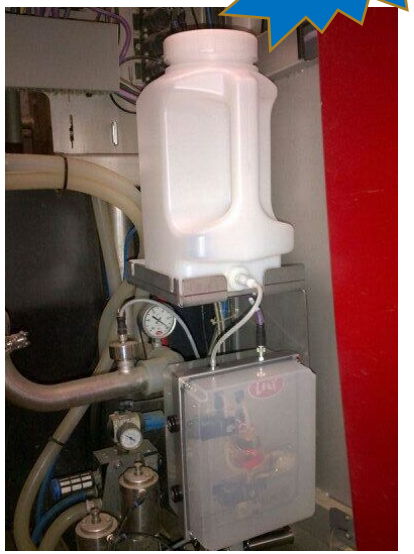
By-pass / destructive / consumables

Allflex – Sense

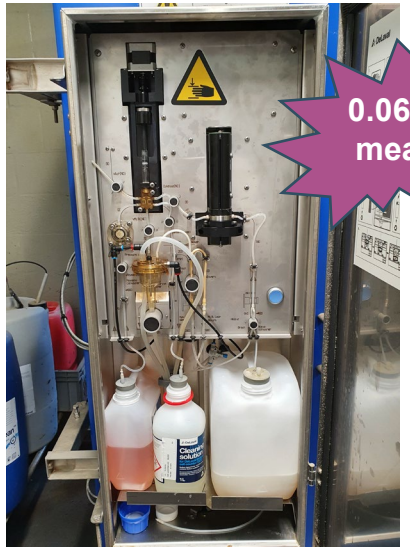
0.02 € / meas.

0.1 – 0.5 € / meas.

DeLaval – Herd Navigator



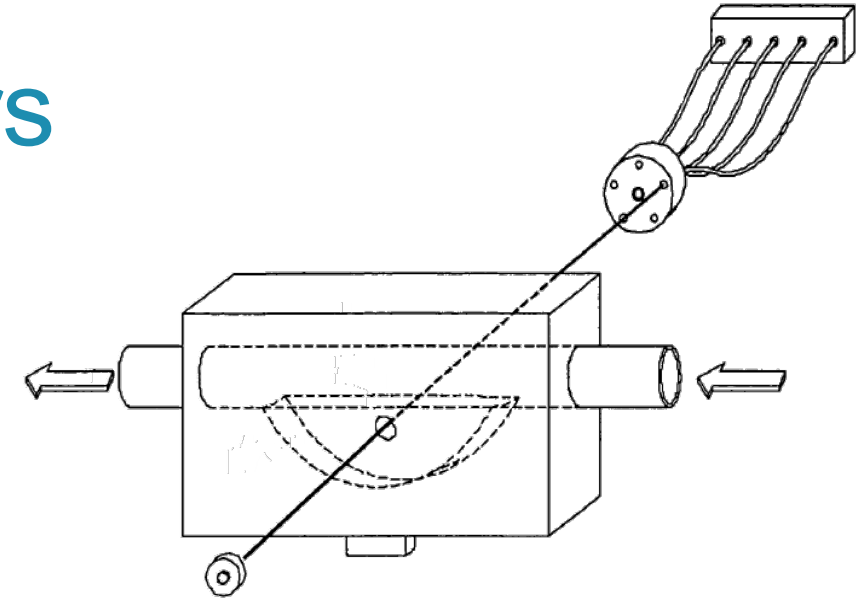
Lely MQC-C

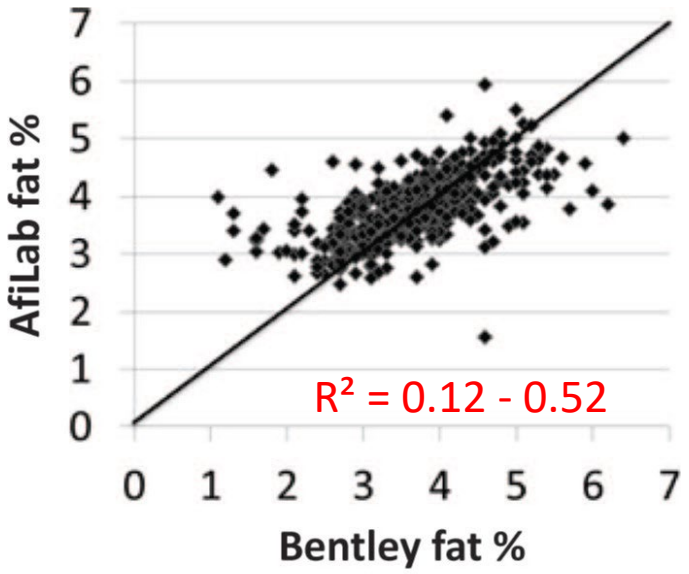


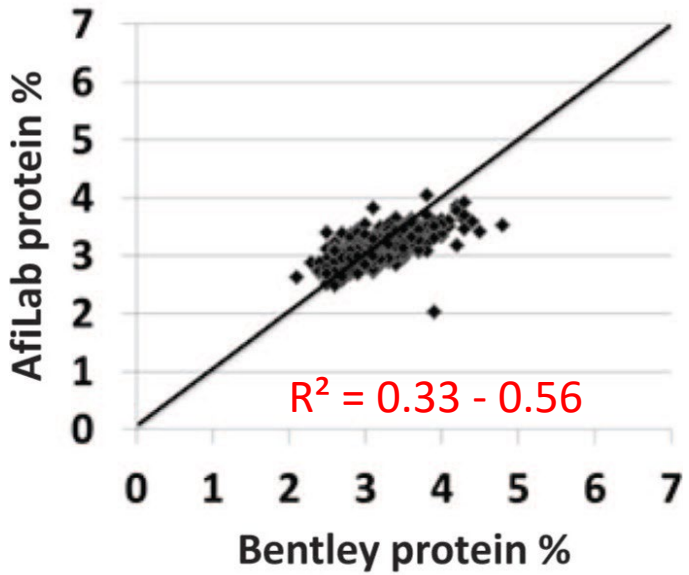
0.06 € / meas.

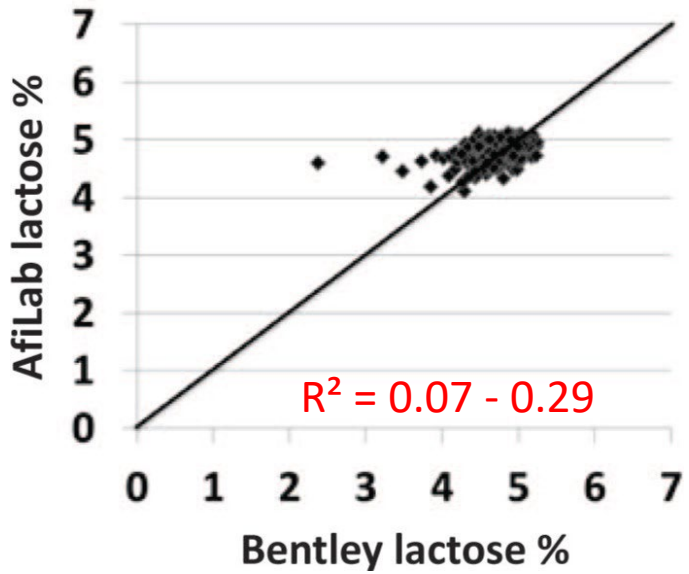
DeLaval OCC

Milk composition sensors



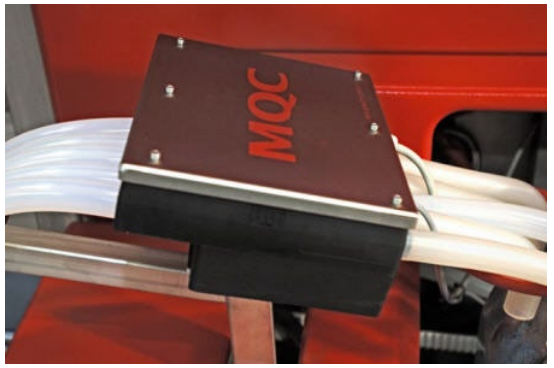


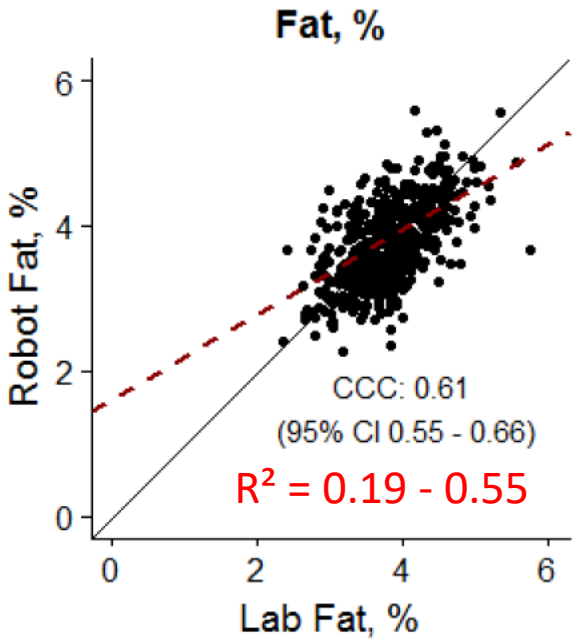


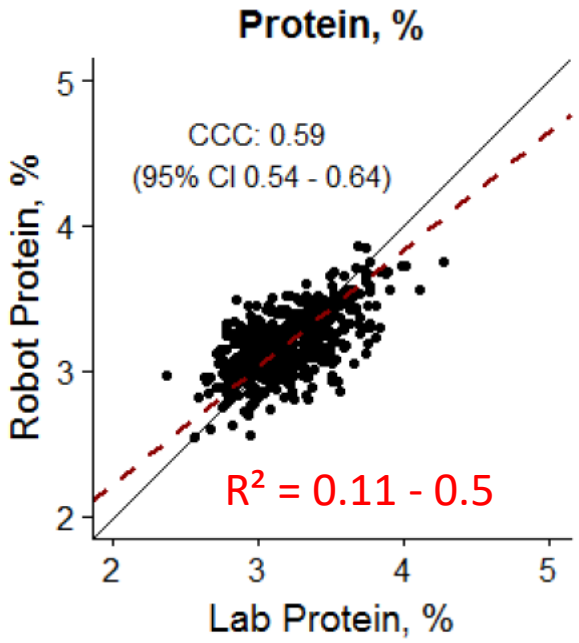


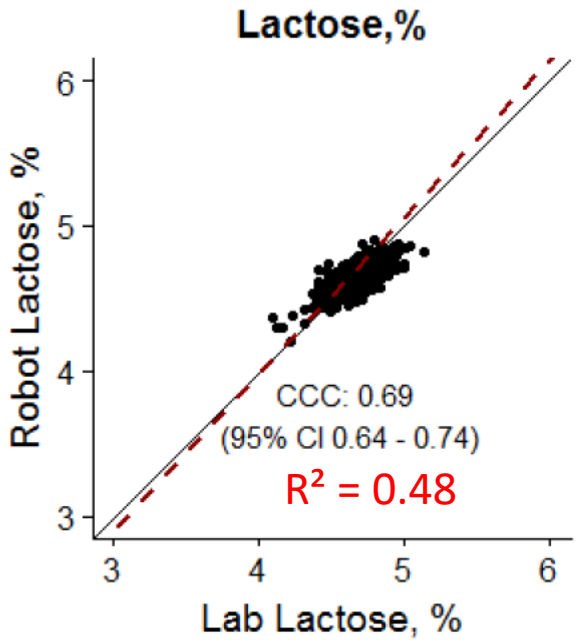
Kaniyamattam & De Vries (2014). Agreement between milk fat, protein, and lactose observations collected from the Dairy Herd Improvement Association (DHIA) and a real-time milk analyzer. J. Dairy Sci. 97:2896-2908.
Hanuš et al. (2016). The evaluation of real time milk analyse result reliability in the Czech Republic. Acta Univ. Agric. Silvic. Mendel. Brun. 64:1155-1166.
Schmilovitch et al. (2007). Spectroscopic fluid analyzer. U.S. Patent No. 7,236,237.

Milk composition sensors







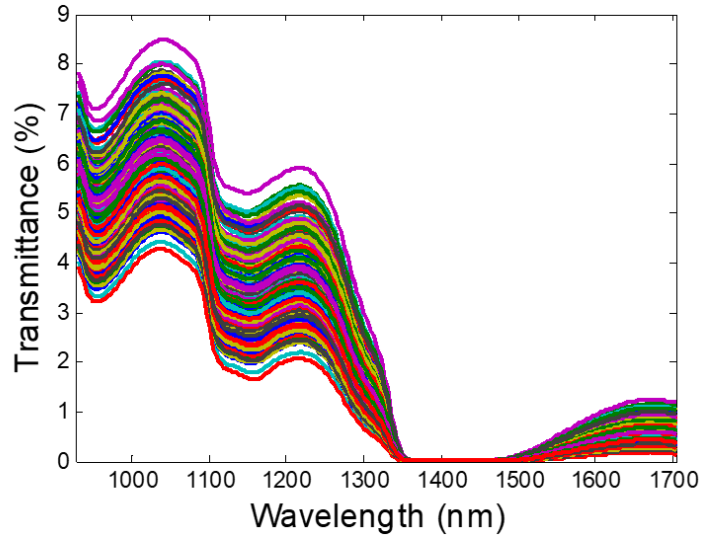


Pecová et al. (2017). Evaluation of the result reliability of basic milk composition in an automated milking system through indirect real-time analysis. Proc. of the 24 Int. Phd Stud. Conf. Brno, Czech, 8-9.
Fadul-Pacheco et al. (2018). Characterization of milk composition and somatic cell count estimates from automatic milking systems sensors. ICAR Tech. Ser. 23:53-63.

Near-infrared spectroscopy

950 – 1700 nm Near-infrared:

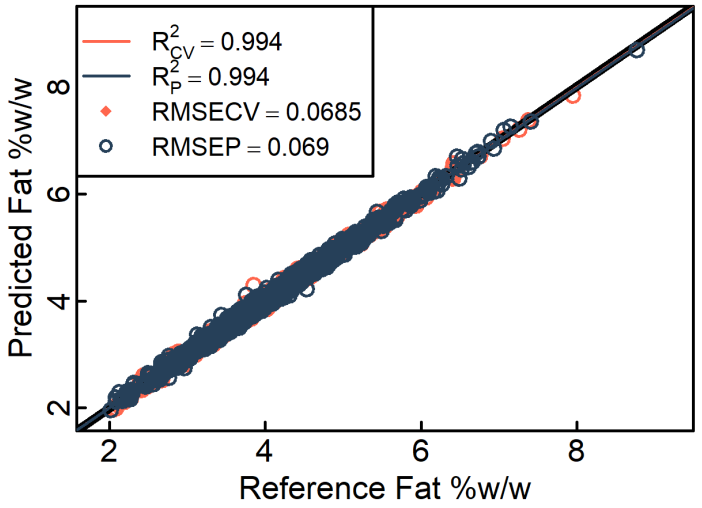
- Fast
- Accurate
- Non-destructive
- No sample preparation
- Cost-effective
- Possible to measure online

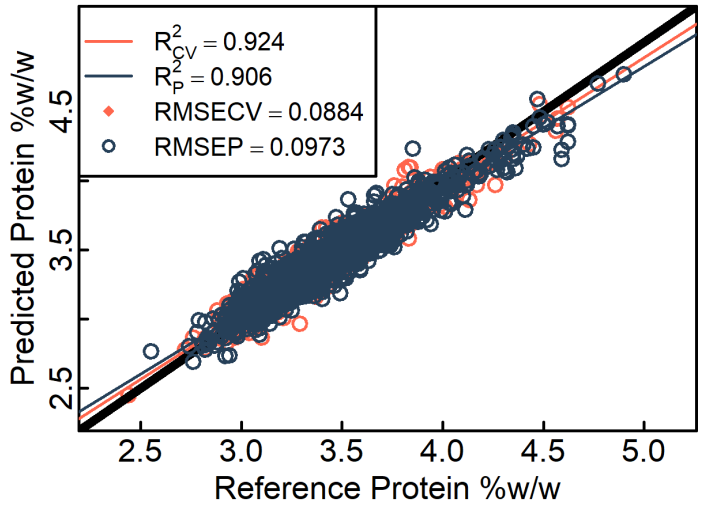


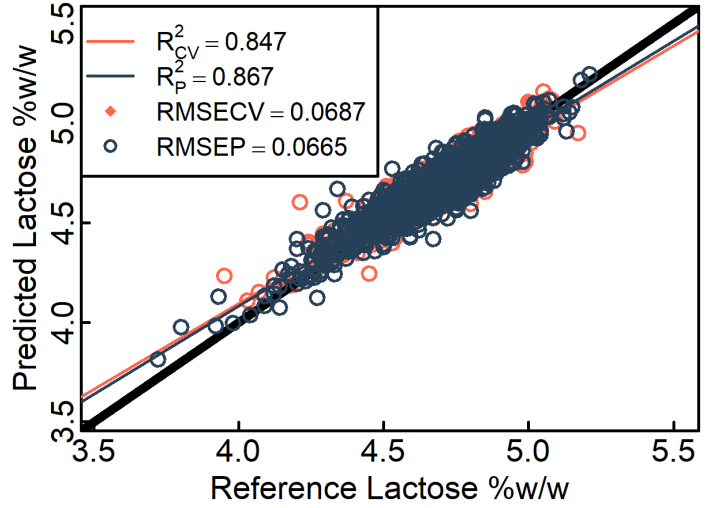
Díaz Olivares et al. (2020). Online milk composition analysis with an on-farm near-infrared sensor. Comput. Electron. Agr. 178:105734.

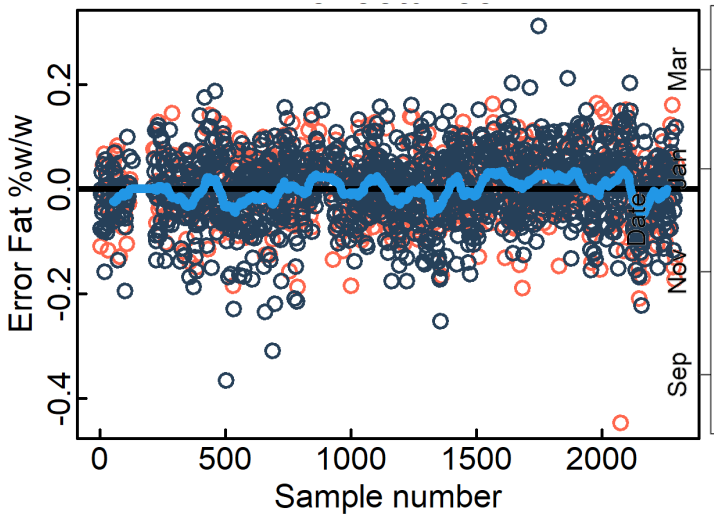
Post-hoc calibration & validation

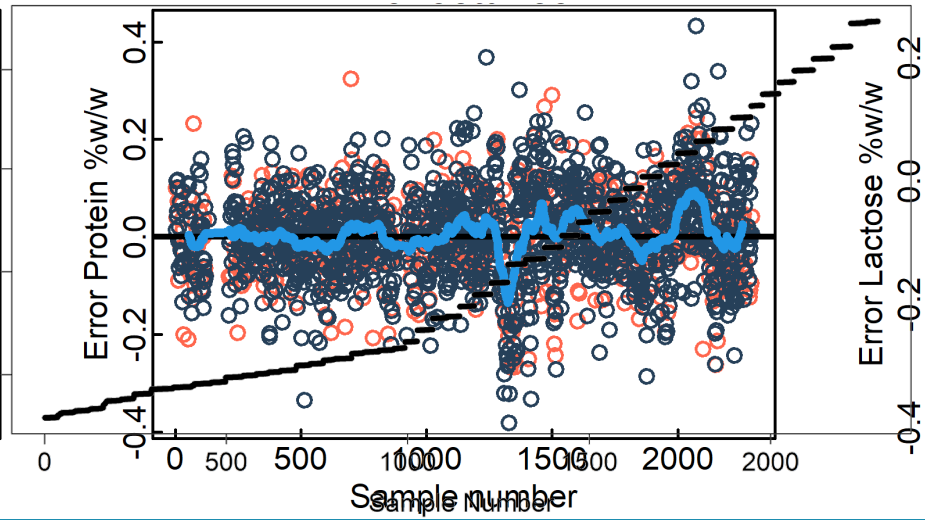
600 calibration samples (cross validation)
1700 validation samples
Random sampled over 9 months
August 2021 – April 2022

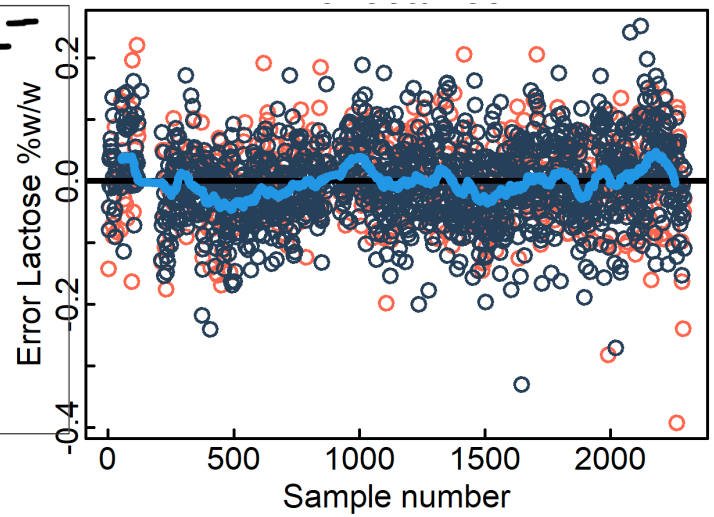






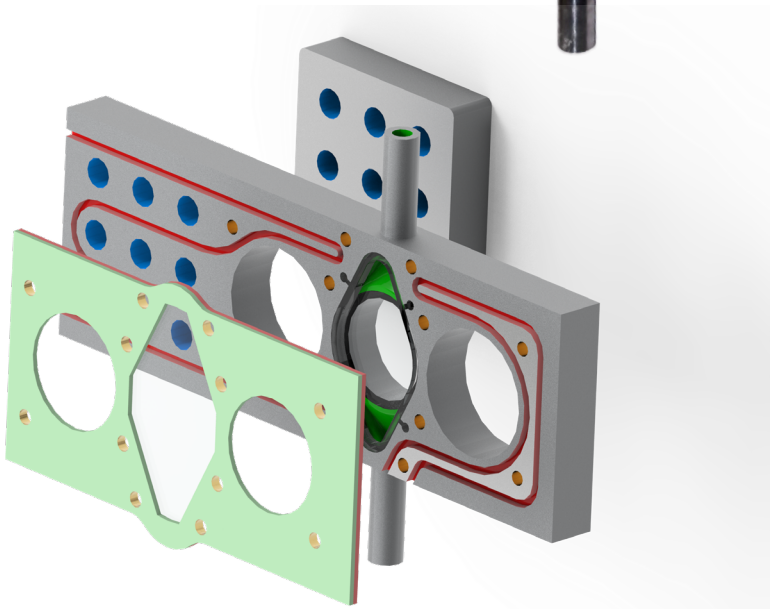


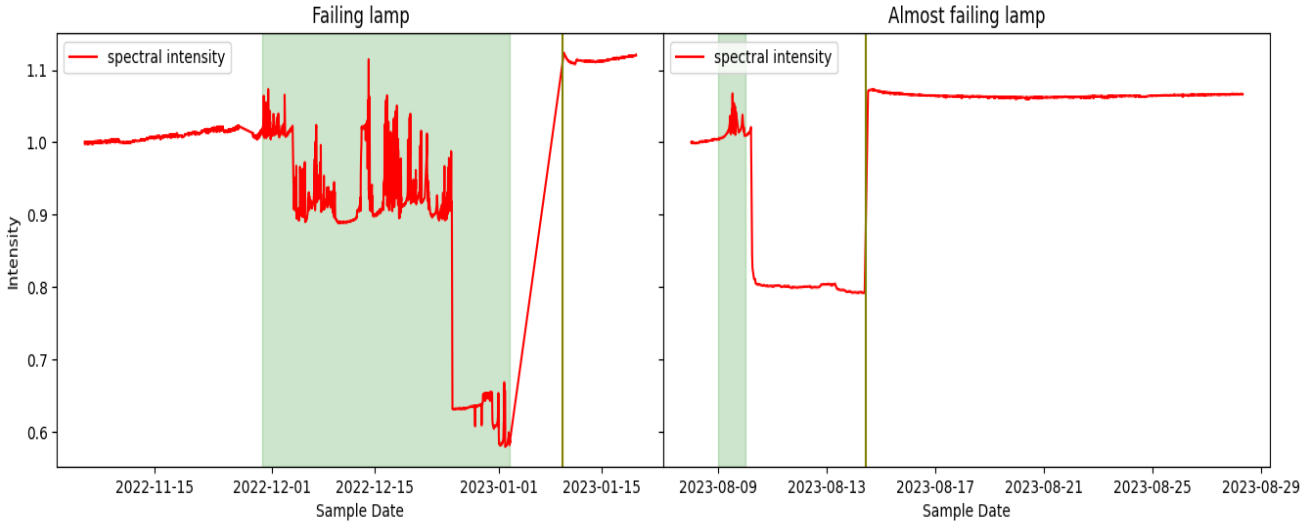


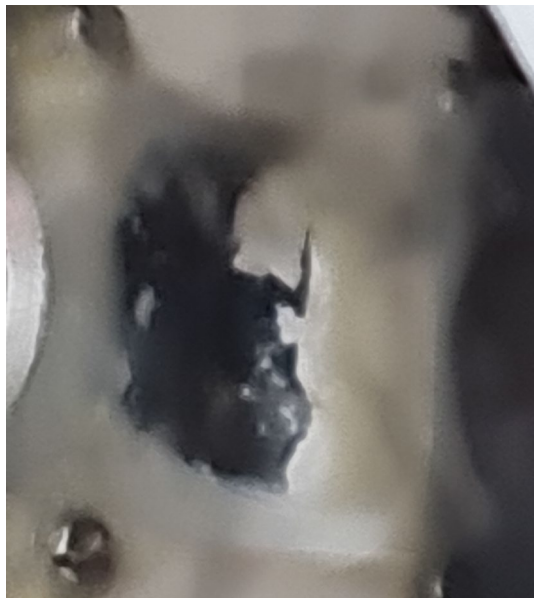


Díaz Olivares et al. (2020). Online milk composition analysis with an on-farm near-infrared sensor. Comput. Electron. Agr. 178:105734.

Long-term validation

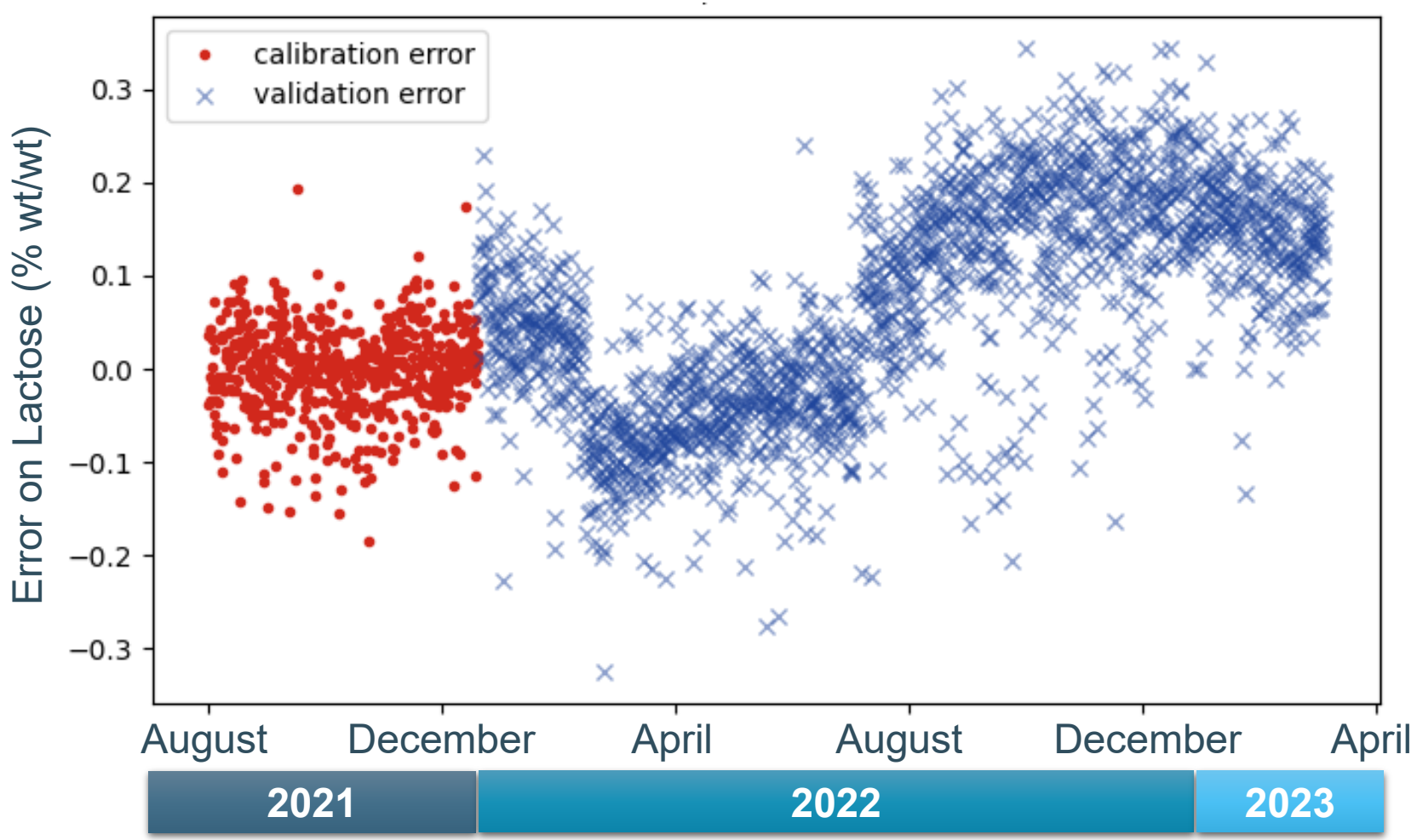






Long-term validation

1200 calibration samples
3400 validation samples



van Nuenen et al. (2024). On-farm NIR sensor for milk analysis: Exploitation of bias monitoring and bias correction. Spectrochim. Acta A Mol. Biomol. Spectrosc. 320:124544.

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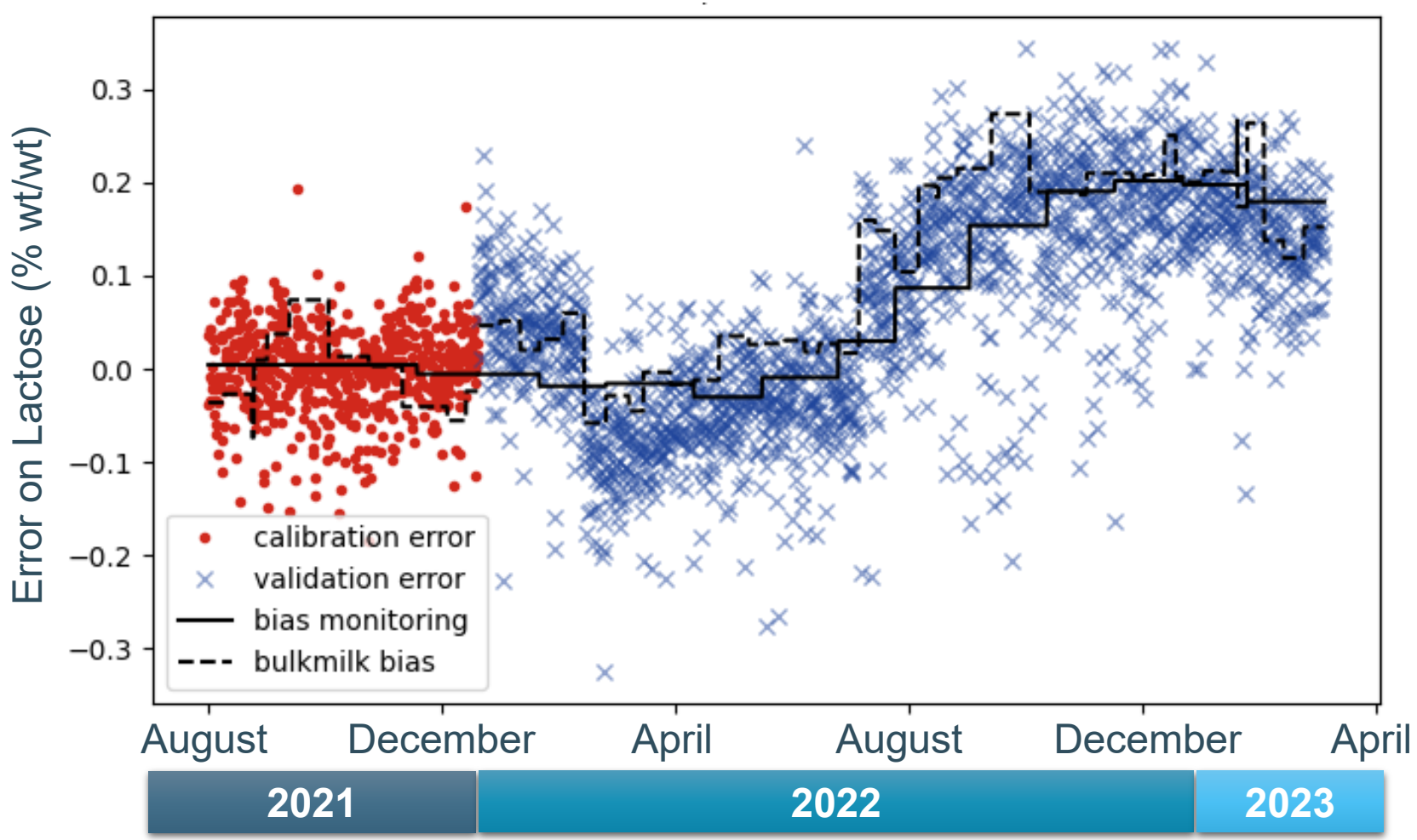

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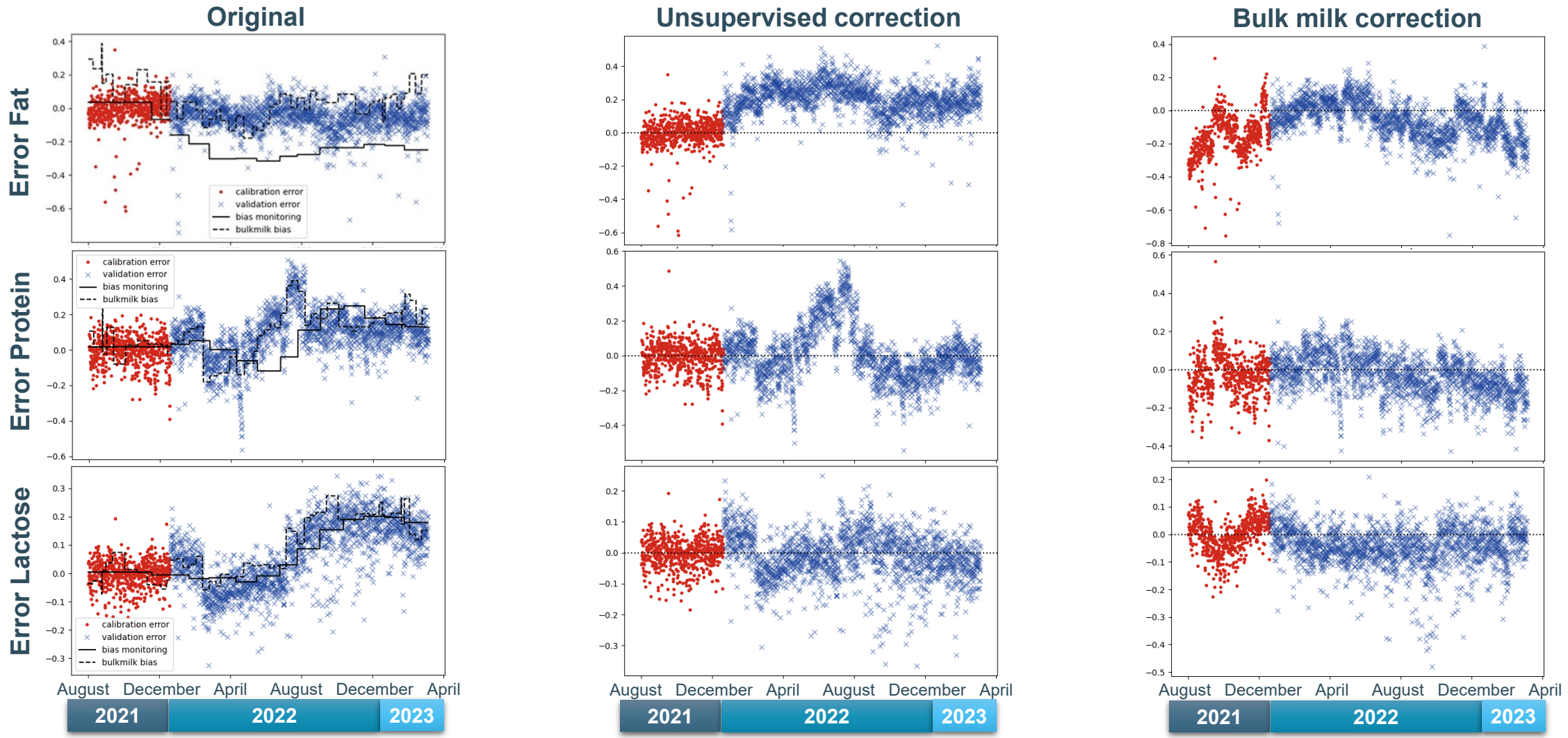


van Nuenen et al. (2024). On-farm NIR sensor for milk analysis: Exploitation of bias monitoring and bias correction. Spectrochim. Acta A Mol. Biomol. Spectrosc. 320:124544.

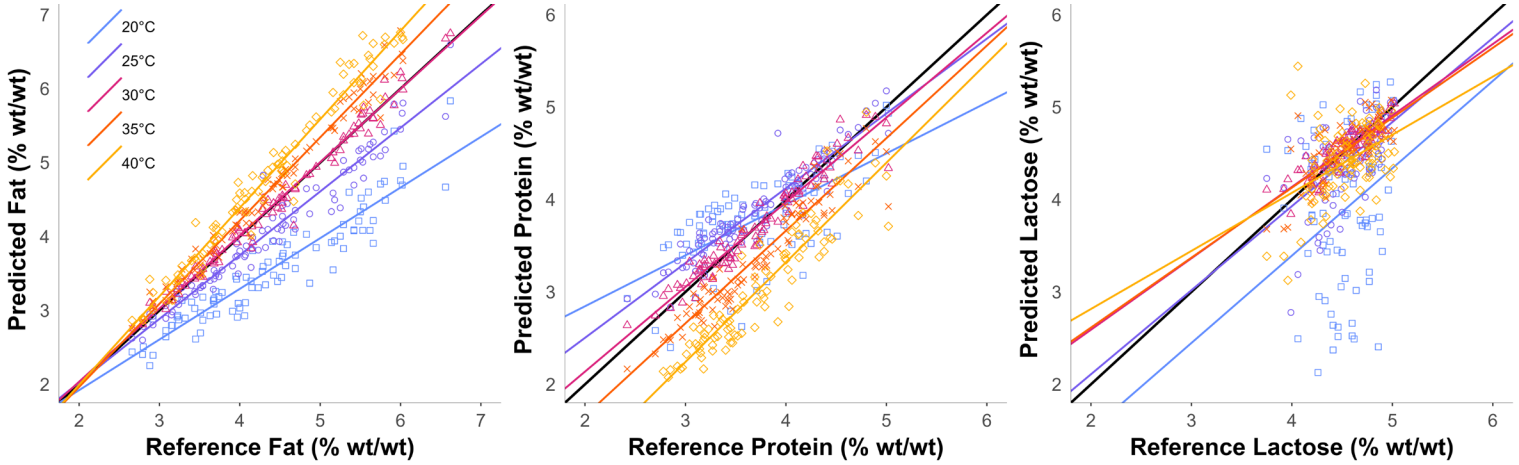
Long-term validation

Component	Original	
	RMSEP	SEP
Fat	**0.12**	**0.10**
Protein	**0.35**	**0.29**
Lactose	**0.18**	**0.14**

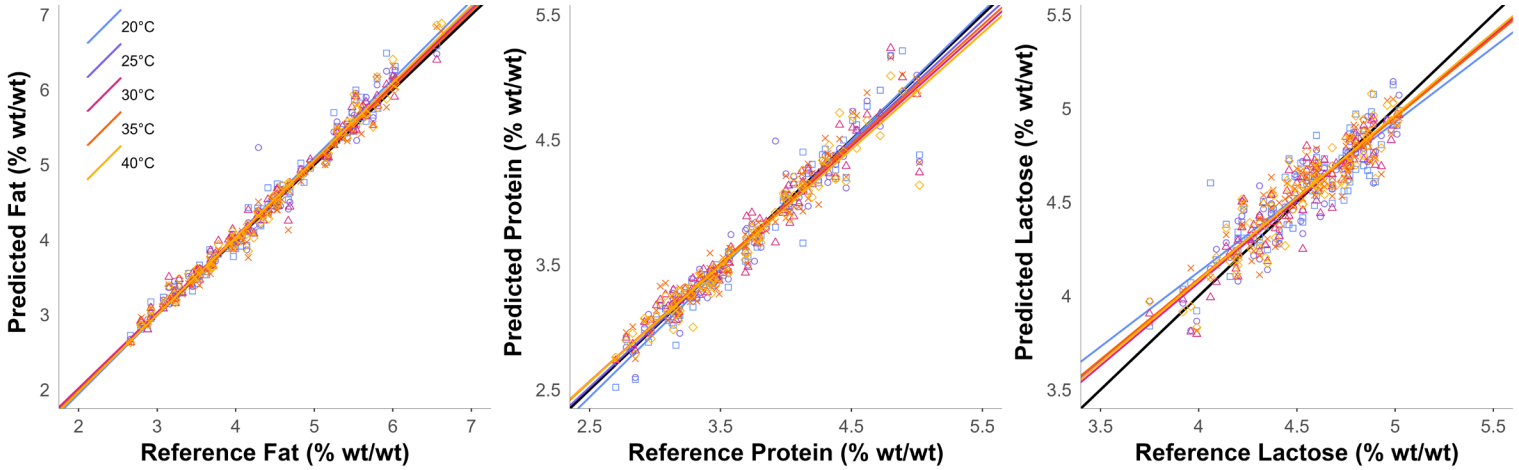
van Nuenen et al. (2024). On-farm NIR sensor for milk analysis: Exploitation of bias monitoring and bias correction. Spectrochim. Acta A Mol. Biomol. Spectrosc. 320:124544.

Effect of temperature

Calibrated at 30°C, validated at 20, 25, 30, 35 and 40°C



External parameter orthogonalization (Roger et al., 2003)



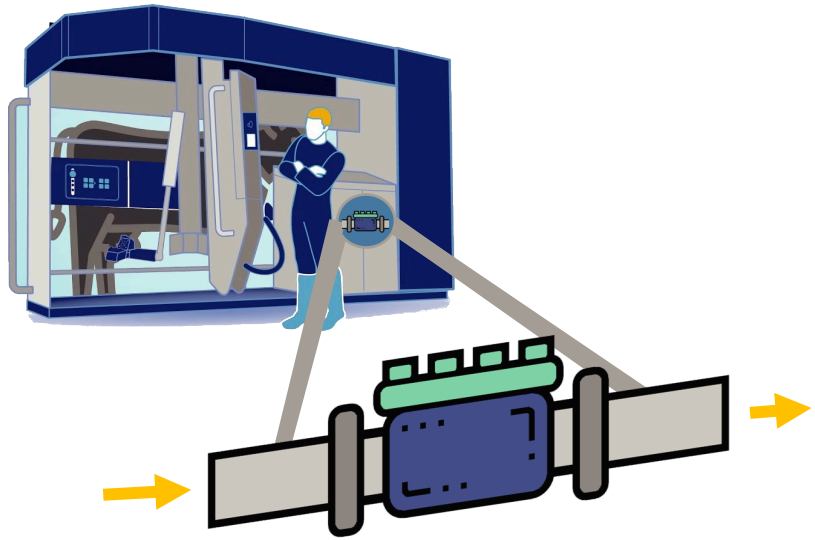
Roger et al. (2003). EPO–PLS external parameter orthogonalisation of PLS application to temperature-independent measurement of sugar content of intact fruits. Chemometrics and Intelligent Laboratory Systems, 66(2), 191-204.

Conclusions

- Accuracy commercial in-line milk composition sensors insufficient
- Higher performance is possible with more advanced technology
- Short-term performance and validation is stable
- Long-term validation exposes the main challenges and limitations
  - Maintenance
  - Extreme and harsh environmental conditions
  - Variation in the milk properties
- Bias correction and orthogonalization methods can help to improve performance

Future perspectives

- Replicates:
  - Different farm/management/feed/genetics
  - Different milking systems
  - Calibration transfer
- Inline measurements:
  - At quarter level for udder health
  - Evolution during milking process
  - Miniature spectrometers or probe technology
- Other milk components and properties
- Link with cow health



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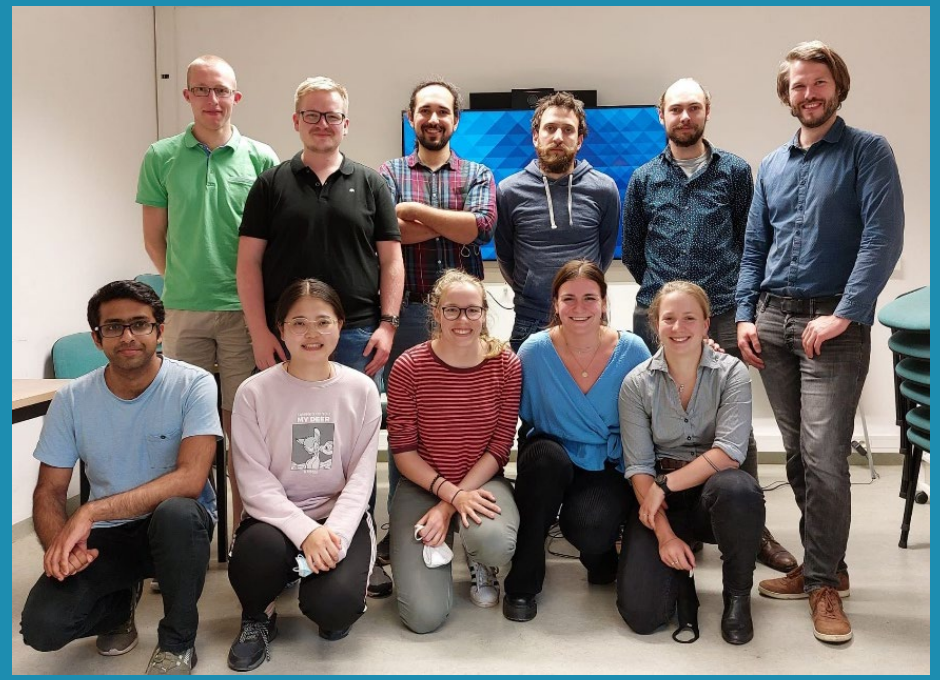
Thanks to the team!

Questions?



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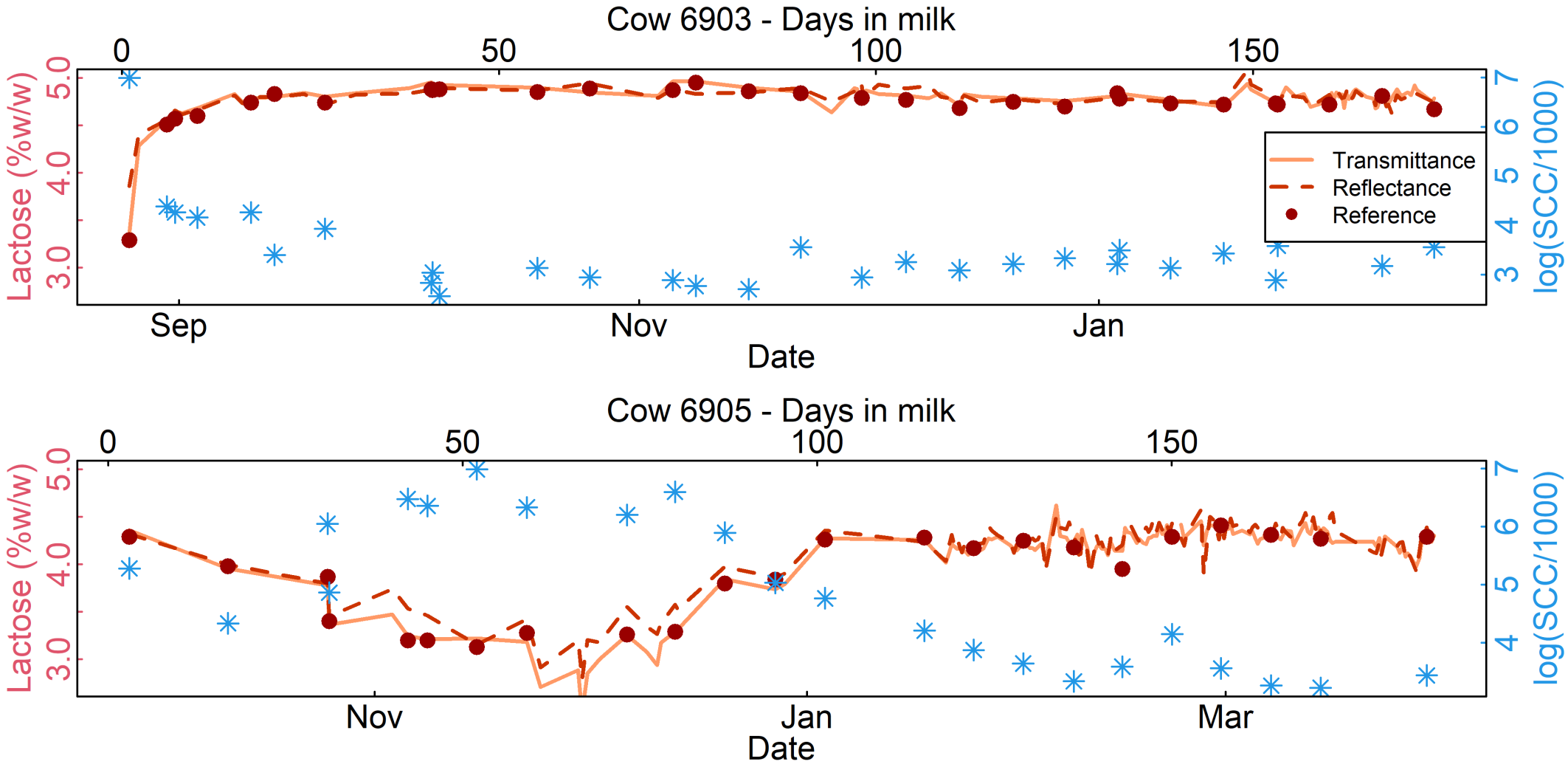
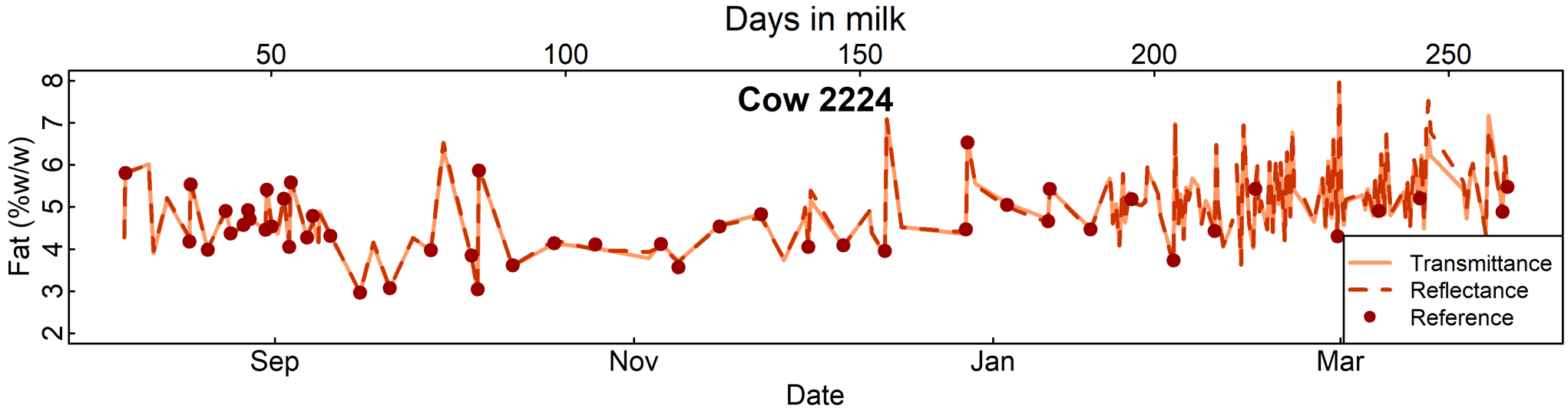
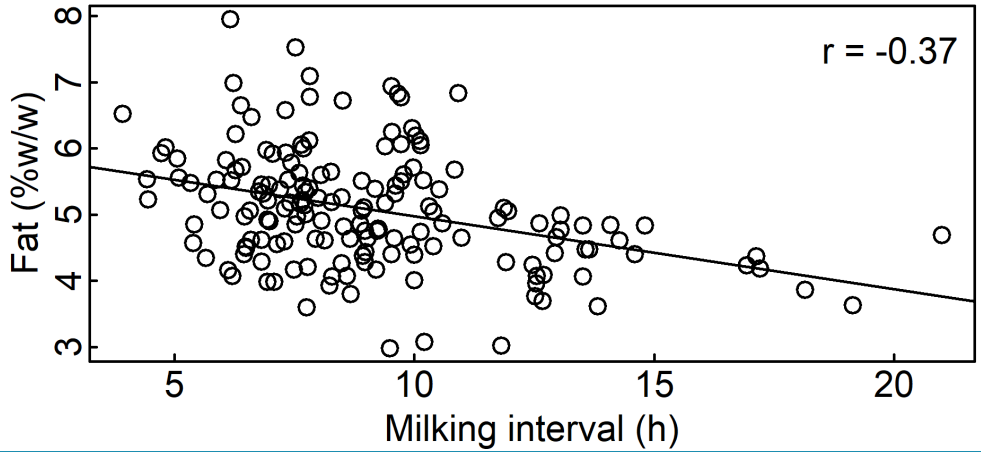
Livestock Technology

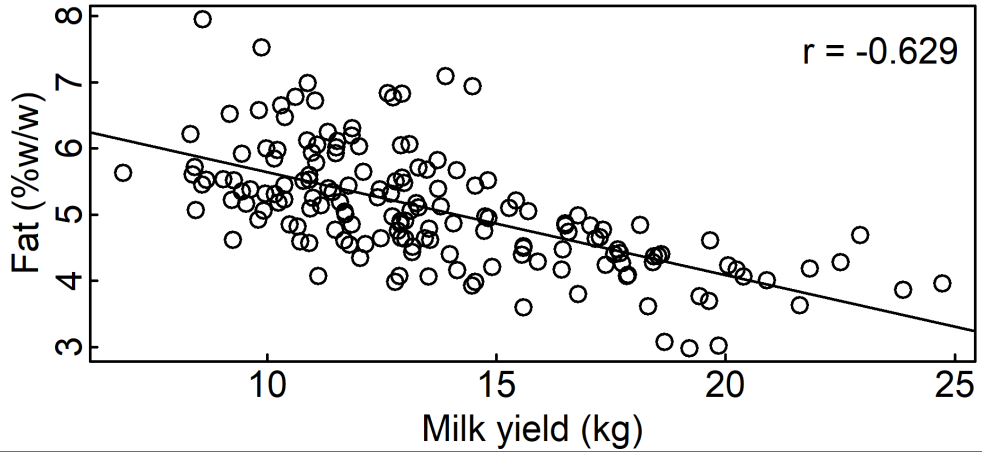
Milk composition sensors - lactose



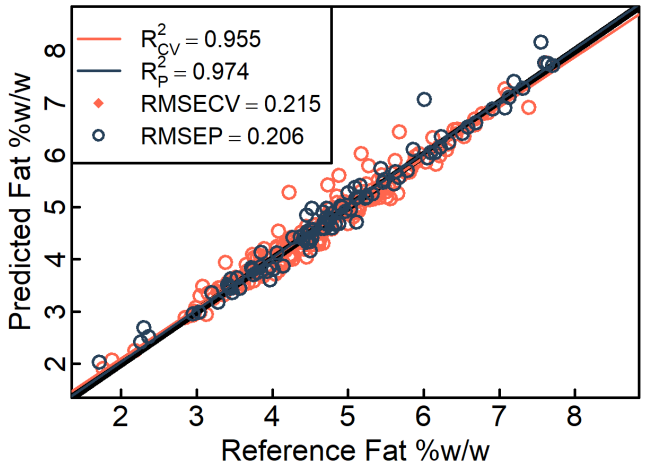
Milk composition sensors - fat

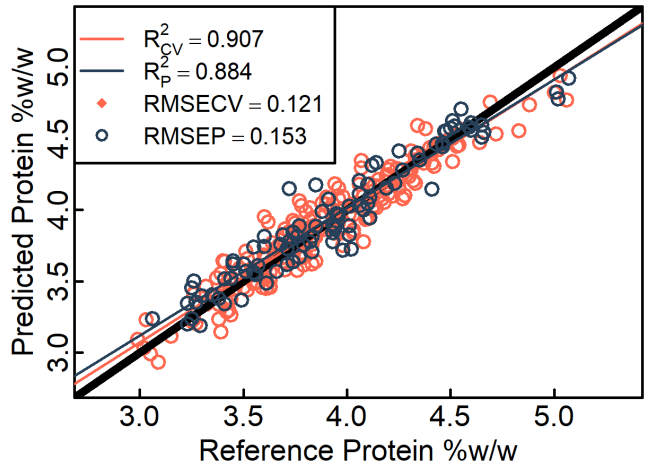


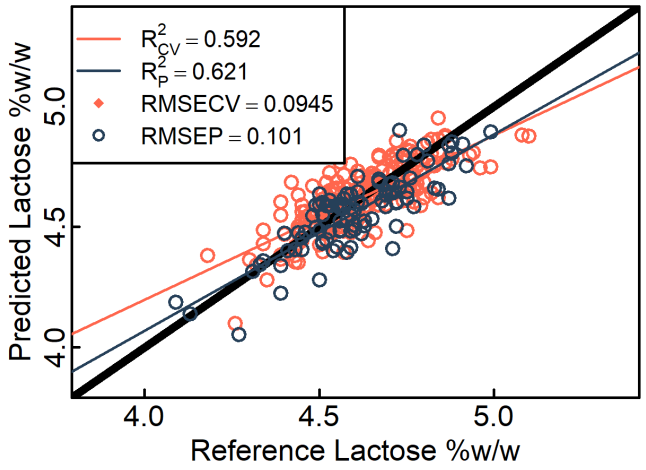




Milk composition sensors - miniaturization







Uusitalo et al. (2021). Evaluation of MEMS NIR Spectrometers for On-Farm Analysis of Raw Milk Composition. Foods. 10:2686.