# Standardization of goat milk MIR spectra and fatty acid prediction equations

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# CONTEXT & OBJECTIVES

**Mid-infrared (MIR) spectroscopy is widely used for routine analysis of cow milk but**

> No dedicated standardization network for goat milk spectra

> Few prediction equations available

**Objectives**

1. Assess whether cow-based standardization coefficients can be applied to goat milk spectra

2. Develop a goat-specific set of MIR prediction equations for fatty acids (FA) within the OptiMIR network

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# STANDARDIZATION OF GOAT MILK SPECTRA

**Principle of EMR standardization (Grelet et al., 2015, 2017)**

> Analyze of a common set of reference samples on every instrument
> Correction of spectra of each instrument (slave) to match a reference instrument (master)
> Designed and validated for cow and ewe milk

**Two standard sample sets compared on 1 master instrument and 6 slave instruments**

> Cow set: 5 raw cow milk samples, the EMR network set
> Goat set: 5 raw goat milk samples, prepared for this study

**Independent validation**

> 20 individual goat milk samples
> 4 prediction models used to compare the two options: fat, C6:0, polyunsaturated FA, lactoferrin

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# STANDARDIZATION: VALIDATION RESULTS

| Trait (model $R^2$) | No standardization mean RMSE | Cow set mean RMSE | Goat set mean RMSE | ANOVA p-value |
|---|---|---|---|---|
| **Fat content ($R^2$ = 0.99)** | 0.176 g/100 mL | 0.062 g/100 mL | 0.072 g/100 mL | 0.019 * |
| **C6:0 ($R^2$ = 0.91)** | 0.0059 g/100 mL | 0.0024 g/100 mL | 0.0046 g/100 mL | 0.021 * |
| **Polyunsaturated FA ($R^2$ = 0.77)** | 0.044 g/100 mL | 0.009 g/100 mL | 0.017 g/100 mL | 0.001 ** |
| **Lactoferrin ($R^2$ = 0.66)** | 111 mg/L | 83 mg/L | 91 mg/L | 0.651 ns |

## Take-away

Cow-based standardization coefficients distributed by the EMR network can be used for routine goat milk analysis without loss of accuracy
→ **No need to maintain a dedicated standardization network for goat milk.**

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# TEST OF EXISTING FATTY ACID EQUATIONS

**Test of two existing fatty acid (FA) equation sets on 100 goat milk samples**

- EMR cow milk equations (CRA-W / ULiège, after Soyeurt et al., 2011) : designed for cow milk
- Phénofinlait goat equations (Ferrand-Calmels et al., 2014) : built on no-standardized spectra and on a small goat population

**Both equation sets showed significant systematic deviations for most FA.**

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# New fatty acid equations

## Reference dataset

**345**

**goat milk samples**

*collected in 2024 — 2025*

- 21 commercial farms
- Alpine + Saanen breeds
- Full range of lactation stages

## Diet diversity

**Basal diet**

- Grass silage
- Maize silage
- Hay (grass / lucerne)
- Pasture
- Straw + concentrates

**Complement**

- None
- Protected fat (MGPV)
- **Sunflower (seeds)**
- Linseed meal
- Linseed concentrates

## Two analyses on each sample

**Gas chromatography**

Reference fatty acid composition

**MIR spectrum**

212 OptiMIR wavelengths

***1st derivative pre-treatment***

## Stratified split

| Calibration | Val. |
|---|---|
| 257 samples | 88 samples |

*Stratified on diet × complement*

## Methods

- PLS on 212 / 446 wavelengths
- SVM on 212 / 446 wavelengths

## Performance (validation set)

| Bias | RMSEP | $R^2$ | RPD |
|---|---|---|---|

# RESULTS: 84 GOAT-SPECIFIC FA EQUATIONS

**12**

**Excellent fit**
**$R^2 > 0.90$**

*Short- and medium-chain saturated FA, total C18:1, C18:1 cis-9, MUFA*

**15**

**Good fit**
**$0.80 < R^2 \leq 0.90$**

*C15, C16, C17, individual MUFA, PUFA, omega-6*

**23**

**Acceptable**
**$0.60 < R^2 \leq 0.80$**

*Branched-chain FA, several individual C18:1 and C18:2 isomers*

**34**

**Lower**
**$R^2 \leq 0.60$**

*Minor / very low-concentration FA*

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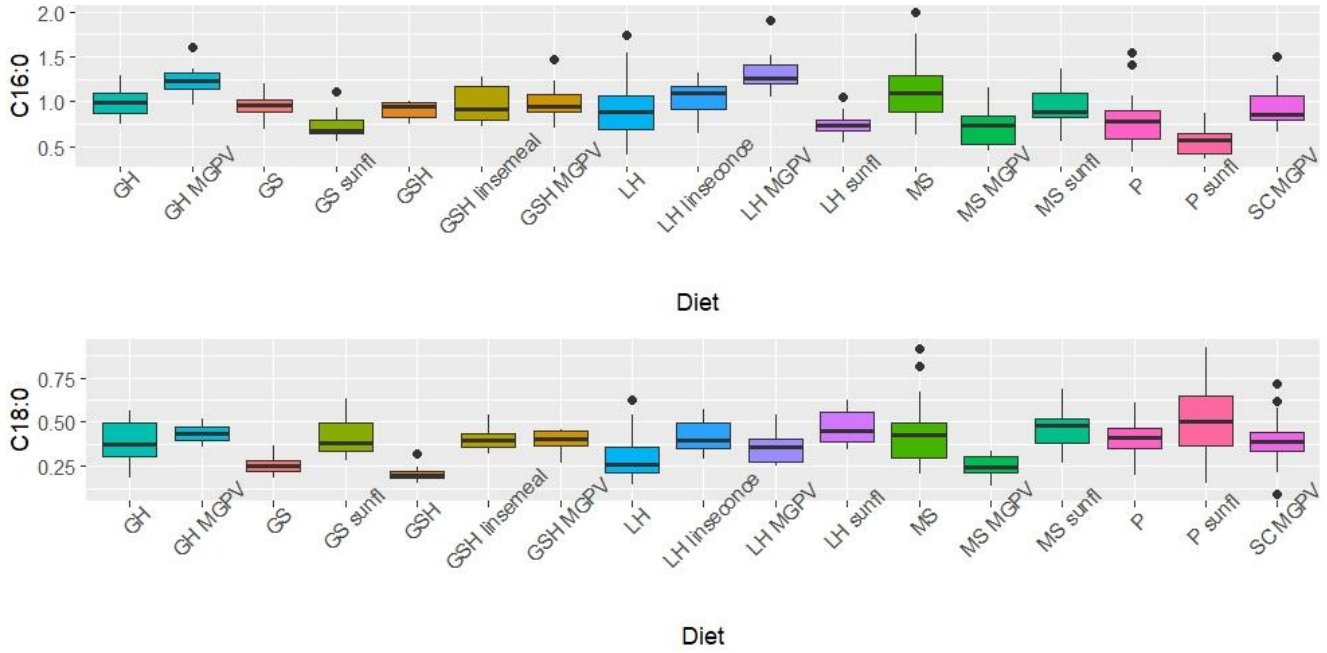
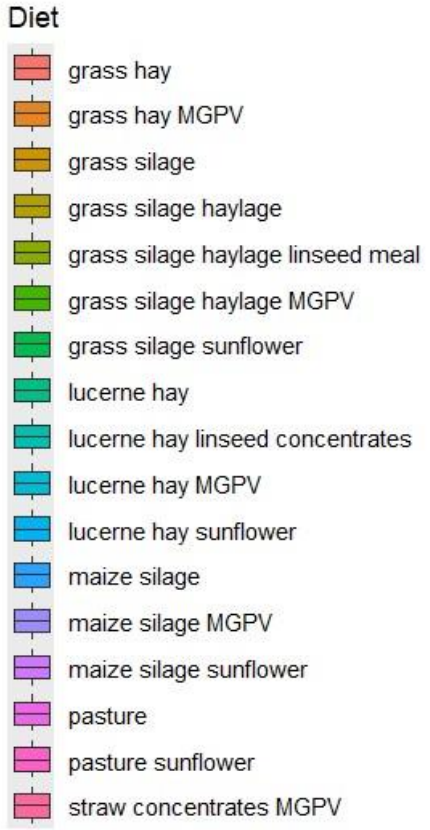
# DIET EFFECT

> C16:0 equation $R^2 = 0.83$ — good but lower than other major FA

> Residuals of C16:0 prediction are correlated with C18:0 reference values




**The diet changes the C16:0 / C18:0 relationship:**

Without specific lipid supplementation: moderate correlation between C16:0 and C18:0 (r=0.54)

**With sunflower oil r=0.14**

**→ A single global equation cannot fit both situations equally well**

# PERSPECTIVES

## To do : build diet-aware FA prediction equations

Combined effect of basal diet and complement = 30–80 % of the variance of the major FA.

Farm and diet effects partially confounded

Joint PLS2 (C16:0 + C18:0 together) : no clear gain

Predicting the complement (5 classes) from the MIR spectrum alone : about 66 % balanced accuracy

## Next step: the CASMIR project (2025-2029)

*From OptiMIR equations to an on-farm energy-status indicator and fine-tuned feeding management for dairy goats*

**Action 1 — Prediction of energy status from body weight dynamics**
**Action 2 — Prediction of energy status from MIR milk spectra**
**Action 3 — Development of a feeding-management method based on energy status**

PARTENAIRES

# TAKE-HOME MESSAGES

**Standardization of goat milk MIR spectra**

- > **Cow milk standard samples (EMR network) can be used to standardize goat milk spectra in routine**
- > Same conclusion as for ewe milk (Grelet et al., 2019)
- > **Three dairy species, one common standardization**

**Fatty acid prediction in goat milk**

- > **A new goat-specific set of 84 MIR equations is available through the OptiMIR network**
- > 27 equations with $R^2 > 0.80$ — including all main short- and medium-chain saturated FA, total C18:1, MUFA
- > **The predictive accuracy of C16:0 / C18:0 may be influenced by diet**

**Next steps**

- > Routine deployment of the new equations in French MRO
- > Build diet-aware FA prediction equations
- > **Managing dairy goat nutrition by estimating the energy status through milk mid-infrared spectra**

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# Thank you for your attention!

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