# FeMIR: MIR Spectral predictions for feed and energy efficiency. Practical Application

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## Abstract

Mid-infrared spectrometry (MIR) is a commonly used and cost-effective method for analyzing milk composition. By utilizing infrared light, MIR spectroscopy reveals specific absorption patterns in milk samples, providing detailed information on its chemical constituents. European Milk Recording (EMR) is a key provider of MIR services, offering standardization and predictions through collaboration with former OptiMIR Project - milk recording organizations (MROs). Researchers have shown the potential of MIR in predicting milk components like fatty acids and minerals, as well as biomarkers and complex traits such as ketosis and mastitis. By analyzing fatty acid patterns in milk spectra, MROs can estimate various traits related to animal health and productivity. Recent projects like eMissionCow and ReMissionDairy optimized calibration equations, improved farm management practices and validated the MIR methane ($CH_4$) equation developed in CRA-Wallonie. The data derived from these equations can help in making informed decisions on feeding practices and climate impact at different levels of animal production. Continuous updates and inclusion of reference data are essential for the advancement of this field in the global context. FeMIR is a new tool developed by LKV Baden-Württemberg for farmers and consultants to improve monitoring of animals' metabolism. The FeMIR report, developed as part of the ReMissionDairy and eMissionCow projects, offers a comprehensive overview of the herd's energy status throughout lactation phases. Over the past two years, the FeMIR report has been successfully tested in practice by four field workers and three consultants. A field test was conducted comparing new parameters such as energy, feed and nitrogen efficiency, and fatty acids (FA). DeNovo and Preform FA were compared with livestock on trial farms. Farm visits were made to different parts of Baden-Württemberg to establish guidelines for these new parameters. The report included MIR spectral data from monthly milk recordings, feed samples, and examinations of animals according to FeMIR. Thresholds and limits for individual parameters were determined to define an optimal framework for farms. The physical condition of animals on site confirmed experts' expectations derived from the report's efficiency and energy parameters. Participants rated the FeMIR report as a valuable tool for feeding and metabolic control of animals.

*Keywords: MIR, spectral data, dairy cows, FeMIR, feed efficiency, methabolic control, herd management.*
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## Introduction

Climate change presents numerous challenges across all sectors of human activity today. The increasing frequency and duration of extreme weather events, such as droughts, along with the rise in global temperatures, pose a greater risk to farms in terms of water scarcity and animal well-being (Huber and Gulledge, 2011). This is particularly evident in livestock systems, which are impacted by the consequences of global warming (Kuczynski *et al*., 2011) and contribute significantly to greenhouse gas emissions, including carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$) (Lesschen *et al*., 2011). In this context, it is crucial to mitigate the impact of climate change on agriculture and animal production, as well as address the contribution of these sectors to the issue. This is essential in ensuring a sustainable food supply for a rapidly expanding global population (Bauer *et al*., 2016).

An essential aspect of achieving these objectives involves utilizing Mid Infrared (MIR) spectral data. Studies have demonstrated the capability of MIR in forecasting milk components such as fatty acids and minerals, along with biomarkers and intricate traits like ketosis and mastitis. Recent initiatives like eMissionCow and ReMissionDairy have been enhancing calibration equations, refining farm management techniques, and validating the MIR methane ($CH_4$) equation established at The Walloon Agricultural Research Center (CRA-Wallonie) (Dale *et al*., 2023). The information obtained from these equations can assist in making well-informed decisions regarding feeding practices and the environmental impact at various stages of animal production. Regular updates and the incorporation of reference data are crucial for the progress of this field on a global scale. Feed and energy efficiency Mid Infrared (FeMIR) is a novel tool created by the Regional Association for Performance and Quality Inspection in Animal Breeding of Baden Württemberg (LKV BW) to enhance the monitoring of animals' metabolism for farmers and consultants.

The FeMIR report provides a thorough assessment of the herd's energy levels throughout various lactation stages. Field workers and consultants have successfully trialed the FeMIR report over the last two years. The report incorporates Mid Infrared (MIR) spectral data from monthly milk recordings, feed samples, and animal assessments based on FeMIR criteria. Threshold values for specific parameters were established to establish an ideal framework for farms. The actual state of the animals on the premises validated the experts' predictions based on the report's effectiveness and energy metrics. Participants deemed the FeMIR report as a valuable resource for managing the feeding and metabolism of dairy cows. Consequently, ongoing efforts will assist farmers in the Upper Rhine region and beyond in enhancing feed efficiency, lowering greenhouse gas emissions, and mitigating their contribution to climate change.

## Material and methods

In recent years, LKV BW has been involved in various international and national projects focused on calibrating different MIR models. One such project was eMissionCow, which aimed to enhance feed intake, feed efficiency, and reduce $CH_4$ emissions in German cattle populations. Accurate individual animal data from experimental farms played a crucial role in developing the models integrated into the LKV BW FeMIR tool. Approximately 900 cows with standardized MIR spectral data provided information on energy balance (EB), the EB were calculated in accordance with GfE (2001), feed efficiency (FE) calculated as kg ECM/kg dry matter, and energy efficiency (EE) calculated as kg ECM/MJ NEL (Lidineck, *et al*., 2021) for key German breeds like Holstein, Simmental (Fleckvieh), and Brown Swiss (Braunvieh) across 13 German teaching and experimental farms (Dale *et al*., 2019). Additionally, with the help of the eMissionCow project 20 Simmental cows were studied in climate chambers to enhance the robustness of the CRA-Wallonie model for $CH_4$ emissions.


*Figure 1. Milk analysis using mid-infrared (MIR) spectra.*

Another MIR project involving LKV BW was ReMissionDairy, which aimed to leverage modern technologies to develop practical tools for feed management that assist dairy farmers in optimizing production efficiency and reducing their farm's emission impact. Both ReMissionDairy and eMissionCow were complementary initiatives focused on decreasing $CH_4$ emissions and enhancing feed efficiency. ReMissionDairy was focussed on the individual herd management, while the eMissionCow was focussed on the individual animal.

How does MIR spectral analysis function? It is both straightforward and somewhat intricate. As illustrated in Figure 1, when infrared light is directed at a sample, only specific frequencies are absorbed, resulting in a characteristic spectrum for that substance. The intensity of absorption is influenced by the substance's concentration in the sample. A significant development from the OptiMIR project is the capability of MIR spectrometers to not only analyse primary components but also fatty acids, minerals, lactoferrin, beta-hydroxybutyric acid (BHB), acetone, and citrates. Additionally, complex attributes can be identified. For instance, models for ketosis, energy balances, and $CH_4$ emissions were established as part of various projects.

The data utilized for modeling was prepared by TiDa (Tier und Daten GmbH) as part of the OptiKuh, OptiKuh2, and eMissionCow projects. This data now serves as the foundation for calculating the FeMIR parameters. Through collaboration with OptiMIR/EMR, the Methagene group, and the European project GplusE at CRA-Wallonie, a methane equation incorporating SF6 and climate chamber measurements was developed. This equation was made accessible not only to EMR members but also to the German Association for Performance and Quality Testing (DLQ) through the eMissionCow project. Within this project, the methane model was expanded to include climate chamber measurements on Simmental cows. The inclusion of the southern breed Simmental and various feed rations enhanced the data variability and strengthened the equation's reliability.

The data used for statistical analyses and machine learning consisted of spectral data from Bentley FTIR analysers, which had been standardized using the European Milk Recording (EMR) and CRA-Wallonie procedures (*Grelet et al., 2014*). The first derivative was computed from the absorbance values of the spectra, and 212 relevant

wave numbers were selected. New parameters have been predicted with the help of the spectral models such as energy balance (EB-NEL), energy, feed, and nitrogen efficiency (EE, FE and NE - calculated as ratio of the amount of milk protein produced to the amount of crude protein consumed), and fatty acids (DeNovo and Preform FA). Different packages in the "R" statistical analysis software were employed to validate the models. Subsequently, the data was utilized to provide guidance to farmers at both herd and individual levels.

## Results and discussion

The LKV BW identified a growing necessity to enhance herd management concerning energy provision by incorporating additional MIR parameters. The FeMIR report emphasizes the energy balance within the herd, integrating various MIR parameters such as EB-NEL, energy efficiency, and feed efficiency from collaborations with DLQ, the OptiKUH Consortium, and LKV BW. Additionally predictions for fatty acids from the OptiMIR/RobustMilk equation, methane emission per day from the MethaMIR equation developed by CRA-Wallonie, and nitrogen efficiency utilizing forage analysis and milk recording data were included (see Figure 2).

The report presents fatty acids as a percentage of total fat (100%) rather than in relation to their content in milk, as per Barbano *et al*. (2019). DeNovo fatty acids are directly linked to rumen functionality and were therefore chosen for visualization in the FeMIR tool. In addition to utilizing and interpreting the report, specific limits for each parameter were identified and established to define an optimal framework for farm management (see Table 1).

Understanding the factors at play, it is important to note that the breakdown of plant cell walls in the rumen primarily produces acetic acid and butyric acid. These acids travel to the udder through the bloodstream, where the mammary gland converts acetic acid into short and medium-chain fatty acids, indicating the conversion of feed protein into milk protein. Low values may suggest low feed intake, excessive crude fat content, poor digestibility of cell walls, or inadequate rumen fermentation. Preform

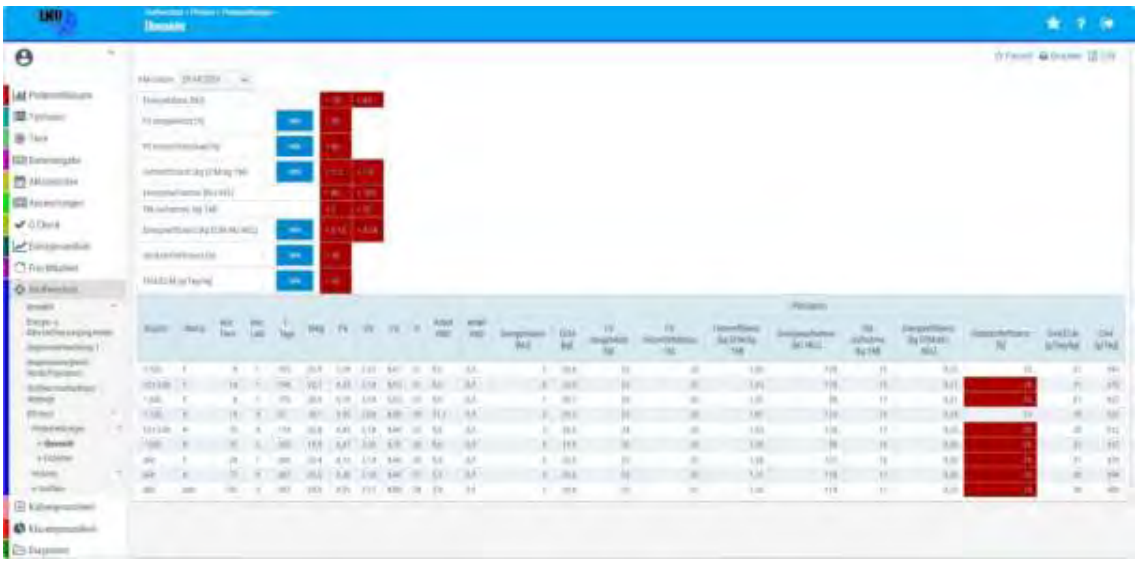

*Figure 2. FeMIR - MIR parameters that indicate the energy condition of the entire herd..*

fatty acids provide insights into the conversion of fatty acids broken down from body tissues. Elevated values indicate a high breakdown of pre-formed (long-chain) fatty acids from body fat.

*Table 1. Optimal ranges of values for herd management.*

| Parameter | Low Value | High Value |
|---|---|---|
| EB [MJ NEL] | < -30 | > 40 |
| FA Denovo [%] | < 20 | |
| FA Preform [%] | | > 50 |
| FE [kg ECM/kg DM] | < 1.2 | > 1.8 |
| EI [MJ NEL] | < 80 | > 180 |
| DMI [kg DM] | < 5 | > 25 |
| EE [kg ECM/MJ NEL] | < 0.12 | > 0.36 |
| NE [%] | < 30 | |
| CH4/ECM [g/day/kg] | < 10 | |


*Figure 3. FeMIR - MIR parameters that reflect the energy status of the cow or herd.*

As part of the ReMissionDairy project, the FeMIR tool was developed for use by farmers and consultants. The FeMIR report shows cases with milk MIR parameters that indicate the energy status of either the individual cow or the entire herd. The variation of the values are larger on individual cow level, than on herd level.

The DeNovo and Preform fatty acids are presented alongside results from milk recording data, including energy corrected milk (ECM), fat (F%), protein (E%), lactose (L%), urea (H), NEL energy balance, feed efficiency, energy efficiency, as well as $CH_4$ and $CH_4$ per kg ECM. Energy-related MIR parameters are color-coded to highlight values outside the normal range. It is evident from the visualization that issues arise at the start of lactation, with negative EB-NEL values indicating a problem.

During fieldwork within the ReMissionDairy project, the FeMIR report underwent testing to establish the limits for each parameter and determine an optimal framework for herd management. Consultants and techniciens of the LKV were involved in evaluating the output on test animal and -herd level.

The physical condition of the animals observed on-site aligned with the experts' expectations derived from the efficiency and energy parameters in the report.

Feed efficiency, as shown in Figure 3, is the ratio of milk produced in kg ECM to feed consumtion in kg dry matter (DM). In individual animals, high efficiency can be falsely indicated by fat decomposition. To improve feed efficiency at the farm level, it is important to reduce maintenance requirements (such as cow weight relative to performance) and avoid overconsumption. This information applies to all components mentioned in the introduction. The next most important component after feed efficiency is energy balance (EB), which can be visually observed when animals have lower EB values during mid-lactation. DeNovo fatty acids provide insight into newly formed fatty acids in the udder and rumen functionality, with lower values indicating low feed intake and cell wall digestibility. Preform fatty acids indicate high digestibility degradation with high values. The final component in the FeMIR report is methane ($CH_4$) emissions and $CH_4$ per kg ECM, which can help monitor emissions and implement measures to reduce methane production. All participants rated the FeMIR report as a valuable and effective tool for managing feeding practices and monitoring animal metabolism. But differences between the informative value of the parameters have been found: according to the consultants of the LKV the feed efficiency value should not be used as "stand alone" parameter due to higher variation, but can be used combined with the energy balance. The energy balance in contrary is a meaningful value regarding to feed management, as is methan emission ($CH_4$). The parameters are particularly expressive on herd level, while critically seen on animal level. The farmers themselves however benefit most of the output $CH_4$. The LKV herd manager was created as part of the Cattle Network cooperation (RDV) and is planned to be utilized by all RDV partners. FeMIR has the potential to be used for all RDV cows in the future, totalling approximately 2.3 million cows. Additionally, the pilot farms' initial data and research data for each MIR parameter are also accessible.

## Conclusions

The FEMIR report tested on-site showed, that the physical condition of the animals observed confirmed the experts' expectations derived from the efficiency and energy parameters in the report. A distinction is made between the usefulness and informative value of the individual parameters. While the feed efficiency can only be used together with the values of the energy balance, the latter is informative enough on its own. On animal level, the report has still to be improved. But all participants agree, that the FeMIR report is a valuable and effective tool for managing feed and monitoring animal metabolism on herd level. Further research is needed on animal level and to investigate

the impact of heat stress on efficiency indicators to assess how climate change and heat stress affect cows feeding systems.

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