Challenges and opportunities in the use of milk MIR spectra: experiences learned from the OptiMIR and HappyMoo projects and beyond

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Abstract

Milk mid-infrared (MIR) spectral data is a rich source of information. Even if the technology has been known for decades, exploring its capacities beyond the estimation of major milk components is rather new. Experiences have shown the necessity to develop high levels of cooperation between industry and science but also across countries. The former North-West European Interreg project OptiMIR created an innovative European network of Milk Recording Organizations (MROs) that shared existing tools and approach of services to farmers, harmonized the way to record key data and allowed the access to the latest technology in getting information out of milk analysis. The tools developed by OptiMIR also allowed MROs easier development of implementations of MIR-based predictions and tools. One major achievement was to develop a method allowing the standardization of different MIR spectrometers across laboratories, and brands of apparatus. This standardization is now available to industry through an association of European MROs called European Milk Recording (EMR). Amongst the most important current issues in dairy herd improvement is the research of technologies for health and welfare monitoring. The current North-West European Interreg project HappyMoo develops novel strategies, methods, and tools to address this taking up the linked challenges but also feeding on opportunities in the use of MIR spectra. Amongst the five freedoms of animal welfare, we are addressing especially three, the absence of disease, hunger and stress. The ongoing research shows the importance of clear final objectives, precise trait definitions and collaborative work of industry and science. Among the topics that will be exemplified are the difficulties to combine reference data across systems (scales x implementation) for lameness, the problems to use sensor data provided in the field for BCS, the issue of synchronising reference and MIR data and the design of experiences to generate the needed reference data. The obtention of correct, variable, and validated reference data is one of the major challenges. Particularly considering more the biological background, but also concepts like deep phenotyping and molecular phenotypes will play certainly also a role in the future. Moreover, MIR-based phenotypes are always linked to the availability of the, at the most monthly, MIR data and innovative ideas are needed to go beyond this limitation. Advances in computational strategies will be needed as the use of pre-defined calibrations should be replaced by more advanced cloud-based learning and decision-making algorithms integrating sensors or other on-farm technologies.

Introduction

Importance of fine milk composition for dairy cow management and breeding was already highlighted by several previous reviews (e.g., Gengler *et al.,* 2016) and the use of milk mid-infrared (MIR), often also called FT-MIR, for Fourier-Transform MIR as currently predominant implementation, spectrometry (e.g., De Marchi *et al*., 2014) has been recognized in this context. The technology has evolved for decades but until rather recently in milk analysis its use was limited to major milk components. This document draws major conclusions on the challenges and opportunities in the use of milk MIR spectra in the context of management and breeding. Emphasis will be given to the experiences learned from the OptiMIR and HappyMoo projects and additional aspects beyond these will be highlighted.

Context

Large-scale phenotyping using milk MIR spectra was extensively developed during the last years. This phenotyping has become an important source of improvement in herd management, animal genetic evaluation, and control of quality of milk and subsequently milk products. But as highlighted by Grelet *et al.* (2021) key factors affect the quality of prediction. As a matter of fact, a priory the milk MIR spectra are very similar to marker genomic data and needs to be “calibrated” to make it a posteriori useful. Currently extensive research is ongoing to advance in the understanding of the requirements to achieve high quality prediction equation. Research illustrated the need to address several issues as the precise definition of the target trait (reference phenotype) and its nature, the excellent control of the variability in reference and MIR data, both in the calibration datasets but also the application datasets. Also, some merely technical issues were highlight as the potential difficulty to get access to raw spectra and the need to harmonize spectra coming from different brands models and machines, but also improve stability over time. All these experiences have shown the necessity to develop high levels of cooperation between industry and science but also across countries.

OptiMIR and HappyMoo

From 2009 to 2015 supported by 3.7 M€ European Union funding through the North-West European Interreg scheme the OptiMIR project (https://keep.eu/projects/6989/OptiMIR-new-tools-for-a-more-EN/) joint 11 milk recording organizations, 1 lab and 5 research units creating an innovative European network of Milk Recording Organizations (MROs). Figure 1 gives the partnership but also the geographical distribution across 6 countries. These MROs shared existing tools and approach of services to farmers, harmonized the way to record key data and allowed the access to the latest technology in getting information out of milk analysis. Very relevant was the joint acquisition of reference data covering the variability across the different production systems but also the joint developments of functional specifications. This allowed MROs much easier development of implementations of MIR-based predictions and tools. From a research point of view several equations were improved, new equations initiated. One major achievement was the development of a method allowing the standardization of different MIR spectrometers across laboratories, and brands of apparatus (Grelet *et al.,* 2015). This standardization is now available to industry through an association of European MROs called European Milk Recording (EMR) (https://www.milkrecording.eu/).

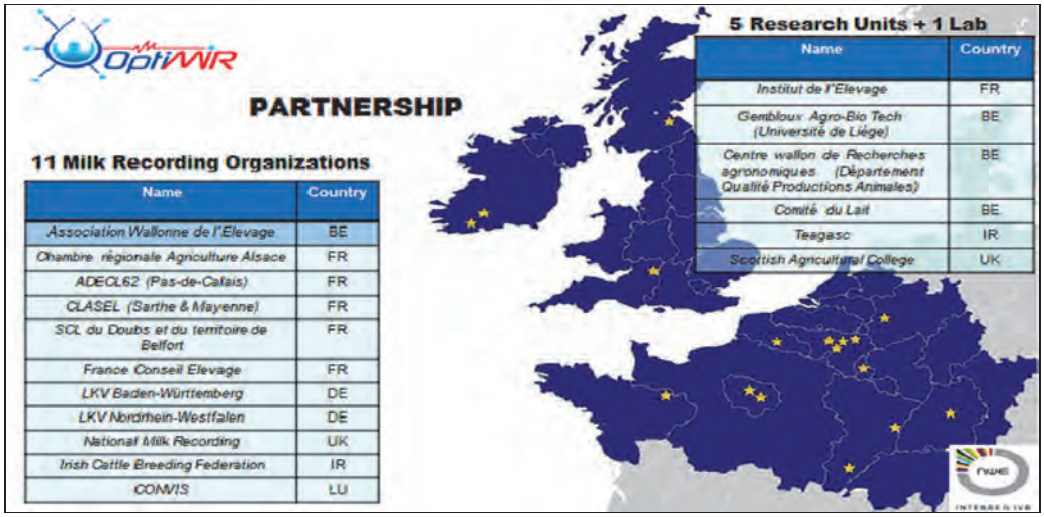

Figure 1. OptiMIR partnership and geographical distribution.

Based on this success and in order to address one of the most important current issues in dairy herd improvement, the research of technologies for health and welfare monitoring, in 2018 several of the groups involved in OptiMIR (https://keep.eu/projects/21152/Delivering-NWE-dairy-farmer-EN/) but also new partners, joint forces in 2018 for a four year project supported by 2.3 M€ European Union funding through the North-West European Interreg scheme (Figure 2). OptiMIR develops novel strategies, methods, and tools to address this taking up the linked challenges but also feeding on opportunities generated by OptiMIR.

Amongst the five freedoms of animal welfare, especially three, the absence of disease, hunger and stress are addressed by HappyMoo.

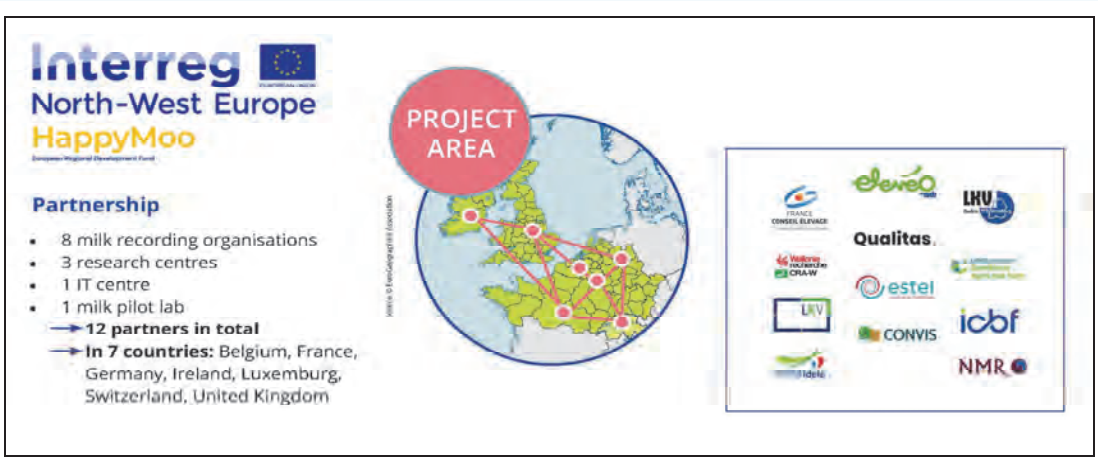

Figure 2. HappyMoo partnership and geographical distribution.

Lessons learned

The ongoing research shows the importance of clear final objectives, precise trait definitions and collaborative work of industry and science. Among the precise issues that were found were the difficulties to combine reference data across systems. This was recently exemplified for lameness illustrating the fact that harmonization is not only an issue of scales but also their implementation and use are critical. Similarly, in the context of studying BCS provided by sensors, problems to use this data, the issue of synchronising reference and MIR data and the design of experiences to generate the needed reference data is an important issue. The obtention of correct, variable, harmonized and validated reference data is one of the major challenges. Here the role of ICAR as harmonizing body comes into focus. However, if for good reasons, reference data reflects differences in traits, breeds, circumstances, the question that needs to be answered if a general prediction equation can be achieved, or even ii the preferable option. Equations adapted to specific situations could be an alternative.

Potential future challenges and opportunities

A bottleneck that MIR-based phenotypes cannot avoid is the precise definition and recording of needed high quality reference phenotypes. Novel concepts like deep phenotyping and molecular phenotypes adding more biological background will play certainly a role in the future. Moreover, MIR-based phenotypes are always linked to the availability of the, at the most monthly, MIR data and innovative ideas are needed to go beyond this limitation. Advances in computational strategies will be needed as the use of pre-defined calibrations should be replaced by more advanced cloud-based learning and decision-making algorithms integrating sensors or other on-farm technologies. Finally, all developments will have to be integrated in the development of technical, scientific, and regulatory frame works, obviously a field were ICAR but also IDF potentially through ExtraMIR (Extra value from -smart use of- MIR spectra), a new joint action team of both organisations, will be important players.

Conclusion

Uses of MIR spectra in the dairy sector are increasing. International collaboration as exemplified by OptiMIR and HappyMoo with the objectives to offer concrete solutions and tools, both for MROs but also at the end to the farmer, was recognized as a promising strategy. Despite these experiences, current challenges, and opportunities in the use of milk MIR spectra subsist and new ones appear.

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