"KetoMIR2" - modelling of ketosis risk using vets diagnosis and MIR spectra for dairy cows in early lactation

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Abstract

Ketosis is a problematic disease in dairy cattle and it is a metabolic disorder in ruminants, it is producing indigestion and decreasing food consumption; as well it may increase milk fat percentages and ketone bodies and induces a rapid decrease in milk yield. Because ketosis is associated with a wide range of characteristics that can be measured in milk and with recent advances in the estimation of milk components using mid-infrared (MIR) spectrometry, now exists the possibility to determine the composition of several additional milk or blood components such as: negative energy balance or ketone bodies: acetone and â-hydroxybutyrate and citrate milk components, or blood components, such as: BHB, NEFA, glucose und IGF1, etc. The underlying idea is currently to build spectrometric tools, for dairy cows' ketosis risk determination based on veterinary diagnosis and milk MIR spectra from routine milk recording.

The first approach, KetoMIR1, was based on milk components predicted from standardised milk MIR spectra and is routinely applied by LKV Baden Württemberg and LKV Austria since 2015 respective 2017. The objective of this study was to improve the KetoMIR1 model by directly using the milk MIR spectra and other modelling approaches. The trial data set contains around 810,496 spectral data from around 10,079 LKV Baden Württemberg and LKV Austria herds participating in health monitoring programs. The spectral data set was first pre-processed by Savitzky-Golay first derivative to remove the offset differences between samples for baseline correction, before performing Legendre polynomial modelling. To identify the main variables that were positively or negatively associated with ketosis determination, the data was submitted to logistic regression in combination with lasso parameter optimization using the "glmnet" R package. For the non-healthy group the spectral data recorded within ±14 days around a ketosis diagnosis was used. For the healthy group only spectra which had no diagnosis associated within ±60 days were used.

Furthermore, the sampling moment, lactation stage and important breeds and the Legendre polynomial data based on days in milk correction for the 212 OptiMIR selected wavenumbers of spectral data were input variables for KetoMIR2 model. The validation approach was first 10 fold cross validation and an external validation set from a lot of 11 representative farms was selected. The KetoMIR2 calibration model showed medium sensitivity (0.72) and good specificity (0.84). It has to be underlined that no information could be found in the literature of direct use of spectral data to predict the ketosis threat. The ketosis was usually detected using ketostix, blood analysis or by modelling of BHB, acetone or citrate in milk.

The KetoMIR2 model shows better classification as KetoMIR1. KetoMIR2 model probability shows high correlation with NEB, BHB and milk yield. KetoMIR2 provides three classes of ketosis warning such as not, moderately and severely endangered. The moderately endangered class is a signal for the farmer. In that case the farmer would contact the veterinary and a control would be made in order to prevent the ketosis diseases in time. The KetoMIR2 prediction can also be used in herd management to detect general feeding deficiencies in the late and early lactation transition period at herd level.

Keywords: KetoMIR, ketosis risk, ketosis detection, early lactation, MIR milk spectra, dairy cow, dairy farming

Introduction

Because ketosis is associated with a wide range of characteristics that can be measured in milk and with recent advances in the estimation of milk components using mid-infrared (MIR) spectrometry, now exists the possibility to determine the composition of several additional milk or blood components such as: negative energy balance or ketone bodies: acetone and beta-hydroxybutyrate and citrate milk components, or blood components, such as: BHB, NEFA, glucose und IGF1, etc. The underlying idea is currently to build spectrometric tools, for dairy cows' ketosis risk determination based on veterinary diagnosis and milk MIR spectra from routine milk recording. The first approach, KetoMIR1 (Hamann et al . 2017), was based on milk components predicted from standardised milk MIR spectra and is routinely applied by LKV Baden-Württemberg and LKV Austria since 2015 respectively 2017. The objective of this study was to improve the KetoMIR1 model by directly using the milk MIR spectra and other modelling approaches. Furthermore a more robust and transnationally applicable MIR model was envisioned by combining reference data and standardized spectra produced by different FTIR analyser models in different milk recording organisations.

Material and methods

The trial data set contained 810,496 spectral data from 10,079 LKV Baden Württemberg and LKV Austria herds participating in health monitoring programs at least for one year. Since ketosis is a mainly a problem in early lactation only days in milk ranging from 5 to 120 days in milk (DIM) were taken into account. The spectral data set was first standardized by applying the OptiMIR/EMR method (Grelet *et al.,* 2015) and pre-processed by Savitzky-Golay first derivative to remove the offset differences between samples for baseline correction, before performing Legendre polynomial modelling. To identify the main variables that were positively or negatively associated with ketosis determination, the data was submitted to logistic regression in combination with lasso parameter optimization (Friedman *et al.* 2010) as implemented in the "glmnet" R package. For the non-healthy group the spectral data recorded within ±14 days around a ketosis diagnosis was used. For the healthy group only spectra which had no diagnosis associated within ±60 days were used. The sampling moment, lactation stage and important breeds together with the Legendre polynomial data based on days in milk correction for the 212 OptiMIR selected wavenumbers of spectral data were input variables for KetoMIR2 model. The calibration was performed with 10 fold cross validation on a subset of 1.472 non-healthy and 793.976 healthy data records. For external validation a subset of 18 representative farms was selected consisting of 166 non-healthy records and 14.882 healthy records.

Since logit binomial classification provides a sigmoid linear probability with a standard threshold of 0.5 there is the option of using this probability as a quasi linear index for risk of ketosis. The plausibility of this ketosis risk probability has been assessed by correlating it to standard milk components, new milk MIR components like ketone bodies (Grelet C. et al. 2016), fatty acids (Grelet C. et al. 2014), minerals (Soyeurt H. et al. 2009) and MIR based blood components (BHB, NEFA, Glucose, IBF1, Insuline, Calcium) (Dale L. et al. 2019 not yet published) or traits like energy balance (NEL and ME) (Dale L. et al. 2019) with the help of the R package “corrplot”.

Results and discussions

The KetoMIR2 calibration model showed medium sensitivity (0.72) and good specificity (0.84).in the external validation set. It also shows a better accuracy than KetoMIR1.

The application of the model to the LKV-BW and LKV-AT test subsets showed nearly equal accuracy supporting the assumption that transnational model creation and application is feasible. The accuracy of the breed test subsets showed comparable results for the single purpose breeds Holstein (HOL) and Brown-Suisse (BSW) but a lower sensitivity and higher specificity for the mixed purpose breed Simmental (SIM) which can be explained by the lower prevalence of Ketosis diagnosis in the Simmental calibration set.

Table 1. KetoMIR calibration and validation statistics.

Model	Calibration Set		Test Set	
	Sensitivity	Specificity	Sensitivity	Specificity
Final Model	0,76	0,84	0,72	0,83
LKV-AT	0,76	0,84	0,72	0,81
LKV-BW	0,76	0,85	0,72	0,84
SIM	0,73	0,86	0,58	0,88
BSW	0,79	0,79	0,72	0,81
HOL	0,79	0,82	0,76	0,83

As a result of the correlation analysis of the ketosis risk probability against different milk components the probability shows high positive correlation with blood NEFA (0.79), blood BHB (0.6), aceton (0.65) and the fatty acid C18-1Cis9 (0.73) but only medium positive correlation with fat/protein ratio (0.46) and Citrate (0.25). High negative correlations were found with energy balance (EB NEL and ME) (-0.78), glucose in blood (-0.67), IGF1 in blood (-0.66) and insulin in blood (-0.55) whereas medium negative correlations were found with middle chained fatty acids C12 (-0.44) and C10 (-0.44). However for the short chained fatty acid C4 a positive correlation of 0.4 was found.

The correlations fit well with the usual metabolic effects of extreme body fat mobilisations e.g. an increased concentration of NEFA, ketone bodies and long chained unsaturated fatty acids and the concentration decrease of middle chained fatty acids and an extreme negative energy balance. (Overton T.R. 2017) The positive correlation of the short fatty acid C4 could not be explained by a special physiological role as counterpart to long chained fatty acids in order to stabilise the melting point of the milk fat. The lower correlation of the fat protein ratio shows that negative energy balance is better linked to fatty acid and ketone body profiles than to fat protein ratio.

The strong correlation with the main ketosis indicators justified the construction of a multi class scheme based on thresholds applied to the ketosis risk probability in order to overcome the restrictions of a binary classification in the central region of probability. As already done in KetoMIR-1 the probability was divided into three areas, a traffic light scheme, defining the classes as not, moderately and severely endangered associated with the colours green, yellow and red.

Since the shape of the sigmoid probability curve changes with increasing weeks in milk the probability thresholds were chosen per week of milk based on the assumption that the share of the medium and high risk classes is constantly shrinking from 5 to 120 DIM. Based on these class definitions further analysis was done showing that the prevalence of ketosis and other related diseases like displaced abomasum as well as fertility problems is higher in the endangered classes than in the not endangered class.

Conclusions

It has to be underlined that no information could be found in the literature of direct use of spectral data to predict the ketosis risk. The ketosis was usually detected using ketostix, blood analysis or by using thresholds of BHB and Acetone concentration in milk and BHB and NEFA concentration in blood. The KetoMIR2 model shows better classification as KetoMIR1. The KetoMIR2 model probability predictions show high correlation with common ketosis indicators like NEFA, BHB, Acetone and fatty acids and a stagnation and drop of the milk yield with higher probability values. KetoMIR2 provides three classes of ketosis warning such as not, moderately and severely endangered with room for a local adaption of the thresholds. The moderately endangered class is a signal for the farmer. In that case the farmer would contact the veterinary and a control would be made in order to prevent the ketosis diseases in time. The KetoMIR2 prediction can also be used in herd management to detect general feeding deficiencies in the late and early lactation transition period at herd level. KetoMIR2 has been developed in the international big data project D4Dairy – P2.2 Disease Detection with Milk Spectral Data (*https://d4dairy.com/en*, 2018 - 2022). Within this project the model will be further evaluated and optimized for use in routine herd management and breeding.

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