

Le Corps professoral de
Gembloux Agro-Bio Tech - Université de Liège vous prie
de lui faire l'honneur d'assister à la défense publique de la dissertation originale que

Madame VANLIERDE Amélie,

**Titulaire d'un diplôme de master bioingénieur : sciences agronomiques,
à finalité spécialisée,**

présentera en vue de l'obtention du grade et du diplôme de

DOCTEUR EN SCIENCES AGRONOMIQUES ET INGENIERIE BIOLOGIQUE,
le 23 août 2019, à 14h précises (personne ne sera admis après cette heure),
en l'auditorium ZT1 (Bât. 1),
Passage des Déportés, 2, à 5030 GEMBLOUX.

Cette dissertation originale a pour titre :

« Development of equations to predict methane eructed by lactating cows from milk
mid-infrared spectra ».

Le jury est composé comme suit :

Président : Prof. Y. BECKERS, Professeur ordinaire,
Membres : Prof. H. SOYEURT (Promoteur), Prof. P. DARDENNE (Copromoteur - CRA-W), Prof.
J. BINDELLE, Prof. N. GENGLER, Dr F. DEHARENG (CRA-W), Dr E. FROIDMONT (CRA-
W), Prof. A. BUITENHUIS (Aarhus University, Danemark).

Summary

In the current context of rising awareness of climate change, all sectors, including agriculture, have to make efforts to reduce their greenhouse gas (GHG) emissions in the common interest. Methane (CH_4) is one of the major GHGs and accounts for a significant proportion of emissions attributed to the agricultural sector, as it is naturally produced during the digestion process of ruminants. Eradicating this enteric production of CH_4 from cattle is not physiologically feasible, but factors can have an impact on the quantity of CH_4 emitted, such as: feed, herd management, or genetic selection for efficient animals. However, it is crucial in such an approach to be able to quantify individual CH_4 emissions on a large scale. Existing measurement methods (respiratory chambers, SF_6 tracer gas method, etc.) are often hard to implement and difficult or impossible to apply to large populations of individuals. It would be useful to have a proxy for easily estimating these emissions.

The work described in this PhD thesis relates to the development of equations to estimate daily and individual CH_4 emissions of dairy cows from mid-infrared spectra (FT-MIR) of milk. This is because, from a metabolic point of view, ruminal fermentation mechanisms will influence both CH_4 emissions and milk composition, particularly in terms of fat content. The FT-MIR spectrum of milk reflects its chemical composition, and is already routinely collected and analyzed in connection with the payment and milk recording procedure.

After first establishing a relationship between the FT-MIR spectrum of milk and the CH_4 emissions of dairy cows ($n = 77$), various steps were taken to improve and refine the prediction model.

The lactation stage of the animals was taken into account in a new predictive model ($n = 446$) via a spectral modification. Variations in body tissue mobilization during lactation strongly impact milk's fatty acid profile, and hence too the relationship between the FT-MIR spectrum of milk and CH_4 emissions. This adaptation made it possible to obtain predictions of CH_4 emissions consistent with zootechnical expectations over lactation.

The addition of new reference data presenting a zootechnical characteristic (breed, lactation stage, feed ration, etc.) poorly represented beforehand in the calibration set improved the quality of the predictive model as well as its application potential ($n = 532$). The acquisition of such data was possible through experimental trials targeting specific diets or animals, but also through international collaborations and data exchanges. This highlighted the importance of covering local variability before applying the model in order to guarantee the relevance of the prediction obtained.

The first versions of the prediction equation were based on CH_4 measurements obtained using the SF_6 tracer gas technique. In order to confirm the results obtained, a new equation was developed, based this time only on measurements of CH_4 obtained in respiratory chambers (RC). This technique is considered the "gold standard" for measuring CH_4 emitted by cattle. These data were collected by European research teams and were shared through collaborations. However, they were not collected with the purpose of developing such an equation and thus did not present an ideal range of variability in this respect. However, thanks to the large number of data collected ($n = 584$), the statistical results showed a trend that is substantially similar to the previous results and confirmed the potential of the FT-MIR spectrum of milk as a proxy for estimating CH_4 emissions on a large scale.

The attempt to externally validate the prediction equation based on the SF_6 data with the data collected in the RC (and *vice versa*) did not give satisfactory results. Data from the respective datasets were collected from different countries, breeds, diets, etc. so the calibration datasets did not include the information of the datasets used as validation in each case. The need to modify the reference CH_4 values to take account of a potential method bias between the SF_6 measurements and the respiratory chambers was considered and discounted at this stage, and new equations combining all the available data (SF_6 tracer method and respiratory chambers) were then developed ($n = 1089$).

Finally, in order to improve the quality of the predictions obtained, relevant and readily available phenotypic data were added as predictive values to the milk FT-MIR spectrum. The model with the best statistical performances is currently based on the 1089 reference data and takes into account the stage of lactation, the daily milk yield, the breed and the parity of the animals (R^2 and standard error of cross-validation of 0.68 and 57 g of CH_4 /day respectively).

The developed models have great potential for practical application because of their ability to provide estimations of CH_4 emissions on a large scale. Their performance will have to be validated in the field and the limits of applicability must still be defined in order to ensure the relevance of the predictions obtained before the models can be used in practical conditions.