Experiences with Large Scale Individual Measurements of Methane Emission in Dairy Cattle using a Fourier Transform Infrared (FTIR) Measuring Unit

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Introduction

Emission of green house gasses is a great concern in the society today. Dairy cattle are a contributor of green house gasses in terms of methane from rumination. Methane is a highly active greenhouse gas compared to carbon dioxide. About 90% of the methane from dairy cattle is emitted through the cow's breath. The dairy cattle industry World wide has a responsibility to lower the methane emissions if possible.

The diet and management of the cow has a strong impact on the amount of methane emitted from each cow, but a genetic component may well be involved too. In precise studies where methane emission has been investigated, a whole animal gas calorimetric equipment has been used (Ellis et al., 2007). In such a system the experimenter has full control of gas entering and leaving the chamber and precise information about the physiology of the cow and her methane emission is obtained, but only a very limited number of cows can be studied. However, for genetic selection on methane emission, individual measurements on large numbers of cows are necessary.

To quantify the methane production from a cows it is necessary to be able to measure the methane concentration in air originating from the cow and to be able to quantify the volume of air that comes from the cow. The methane concentration can be measured by using different equipment such as photo acoustic analyzers, gas chromatographs or Fourier Transform IR (FTIR) gas analyzers. The FTIR techniques use an infrared transmission spectrum of an air sample. Examination of the transmitted light reveals how much energy was absorbed at each wavelength. From this, an absorbance spectrum can be produced, showing at which IR wavelengths the sample absorbs. The spectrum can then be calibrated to provide gas densities in each sample. The FTIR instrument can also be used to measure many different gasses at the same time, e.g. CO_2 and CH_4. It is more difficult to measure the volume of the breath. Sulfuric hexafluoride (SF6) has previously been used as a tracer, but is a greenhouse gas itself. Another ways is based on the cows CO2 production (Madsen et al 2010). The so far published studies on individual variation in methane emission have shown rather low estimates of repeatability in the magnitude of 20% (Grainger et al., 2007;

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McCourt et al., 2005). In these studies a relatively small number of animals were studied. So far no real genetic evaluation of methane emission from dairy cattle has not been performed in realistic scale.

The aim of this study was to obtain and analyze data on measurements of methane emission from individual dairy cattle and to estimate repeatability for the trait as a first step towards a genetic evaluation.

Material and methods

In this study data was obtained at the experimental herd at the Danish Cattle Research Centre (DCRC, Foulum, Denmark). A total of 93 cows were in the study. These included 50 Holstein and 43 Jersey cows. Methane emissions were measured using a FTIR gas analyzer (GASMET 4030). The instrument air inlet was placed in front of the cows head in each of the two automated milking systems (AMS) and methane and carbon dioxide was measured continuously every 5 seconds for Holstein and every 20 seconds for Jerseys. Data was recorded for 3 days in both AMS. There were between 2 and 12 repeated measurements per cow during that period. In figure 1, a sample of the data is shown. When a cow enters the AMS the methane level increases. From figure 1 it can be seen that the first two to three records after a cow enters the AMS have lower values than the rest of the period. Also it can be seen that the methane level fluctuates during the visit.

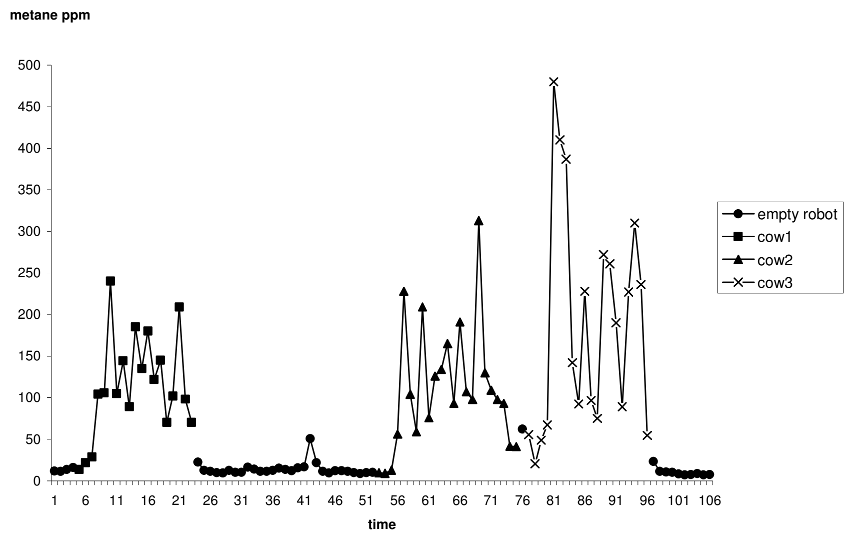


Figure 1 Data points of measured methane in ppm from a time sample when 3 Holstein cows were milked in the AMS. Each time step covers a 5 second period.

Data on feed intake, weight and milk production are recorded routinely at the DCRC. In this study the phenotype used for these 3 traits were the mean of the daily records for each trait over a three week period starting one week before the week of methane recording and ending one week after the methane recording. The feed intake is recorded separately for roughage and for concentrates. The roughage is a mixed ration consisting of corn silage, grass silage, rapeseed meal and soya bean meal. The concentrate feed in the AMS was used to attract the cows into the AMS.

It is possible to estimate the quantitative carbon dioxide production from cows in different ways (Pedersen et al. 2008; Madsen et al. 2010) and by using this estimate together with the measured methane/carbon dioxide ratio it is possible to quantify the methane production (Madsen et al., 2010). In this article the pure ratio between methane and carbon dioxide ratio were used for the evaluation and no calculations were made to quantify the methane production. Given that the methane/carbon dioxide ratio is concentration independent this ratio describes the methane production of each cow.

Data was analyzed using a linear model from the MIXED procedure in SAS.

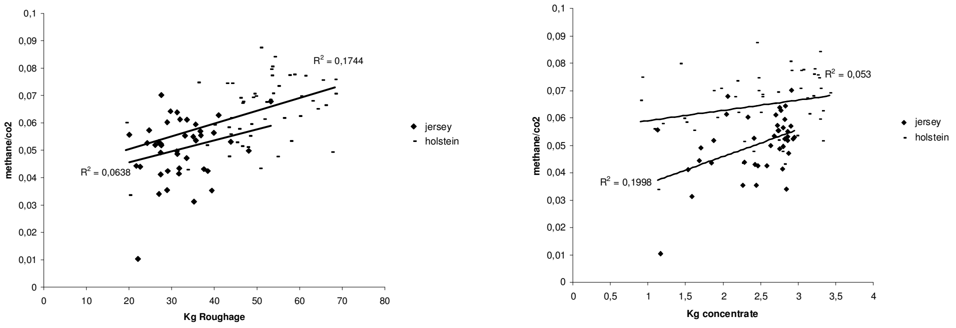
$$y_i = \mu + \beta_1 \times roug + \beta_2 \times conc + \beta_3 \times milk + a_i + e_i$$

Where y is the median methane/carbon dioxide level of each AMS visit, μ is the overall intercept, *roug* is the mean roughage intake in kg over a three week period, *conc* is the mean concentrate intake over a three week period and milk is the mean milk production over a three week period. The *β's* are fixed regression coefficients, *a* is the random animal effect and *e* is the random residual effect.

Results and discussion

The estimated repeatability of methane emission in terms of the methane/carbon dioxide ratio were 0,37 for Holstein and 0,35 for Jerseys. Animal variance as well as residual variance was very low for this trait. Repeatability estimates of similar magnitude were found for pure methane measurements as well as carbon dioxide level. This is somewhat higher than the previous results by McCourt et al., 2005 and Grainger et al., 2007 who found repeatability of 0,17 and 0,18 for methane emission. Their results came from a SF_6 tracer study and a whole animal gas calorimetric study. In the study by Grainger et al. (2007) only xx animals were measured and in the study by McCourt et al (2005) the methane emission was measured on beef cattle steers. For both the Holstein and the Jersey data significant effects of roughage and concentrate intake was found. That means with higher roughage and concentrate intake more methane/carbon dioxide emission. This pattern is also illustrated in simple plots (figure 2). On the other hand there was no significant effect of production level on the methane/carbon dioxide relationship – neither for Jersey nor for Holstein.

The pure ratio between methane and carbon dioxide will picture differences between cows with the same feed intake and production. However, the ratio may be influenced by the feed intake, the composition of the diet and the production of the cow. A higher ratio is expected if the porportion of roughage is high as the ratio of acetic acid in the VFAs produced in the rumen is expected to increase. On the other hand, cows that eat more feed because of a higher milk production will ferment proportionally more feed and produce more methane but not produce proportionally more carbon dioxide as more of the carbon is excreted as milk and not metabolised to carbon dioxide. These two effects may counterbalance each other showing no relation between the milk production level and the methane carbon dioxide ratio.



(a) (b)

Figure 2 Plots of mean of medians for all AMS visits for methane/carbon dioxide ratio against kg roughage intake (a) and kg concentrate intake (b) for Jersey (♦) and Holstein (-) cows respectively.

The repeatability is assumed to be the upper boundary for the heritability of the trait. With only 50 and 43 cows it is not possible to estimate reliable genetic parameters for any trait. It will definitely be interesting to make more registrations for the trait in order to both estimate heritability and correlations to other traits such as milk production and disease traits. With repeatabilities of 0,35 and 0,37 for the relationship between methane and carbon dioxide we have reasons to believe that the FTIR instrument will provide further insight to genetic variation in methane emission and possible correlations to production and health traits.

Conclusion

Using a FTIR measuring unit in an AMS system to measure methane emission from dairy cattle showed promising results. Repeatability estimates of 0,37 and 0,35 was found for Holsteins and Jerseys respectively for the relation between methane and carbon dioxide. The FTIR instrument combined with AMS may be useful to generate large scale data for genetic evaluation of the trait.

References

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