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Research Report

Greenhouse gas accounting for the UK dairy industry

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Non-technical abstract

UK net zero policies aim to decrease the emission of greenhouse gases and offset any remaining emissions with carbon uptake processes. These efforts are critical for mitigating climate change, however implementation is challenging for many sectors, including the agricultural industry. The UK currently has approximately 12,000 active dairy farms that account for approximately 10% of total UK food manufacturing output. Approximately 50% of the total greenhouse gas emissions by UK agriculture are due to methane produced by dairy farms. This project aimed to demonstrate that low-cost technology and analytical procedures can quantify greenhouse gas emissions from dairy cattle. Enteric methane measurements were conducted for a one-year period to investigate whether emissions varied according to physiological factors (age, stage of lactation, weight, milk yield), management (indoors vs outdoors, grazing type, diet) as well as other factors such as seasonal variability. These measurements laid the groundwork for comparison with other UK dairy farmers and the implementation of mitigation measures such as feed additives. The method of emission measurement has been designed so that the data can be transmitted wirelessly enabling remote accessibility of the datasets.

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Non-technical executive summary

Dairy farmers currently rely on greenhouse gas (GHG) calculators and toolkits to estimate emissions which can be unrepresentative of their own farm management practices, resulting in farmer confusion and distrust. The UK currently has approximately 12,000 active dairy farms that account for approximately 10% of total UK food manufacturing output. Approximately 50% of the total GHG emissions by UK agriculture are due to methane produced by dairy farms. The aim of this project was to demonstrate proof-of-concept using low-cost technology and analytical procedures to quantify GHG emissions by dairy cattle using Nafferton Farm, a Northumberland commercial and research dairy farm, as the test case. GHG measurements (methane and carbon dioxide) were conducted for a one-year period to explore whether emissions varied according to physiological factors (age, stage of lactation, weight, milk yield), management (indoors vs outdoors, grazing type, diet) as well as other factors such as seasonal variability. The research findings laid the groundwork for comparison with other UK dairy farms and the implementation of mitigation measures such as feed additives. The project also engaged with the Smart Rural Network by leveraging testbed 5G capabilities to transmit the GHG measurements wirelessly enabling remote accessibility of the datasets. This NICRE-funded project has enabled multi-year, comprehensive data collection resulting in a commercial feed trial and over £1million in funded research projects.

Introduction and background

The dairy industry is under intense scrutiny, with decreasing demand and increased awareness around the environmental impact of agricultural management. The consumption of milk per person in the UK has steadily declined since 1974 (Figure 1). However, due to population increase the sales in volume of milk have only decreased a marginal amount. A complicating factor is the effect of Brexit on trade as the EU is the UK's most significant trading partner, accounting for 70% of imports and 60% of exports. The increased checks and declarations due to Brexit make trade slower and more expensive, which could result in an increase in the volume of goods requiring veterinary checks (British Veterinary Association, 2017).

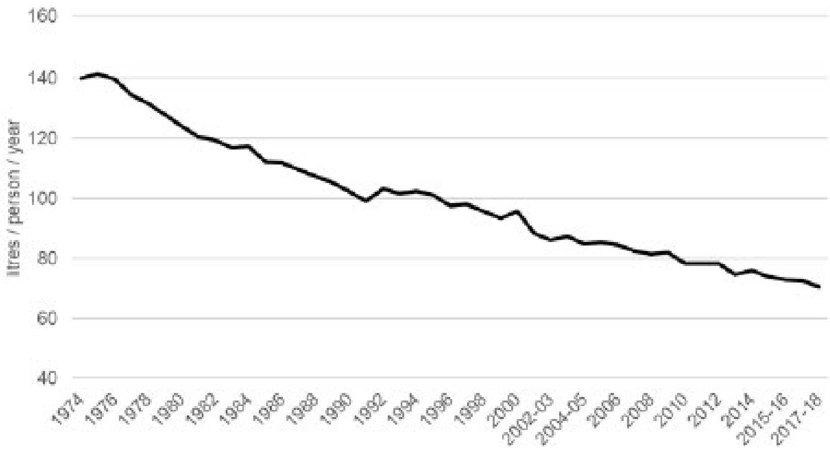


Figure 1. Milk consumption in the UK (DEFRA Family Food Survey, 2019)

Alongside the long-term changes to the dairy industry and the UK Government's efforts to decarbonise the economy, the UK Government has pledged to reduce GHG emissions across the economy to reach net zero by 2050. Policy discussions and agreements typically focus on methane and nitrous oxide as they can be less expensive to mitigate. Also, methane is more than 20 times as effective as carbon dioxide at trapping heat in the atmosphere and is second only to carbon dioxide for its global warming impact, despite lasting in the atmosphere for a much shorter time span (Kirschke et al, 2013). The Global Methane Pledge, launched at COP26, is a plan which aims to reduce global methane emissions by at least 30% by 2030 (Figure 2). Over 110 countries have joined the pledge and hope to achieve under 0.2°C warming by 2050. One key factor to meeting any Methane Pledge is to better understand the cause of emissions from dairy farms.

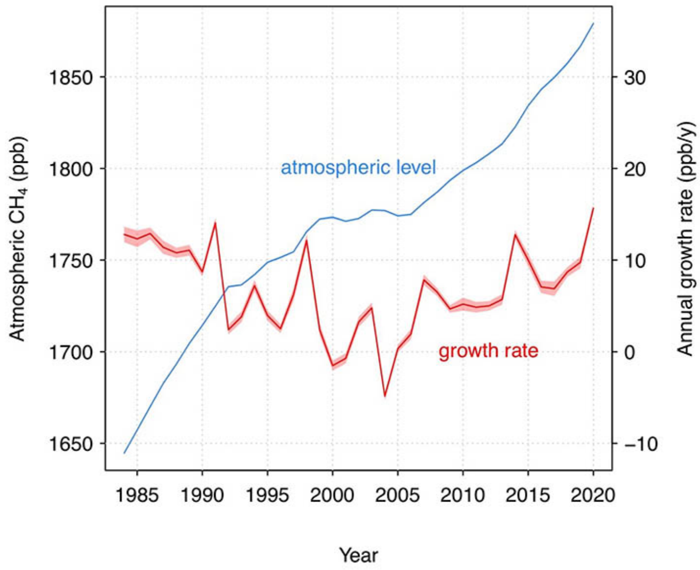


Figure 2. Global mean atmospheric methane level (in parts-per-billion, ppb) and its annual growth rate (data from: https://gml.noaa.gov/ccgg/trends_ch4/)

Livestock enteric fermentation is known to be one of the largest sources of methane (US EPA, 2022; Khalil, 2000). The enteric methane of livestock, generated in the gastrointestinal tract, is one of the largest sources of anthropogenic methane (Figure 3). The methane produced by ruminants is a by-product of their specialised quadra compartmental digestive sac, with methanogenic bacteria breaking down the complex carbohydrates in their food through fermentation. This process is important as it allows ruminants to extract nutrients from plant material, which is indigestible to many other animals (Takahashi et al, 2019).

It is known that a high intake of low-quality feed results in higher methane emissions, and that high feed intake is positively correlated with milk production (Knapp et al, 2014). Scientists have also estimated that achieving a 20% reduction in cattle's enteric methane production could result in an additional 1L of milk per day from dairy cows (Min et al, 2022). This suggests that there is a negative correlation between cow's methane emissions and milk production, however, current knowledge and research of this relationship is limited and often contradicting.

A major reason for the contradictory findings is the limited quantity and quality of data that is collected and the units that are used to express results. There are no studies that have collected GHG emissions consistently and non-invasively. This creates unreliable predictive models and toolkits for farmers to use. This research therefore aims to create a level playing field for UK dairy farmers by demonstrating the ease of direct methane measurements from dairy cows. Thus, developing a robust method for data collection, a reliable, extensive dataset to analyse and opportunities for further funded projects.

Research design and methodology

The research took place on Nafferton Farm between January to December 2023. Nafferton is a 498-acre working dairy farm located 12 miles west of Newcastle with approximately 200 dairy cows. The dairy parlour has a 24-station herringbone milking parlour which hosted the methane measurements. Cows are milked twice daily at 6am and 2pm (Figure 3).

Methane emissions were determined by taking samples of the cow's breath while they were being fed and milked (Figure 3). On one side of the dairy parlour (n=12), a 6mm sampling tubing connected the feeding trough to the sampling apparatus on the other side of the parlour wall. Once the first set of cows had entered into the dairy parlour feeding station a gas sample was collected. The process was repeated for the next feeding slot, until all cows were fed and milked. It was important to let the vacuum flush out the tube in between cows to be sure the gas in the sample bags were representative of that specific cow's breath being measured.

Figure 3. Dairy parlour during milking. The cows head enters the feed trough, and while they are eating their breath is vacuum pumped into an airtight sample bag.

Gas samples were analysed on the main Newcastle University campus using an Agilent 8890 gas analyser. A subsample was injected into the gas analyser and the quantity of methane and carbon dioxide was recorded. Prior and after sample analysis, calibration gases were analysed to verify the equipment was properly working.

Findings

The data collected throughout 2023, resulted in over 1,300 data entries from 79 days of data collection, with an average of 26 samples taken per day. In total 174 dairy cows had their breath samples analysed (Table 1, Figure 4), approximately 11 times per cow.

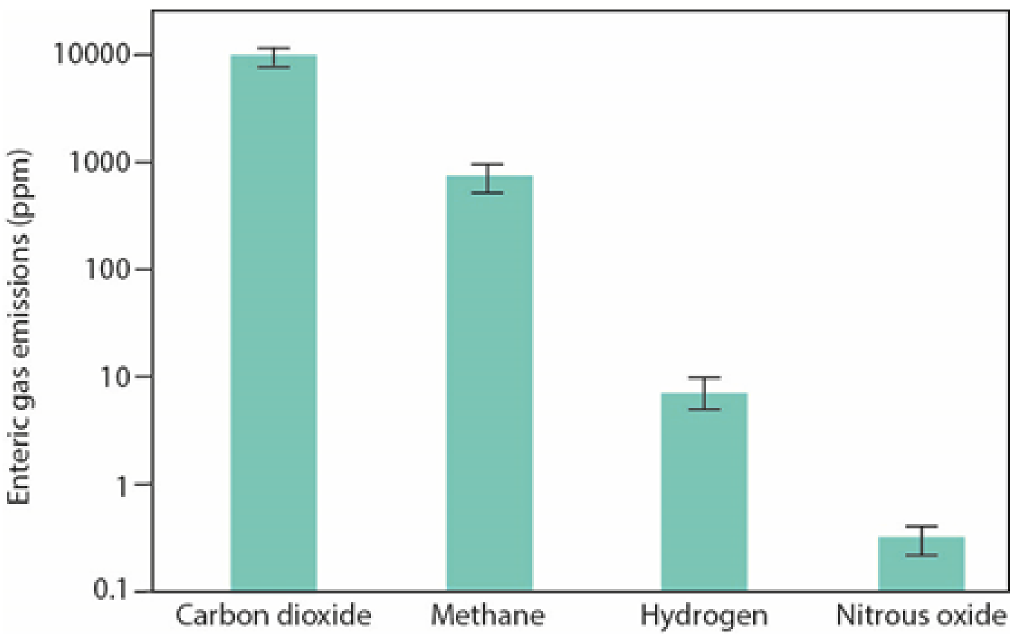
Whilst cattle have their heads in the trough, they may move their heads around and create uneven air distribution. This can cause a dilution of breath: air, an effect which has been well documented for the sniffer method (Garnsworthy et al., 2012). Despite potential dilution, these findings present similar averages of methane, carbon dioxide and their ratio to other published literature (Difford et al.,, 2018; Wu et al., 2018), demonstrating the 'sniffer' methods developed and implemented through this project work effectively to monitor the carbon dioxide and methane emissions from dairy cattle breath.

The data collected follows an expected normal distribution (Figure 5). This makes the dataset more straightforward to work with statistically, as many tests and models are based on the assumption of a normal distribution.

Table 1. Summary of results, data collected over a total of 79 days from 174 different dairy cows from 24th January 2023 to 13th December 2023.

	CO_2 (ppm)	CH_4 (ppm)
n	1334	1305
Mean	9630.20	749.10
Median	9577.70	708.44
Standard Deviation	3119.80	368.20
Min	579.70	11.23
Max	19751.20	3065.62

Figure 4. Mean enteric gas emissions (ppm) of carbon dioxide, methane, hydrogen and nitrous oxide with error bars displaying standard deviation.



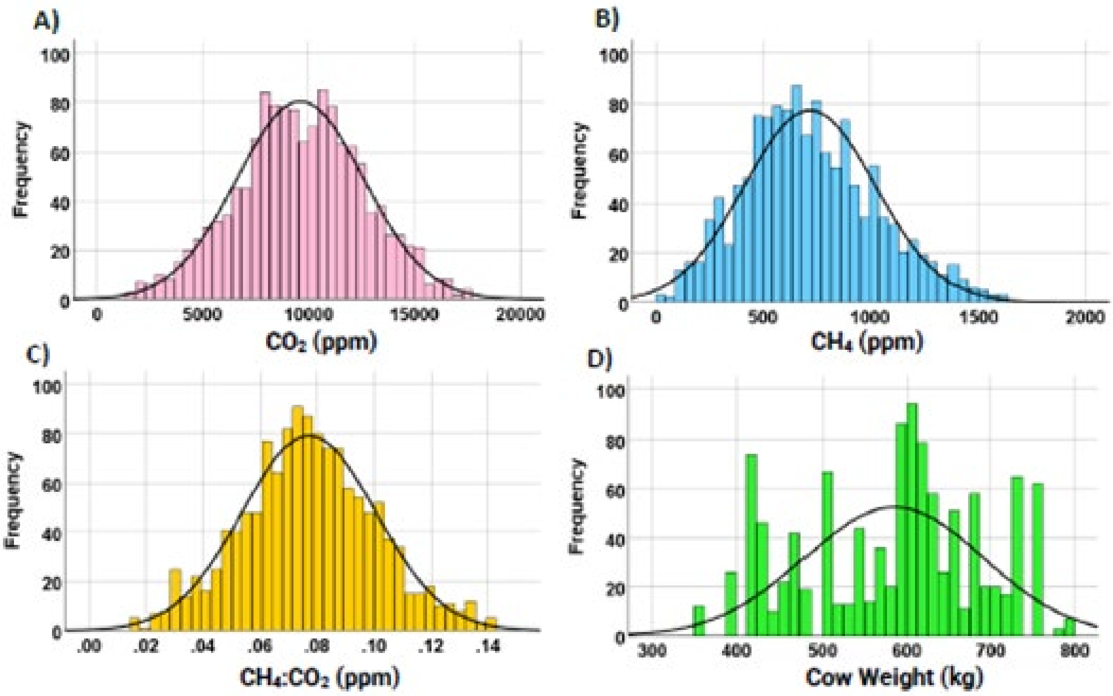


Figure 5. Histograms indicating normal distribution of results for A) carbon dioxide, B) methane and C) methane: carbon dioxide ratio, however D) weight is unevenly distributed.

At a glance, >1,300 data entries (breath concentration data points) appears to be an impressive data set, however the reality is just 26 (average) recordings per milking and/or 7-10 (average) recordings per cow. Ultimately, this number of measurements results in very low power statistical analysis. For example, identifying whether emissions vary between early, mid and late lactation would require data from at least 20 of the same cows at each stage of lactation (with at least three replicates for each cow in each stage). These cows would need to have a similar milk yield, milk quality and age (to control the variability between cows). Additionally, the data would need to be assessed for quality, for example, removing anomalous data based on a pre-defined quality control rule such as, data falling within two standard deviations of the mean value. As mentioned, cows move, so identifying the parameters for 'normal' would need to be pre-determined prior to data analysis. Unavoidably, this would result in data removal, which means more recordings are needed than strictly necessary to ensure good quality statistics. Whilst power is in the quality of the data collected, when conducting research with animals, quantity is also essential to account and accommodate for within and between animal differences.

Despite the limitations, this 'sniffer' method development and data quality shows great promise and scope, having demonstrated similar averages to the published literature. But data collection through expansion to both sides of the parlour to capture all cows during milking is required. This expansion of capacity will enable more data collection, resulting in stronger statistical analysis and more convincing conclusions.

Key conclusions and implications

There are various methods for monitoring emissions from livestock, including the gold-standard respiration chambers, the sulphur hexafluoride (SF6) method, or the patented GreenFeed spot measurement technology, but these methods are expensive, time consuming, and can affect animal behaviour, making it impractical to obtain data from large study groups (Bekele et al., 2022). The sniffer method as described by Garnsworthy et al. (2012), has the potential to produce large data sets, as demonstrated in this project, that quantify individual emissions within an entire herd. The sniffer method is less expensive, more time efficient and affects animal behaviour minimally. In the future, sniffer-based measurements on enteric methane have the potential to conduct analyses across whole farming regions and to be coupled with cross-comparison using the respiration chamber method for selected individuals (Difford et al., 2018; Wu et al., 2018). The average enteric gas concentrations quantified from dairy cows' breath in this project are in line with many other studies (van Breukelen et al., 2022, Uemoto et al., 2024, Wu et al., 2018), which further supports the reliability of the data collected during this project. Therefore, the sniffer method developed through this project is an effective approach to quantifying the carbon dioxide and methane breath concentration from dairy cows.

This NICRE-funded project demonstrated proof-of-concept that low-cost technology can be installed in a commercial setting and used to collect valuable emissions data. This has helped to create a Newcastle University Research Platform at Nafferton Farm, generating interest from farmers, consultants, commercial companies, local authorities and research institutes. The data collected through this project has resulted in a successful commercial feed trial (summer, 2024), £1.3million funding from Department for Science, Innovation and Technology to improve on farm measurements and test data access using 5G, DEFRA-funded research, numerous undergraduate and postgraduate student projects (2023 and 2024) and well-attended farm open days and events. This interest and further funding results in more technology and staff, better quality science and data that can be used to guide policy, farmers and commercial companies.

References

Bekele, W., Guinguina, A., Zegeye, A., Simachew, A. and Ramin, M. (2022) 'Contemporary Methods of Measuring and Estimating Methane Emission from Ruminants', Methane, 1(2), pp. 82-95.

van Breukelen, A.E., Aldridge, M.A., Veerkamp, R.F. and de Haas, Y., (2022). 'Genetic parameters for repeatedly recorded enteric methane concentrations of dairy cows'. Journal of Dairy Science, 105(5), pp.4256-4271.

Difford, G.F., Olijhoek, D.W., Hellwing, A.L.F., Lund, P., Bjerring, M.A., De Haas, Y., Lassen, J. and Løvendahl, P. (2018) 'Ranking cows' methane emissions under commercial conditions with sniffers versus respiration chambers', Acta Agriculturae Scandinavica, Section A — Animal Science, 68(1), pp. 25-32.

Garnsworthy, P.C., Craigon, J., Hernandez-Medrano, J.H. and Saunders, N. (2012) 'On-farm methane measurements during milking correlate with total methane production by individual dairy cows', Journal of Dairy Science, 95(6), pp. 3166-3180.

Huhtanen, P., Cabezas-Garcia, E.H., Utsumi, S. and Zimmerman, S., (2015). 'Comparison of methods to determine methane emissions from dairy cows in farm conditions'. Journal of dairy science, 98(5), pp.3394-3409.

Kirschke, S., Bousquet, P., Ciais, P., Saunois, M., Canadell, J.G., Dlugokencky, E.J., Bergamaschi, P., Bergmann, D., Blake, D.R., Bruhwiler, L. and Cameron-Smith, P., (2013). 'Three decades of global methane sources and sinks'. Nature geoscience, 6(10), pp.813-823.

Min, B.R., Lee, S., Jung, H., Miller, D.N. and Chen, R., (2022). 'Enteric methane emissions and animal performance in dairy and beef cattle production: Strategies, opportunities, and impact of reducing emissions'. Animals, 12(8), p.948.

Takahashi T., McAuliffe GA., Lee MRF (2019) 'Assessing the environmental impact of ruminant production systems', pp 121–138. https://doi.org/10.19103/as.2018.0044.14

Uemoto, Y., Tomaru, T., Masuda, M., Uchisawa, K., Hashiba, K., Nishikawa, Y., Suzuki, K., Kojima, T., Suzuki, T. and Terada, F., (2024). Exploring indicators of genetic selection using the sniffer method to reduce methane emissions from Holstein cows. Animal Bioscience, 37(2), p.173.

Wu, L., Koerkamp, P.W.G.G. and Ogink, N. (2018) 'Uncertainty assessment of the breath methane concentration method to determine methane production of dairy cows', Journal of Dairy Science, 101(2), pp. 1554-1564.

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