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PORTABLE ACCUMULATION CHAMBERS FOR MEASURING ENTERIC METHANE IN CATTLE

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SUMMARY

Breeding has been shown to be a viable solution for reducing methane emissions in ruminants but requires obtaining on-farm measurements of methane. One technology that has successfully been used on-farm to obtain short-term commercial methane measurements in sheep and goats is portable accumulation chambers (PAC). However, the original PAC units are unsuitable for cattle. In this project, PAC units designed and engineered specifically for cattle were developed and used to measure methane and carbon dioxide emissions from 125 Angus-Hereford (pure or crossbred) heifers across two time-periods. PAC performed as expected with no animal behaviour problems and were shown to be a suitable high-throughput method for the measurement of methane emissions from young beef cattle. The repeatability was found to be 0.35 ± 0.08 for methane emissions (g/day) (CH_4), 0.13 ± 0.09 for carbon dioxide emissions (g/day) (CO_2), and 0.31 ± 0.09 for the molar ratio trait of $CH_4/(CH_4 + CO_2)$. These results suggest that the newly designed cattle PAC units could enable large-scale on-farm methane measurements to be collected for the purpose of ranking animals on their methane emissions. This would facilitate the development of breeding schemes to select for low methane emitting cattle. Future studies should be conducted to investigate the heritability of PAC traits obtained from the cattle chambers.

INTRODUCTION

Concern regarding the impact of greenhouse gases on climate change has increased in recent years and has led to renewed efforts for developing solutions to reduce global emissions in line with international reduction targets set by governments and international organizations. In New Zealand, one third of all greenhouse gas emissions are generated through enteric methane emissions from grazing livestock, with over 70% coming from cattle (MfE 2024). Current targets in New Zealand for biogenic emissions are a 24-47% reduction by the year 2050. Many mitigation technologies, such as feed additives, require daily individual feeding which is untenable in extensive pasture systems. Breeding is currently the only technology commercially available for methane mitigation in ruminants grazing pasture and for the New Zealand sheep industry, methane genomic breeding values are generated as part of routine genetic evaluations (Archer *et al.* 2023). However, breeding for low methane animals requires phenotypic measures of methane and measurements of methane emissions in grazing ruminants is challenging as current technologies (i.e., GreenFeed (C-Lock Inc., Rapid City, SD), SF_6 tracers (Johnson *et al.* 1994)) are low-throughput and expensive for pastoral based systems. In sheep, one technology that has successively been implemented commercially is portable accumulation chambers (PAC) with over 5,000 commercial measures per year routinely collected in New Zealand (Archer *et al.* 2023; Jonker *et al*. 2018). However, the original PAC units were not designed for large animals such as cattle. The objective of this study was to test a newly designed cattle PAC unit to measure methane emissions on a young beef cattle, and whether there is sufficient variation and repeatability in the measures to warrant upscaling to more herds.

MATERIALS AND METHODS

The trial was carried out in accordance with the Animal Welfare Act 2006 and AgResearch Code of Ethical Conduct, and experimental animals and protocols applied in this study were approved by the AgResearch Animal Ethics committee (application number 2008).

Animals. Beef heifers (n=125) bred for the 'Informing New Zealand Beef programme' were transported to AgResearch, Invermay in July 2023, for a period of one month. They were 10 months of age at time of transportation and were a reciprocal cross of Angus (A) and Hereford (H) with four genetic groups represented (AA, AH, HA and HH). The heifers were progeny of cows in their first (dam born in 2020) or second parity (dam born in 2019). There were four management groups that had equal representation of genetic groups but were separated into age of dam and liveweight, where these groups were born 2019 dams with light (L19) and heavy (H19) heifers and born 2020 dams with light (L20) and heavy (H20) heifers (Table 1). An additional 4 animals were originally included in the trial, but were excluded from the analysis due to being identified as steers or failure to be successfully measured using PAC.

PAC measurements. Animals were grazed in management groups on ad-libitum pasture and baleage for 10 days prior to measurement in sealed PAC units designed and engineered specifically for cattle. For the first round of measurements, animals were removed from pasture at 8 am and held in yards with no feed prior to measurement. The animals in each management group had been randomly allocated into measurement 'lots' (n=6 per lot) within sire and breed and were measured on the same day. After one hour off feed, the first lot of six heifers were each loaded into one of the six PACs. Liveweight was taken immediately prior to the animals entering the chambers. At the start of the measurement period, methane, carbon dioxide, and oxygen levels were recorded using a hand-held analyser for each chamber together with ambient temperature and pressure outside the chamber. After 25 minutes an interim gas measure was collected and after 50 minutes a final gas measure was taken from each chamber. After 14 days, a second 'round' of measures were repeated on the same animals that were re-allocated to different lots of 6.

For direct emissions, methane in parts per million (ppm) and percentage of carbon dioxide in the air volume were recorded at 50 min, which were converted to litres, moles and then to grams emitted per measurement period. These were calculated using the equations presented in Rodrigues *et al.* (2024) to produce estimates of grams of methane (CH_4) and grams of carbon dioxide (CO_2) emitted per day. A ratio trait was also derived as an indicator of methane yield (i.e., grams of methane per kg of dry matter intake) and was calculated as the moles of methane per day divided by the total moles ($CH_4/(CH_4 + CO_2)$).

Table 1. Number of animals (mean liveweight[1]) per management group and breed

Breed	Management Group				
	L19	H19	L20	H20	Total
Angus-Angus (AA)	9 (223)	9 (253)	6 (223)	6 (252)	30 (238)
Angus-Hereford (AH)	6 (209)	6 (238)	7 (216)	6 (246)	25 (227)
Hereford-Angus (HA)	8 (240)	8 (271)	6 (218)	7 (245)	29 (245)
Hereford-Hereford (HH)	11 (208)	11 (242)	10 (207)	9 (232)	41 (223)
Total	34 (220)	34 (251)	29 (215)	28 (243)	125 (232)

[1]Liveweight (kg) of the heifers 3-months prior to PAC measurements being collected.

Statistical Analysis. Repeatability of PAC methane traits for cattle, fixed effects and covariates were tested using a linear mixed model in SAS JMP statistical software. The model used to estimate repeatability was:

$$Trait_{ijklm} \sim Round_j + Group_k + Round_j*Group_k + Lot_l + Wait\_Time_m + \alpha_i + e_{ijklm} \quad \text{(M1)}$$

where $Trait_{ijkl}$ is the PAC trait (CH_4, CO_2 or $CH_4/(CH_4 + CO_2)$), $Round_j$ is the four-day measurement period (1 or 2), $Group_k$ is the management group, $Round_j*Group_k$ is the interaction between $Round_j$ and $Group_k$, Lot_l is the group of 6 animals measured at the same time on a given day, $Wait\_Time_m$ is a covariate of the time (minutes) between the animal being removed from feed and entering the chambers, α_i is the animal random effect where $\alpha_i \sim N(0,\sigma_p^2\mathbf{I})$ and $\mathbf{I}$ is the identity matrix, and e_{ijklm} is residual error term where $e_{ijklm} \sim N(0,\sigma_e^2\mathbf{I})$. The repeatability is $\sigma_p^2/(\sigma_p^2+\sigma_e^2)$.

RESULTS AND DISCUSSION

The mean liveweight of the heifers at measurement was 250 kg and the mean methane emission was 85.5 g/day across both rounds of PAC (Table 2). In comparison, the average methane emissions for a research sheep flock (Booker *et al.* 2024) in the same season was 12.8 g/day from 323 growing lambs weighing an average of 48.7 kg. Thus, the mean methane emissions per kg of liveweight was 0.342 for cattle, which is similar to sheep (0.263). The coefficient of variation for methane emissions from the heifers was 22.46%, which is in line with values observed in sheep (26.4%), and for the measurement technologies GreenFeed (25.8%) and sulfur hexafluoride tracer (38.6%) when used on cattle (Hristov *et al.* 2016). These results suggest that the cattle PAC units are performing as expected when comparable to PAC data obtained from sheep after adjusting for differences in liveweights.

The mean carbon dioxide percentage was 1.6% for the heifers, which is also in line with values from the same sheep flock which had a mean carbon dioxide percentage of 2.2%. These carbon dioxide percentages were measured after approximately 50 minutes of the animals being in the chambers for both cattle and sheep. The decision to measure cattle for 50 minutes was based on sheep protocols and a pilot study of 30 dairy heifers that showed that a 50-minute measurement period yielded sufficient methane (>800-1000ppm) for animals to express individual differences. The mean chamber temperature was 12.4°C for the heifers, where chambers tended to be cooler than the outside temperature by 1 or 2 degrees on average. Chamber temperatures ranged from 4.7°C to 29.6°C and below 20°C for 93.2% of the lots.

Table 2. Summary statistics[1] for various traits and measurement collected during PAC for the 125 beef cattle at ~10 months of age

Trait	Mean	S.D.	Minimum	Maximum
Liveweight (kg)	250	23.0	194	317
Methane (g/day) (CH_4)	85.5	19.2	43.2	152.2
Carbon dioxide (%)	1.6	0.27	1.1	3.3
Chamber temperature (°C)	12.4	5.6	4.7	29.6

[1]Computed across both PAC rounds.

Table 3 gives the results from fitting the linear mixed model for the three PAC traits. The factors for round and management group were found to be significant (except for CO_2), while PAC lot was slightly significant and wait time was non-significant across all traits. Note that management group is partly confounded with liveweight. The variation in the traits explained by the model was 84.0% for methane emissions and 75.9% for the ratio trait, while there was a poorer fit for carbon dioxide emissions (46.9%). The repeatability estimates were moderate for methane emissions (0.35) and ratio trait (0.31), but the repeatability for carbon dioxide was low (0.13). The repeatability estimate for CH_4 is similar to values obtained in sheep (0.33) but the repeatability estimates for CO_2 and the ratio trait were 0.41 in sheep (Jonker *et al.* 2018) which is higher than the estimates obtained in this study. The lower repeatability for CO_2 could be due to the management groups being partly confounded with liveweight (and hence feed intake). Overall, these results suggest that PAC methane for cattle is repeatable for the methane traits, but further studies should be performed to validate these conclusions.

Table 3. Model fit, explanatory variables and repeatability for methane emissions (CH_4), carbon dioxide (CO_2) and the molar ratio $CH_4/(CH_4 + CO_2)$ traits

	CH_4 (g/day)	CO_2 (g/day)	$CH_4/(CH_4 + CO_2)$
Adjusted r-square	0.840	0.469	0.759
Fixed effects (Prob>*F*)			
Round	0.166	0.759	0.271
Group	<.0001	<.0001	0.0004
Round.Group	<.0001	0.042	<.0001
Lot	0.022	0.061	0.008
Wait_Time	0.703	0.069	0.091
Animal variance (σ_p^2)	43.52	28399	2.62e-05
Error variance (σ_e^2)	79.95	185945	5.85e-05
Repeatability (mean ± s.e.)	0.35 ± 0.08	0.13 ± 0.09	0.31 ± 0.09

CONCLUSION

Portable accumulation chambers (PACs) performed as expected to measure methane emissions in cattle based on previous experience in sheep, with no animal behaviour problems. Furthermore, methane traits computed from the cattle PAC measurements were found to be repeatable. These results are promising and suggest that PAC is a suitable high-throughput method for the measurement of methane emissions from young beef cattle. Additional trials should be undertaken to obtain sufficient measurements to investigate the heritability of PAC traits from the cattle units.

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