

EVALUATION OF THE AGSCENT OPTIWEIGH SYSTEM TO MEASURE METHANE GAS EMISSIONS FROM CATTLE

FINAL REPORT

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April 2024

SUMMARY

The Agscent/Optiweigh station was evaluated in 3 trials under pen and grazing conditions against GreenFeed unit and feed intake, live weight and growth rate. Each Trial lasted for 2 to 3 weeks. In pen Trial 1, variables collected by the Agscent unit had strong correlations ($r \sim 0.70$; $P < 0.001$) with CH_4 (g/d), feed intake, live weight and growth when data was averaged for the entire trial for each animal. In paddock Trial 3, results were similar although correlations were slightly lower ($r \sim 0.50$; $P < 0.05$). Correlations with daily data (instead of whole trial average) resulted in lower correlations suggesting that longer period and averages is recommended. Wind speed did not seem to play a critical role in the estimation of emissions as did not selecting data with longer visits or more peaks identified. However, the dataset was relatively small for this latter analysis. It is concluded that the Agscent unit has great potential to detect differences between animals in CH_4 emissions.

INTRODUCTION

Agscent is developing an Optiweigh unit with a methane sensor to measure CH₄ production (or proxis) in a practical way for large number of animals. The data collected with this sensor could be correlated with measurements of the GreenFeed unit and feed intake, live weight (LW) and growth rate (ADG) of individual animals because methane emissions are strongly correlated with feed intake (Charmley et al., 2015). It has previously been reported that measuring techniques of CH₄ emissions from cattle that rely on measuring its concentration in the exhaled breath through spot (infrequent) measurements require a minimum number of measurements to obtain accurate data and that factors such as wind speed can also affect the measurements. Therefore, sniffer techniques may be affected by the environment where measurements are taken (e.g. indoor vs outdoor conditions) because of the effects of wind speed and direction and the number of measurements obtained per animal in a given period of time. The objective of the present study was to assess the relationship between indicators of CH₄ production collected by a sniffer technique implemented by the Agscent/Optiweigh units under both pen covered and paddock grazing conditions with those obtained by the GreenFeed units, feed intake, live weight, and growth rate of beef cattle.

MATERIALS AND METHODS

The study was conducted at John Pye Farm (NSW, The University of Sydney) in December 2023 for 2 weeks and January 2024 for another two weeks. All experimental procedures were approved by the institutional Animal Ethics Committee from The University of Sydney (Project number: 2023/2293).

EXPERIMENTAL DESIGN

Data was collected in 3 trials or experimental periods:

- 1) Two weeks in a pen trial with a GreenFeed unit, electronic feeders, electronic animal weighing scales, and the Agscent/Optiweigh unit.
- 2) Three weeks in a paddock with **no** GreenFeed unit and only the Agscent/Optiweigh unit.
- 3) Two weeks in a paddock with a GreenFeed and the Agscent/Optiweigh unit.

Animals, treatments, and management

Trial 1.

This trial lasted between 8 December 2023 and 9 January 2024 with the first 2 weeks in a pen situation with a GreenFeed unit and the rest in a paddock without a GreenFeed. Twenty 18-month-old Angus steers weighing (mean $\pm$ SD) 340 kg $\pm$ 54.9 kg/hd were housed in a pen (20 m length $\times$ 20 m width; Figure 1) and fed low-quality oaten hay in electronic feeders and grain pellets in a GreenFeed unit as attractant (Table 1a). Oaten hay and freshwater were allowed for ad libitum consumption. Each steer had been fitted with a unique radio-frequency identification (RFID) number tag. All steers were vaccinated against BVD virus, major clostridial diseases (Ultravac® 5 in 1, Zoetis Australia Pty Ltd., Rhodes, New South Wales, Australia), and BRD (Bovilis® MH + IBR; Intervet Australia Pty Ltd., East Bendigo, Victoria, Australia). This Trial was completed in late December 2023 and lasted for 2 weeks.

Animals were fed oaten hay in electronic feeders (Intergado®, Betim, MG, Brazil) and barley grain pellets in the GreenFeed unit (C-Lock Inc., Rapid City, SD, USA) to attract the animals for measurements of methane, CO₂, H₂, and O₂ consumption. Individual feed intake, live weight (LW), average daily gain (ADG), and CH₄ emissions were measured throughout the trial. A commercial molasses lick block was provided in the Agscent/Optiweigh system (Calcium Molasses, bypass Protein Meal = 3.5%, Total Protein Equivalents = 1%, Molasses = 6%, Salt (NaCl) = 64.4%; Olsson's, Yennora NSW).



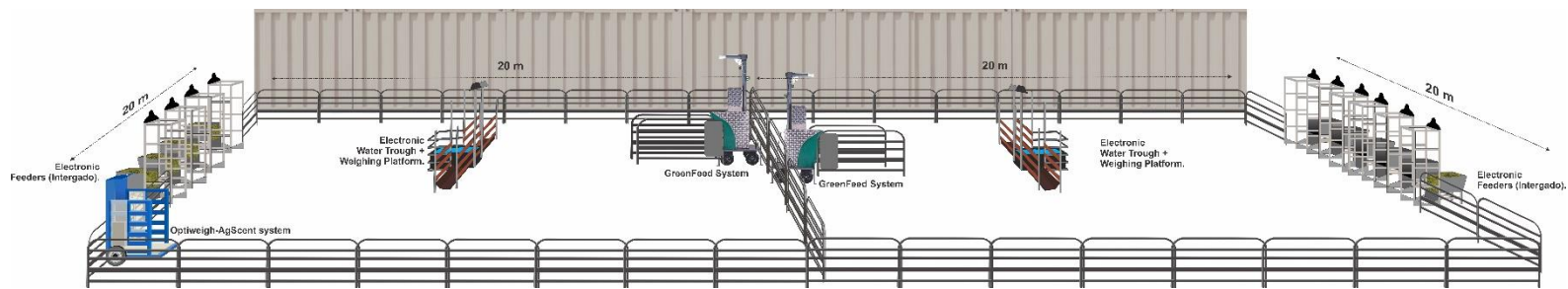


Figure 1. Pen of the trial site utilized for measuring CH₄ and CO₂ emissions from individual animals.

Trial 2.

This trial was done during the Christmas and New Year's shutdown period to collect data from beef cattle using the Agscent/Optiweigh unit but not with a GreenFeed unit during a 3-week period.

Table 1a. Chemical composition of Oaten hay delivered to the feeders and pellets delivered via the GreenFeed in pen Trial 1.

	Unit	Oaten hay	Pellets	Paddock forage
Moisture	%	3.8	8.8	70.6
Neutral Detergent Fibre (NDF)	% DM	59.4	34.3	70.0
Acid Detergent Fibre (ADF)	% DM	34.9	12.3	38.7
Crude Protein (CP)*	% DM	9.7	14.7	5.3
Crude Fat (Ether Extract)	% DM	-	3.0	-
Water Soluble Carbohydrates	% DM	9.4	5.6	4.7
Dry Matter Digestibility (DMD)	% DM	55.7	71.0	43.8
DOMD	% DM	53.1	70.3	44.9
Inorganic Ash	% DM	8.9	8.0	8.8
Organic Matter (OM)	g/kg DM	91.1	92.0	91.2
Metabolisable Energy (ME)	MJ/kg DM	7.8	11.4	6.1
Total Starch	% DM	-	26.3	-

Trial 3.

This Trial was performed with 26 steers (329 ± 46.9 kg/hd) in a grazing rotation dominated by C4 grasses such as Rodhes grass and Kangaroo grass during the last 2 weeks of February 2024. Chemical composition is shown in Table 1a. Animals had ad-libitum access to forage in the paddocks and fresh water. An Agscent/Optiweigh unit with the same molasses lick block as in trial 1 and a GreenFeed unit delivering the same pellets as in trial 1 were deployed near the water trough central to the paddocks (Figure 2).

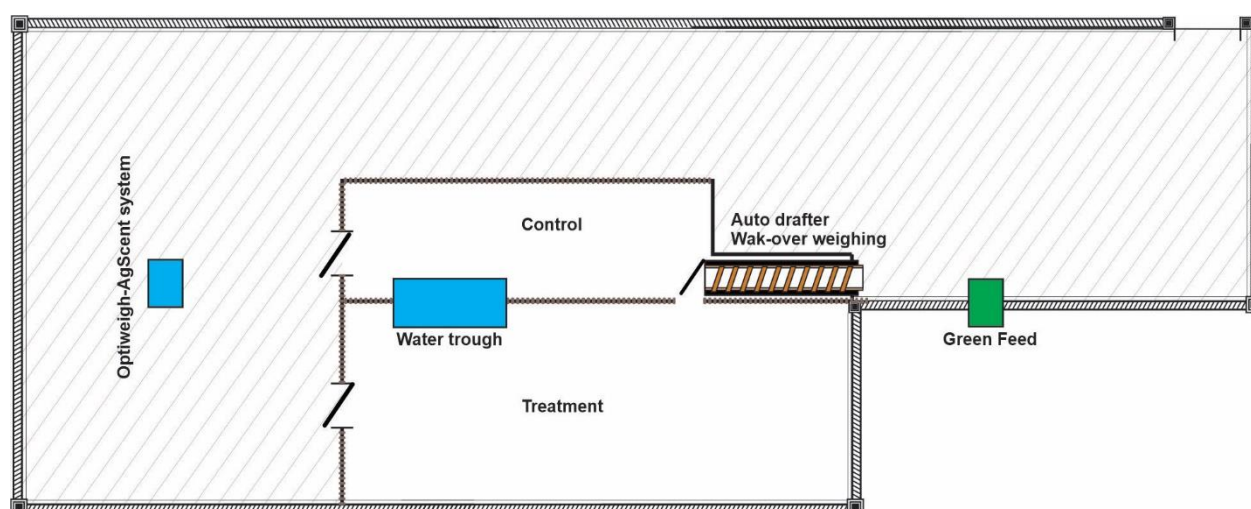


Figure 2. Trial 2 and 3 set up to measure GHG emissions from grazing cattle.

GreenFeed system

The GF is a system designed to measure enteric gas fluxes from individual animals and it has been widely utilized and validated in research with beef and dairy cattle. More detailed information of the operation of the GF unit can be found in Hristov et al. (2015) and Velazco et al. (2016).

The GF unit utilizes small quantities of pellets, or grain-based concentrates, as an attractant to encourage animals to visit the unit multiple times per day (Figure 3). The GF was configured to deliver up to 5 cups (45 grams/cup) every 40 seconds comprising a visit, and a maximum of 5 visits or feeding periods per day at a minimum time between feeding periods of 4 hours. While the animal remains with the head inside the unit consuming the pellets, breathing, and eructating, the air around the animal is aspirated automatically for real-time analysis to determine the concentration of CH₄, H₂, O₂, and CO₂. The flux rate of air is also measured and thus the total production of each gas emitted per unit of time is estimated. For each animal, information generated by the GF includes animal identification, time and duration of each visit, and amount of each gas emitted during that time (converted to g/day).

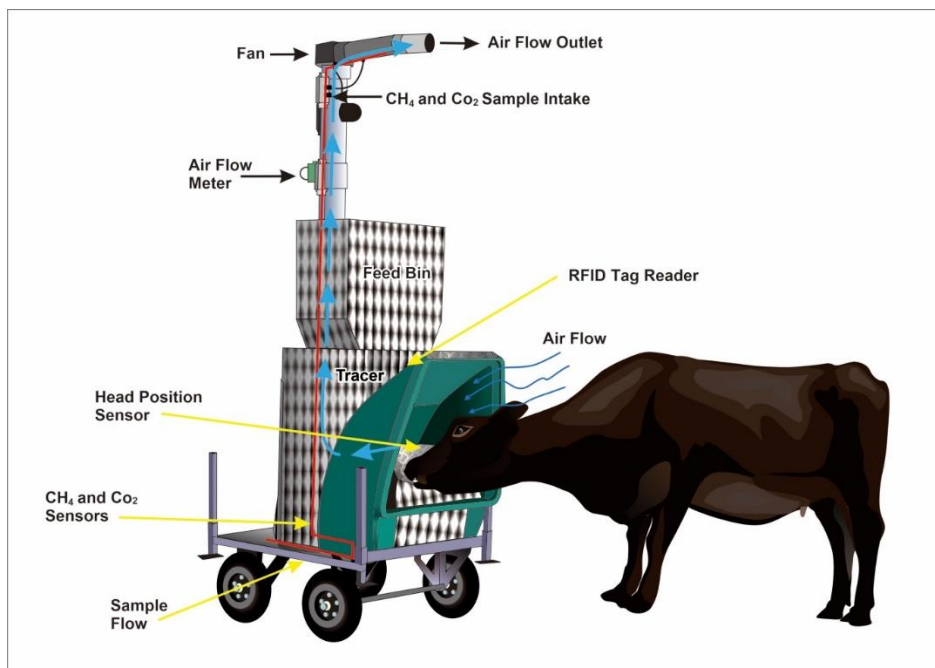


Figure 3. Greenfeed Unit (C-Lock Inc., Rapid City, South Dakota, US) utilized for measuring CH₄ and CO₂ emissions from individual animals.

The Agscent/Optiweigh system (Figure 4) is a stand-on platform scale to weigh the animals while they lick molasses lick blocks and has a CH₄/CO₂ sensor connected to a small air intake tube (approximately 5 mm diameter) approximately 0.5 m above the lick block container. This system is considered similar to the sniffer technique described elsewhere (Tedeschi et al., 2022) and the main difference with the GreenFeed system is that the air pump and intake are

much smaller so estimation of daily CH_4 production is more difficult as it relies on the assumption that the concentration of CH_4 is directly related to daily production. Both system are highly reliant on obtaining high number of measurements for each animal over the experimental period for accurate estimations. The challenges of this system are around the movement of the head of the animal and proximity of the head to the sample intake both of which affect the air-breath mixing conditions (Tedeschi et al., 2022). It has been suggested that the distance between the sniffers' intake and the mouth should be less than 30 cm (Huhtanen et al., 2015).



Figure 4. Agscent/Optiweigh utilized for measuring CH_4 and CO_2 emissions from individual animals.

Data analysis

Pearson correlation analysis and summary statistics between all variables in the raw data collected by the Agscent unit were performed for each of the three trials to assess if there were differences between trials.

Data from the GreenFeed and the Agscent unit were averaged for each animal and day of the trial if more than one visit existed and then merged together. It is important to note that animals with fewer than 30 visits with good data to the GF during a trial are considered inaccurate (Arthur et al., 2017). These number of measurements were not achieved in the present trials and results should be interpreted with caution. In addition, it is important to highlight that the concentration (ppm) and estimated CH₄ emissions (g/day) change throughout the day in cattle and measurements in the GreenFeed and the Agscent units are not simultaneous, and the number of measurements per day for each animal are not equal in both units. This can have a large influence in the results and data should be interpreted with these and other limitations of the present study. All data was analysed using SAS software (v9.4, SAS Inc., Cary, NC) using a linear regression model and Pearson correlation analysis.

RESULTS AND DISCUSSION

There were 744 data points collected from the 20 animals in Trial 1 but only 28.5% of those data points had at least an identifiable peak (Table 1). This suggests that the raw data was provided for analysis. The lack of a clearly identifiable CH₄ peak in the data could reduce the accuracy of the predictions. Steers seemed to have spent an average of 2 min and up to 20 min in the Optiweigh unit. The GreenFeed system only analyses visits longer than 3 min because the accuracy decreases sharply below this threshold. Only 21.7 and 20.1% of the visits were longer than 3 min in Trial 1 and 2, respectively. In contrast, 53% of the visits in Trial 3 were longer than 3 min because the data provided did not seem to be raw.

Pasture quality was better in the grazing trial 3 compared to the oaten hay in the pen trial 1 and thus, the reasons for fewer but longer visits in paddock trial 3 may be explained by the environment with higher animal density and more competition between animals to access the lick block in the pen compared to the paddock environment.

Table 1. Summary statistics of the raw data from the Agscent/Optiweigh unit deployed in Trial 1 with 20 steers in a pen.

Variable	N	Minimum	Mean	Maximum	Std Dev	Coeff of Variation
Weight (kg)	744	131.00	343.20	472.00	57.33	16.70
Visit duration (seconds)	744	3.00	123.05	1,174.00	148.91	121.02
Avg_ CH ₄ (ppm)	744	1.67	25.51	250.20	36.20	141.92
AUC_ CH ₄ ^a	744	6.72	4,490	102,665	10,096.02	224.86
AUC_ CH ₄ _Dur ^b	744	1.18	25.56	253.01	36.36	142.28
peakCount	744	0	0.50	10.00	1.10	221.20
peakAvg (ppm)	212	56.53	176.87	739.92	119.87	67.77
peakMin (ppm)	212	56.53	158.49	739.92	109.78	69.27
peakMax (ppm)	212	56.53	202.19	1,608.10	170.84	84.49
Avg_baseline_ CH ₄ (ppm)	744	1.71	2.47	2.86	0.25	9.99
Max Rise CH ₄ (seconds)	212	-	83.44	435.00	68.72	82.36
Avg Rise CH ₄ (seconds)	212	-	71.37	435.00	64.45	90.31
Avg CO ₂ (ppm)	744	387.00	697.35	2,637.30	344.17	49.35
AUC CO ₂ ^a	744	1,281	97,678	1,366,713	152,770	156.40
AUC CO ₂ Dur ^b	744	150.95	697.79	2,651.02	345.44	49.51
CO ₂ _at Max peak_ CH ₄ (ppm)	212	600	1,405	6,515	744.9	53.02
Avg baseline CO ₂ (ppm)	744	375.55	399.41	413.61	7.99	2.00
Avg Pressure (hPa)	707	138.42	999.08	1,010.00	52.17	5.22
Avg Temp (°C)	707	5.90	31.03	48.96	7.40	23.85

^a AUC= area under the curve

^b AUC_Duration is the sample time adjusted area under the curve

The frequency distribution of peakAvg for each trial were very similar although Trial 3 showed higher peakAvg (Figure 5) with a logarithm distribution due to some datapoints with high values. However, the proportion of datapoints with no or zero peaks in the data was much lower in Trial 3 compared to Trials 1 and 2 and these distributions also showed a logarithm distribution (Figure 6).

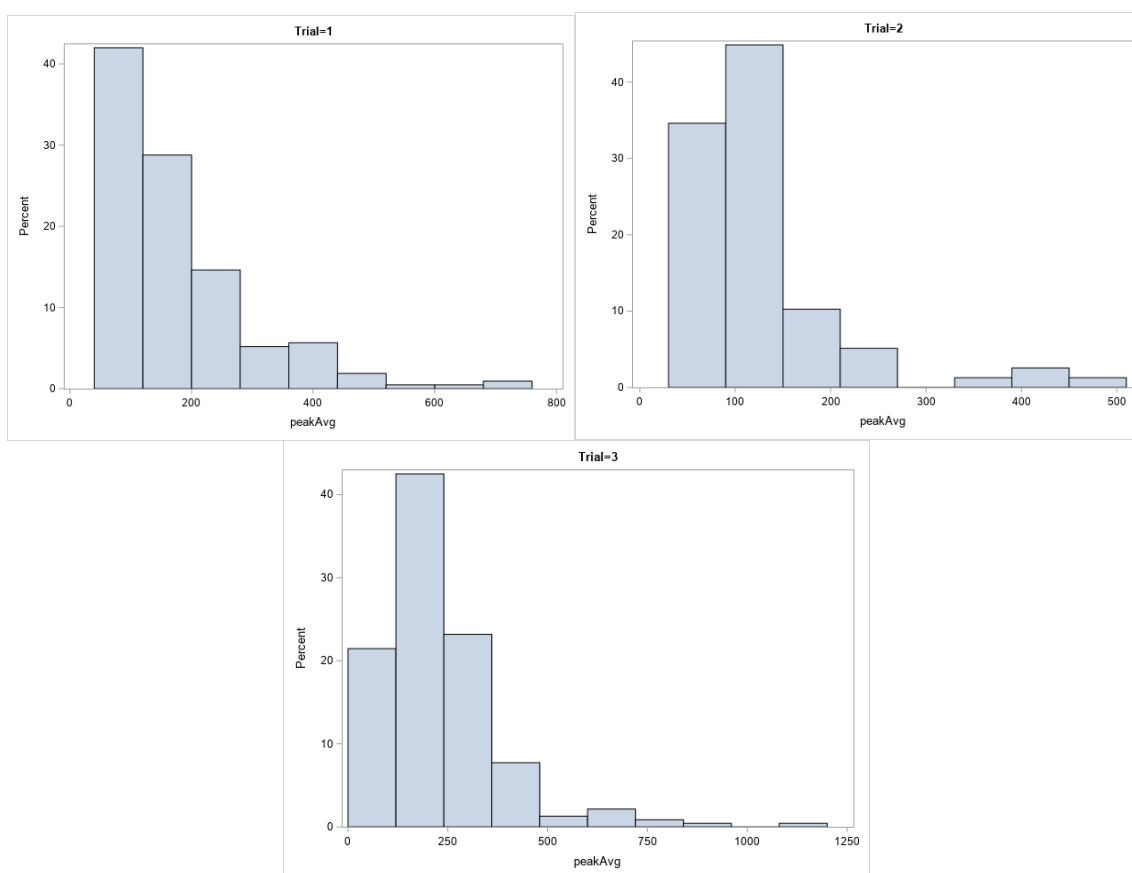


Figure 5. Frequency distribution of peak average concentration (ppm) in Trial 1, 2, and 3 under pen and paddock conditions.

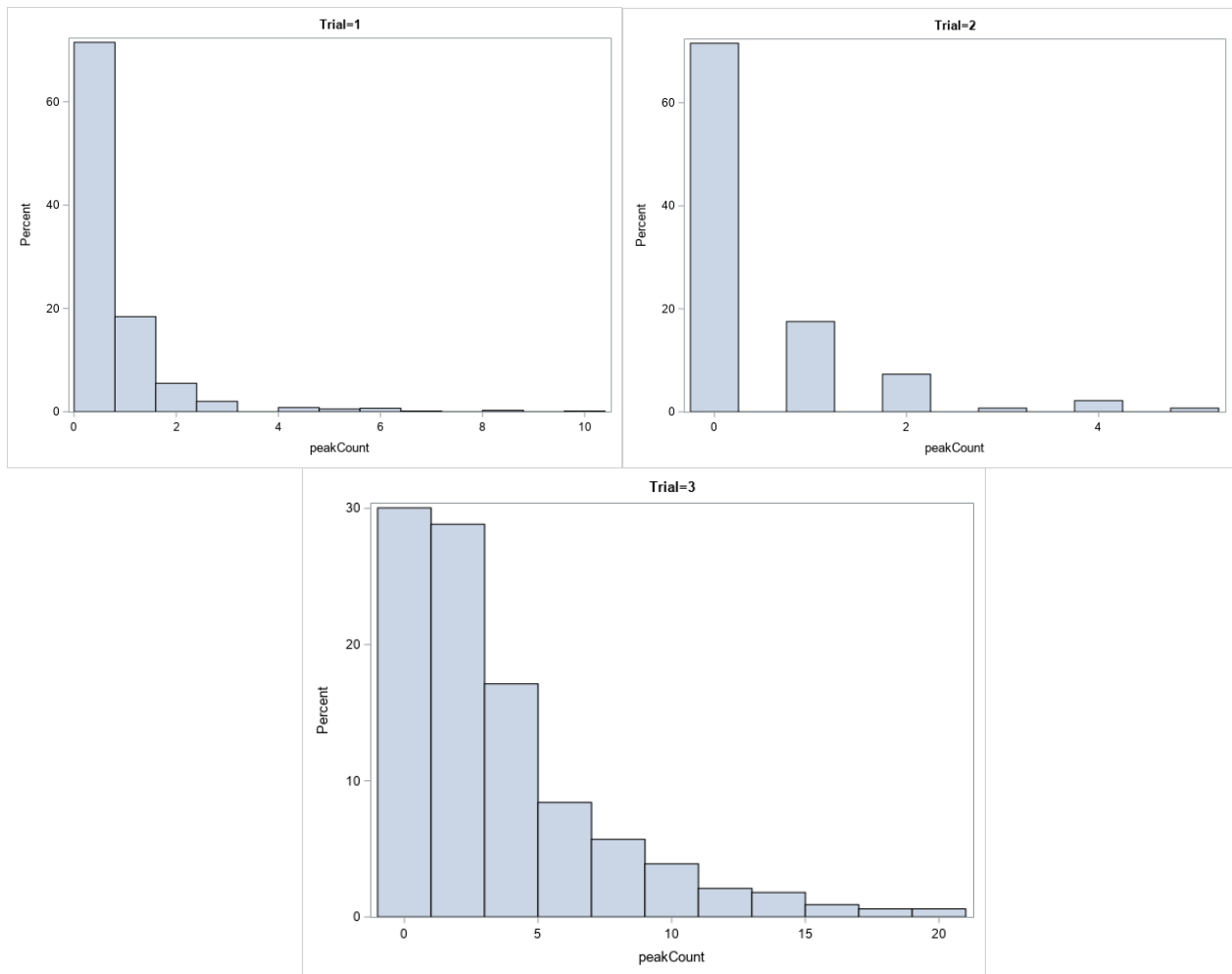


Figure 6. Frequency distribution of the number of peaks per visits in Trial 1, 2, and 3 under pen and paddock conditions.

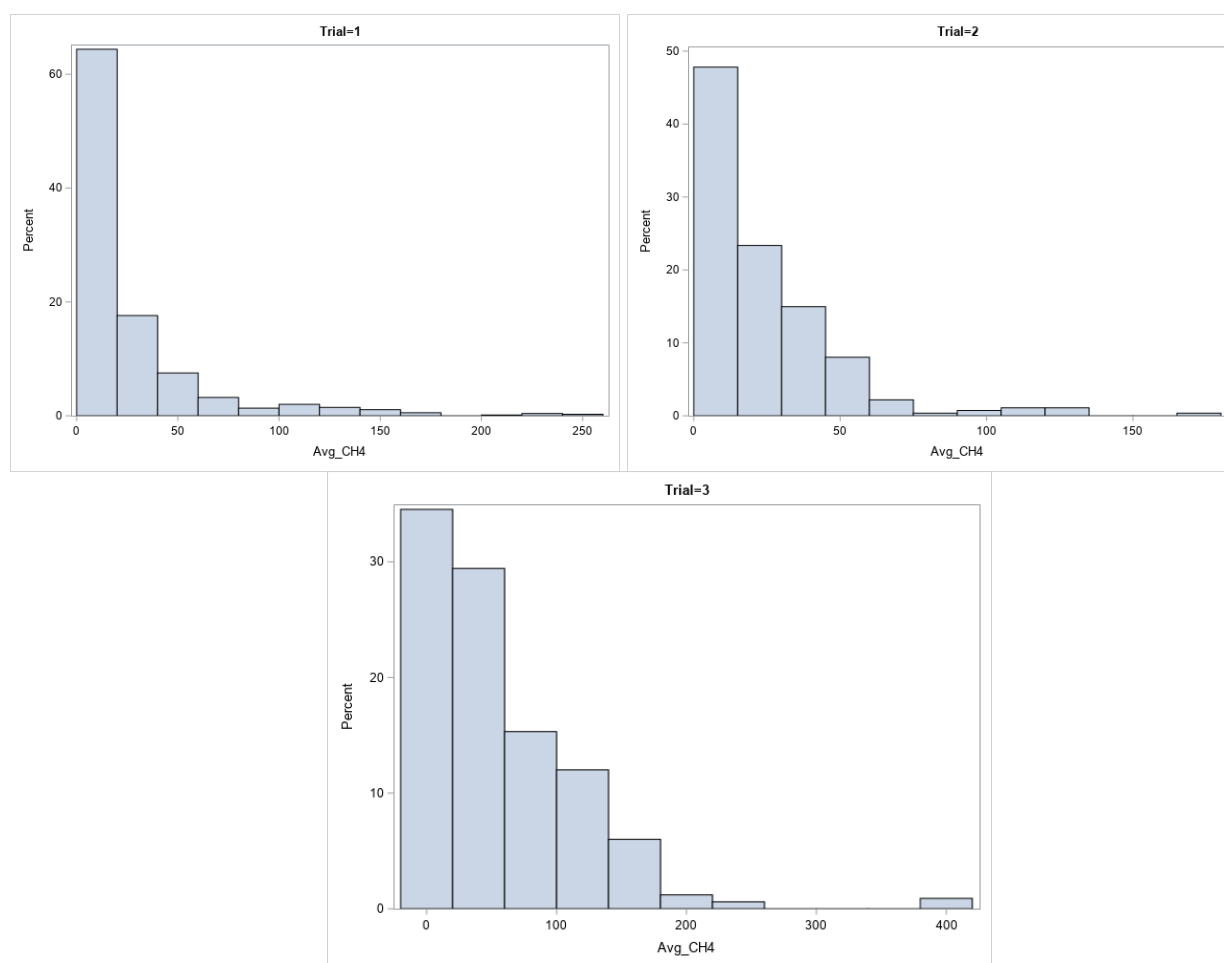


Figure 7. Frequency distribution of average methane concentration per visits in Trial 1, 2, and 3 under pen and paddock conditions.

Table 2. Summary statistics of the raw data from the Agscent/Optiweigh unit deployed in Trial 2 with 40 steers in a paddock.

Variable	N	Minimum	Mean	Maximum	Std Dev	Coeff of Variation
Weight (kg)	274	147.0	330.6	455.0	46.57	14.08
Visit duration (seconds)	274	3.0	120.8	1,194.0	163.49	135.36
Avg CH ₄ (ppm)	274	1.88	23.97	173.42	24.55	102.44
AUC CH ₄	274	7.62	3,738.6	37,550.4	6,244.35	167.02
AUC CH ₄ _Dur	274	1.90	24.03	174.69	24.64	102.56
peakCount	274	-	0.47	5.00	0.92	197.42
peakAvg (ppm)	78	57.46	128.13	474.43	79.68	62.19
peakMin (ppm)	78	57.09	114.21	474.43	78.42	68.66
peakMax (ppm)	78	57.46	143.97	474.43	93.15	64.70
Avg_baseline_CH ₄ (ppm)	274	1.52	1.70	1.94	0.13	7.50
Max_Rise_CH ₄ (seconds)	78	-	87.19	459.00	79.94	91.68
Avg_Rise_CH ₄ (seconds)	78	-	73.49	413.00	64.37	87.58
Avg_CO ₂ (ppm)	274	394.0	785.0	2,083.3	313.36	39.92
AUC_CO ₂	274	1,576	95,853	684,685	126,356	131.82
AUC_CO ₂ _Dur	274	394.0	787.1	2,091.6	313.10	39.78
CO ₂ _atMax peak_CH ₄ (ppm)	78	627	1,391	2,838	553.82	39.82
Avg_baseline_CO ₂ (ppm)	274	378.7	385.0	398.6	4.20	1.09
Avg_Pressure (hPa)	234	997	1,004	1,012	5.04	0.50
Avg_Temp (°C)	234	17.41	26.63	35.80	4.50	16.90

AUC= area under the curve

AUC_Duration is the sample time adjusted area under the curve

Table 3. Summary statistics of the raw data from the Agscent/Optiweigh unit deployed in Trial 3 with 26 steers in a paddock.

Variable	N	Minimum	Mean	Maximum	Std Dev	Coeff of Variation
Weight (kg)	333	126.00	354.11	484.00	71.58	20.21
Visit duration (seconds)	333	3.00	294.44	1,275.00	299.70	101.79
Avg_ CH ₄ (ppm)	333	-	56.67	413.78	60.73	107.17
AUC_ CH ₄	333	-	18,832	150,489	26,143	138.8
AUC_ CH ₄ _Dur	333	-	56.84	419.77	61.23	107.72
peakCount	333	-	3.07	20.00	3.81	124.14
peakAvg (ppm)	233	56.2	231.7	1,163.6	151.57	65.41
peakMin (ppm)	233	51.6	158.6	1,163.6	137.44	86.65
peakMax (ppm)	233	56.2	351.2	2,164.4	263.45	75.02
Avg baseline CH ₄ (ppm)	333	1.48	2.16	2.41	0.18	8.21
Max Rise_ CH ₄ (seconds)	233	10.00	86.93	630.00	73.79	84.89
Avg Rise_ CH ₄ (seconds)	233	7.00	51.20	630.00	62.94	122.94
Avg_ CO ₂ (ppm)	333	373.20	984.04	2,528.41	478.79	48.66
AUC_ CO ₂	333	1,493	301,763	1,981,023	348,047	115.3
AUC_ CO ₂ _Dur	333	373.25	985.15	2,525.60	477.29	48.45
CO ₂ _atMax peak_ CH ₄ (ppm)	233	521.00	1,941.58	5,058.00	965.94	49.75
Avg_baseline_ CO ₂ (ppm)	333	341.75	386.93	420.74	9.33	2.41
Avg_ Pressure (hPa)	333	563.77	1,001.46	1,012.00	34.29	3.42
Avg_ Temp (°C)	333	16.19	29.07	44.14	6.08	20.90

AUC= area under the curve

AUC_Duration is the sample time adjusted area under the curve

Pearson correlation coefficients using the daily data are shown in Tables 4, 5 and 6 for Trial 1, 2, and 3, respectively. In Trial 1, body weight (BW) was positively correlated ($P < 0.05$) with most variables (higher with average CH₄ and CO₂) except for no correlation with average ambient temperature and pressure and visit duration ($P > 0.05$; Table 4). However, BW had a negative correlation with maximum and average rise in CH₄ ($P < 0.05$). These are important findings because heavier animals most often consume more feed and thus have higher CH₄ emissions. Therefore, the positive correlations between BW and CH₄ metrics agree with these expectations.

Longer visits had higher average, rise and AUC CH₄ and CO₂, and more peaks ($P < 0.05$) suggesting that visit duration has a large impact on estimated CH₄ and CO₂ metrics particularly with AUC_ CH₄ ($r=0.67$) and peakCount ($r=0.68$). Visit duration positively influence peak detection and more peaks detected in the visit was also associated with greater values for Avg_ CH₄, AUC_ CH₄, AUC_ CH₄_Dur, peakMax, and estimated CH₄ emissions ($P < 0.05$).

Pearson correlations were similar in Trial 2 although the positive correlations with BW tended to be stronger compared to Trial 1 and the rise in CH₄ was not correlated with BW ($P > 0.05$; Table 6). Interestingly, in Trial 2, BW had a stronger correlation with emission of CH₄ and CO₂ at max CH₄ compared to Trial 1. Visit duration was strongly correlated with AUC_CH4 ($r=0.74$) in Trial 2.

Trial 3 also yielded similar results to Trial 1 and 2 although heavier animals had longer visit duration ($P < 0.05$) and there was no correlation between BW and estimated CH₄ emissions and rise ($P > 0.05$; Table 6) which is not consistent with Trials 1 and 2.

These results do not suggest that measurements in the paddock are less accurate than those in a covered pen and the Agscent sensor produces expected correlations with BW particularly.

Table 4. Pearson correlation coefficients between multiple variables from the Agscent sensor for Trial 1 (P-values below the diagonal).

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. weight (kg)		0.06	0.24	0.14	0.24	0.15	0.21	0.16	0.19	0.07	0.17	0.21	-0.17	-0.23	0.25	0.12	0.25	0.24	0.12	-0.03	0.04
2. sample duration (sec)	0.12		0.25	0.67	0.25	0.68	-0.08	-0.20	0.09	-0.10	-0.08	-0.14	0.48	0.24	0.23	0.85	0.23	0.07	-0.15	-0.07	-0.19
3. Avg_CH ₄ (ppm)	0.00	0.00		0.67	1.00	0.54	0.80	0.67	0.77	0.05	0.74	0.78	-0.26	-0.31	0.82	0.51	0.82	0.77	0.09	0.02	0.01
4. AUC_CH ₄	0.00	0.00	0.00		0.66	0.86	0.43	0.20	0.61	0.01	0.43	0.35	0.08	-0.11	0.63	0.93	0.62	0.61	-0.03	-0.01	-0.10
5. AUC_CH ₄ _Dur	0.00	0.00	0.00	0.00		0.54	0.80	0.67	0.77	0.05	0.74	0.78	-0.26	-0.31	0.82	0.51	0.82	0.76	0.09	0.02	0.01
6. peakCount	0.00	0.00	0.00	0.00	0.00		0.08	-0.15	0.34	0.01	0.25	0.17	-0.02	-0.24	0.47	0.82	0.47	0.34	-0.03	-0.03	0.00
7. peakAvg (ppm)	0.00	0.26	0.00	0.00	0.00	0.23		0.91	0.88	0.09	0.73	0.76	-0.06	-0.08	0.60	0.23	0.60	0.76	0.18	0.05	0.08
8. peakMin (ppm)	0.02	0.00	0.00	0.00	0.00	0.03	0.00		0.62	0.06	0.56	0.65	-0.05	-0.01	0.47	0.04	0.47	0.54	0.16	0.07	0.05
9. peakMax (ppm)	0.01	0.20	0.00	0.00	0.00	0.00	0.00	0.00		0.10	0.81	0.73	-0.06	-0.14	0.58	0.39	0.58	0.85	0.17	0.02	0.11
10. Avg_baseline_CH ₄ (ppm)	0.04	0.01	0.14	0.76	0.14	0.69	0.20	0.41	0.14		0.03	0.02	-0.05	-0.03	0.06	-0.04	0.06	0.14	0.75	0.04	0.05
11. Est_emis_Max_CH ₄ (ppm)	0.01	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66		0.95	-0.31	-0.32	0.47	0.19	0.47	0.65	0.11	0.02	0.18
12. Est_emis_Avg_CH ₄ (ppm)	0.00	0.04	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.77	0.00		-0.34	-0.35	0.49	0.13	0.49	0.59	0.09	0.02	0.18
13. Max_Rise_CH ₄ (seconds)	0.01	0.00	0.00	0.24	0.00	0.80	0.37	0.46	0.35	0.44	0.00	0.00		0.92	-0.14	0.28	-0.14	-0.03	-0.02	0.05	-0.22
14. Avg_Rise_CH ₄ (seconds)	0.00	0.00	0.00	0.11	0.00	0.00	0.24	0.92	0.05	0.65	0.00	0.00	0.00		-0.21	0.05	-0.21	-0.11	0.00	0.07	-0.18
15. Avg_CO ₂	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.04	0.00		0.56	1.00	0.78	0.16	0.04	-0.10
16. AUC_CO ₂	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.25	0.01	0.06	0.00	0.50	0.00		0.55	0.46	-0.07	-0.03	-0.18
17. AUC_CO ₂ _Dur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.04	0.00	0.00	0.00		0.79	0.15	0.04	-0.10
18. CO ₂ _atMax																					
peak_CH ₄ (ppm)	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.71	0.11	0.00	0.00	0.00		0.24	0.05	0.05
19. Avg_baseline_CO ₂ (ppm)	0.00	0.00	0.01	0.46	0.01	0.49	0.01	0.02	0.01	0.00	0.12	0.18	0.81	0.95	0.00	0.04	0.00	0.00		-0.13	0.14
20. Avg_Pressure (hPa)	0.49	0.05	0.66	0.81	0.66	0.35	0.51	0.35	0.74	0.28	0.82	0.79	0.45	0.35	0.31	0.41	0.31	0.46	0.30		0.14
21. Avg_Temp (°C)	0.27	0.00	0.85	0.01	0.88	0.95	0.23	0.49	0.11	0.21	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.44	0.00	0.00	

AUC= area under the curve

AUC_Duration is the sample time adjusted area under the curve

Table 5. Pearson correlation coefficients (above the diagonal) between variables by the Agscent unit in Trial 2. P-values are below the diagonal.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. weight (kg)		0.11	0.22	0.19	0.22	0.16	0.27	0.19	0.32	-0.07	0.37	0.37	-0.06	-0.17	0.13	0.14	0.13	0.37	-0.09	-0.01	0.09
2. sample duration (sec)	0.06		0.21	0.74	0.21	0.67	-0.14	-0.20	-0.04	-0.08	-0.18	-0.21	0.54	0.29	0.02	0.91	0.02	0.03	-0.06	0.06	0.05
3. Avg_CH ₄ (ppm)	0.00	0.00		0.64	1.00	0.52	0.80	0.66	0.83	0.05	0.83	0.81	-0.30	-0.32	0.70	0.45	0.70	0.71	0.21	-0.13	-0.10
4. AUC_CH ₄	0.00	0.00	0.00		0.64	0.87	0.38	0.17	0.56	-0.02	0.39	0.33	0.18	-0.05	0.38	0.93	0.38	0.57	0.08	-0.04	-0.14
5. AUC_CH ₄ _Dur	0.00	0.00	0.00	0.00		0.52	0.80	0.66	0.83	0.05	0.83	0.81	-0.30	-0.32	0.69	0.44	0.69	0.71	0.21	-0.13	-0.09
6. peakCount	0.01	0.00	0.00	0.00	0.00		-0.02	-0.24	0.21	-0.09	0.14	0.10	0.11	-0.22	0.28	0.82	0.27	0.21	0.04	-0.05	-0.02
7. peakAvg (ppm)	0.01	0.24	0.00	0.00	0.00	0.84		0.94	0.93	0.22	0.76	0.77	-0.15	-0.10	0.59	0.10	0.59	0.77	0.06	-0.19	-0.05
8. peakMin (ppm)	0.09	0.07	0.00	0.14	0.00	0.03	0.00		0.75	0.26	0.60	0.65	-0.09	-0.01	0.47	-0.05	0.47	0.61	0.09	-0.10	-0.03
9. peakMax (ppm)	0.00	0.74	0.00	0.00	0.00	0.06	0.00	0.00		0.14	0.82	0.78	-0.18	-0.18	0.62	0.25	0.62	0.83	0.02	-0.23	-0.07
10. Baseline CH ₄ (ppm)	0.24	0.18	0.39	0.80	0.37	0.15	0.06	0.02	0.22		0.14	0.14	-0.03	0.04	0.08	-0.04	0.09	0.12	0.11	0.14	0.12
11. Est emis Max CH ₄ (ppm)	0.00	0.11	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.23		0.98	-0.41	-0.42	0.58	0.06	0.58	0.61	-0.05	-0.21	0.09
12. Est emis Avg CH ₄ (ppm)	0.00	0.06	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.24	0.00		-0.43	-0.44	0.56	0.01	0.56	0.57	-0.04	-0.18	0.08
13. Max Rise CH ₄ (sec)	0.58	0.00	0.01	0.11	0.01	0.35	0.20	0.43	0.12	0.79	0.00	0.00		0.86	-0.28	0.40	-0.28	-0.08	-0.17	0.33	0.01
14. Avg_Rise_CH ₄ (sec)	0.15	0.01	0.00	0.69	0.00	0.06	0.38	0.95	0.12	0.72	0.00	0.00	0.00		-0.29	0.15	-0.29	-0.08	-0.12	0.31	0.04
15. Avg_CO ₂	0.03	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.01	0.01		0.29	1.00	0.71	0.42	-0.12	-0.25
16. AUC_CO ₂	0.02	0.00	0.00	0.00	0.00	0.00	0.39	0.65	0.03	0.48	0.64	0.91	0.00	0.20	0.00		0.28	0.36	0.06	0.02	-0.11
17. AUC_CO ₂ _Dur	0.03	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.01	0.01	0.00	0.00		0.70	0.42	-0.12	-0.25
18. CO ₂ atMax peak CH ₄ (ppm)	0.00	0.81	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.28	0.00	0.00	0.50	0.51	0.00	0.00	0.00		0.19	-0.12	-0.23
19. Baseline_CO ₂ (ppm)	0.14	0.30	0.00	0.20	0.00	0.49	0.61	0.44	0.88	0.06	0.68	0.74	0.14	0.29	0.00	0.30	0.00	0.09		-0.22	0.14
20. Avg Pressure (hPa)	0.83	0.34	0.05	0.57	0.05	0.46	0.12	0.44	0.06	0.04	0.09	0.14	0.01	0.01	0.08	0.72	0.08	0.33	0.00		-0.06
21. Avg Temp (°C)	0.77	0.18	0.08	0.21	0.08	0.02	0.53	0.88	0.34	0.00	0.52	0.98	0.53	0.17	0.24	0.26	0.24	0.01	0.00	0.05	

AUC= area under the curve

AUC_Duration is the sample time adjusted area under the curve

Table 6. Pearson correlation coefficients (above the diagonal) between variables by the Agscent unit in Trial 3. P-values are below the diagonal.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. weight (kg)		0.17	0.19	0.19	0.19	0.21	0.07	-0.01	0.12	0.27	0.12	0.08	-0.10	-0.12	0.18	0.18	0.17	0.12	0.05	0.04	0.09
2. sample duration (sec)	0.002		0.12	0.67	0.11	0.80	-0.23	-0.38	0.08	0.08	-0.10	-0.17	0.46	0.15	0.08	0.83	0.08	0.15	0.00	-0.04	0.05
3. Avg CH ₄ (ppm)	0.000	0.033		0.56	1.00	0.39	0.84	0.68	0.71	0.20	0.74	0.75	-0.29	-0.29	0.79	0.41	0.79	0.65	0.03	-0.02	-0.10
4. AUC CH ₄	0.000	0.000	0.000		0.55	0.89	0.27	-0.05	0.58	0.13	0.31	0.25	0.00	-0.22	0.57	0.95	0.58	0.65	0.02	-0.04	-0.14
5. AUC CH ₄ Dur	0.001	0.037	0.000	0.000		0.38	0.84	0.68	0.71	0.20	0.74	0.75	-0.29	-0.29	0.79	0.40	0.79	0.64	0.03	-0.02	-0.09
6. peakCount	0.000	0.000	0.000	0.000	0.000		0.01	-0.27	0.37	0.12	0.13	0.07	0.04	-0.25	0.38	0.91	0.38	0.46	0.02	-0.03	-0.02
7. peakAvg (ppm)	0.292	0.000	0.000	0.000	0.000	0.908		0.85	0.79	0.10	0.76	0.77	-0.24	-0.22	0.65	0.08	0.65	0.63	0.01	0.02	-0.05
8. peakMin (ppm)	0.908	0.000	0.000	0.477	0.000	0.000	0.000		0.41	0.10	0.54	0.60	-0.22	-0.09	0.46	-0.19	0.46	0.31	0.03	0.06	-0.03
9. peakMax (ppm)	0.063	0.212	0.000	0.000	0.000	0.000	0.000	0.000		0.08	0.76	0.64	-0.16	-0.26	0.63	0.41	0.63	0.79	-0.02	0.00	-0.07
10. Avg baseline CH ₄ (ppm)	0.000	0.129	0.000	0.018	0.000	0.029	0.125	0.137	0.220		0.11	0.07	-0.04	-0.05	0.25	0.13	0.25	0.07	0.60	-0.12	0.12
11. Est emis Max CH ₄ (ppm)	0.078	0.112	0.000	0.000	0.000	0.042	0.000	0.000	0.000	0.098		0.93	-0.34	-0.29	0.50	0.13	0.50	0.55	0.00	0.01	0.09
12. Est emis Avg CH ₄ (ppm)	0.202	0.008	0.000	0.000	0.000	0.259	0.000	0.000	0.000	0.293	0.000		-0.34	-0.29	0.53	0.07	0.53	0.49	0.01	0.03	0.08
13. Max Rise CH ₄ (seconds)	0.135	0.000	0.000	0.946	0.000	0.504	0.000	0.001	0.016	0.566	0.000	0.000		0.83	-0.24	0.18	-0.24	-0.11	0.02	0.04	0.01
14. Avg Rise CH ₄ (seconds)	0.060	0.019	0.000	0.001	0.000	0.000	0.001	0.182	0.000	0.433	0.000	0.000	0.000		-0.28	-0.10	-0.28	-0.25	0.01	0.03	0.04
15. Avg CO ₂	0.001	0.128	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.47	1.00	0.78	0.08	0.00	-0.25
16. AUC CO ₂	0.001	0.000	0.000	0.000	0.000	0.000	0.215	0.004	0.000	0.017	0.044	0.260	0.006	0.147	0.000		0.47	0.54	0.03	-0.04	-0.11
17. AUC CO ₂ Dur	0.001	0.135	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.77	0.08	0.00	-0.25
18. CO ₂ atMax peak CH ₄ (ppm)	0.069	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.317	0.000	0.000	0.099	0.000	0.000	0.000	0.000		0.01	0.02	-0.23
19. Avg baseline CO ₂ (ppm)	0.335	0.949	0.603	0.673	0.595	0.704	0.881	0.670	0.791	0.000	0.978	0.926	0.732	0.927	0.158	0.573	0.151	0.844		0.06	0.14
20. Avg Pressure (hPa)	0.463	0.489	0.723	0.476	0.725	0.530	0.797	0.376	0.998	0.031	0.832	0.690	0.516	0.602	0.995	0.476	0.977	0.745	0.299		-0.06
21. Avg Temp (°C)	0.121	0.325	0.083	0.011	0.084	0.708	0.446	0.679	0.281	0.028	0.166	0.217	0.822	0.526	0.000	0.041	0.000	0.000	0.011	0.301	

AUC= area under the curve

AUC_Duration is the sample time adjusted area under the curve

Once the data was averaged for each animal and date, the relationship between the metrics obtained by the Agscent and GreenFeed units was assessed. Summary statistics for these data for Trials 1 to 3 are shown in Tables 7 and 8 respectively.

The pen trial 1 resulted in 195 datapoint representing animal days that contained at least 1 observation from the Agscent unit. However, only 114 observations contained a peak identified. The average concentration of CH₄ measured by the Agscent was approximately 5-fold lower than that measured by the GreenFeed. However, CO₂ concentration was similar between units. The lower CH₄ concentration in the Agscent unit may be due to the lack of a potent air pump to aspirate the air around the animal as it consumes feed in the hood. The temperature of the Agscent unit was approximately 4 °C lower than that of the GreenFeed. In elevated temperatures, the molecules' kinetic energy escalates, prompting methane to disperse more swiftly into the atmosphere. In contrast, cooler temperatures entail diminished kinetic energy, resulting in restrained molecular movement and diminished vaporization rates. Interestingly, the number of visits per day to the Agscent was similar to the GreenFeed.

In paddock Trial 3, the concentration of CH₄ measured by the Agscent was only half to that of the GreenFeed whereas CO₂ concentrations were similar. However, the reason for such a lower difference between units across both trials cannot be ascertained and speculation could include the effect of wind speed on each unit's data under different environments or the longer visits to the Agscent unit between trials increasing concentration for CH₄ which is expected to be more affected by the closeness of the animals' muzzle to the air intake. It is important to note that the Agscent unit in pen Trial 1 was setup on the outside fence of the shed whereas while the GreenFeed was setup in the middle of the shed and thus could have been more protected from wind. From GreenFeed data, it revealed that wind speed and airflow slightly influence CH₄ and CO₂ measurements, AgscentOptiweigh does not have this facility, thus possibility might not be excluded that lower CH₄ reading in Agscent/Optiweigh is linked with these factors. In contrast, both the Agscent unit and the GreenFeed were under similar environments and conditions. The number of visits per animal and day was also similar between units in Trial 3, which is important for data robustness when comparisons between units are made.

Table 7. Summary stats of the daily data merged from Agscent and GreenFeed for the final analysis in pen Trial 1.

Variable	NObs	Mean	StdDev	Sum	Min	Max
Agscent data						
AUC_CH ₄ _Dur	195	28.11	28.46	5481.56	2.08	175.47
AUC_CH ₄	195	5710	10331	1113528	12	101424
AUC_CO ₂ _Dur	195	719.94	295.49	140389.10	382.14	2190.14
AUC_CO ₂	195	113519	143319	22136144	1698	1131699
Avg_CH ₄ (ppm)	195	28.06	28.45	5472.58	1.93	175.30
Avg_CO ₂ (ppm)	195	719.00	295.32	140204.58	403.07	2187.35
Avg_Pressure (hPa)	182	994.62	68.33	181020.85	138.42	1010.00
Avg_Rise_CH ₄ (sec)	114	75.97	58.22	8660.51	12.00	339.00
Avg_Temp (°C)	182	30.22	6.42	5500.27	5.90	48.40
Avg_baseline_CH ₄ (ppm)	195	2.48	0.27	483.46	1.71	2.86
Avg_baseline_CO ₂ (ppm)	195	399.32	8.05	77868.29	375.55	413.61
CO ₂ _atMax_CH ₄ (ppm)	114	1462.46	646.86	166720.50	627.00	3717.00
Max_Rise_CH ₄	114	88.77	62.69	10120.25	12.00	339.00
Visit frequency (#/d)	195	3.77	3.37	735.00	1.00	22.00
Peak CH ₄ Avg (ppm)	114	184.03	97.99	20979.88	56.53	487.27
Peak CH ₄ Count	195	0.58	0.96	113.27	0.00	8.00
Peak CH ₄ Max (ppm)	114	212.29	138.93	24200.81	56.53	847.51
Peak CH ₄ Min (ppm)	114	163.89	95.28	18683.47	56.53	487.27
Visit duration (sec)	195	130.12	113.74	25373.33	4.00	578.00
Weight (kg)	195	352.50	56.54	68737.79	136.00	469.00
GreenFeed data						
CO ₂ (g/d)	158	5366	1225.3	847970	2622	9059
CH ₄ (g/d)	158	227	69.56	35877	67	446
O ₂ (g/d)	156	4451	898.61	694415	2655	7199
H ₂ (g/d)	158	0.31	0.17	49.23	0.04	1.05
CH ₄ (ppm)	158	132.33	51.72	20908.41	25.33	307.65
CO ₂ (ppm)	158	1144	378.7	180809	361	2333
Airflow (L/s)	158	26.07	5.24	4118.98	20.16	38.42
Wind Speed (m/s)	158	0.12	0.08	18.36	0.00	0.52
Visit duration (sec)	158	225	31.10	35533	133	326
Temperature (°C)	158	34.83	2.13	5503.88	30.55	42.40
Visit frequency (#/d)	188	3.52	2.13	662.00	0.00	11.00
Weight (kg)	188	353	56.13	66288	255	454
ADG (kg/d)	188	-0.13	1.44	-24.50	-5.63	2.89
Total DMI (kg/d)	188	7.95	3.44	1494.69	0.89	15.77
Total MEI (MJ/d)	188	59.67	24.11	11218	10.34	114.53
Water (L/d)	188	51.31	27.38	9645.88	0.00	137.23

AUC= area under the curve

AUC_Duration is the sample time adjusted area under the curve

Table 8. Summary stats of the daily data merged from Agscent and GreenFeed for the final analysis in paddock Trial 3.

Variable	NObs	Mean	StdDev	Sum	Min	Max
Agscent data						
AUC_CH ₄ _Dur	207	58.08	49.27	12021.87	0.00	243.72
AUC_CH ₄	207	19441	21751	4024296	0	92934
AUC_CO ₂ _Dur	207	1012	439	209474	373	2526
AUC_CO ₂	207	313450	291586	64884251	1493	1411813
Avg_CH ₄ (ppm)	207	57.94	49.07	11994	0.00	238.08
Avg_CO ₂ (ppm)	207	1011.26	438.10	209331	373.20	2528.41
Avg_Pressure (hPa)	207	1003.15	17.46	207651	831.79	1011.00
Avg_Rise_CH ₄ (sec)	162	51.67	58.16	8370.86	7.50	601.00
Avg_Temp (°C)	207	28.94	5.53	5990.33	18.20	41.50
Avg_baseline_CH ₄ (ppm)	207	2.16	0.15	447.31	1.71	2.41
Avg_baseline_CO ₂ (ppm)	207	386	8.69	80034	375	409
CO ₂ _atMax_CH ₄ (ppm)	162	1962	896	317990	648	5058
Max_Rise_CH ₄	162	89.32	71.82	14469.75	10.00	601.00
Visit frequency (#/d)	207	1.53	0.83	317.00	1.00	6.00
Peak CH ₄ Avg (ppm)	162	233.63	134.68	37847.92	57.85	891.99
Peak CH ₄ Count	207	3.22	3.39	666.53	0.00	17.00
Peak CH ₄ Max (ppm)	162	355.08	242.90	57522	57.85	2164.39
Peak CH ₄ Min (ppm)	162	160.27	118.07	25963	51.60	835.86
Visit duration (sec)	207	309.53	280.46	64072	4.00	1275.00
Weight (kg)	207	363.03	57.74	75148	166.00	483.00
GreenFeed data						
CO ₂ (g/d)	177	5281	717	934816	3581	7542.32
CH ₄ (g/d)	177	198	43.41	35210	97.99	346.53
O ₂ (g/d)	177	3565	538	631148	1413	5046
H ₂ (g/d)	177	0.21	0.07	36.95	0.07	0.44
CH ₄ (ppm)	177	110.49	30.85	19556	48.73	258.94
CO ₂ (ppm)	177	1087	292.77	192532	585	2647
Airflow (L/s)	177	26.87	4.44	4756.00	9.74	34.11
Wind Speed (m/s)	177	0.18	0.22	32.25	0.00	1.42
Visit duration (Sec)	177	260.18	47.55	46051	178.00	443.75
Temperature (°C)	177	33.35	3.35	5903.42	26.10	44.17
Wind CF	177	1.02	0.02	180.23	1.00	1.14
Visit frequency (#/d)	177	3.43	1.65	607.00	1.00	7.00

AUC= area under the curve

AUC_Duration is the sample time adjusted area under the curve

The relationships between variables collected by the Agscent unit and those from GreenFeed and the electronic feeder for pen Trial 1 are shown in Table 9. The CH₄ emissions in g/hd/d were positively and moderately correlated with AUC_CH₄_Dur, Avg_CH₄, peakAvg, peakMax ($P < 0.001$; Table 9). Interestingly, animals that had more visits per day to the Optiweigh unit also had lower CH₄ emissions in g/d ($P < 0.001$). A positive finding was the moderate and positive correlation between the concentration of CH₄ measured by both systems despite the fact that their design and operation is very different. As expected, greater wind speed measured by the GreenFeed was associated with lower average CH₄ and CO₂ concentrations measured by the Agscent unit ($P < 0.10$; Table 9). Very positive findings are the positive relationships between peakAvg and CO₂_atMax_CH₄ with animal weight, growth rate (ADG), total feed intake (DMI) and total metabolisable energy intake (MEI). These may be more important metrics to calibrate the Agscent sensor than the GreenFeed data because the stronger such correlations the better estimation of CH₄ emissions from the animals are expected.

Table 9. Pearson correlation between variables collected by the Agscent unit (rows) and the GreenFeed unit or electronic feeders (columns) in pen Trial 1.

Variable	CO ₂ , g/d	CH ₄ , g/d	O ₂ , g/d	H ₂ , g/d	CH ₄ _p pm	CO ₂ _p pm	Airflow , L/s	Wind Speed	Seco nds	Tempe rat	# Visits	Start_T ime	Weight	ADG	Total DMI, kg	Total MEI, MJ	Water, L/d
AUC CH ₄ Dur	0.36 ^a	0.26 ^a	0.36 ^a	0.24 ^b	0.23 ^b	0.29 ^a	-0.11	-0.19 ^c	0.05	0.00	-0.03	-0.04	0.26 ^a	0.19 ^b	0.12	0.12	0.14 ^d
AUC CH ₄	0.22 ^b	0.17 ^b	0.21 ^b	0.12	0.15 ^d	0.17 ^c	-0.05	-0.03	0.06	0.15 ^d	-0.05	0.01	0.14 ^c	0.18 ^c	0.09	0.09	0.05
AUC CO ₂ Dur	0.33 ^a	0.19 ^b	0.35 ^a	0.13	0.16 ^c	0.24 ^b	-0.05	-0.15 ^d	0.08	0.00	-0.04	-0.06	0.28 ^a	0.24 ^a	0.15 ^c	0.14 ^c	0.14 ^d
AUC CO ₂	0.19 ^c	0.11	0.19 ^c	0.08	0.09	0.13	-0.01	0.02	0.06	0.12	-0.06	0.06	0.14 ^c	0.16 ^c	0.11	0.10	0.04
Avg CH ₄ (ppm)	0.36 ^a	0.26 ^a	0.36 ^a	0.24 ^b	0.23 ^b	0.29 ^a	-0.11	-0.19 ^c	0.05	0.00	-0.03	-0.04	0.26 ^a	0.20 ^b	0.12 ^d	0.12	0.14 ^d
Avg CO ₂ (ppm)	0.33 ^a	0.20 ^b	0.35 ^a	0.13	0.16 ^c	0.24 ^b	-0.05	-0.15 ^c	0.08	0.00	-0.04	-0.06	0.28 ^a	0.25 ^a	0.15 ^c	0.15 ^c	0.14 ^d
Avg Pressure (hPa)	-0.07	-0.14 ^d	-0.05	0.00	-0.14 ^d	-0.09	0.08	0.02	-0.03	-0.07	-0.10	-0.01	-0.03	0.20 ^b	-0.01	-0.01	-0.04
Avg Rise CH ₄ (sec)	-0.19 ^d	-0.08	-0.19 ^d	0.03	-0.12	-0.19 ^d	0.10	0.04	0.00	-0.03	0.05	0.04	-0.29 ^b	-0.18 ^d	-0.06	-0.05	-0.05
Avg Temp	-0.11	-0.06	-0.15 ^d	-0.08	0.09	0.09	-0.34 ^a	-0.14 ^d	-0.13	0.25 ^b	-0.13	-0.34 ^a	-0.14 ^c	0.19 ^c	0.09	0.09	0.06
Avg baseline CH ₄ (ppm)	0.11	0.15 ^d	0.12	0.04	0.17 ^c	0.15 ^d	-0.14 ^d	-0.10	-0.01	0.28 ^a	-0.08	-0.22 ^b	0.01	0.08	-0.16 ^c	-0.16 ^c	0.06
Avg baseline CO ₂ (ppm)	0.16 ^c	0.20 ^c	0.14 ^d	-0.04	0.27 ^a	0.26 ^a	-0.27 ^a	-0.40 ^a	0.02	0.30 ^a	0.11	-0.69 ^a	0.00	0.30 ^a	0.18 ^c	0.18 ^c	0.23 ^a
CO ₂ atMax CH ₄ (ppm)	0.34 ^a	0.24 ^c	0.32 ^a	-0.04	0.26 ^c	0.33 ^b	-0.22 ^c	-0.09	-0.10	0.22 ^c	0.18	-0.13	0.28 ^b	0.32 ^a	0.29 ^b	0.28 ^b	0.15
Est emis Avg CH ₄	0.27 ^c	0.20 ^d	0.28 ^b	0.02	0.25 ^c	0.31 ^b	-0.25 ^c	-0.13	-0.03	0.09	0.14	-0.14	0.27 ^b	0.06	0.13	0.13	0.06
Est emis Max CH ₄	0.25 ^c	0.22 ^c	0.24 ^c	0.02	0.29 ^b	0.31 ^b	-0.26 ^c	-0.15	-0.06	0.16	0.13	-0.18	0.17 ^d	0.07	0.13	0.13	0.06
Max Rise CH ₄ (sec)	-0.11	-0.06	-0.11	0.04	-0.11	-0.14	0.12	0.10	0.01	0.07	0.04	0.05	-0.18 ^c	-0.11	0.03	0.04	-0.05
Visit Frequency (#/d)	-0.34 ^a	-0.36 ^a	-0.27 ^a	-0.21 ^b	-0.25 ^b	-0.20 ^b	-0.01	0.09	-0.10	0.00	-0.23 ^a	-0.17 ^b	-0.17 ^c	0.08	-0.26 ^a	-0.26 ^a	0.03
Peak CH ₄ Avg (ppm)	0.31 ^b	0.28 ^b	0.30 ^b	0.10	0.29 ^b	0.31 ^b	-0.21 ^c	-0.09	0.15	0.12	0.27 ^b	-0.16	0.27 ^b	0.19 ^c	0.25 ^b	0.25 ^b	0.10
Peak CH ₄ Count	0.22 ^b	0.16 ^c	0.21 ^b	0.07	0.14 ^d	0.16 ^c	-0.03	-0.04	0.05	0.13	-0.06	-0.01	0.17 ^c	0.17 ^c	0.09	0.09	0.09
Peak CH ₄ Max (ppm)	0.30 ^b	0.26 ^c	0.28 ^b	0.05	0.31 ^b	0.34 ^a	-0.25 ^c	-0.10	-0.03	0.26 ^c	0.18 ^d	-0.19 ^d	0.22 ^c	0.20 ^c	0.22 ^c	0.21 ^c	0.09
Peak CH ₄ Min (ppm)	0.23 ^c	0.25 ^c	0.22 ^c	0.12	0.24 ^c	0.22 ^c	-0.14	-0.09	0.23 ^c	0.00	0.30 ^a	-0.15	0.21 ^c	0.15	0.23 ^c	0.23 ^c	0.10
Visit duration (sec)	0.10	0.05	0.11	0.04	0.04	0.06	0.01	0.03	0.05	0.10	-0.11	0.07	0.08	0.09	0.06	0.06	0.00
Weight (kg)	0.76 ^a	0.59 ^a	0.83 ^a	0.27 ^a	0.50 ^a	0.57 ^a	-0.07	-0.01	0.23 ^b	0.05	-0.01	0.04	0.98 ^a	0.24 ^a	0.45 ^a	0.45 ^c	0.30 ^a

^{a, b, c, d} Pearson correlation coefficient is different than zero at P < 0.001, P < 0.01, P < 0.05, and P < 0.10, respectively.

AUC= area under the curve

AUC_Duration is the sample time adjusted area under the curve

Table 10 shows the correlations between Agscent and GreenFeed unit for the paddock Trial 3. It was expected that these correlations were going to be weaker in the paddock compared to the pen conditions because of the effect of wind speed. However, most of the correlations for CH₄ measured by both systems were stronger in the paddock compared to the pen trial, possible due to more data processing and less outliers in the data provided to the research team. Nevertheless, the correlation between wind speed and CH₄ metrics were more strongly negative in the paddock trial suggesting that greater wind speed reduced estimated CH₄ emissions. Better wind protection for the Agscent/Optiweigh unit is recommended and perhaps with the addition of a hood.

An attempt was also made to analyse the data considering only visits longer than 120 seconds to the Agscent unit. This resulted in stronger correlation with CH₄ emissions measured by GreenFeed in Trial 1 but weaker in Trial 3 in the paddock (data not shown). For instance, the correlation between CH₄ (g/d) and Avg_CH₄ was 0.37 (N = 61; P = 0.003). Therefore, visit length does not seem to play a relevant role in the estimation of CH₄ of the Agscent unit.

Similar, analysing data with more than 2 peakCount of the Agscent unit resulted in a large increase in the correlation with CH₄ (g/d) of up to 0.87 but this left only 6 datapoints in Trial 1. Therefore, it is difficult to conclude whether or not filtering for peakCount would have a positive influence on the estimations of CH₄ from the Agscent unit.

Table 10. Pearson correlation between variables collected by the Agscent unit (rows) and the GreenFeed unit or electronic feeders (columns) in paddock Trial 3.

	CO ₂ , g/d	CH ₄ , g/d	O ₂ , g/d	H ₂ , g/d	CH ₄ , ppm	CO ₂ , ppm	Airflow	Wind Speed	Seconds	Temp	# Visits
AUC_CH ₄ _Dur	0.25 ^a	0.23 ^b	0.21 ^b	0.22 ^b	0.11	0.06	0.18 ^c	-0.22 ^b	0.02	0.06	0.03
AUC_CH ₄	0.22 ^b	0.10	0.16 ^c	0.15 ^c	0.03	0.07	0.09	-0.14 ^d	0.01	0.07	0.00
AUC_CO ₂ _Dur	0.19 ^b	0.15 ^c	0.16 ^c	0.16 ^c	0.14 ^d	0.14 ^d	0.08	-0.28 ^a	0.02	0.06	0.05
AUC_CO ₂	0.16 ^c	0.05	0.11	0.10	0.00	0.05	0.07	-0.10	0.05	0.10	0.01
Avg_CH ₄ (ppm)	0.25 ^a	0.23 ^b	0.20 ^b	0.22 ^b	0.11	0.06	0.19 ^c	-0.22 ^b	0.02	0.06	0.03
Avg_CO ₂ (ppm)	0.19 ^b	0.15 ^c	0.16 ^c	0.16 ^c	0.14 ^d	0.14 ^d	0.09	-0.28 ^a	0.02	0.06	0.05
Avg_Pressure (hPa)	0.16 ^c	0.09	0.11	0.14 ^d	0.11	0.12	-0.02	-0.13 ^d	0.00	-0.21 ^b	-0.11
Avg_Rise_CH ₄ (sec)	-0.09	-0.14 ^d	-0.10	-0.19 ^c	-0.08	-0.02	-0.06	0.03	0.08	-0.02	-0.18 ^c
Avg_Temp	0.10	0.20 ^b	0.21 ^b	0.08	0.08	-0.05	0.02	0.11	-0.04	0.39 ^a	0.24 ^a
Avg_baseline_CH ₄ (ppm)	0.09	0.11	0.02	-0.13 ^d	-0.17 ^c	-0.24 ^a	0.34 ^a	-0.16 ^c	0.02	0.24 ^a	0.26 ^a
Avg baseline CO ₂ (ppm)	0.18 ^c	0.24 ^a	0.11	-0.18 ^c	0.03	-0.10	0.07	-0.09	-0.01	0.46 ^a	0.20 ^b
CO ₂ _atMax_CH ₄	0.24 ^b	0.19 ^c	0.18 ^c	0.26 ^b	0.18 ^c	0.17 ^c	0.09	-0.27 ^a	-0.10	-0.02	-0.02
Est_emis_Avg_CH ₄	0.18 ^c	0.29 ^a	0.21 ^c	0.20 ^c	0.15 ^d	0.03	0.09	-0.08	-0.06	0.06	0.12
Est_emis_Max_CH ₄	0.20 ^c	0.29 ^a	0.21 ^c	0.18 ^c	0.13	0.01	0.12	-0.09	-0.06	0.03	0.12
Max_Rise_CH ₄ (sec)	-0.05	-0.09	-0.02	-0.09	-0.09	-0.04	0.01	0.03	0.02	0.07	-0.14
Visit Frequency (#/d)	0.03	-0.02	0.02	-0.18 ^c	-0.04	-0.01	0.01	-0.11	0.12	0.09	-0.07
Peak CH ₄ Avg (ppm)	0.14 ^d	0.22 ^b	0.16 ^d	0.21 ^c	0.20 ^c	0.12	0.05	-0.15 ^d	-0.08	0.00	0.04
Peak CH ₄ Count	0.23 ^b	0.10	0.17 ^c	0.13 ^d	0.02	0.05	0.10	-0.10	0.01	0.09	0.03
Peak CH ₄ Max (ppm)	0.24 ^b	0.23 ^b	0.20 ^c	0.19 ^c	0.13	0.08	0.14	-0.16 ^d	-0.09	-0.05	-0.01
Peak CH ₄ Min (ppm)	0.02	0.13	0.05	0.15 ^d	0.22 ^b	0.14	-0.07	-0.10	0.00	0.03	0.12
Visit duration (sec)	0.08	-0.03	0.01	-0.02	-0.12	-0.07	0.11	0.03	0.11	0.07	0.01
Weight (kg)	0.54 ^a	0.35 ^a	0.54 ^a	0.14 ^d	0.30 ^a	0.30 ^a	-0.05	0.01	-0.10	0.03	0.09

^{a, b, c, d} Pearson correlation coefficient is different than zero at P < 0.001, P < 0.01, P < 0.05, and P < 0.10, respectively.

AUC= area under the curve

AUC_Duration is the sample time adjusted area under the curve

Tables 11 and 12 show Pearson correlation coefficients after averaging all data across each trial for each animal for variables collected by the Agscent and GreenFeed unit. For pen Trial 1, all correlation coefficients become stronger although the P-values become slightly higher because of the reduction in the number of observations (N=20; Table 11). Most notably, the correlation coefficients between CH₄ metrics from the Agscent unit and CH₄ (g/d) from the GreenFeed unit were as high as 0.70. These suggests that averaging data over longer periods of time increases the accuracy of the measurements because those values are the average of more datapoints. The strong correlations between CH₄ metrics from Agscent unit and total DMI, MEI, weight, and ADG are also relevant. Therefore, longer periods of data collection averaged for each animal is likely to result in more accurate prediction of CH₄. Avg_CH₄ and Avg_CO had the strongest correlation with DMI and MEI so this seems to be one of the predictors of CH₄.

Results were similar for paddock Trial 3, with the strongest correlations between CH₄ (g/d) and Avg_CH₄ although in this trial the correlation with estimated emissions from average CH₄ being higher than in Trial 1. The contrast between Trial 1 and Trial 3 lies in the dietary differences: in Trial 3, animals had unrestricted access to green forage, while in Trial 1, they were fed hay instead of forage. However, the digestibility of hay seemed to higher compared to green forage, leading to a reliance on microbial digestion to meet the animals' nutrient requirements, consequently resulting in higher methane production. This pattern is consistent with the average methane production observed in the Agscent/Optiweigh system. However, when methane was measured using the GreenFeed system, results were inconsistent. Methane production averaged higher (28 ppm/130 sec) when animals were fed hay compared to when they consumed green fodder (57 ppm/309 sec). Conversely, in the GreenFeed system, lower methane levels (132 ppm/224 sec) were recorded from hay-fed animals than from those fed green fodder (198 ppm/260 sec).

Table 11. Pearson correlation analysis between variables measured by the Agscent unit (rows) and the GreedFeed and electronic feeders (columns) after averaging data for each animal in pen Trial 1. $P < 0.05$ for $r > \pm 0.43$ and $P < 0.001$ for $r > \pm 0.70$.

Variable	CO ₂ (g/d)	CH ₄ (g/d)	O ₂ (g/d)	H ₂ (g/d)	CH ₄ (ppm)	CO ₂ (ppm)	Airflow (L/s)	Wind Speed (m/s)	Visit dur (sec)	Temp (C)	Visit freq (#/d)	Weight (kg)	ADG (kg/d)	Total DMI (kg/d)	Total MEI (MJ/d)	Water (L/d)
AUC_CH ₄ _Dur	0.699	0.638	0.697	0.566	0.569	0.644	0.030	-0.099	0.443	0.039	-0.039	0.574	0.469	0.540	0.539	0.476
AUC_CH ₄	0.458	0.389	0.441	0.408	0.304	0.376	0.184	0.069	0.299	0.270	0.185	0.346	0.546	0.466	0.465	0.209
AUC_CO ₂ _Dur	0.766	0.667	0.763	0.520	0.592	0.696	0.063	0.075	0.455	0.190	0.026	0.684	0.538	0.666	0.665	0.467
AUC_CO ₂	0.397	0.321	0.380	0.333	0.231	0.307	0.198	0.165	0.223	0.348	0.258	0.320	0.516	0.442	0.441	0.177
Avg_CH ₄ (ppm)	0.700	0.638	0.697	0.567	0.569	0.645	0.030	-0.099	0.444	0.042	-0.037	0.575	0.473	0.541	0.540	0.472
Avg_CO ₂ (ppm)	0.764	0.663	0.761	0.523	0.588	0.693	0.068	0.078	0.453	0.197	0.028	0.684	0.544	0.664	0.664	0.464
Avg_Pressure (hPa)	0.067	-0.117	0.075	0.037	-0.083	0.081	0.014	0.275	0.120	0.144	-0.051	-0.060	0.416	0.251	0.250	0.080
Avg_Rise_CH ₄ (sec)	-0.481	-0.497	-0.451	-0.389	-0.501	-0.491	0.192	0.533	-0.215	0.426	0.007	-0.455	-0.420	-0.515	-0.517	-0.244
Avg_Temp (C)	-0.448	-0.309	-0.445	-0.213	-0.210	-0.338	-0.425	-0.290	-0.204	-0.315	0.057	-0.443	-0.171	-0.317	-0.315	-0.162
Baseline_CH ₄ (ppm)	0.143	0.066	0.143	0.186	0.055	0.119	0.136	-0.142	-0.331	-0.339	-0.178	0.210	-0.233	-0.087	-0.085	0.121
Baseline CO ₂ (ppm)	0.078	0.084	0.052	0.266	0.092	0.083	-0.056	-0.297	-0.300	-0.433	-0.062	0.090	-0.279	-0.147	-0.145	0.086
CO ₂ at Max_CH ₄ (ppm)	0.687	0.623	0.686	0.504	0.525	0.594	0.221	0.110	0.290	0.323	-0.090	0.612	0.508	0.585	0.584	0.418
Est_emis_Avg_CH ₄	0.648	0.698	0.627	0.615	0.623	0.592	0.073	-0.170	0.360	0.040	-0.098	0.535	0.207	0.367	0.366	0.328
Est_emis_Max_CH ₄	0.518	0.583	0.484	0.553	0.518	0.473	0.071	-0.201	0.336	0.068	-0.113	0.366	0.235	0.304	0.303	0.213
Max_Rise_CH ₄ (sec)	-0.353	-0.413	-0.324	-0.331	-0.445	-0.397	0.234	0.692	-0.175	0.607	0.221	-0.284	-0.246	-0.328	-0.329	-0.224
Visit Frequency (#/d)	-0.441	-0.481	-0.403	-0.330	-0.505	-0.480	0.421	0.320	-0.319	0.179	0.054	-0.281	-0.224	-0.484	-0.483	0.009
Peak CH ₄ Avg (ppm)	0.689	0.693	0.669	0.523	0.632	0.635	0.104	0.097	0.578	0.221	0.024	0.570	0.312	0.523	0.523	0.298
Peak CH ₄ Count	0.478	0.389	0.465	0.395	0.294	0.391	0.155	-0.031	0.229	0.182	0.114	0.388	0.532	0.464	0.462	0.257
Peak CH ₄ Max (ppm)	0.595	0.607	0.567	0.541	0.538	0.537	0.102	0.014	0.491	0.261	0.009	0.441	0.365	0.450	0.448	0.213
Peak CH ₄ Min (ppm)	0.641	0.669	0.618	0.416	0.628	0.605	0.084	0.105	0.620	0.138	-0.014	0.529	0.213	0.506	0.507	0.317
Visit duration (sec)	0.252	0.230	0.224	0.285	0.148	0.179	0.084	0.089	0.179	0.362	0.277	0.158	0.372	0.277	0.276	0.044
Weight (kg)	0.896	0.798	0.924	0.475	0.766	0.867	-0.076	0.092	0.337	0.131	-0.148	0.990	0.439	0.707	0.707	0.460

AUC= area under the curve

AUC_Duration is the sample time adjusted area under the curve

Table 12. Pearson correlation analysis between variables measured by the Agscent unit (rows) and the GreedFeed (columns) after averaging data for each animal in paddock Trial 3. $P < 0.05$ for $r > \pm 0.40$.

Variable	CO ₂ (g/d)	CH ₄ (g/d)	O ₂ (g/d)	H ₂ (g/d)	CH ₄ (ppm)	CO ₂ (ppm)	Airflow (L/s)	Wind Speed (m/s)	Visit dur (sec)	Temp (C)	Visit freq (#/d)
AUC_CH ₄ _Dur	0.529	0.547	0.451	0.403	0.597	0.614	-0.241	-0.192	-0.131	0.082	-0.021
AUC_CH ₄	0.539	0.411	0.370	0.572	0.452	0.574	-0.284	0.197	0.073	0.065	-0.022
AUC_CO ₂ _Dur	0.387	0.199	0.384	0.115	0.254	0.394	0.011	-0.346	-0.095	0.006	0.120
AUC_CO ₂	0.423	0.275	0.269	0.517	0.317	0.451	-0.250	0.389	0.213	0.153	-0.042
Avg_CH ₄ (ppm)	0.529	0.546	0.450	0.401	0.595	0.613	-0.239	-0.194	-0.126	0.085	-0.029
Avg_CO ₂ (ppm)	0.392	0.208	0.386	0.120	0.262	0.400	0.009	-0.346	-0.088	0.012	0.104
Avg_Pressure (hPa)	0.209	0.111	0.276	0.192	0.197	0.274	-0.196	0.103	0.143	-0.119	0.198
Avg_Rise_CH ₄ (sec)	-0.062	-0.129	-0.106	-0.045	-0.194	-0.166	0.219	-0.088	0.273	-0.051	-0.522
Avg_Temp (°C)	0.025	0.238	0.088	0.179	0.127	-0.048	0.024	0.371	-0.231	0.149	-0.176
Avg_baseline_CH ₄ (ppm)	-0.032	-0.220	-0.003	-0.238	-0.354	-0.283	0.557	-0.265	-0.061	-0.072	0.187
Avg_baseline_CO ₂ (ppm)	-0.022	-0.224	-0.084	-0.066	-0.230	-0.085	0.063	-0.188	-0.360	0.440	0.217
CO ₂ _atMax_CH ₄	0.542	0.426	0.477	0.471	0.420	0.507	0.010	-0.118	-0.201	0.174	0.067
Est_emis_Avg_CH ₄	0.272	0.444	0.310	0.384	0.397	0.272	-0.093	-0.192	-0.193	-0.036	0.269
Est_emis_Max_CH ₄	0.299	0.435	0.312	0.386	0.410	0.319	-0.146	-0.213	-0.217	-0.092	0.295
Max_Rise_CH ₄ (sec)	-0.090	-0.053	-0.122	0.052	-0.035	-0.024	-0.069	0.201	0.106	0.298	-0.524
Visit Frequency (#/d)	0.172	0.024	0.072	-0.249	0.010	0.130	-0.002	-0.025	0.206	-0.037	-0.229
Peak CH ₄ Avg (ppm)	0.368	0.498	0.364	0.523	0.509	0.442	-0.208	-0.148	-0.338	0.078	0.113
Peak CH ₄ Count	0.495	0.398	0.332	0.551	0.408	0.496	-0.244	0.404	0.154	0.121	-0.045
Peak CH ₄ Max (ppm)	0.454	0.584	0.384	0.563	0.622	0.578	-0.321	-0.089	-0.300	0.124	0.034
Peak CH ₄ Min (ppm)	0.204	0.240	0.223	0.358	0.244	0.221	-0.061	-0.142	-0.263	-0.073	0.225
Visit duration (sec)	0.225	0.148	0.095	0.317	0.172	0.251	-0.227	0.614	0.374	0.296	-0.220

Weight (kg)	0.796	0.591	0.786	0.474	0.586	0.718	-0.242	-0.022	-0.276	0.002	0.251
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The equation to predict CH₄ (g/d) from Avg_CH₄ is shown below.

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	4699	4699	8.92	0.0070
Error	21	11058	526		
Corrected Total	22	15757			

Root MSE	22.95	R-Square	0.298
Dependent Mean	194.14	Adj R-Sq	0.265
Coeff Var	11.819		

Parameter Estimates						
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	Intercept	1	159.02557	12.69183	12.53	<.0001
Avg_CH4	Avg_CH4	1	0.64646	0.21639	2.99	0.0070

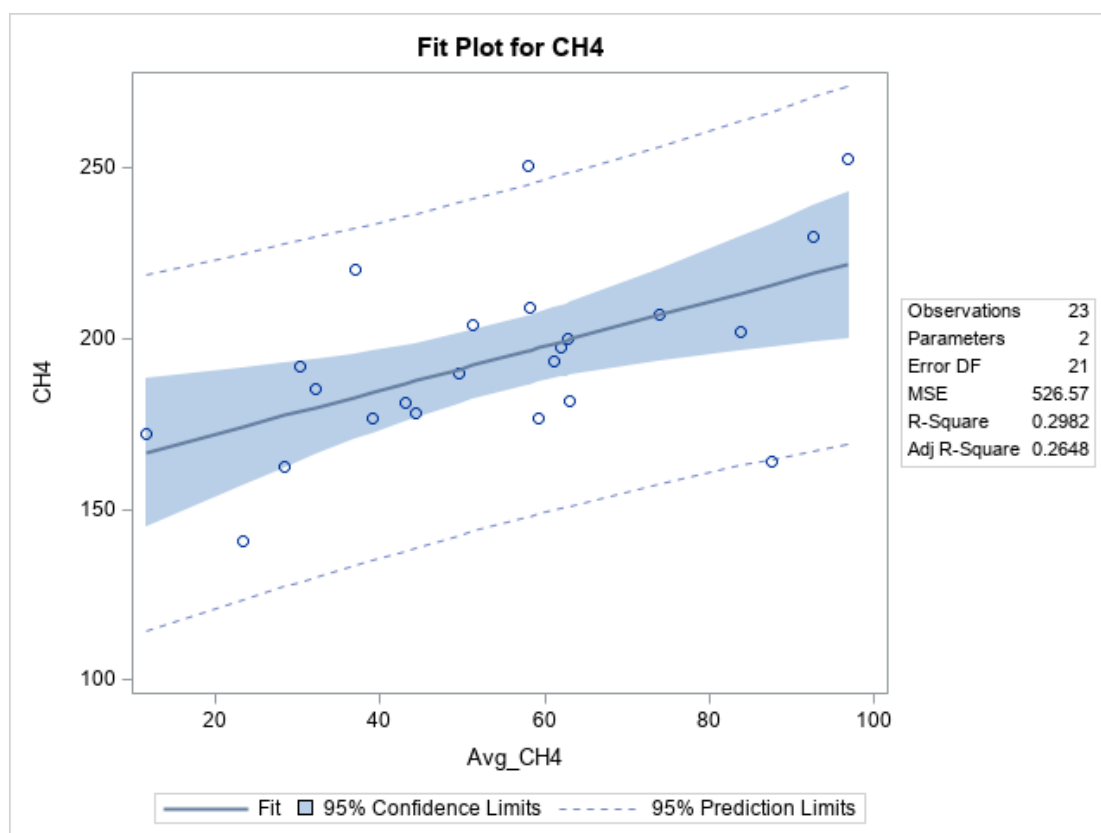


Figure 8. Linear regression between Avg_CH₄ measured by the Agscent unit and CH₄ (g/d) measured by the GreenFeed unit.

CONCLUSIONS

The present 3 Trials demonstrated significant correlations between data obtained by the Agscent unit and the GreenFeed unit, feed intake, growth rate, and body weight. These are promising results suggesting that the Agscent unit can detect differences between animals in CH₄ emissions but more importantly from other variables strongly correlated with CH₄ emissions such as DMI. Data collected for longer periods and averaged for each animal is recommended because this results in stronger correlations.

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