Evaluation of Methane Measurement Systems in Lactating Dairy Cows

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Accurate and scalable measurement tools are critical for quantifying enteric CH_4 and implementing effective mitigation strategies in dairy production. We aimed to evaluate the accuracy of a head-chamber system and a modified sniffer system for measuring enteric CH_4 emissions in lactating dairy cows, using open-circuit respiration chambers as the reference.

Methodology

Twelve multiparous lactating Holstein cows (202 ± 12 days in milk, 46 ± 6.5 kg of milk/day, and 710 ± 30 kg of body weight) were enrolled in a replicated 3 × 3 Latin square to compare 3 measurement technologies: (1) respiration chambers (RC; No Pollution Ltd., Leicester, UK), (2) the GreenFeed system (GF; C-Lock Inc., Rapid City, SD), and (3) the Agscent Air GHG × Optiweigh system (AO; (Agscent Ltd., Carwoola, NSW, Australia). Cows were blocked by parity, days in milk, and baseline CH_4 emission (determined previously with GF), and randomly assigned within blocks to one of the systems during each 3-d period. Animals were transported from the Cornell Dairy Research Center (Harford, NY) to the Cornell Large Animal Research and Teaching Unit (Ithaca, NY), housed in tiestalls, and acclimated to facilities and measurement devices for 2 weeks before data collection. For GF and AO, cows remained in their stalls and were led to the respective units at 3-h intervals across 8 time points (08:00, 11:00, 14:00, 17:00, 20:00, 23:00, 02:00, and 05:00 h). For RC, cows were individually housed in 1 of 4 chambers for 72 h with continuous gas exchange monitoring. All cows received a basal total mixed ration (DM basis: 55% corn silage, 12% haylage, and 33% concentrate) formulated to meet or exceed requirements (AMTS.Cattle.Professional v. 4.14; Agricultural Modeling and Training System LLC, Groton, NY). Feed was offered once daily (09:30 h) with ad libitum access, and an equal amount of pelleted bait (Purina Animal Nutrition, Shoreview, MN) was provided across systems. Cows were milked at 06:00 and 17:30 h using portable milking units, either in tiestalls or inside the RC.

Specifications and operation of the RC units followed Machado et al. (2016) and Keller et al. (2022). Chambers maintained controlled conditions (18°C, 55% relative humidity). Calibration was conducted monthly using certified CH_4 and carbon dioxide (CO_2) standards (Airgas USA, Radnor, PA), with zero calibration via nitrogen. Gas recovery tests using CO_2 were performed regularly to verify accuracy. Total gas production (g/d) was calculated from inlet-outlet concentration differences, corrected for airflow rate, pressure, and temperature. The mean recovery was 99.6% for CO_2 and 99.4% for CH_4. The AO system collected exhaled breath through a vacuum-driven, open-circuit setup and analyzed samples in real time using a tunable diode laser spectroscopy sensor for CH_4 (0 - 40,000 ppm, 0.01 ppm resolution) and a nondispersive infrared sensor for CO_2 (0 - 20,000 ppm, 5 ppm resolution), with integrated temperature, pressure, and humidity probes. Measurements were recorded every second. The GF system used an open-flow design with nondispersive infrared sensors for CH_4 and CO_2, with automatic calibration using certified span and zero gases (Airgas USA). A CO_2 recovery test at the start and end of the trial yielded 99.6% recovery (SD = 2.5).

Ambient temperature and humidity were monitored with HOBO data loggers (model LMX2300; Onset Computer Corp., Bourne, MA). Samples of the total mixed ration were collected 3 times per week for DM determination. Feed ingredients were sampled twice weekly, composited by week, dried at 55 °C for 48 h, ground through a 1-mm screen (Wiley mill; Thomas Scientific, Philadelphia, PA), and stored in sealed bags until analysis. Milk yield was recorded daily. Milk samples were collected every 3 days over 2 consecutive milkings (n = 9) into vials containing 2-bromo-2-nitropropane-1,3-diol (Broad Spectrum Microtabs II; Advanced Instruments Inc.) and stored at 4 °C. Analyses for fat, true protein, lactose, and milk urea nitrogen were conducted by Dairy One DHIA Laboratory (Ithaca, NY) using Fourier-transform infrared spectroscopy (Milkoscan FT+; Foss Inc.). Data were analyzed using the MIXED procedure of SAS (v9.4; SAS Institute Inc., Cary, NC). The model included measurement method, block, repetition, and their interaction as fixed effects, with cow nested within square as a random effect. Least squares means were separated with Tukey's adjustment. Significance was declared at $P \leq 0.05$ and tendencies at $0.05 < P \leq 0.10$.

Preliminary Results

During the experimental period, ambient temperature and relative humidity in the facilities were comparable to those in the RC, averaging 18 ± 0.5°C and 57 ± 7.4%, respectively. Dry matter intake, milk yield, energy-corrected milk, and 3.5% fat-corrected milk averaged 24.6, 33.3, 42.0, and 35.6 kg/d, respectively, with no differences among measurement systems. Milk fat content was also unaffected (mean = 5.27%). True protein concentration was slightly higher for GF (3.43%) than AO (3.36%) or RC (3.33%; $P <$ 0.01), and total solids tended to be greater for GF (14.7 vs. 14.4%; $P = 0.07$), although these differences were not biologically relevant. Yields of milk components, milk urea nitrogen, and feed efficiency were similar across systems. Despite reports that chamber housing can reduce intake, no differences in DM intake were observed, suggesting that the acclimation protocol effectively minimized housing effects.

Daily CH_4 production differed by method ($P < 0.01$), averaging 394 g/d (AO), 403 g/d (GF), and 546 g/d (RC). Respiration chambers measured ~38% higher emissions than spot-sampling approaches. Carbon dioxide showed a similar pattern (8.2, 13.3, and 15.6 kg/d for AO, GF, and RC; $P < 0.01$). Methane yield (g/kg DMI) and intensity (g/kg milk or ECM) were also greatest for RC, reflecting its continuous capture of emissions.

Methane estimates from AO were moderately correlated with RC (r = 0.57), whereas GF showed weaker agreement with RC (r = 0.36). The two spot-sampling systems were moderately correlated ($r = 0.41$). Concordance with RC was poor for both spot methods ($CCC \leq 0.09$). Methane production was positively associated with DMI, strongest for RC ($r = 0.77$), intermediate for AO ($r = 0.62$), and weak for GF. Relationships with ECM were moderate for RC and AO but not significant for GF. Continuous chambers provided the most robust intake-emission associations, whereas spot-sampling methods tended to underestimate absolute emissions and attenuate correlations.

Overall, RC yielded higher CH_4 and CO_2 values and stronger relationships with intake than either spot-sampling system, reflecting their complete diurnal coverage and controlled environment. Spot methods (AO and GF) produced comparable but lower emission estimates and weaker associations with productivity, emphasizing the need to account for methodological differences when interpreting or comparing enteric gas measurements.

Summary

Comparisons between respiration chambers with spot-sampling systems (GreenFeed and Agscent Air × Optiweigh) demonstrated that chambers provide the most complete and precise assessment of enteric CH_4, whereas spot-sampling methods yield lower but consistent estimates suitable for large-scale monitoring when their inherent limitations are considered. Research on dietary FA showed that altering lipid source or substituting starch and fiber influenced milk fat synthesis and nutrient digestibility but produced little additional reduction in CH_4 where baseline emissions were already low, suggesting that starch management may be a more effective strategy in high-intake, low-forage diets. Research on bromoform-based additives integrated storage stability and feeding trials to support practical application. Bromoform remained stable under cool, dark conditions, with oil formulations offering the greatest protection under less favorable environments. A short-term feeding trial indicated that moderate inclusion of synthetic bromoform, seaweed pellets, or seaweed oil reduced CH_4 emissions without compromising intake, milk yield, or composition, and residues in milk were transient, clearing rapidly after supplementation ended. Overall, these findings highlight the importance of accurate emission measurement, targeted dietary strategies, and feed additives as complementary tools to reduce gas emissions while sustaining performance and milk quality in modern dairy systems.

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