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Keep the Bioenergy: Smarter RNG from Canadian Swine Manure

Resume:

Canadian swine manure sits at the intersection of methane mitigation, renewable-energy recovery, and low-carbon fuel production. Anaerobic digestion can convert manure and carcass-derived organic residues into methane-rich biogas that can be upgraded to renewable natural gas (RNG). The central challenge is not simply to maximize methane generation, but to understand the operating conditions that sustain methane recovery, detect instability before performance deteriorates, quantify methane losses across the manure-to-fuel pathway, and translate these processes into defensible greenhouse-gas and carbon-intensity outcomes. Previous studies of manure–carcass co-digestion have reported reductions in selected disease-causing microorganisms, suggesting potential implications for pathogen management; however, pathogen persistence and inactivation are microorganism- and process-dependent and require dedicated microbiological assessment. The six-reactor study presented here focuses on energy recovery and process stability. We integrate anaerobic digestion with interpretable machine learning, fugitive-methane accounting, Agriculture and Agri-Food Canada's Holos whole-farm greenhouse-gas model, and fuel life-cycle assessment to quantify carbon intensity, thereby developing an integrated framework for evaluating swine-manure-to-RNG systems.

Its foundation spans broader research on swine-manure digestion under low-temperature conditions, ammonia stress, high-solids loading, and operational limits relevant to Canada. This research addresses a broader question: how much of the manure's energy can be recovered, where does methane escape, and how do these losses affect the climate value of RNG? In a 1,115-day study of six manure–carcass reactors at 25°C, low-to-moderate loading sustained 60–70% methane in biogas. At high loading, propionate accumulated, total ammonia nitrogen reached 7,983 mg/L and free ammonia nitrogen exceeded 300 mg/L, while methane declined below 55%. A reactor-independent artificial neural network retained predictive performance on held-out digesters, supporting identification of empirical ammonia–volatile fatty acid operating ranges and regime-dependent methane-yield controls.

A complementary comparison of 11 machine-learning models identified retention time, feeding rate, ammonia, and organic-acid accumulation as key indicators of reactor performance and instability. Separate high-solids experiments showed threefold higher methane yield at 25°C than at 35°C (0.30 versus 0.09 L CH_4/g volatile solids), with stable operation at high ammonia concentrations and organic loading rates up to 2.7 g volatile solids/L/day. Early-warning modelling detected instability up to four days in advance, while optimization balanced methane yield and stability. These insights connect farm measurements, stage-specific methane accounting, Holos-compatible parameters, and life-cycle assessment to evaluate methane recovery, fugitive losses, bioenergy production, and the climate performance of RNG in Canadian pork production. Cross-farm modelling extends these insights across heterogeneous Canadian farm systems, enabling assessment of how farm-level variation influences methane recovery and the environmental performance of RNG.