Development of a Pilot Plant for CH_4 and CO_2 Capture from Cattle Barns: From Experimental Tests to Process Simulations

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Ruminants, mainly dairy cattle, are widely recognized as one of the main contributors to methane emissions in the environment, playing a significant role in the global warming phenomenon. Considering that a cow emits about 500 L/d of methane [1] and in view of the increasing population of cows due to the intensive farming activities, the daily methane emission is considerable. Extensive efforts have been made to reduce methane emissions from ruminants prior to their release into the environment; however, considering that the enteric fermentation process is unavoidable, it is crucial to establish methods for capturing the emitted methane.

Given the common practice of implementing forced ventilation within barns for animal well-being, the discussed process aims to capture methane via adsorption on either synthetic or natural zeolites or different active carbons through the barn ventilation. Great limitations come from the Direct Air Capture of both gases due to their limited partial pressure and therefore low adsorption equilibrium concentrations. A key challenge arises from the competitive adsorption between CO_2 and CH_4 on zeolites, where CO_2 preferentially adsorbs and hinders methane capture. To overcome this, a two-stage adsorption system was developed, consisting of two beds in series. The first, a "guard bed," selectively removes CO_2 and other interfering gases, while the second bed efficiently captures methane. The adsorption-based process was designed using Aspen Adsorption V11 software, supported by experimental tests on various zeolites and activated carbons. These included TPD and TGA analyses of samples exposed in barn environment, as well as adsorption/desorption tests performed with a Hiden CATLAB system coupled to a mass spectrometer.

Interestingly, the same gas mixture (methane and carbon dioxide) is also produced during anaerobic digestion of agro-zootechnical waste. Therefore, the same adsorption technology can be applied to upgrade biogas to biomethane, enhancing the techno-economic sustainability of the process.

This study presents an integrated approach combining experimental and simulation tools that led to the development and installation of a pilot-scale plant, currently under testing near Piacenza. This represents a concrete first step toward the real-world application of CH_4 and CO_2 capture technologies in the livestock and biogas sectors, aimed at reducing the environmental impact of intensive animal farming.

Key words: *Greenhouse gases, Enteric methane, Direct air capture, Pilot plant design, Aspen Adsorption*

References:

[1] K. A. Johnson, D. E. Johnson, Journal of Animal Science 1995, Volume 73, 2483 – 2492.

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