CO_2 Recovery from Anaerobic Digestion: Application, Technologies and Potential in the Australian Red Meat Industry

F., Tessele*; K., Ferraro; L., Marinho*****

* WA, Australia, fabiana@tessele.com
** WA, Australia, kendall.ferraro@tessele.com
*** WA, Australia, leticia.marinho@tessele.com

Abstract: Growing concerns about the global energy crisis and environmental pollution have propelled the pursuit of clean energy sources. Anaerobic technology, widely employed for waste treatment, also stands out as a promising means to generate eco-friendly energy. Its primary output, biogas, emerges as a clean energy alternative capable of replacing natural gas across various applications. Biogas primarily comprises CH_4 (55%-65%) and CO_2 (35%-45%), necessitating purification due to the potential impact of CO_2 and trace elements on engine performance and the energy grid. Diminishing CO_2 content not only improves biogas quality but also enhances its calorific value. While efforts focus on recovering all products from the Anaerobic Digestion (AD) process, the remaining CO_2 can find use across diverse industry sectors. This report aims to assess recent academic studies and innovative solutions for recovering and treating CO_2 from biogas production, highlighting the capability of the Australian red meat sector to generate CO_2 at its facilities.

Keywords: Anaerobic Digestion; CO_2 Recovery; Clean Energy.

Introduction

Addressing global energy scarcity and environmental concerns, anaerobic technology has transformed into a promising source of eco-friendly energy known as "waste to energy." Biogas, comprising mostly CH_4 and CO_2, serves as a clean alternative to natural gas. CO_2 plays a crucial role across sectors, spanning physical, chemical, biological, and mineralisation applications.

Physical utilisation spans food, refrigeration, and petroleum industries, employing CO_2 in carbonated beverages, cold storage using solid CO_2, welding, oil extraction, tobacco processing, and cleaning agents. In the chemical realm, CO_2 acts as a vital raw material for urea, salicylic acid, organic fuels, and polymers, finding applications in fertilisation, skincare, pharmaceuticals, and food preservation.

Biological utilisation focuses on mimicking photosynthesis for valuable products, exploring artificial systems and microalgae carbon sequestration for biofuels. Mineralisation utilises CO_2 to convert waste into stable carbonates, managing waste while sequestering carbon, creating marketable products. This comprehensive exploration emphasises CO_2's varied roles and innovative potential.

In this review, recent academic insights delve into CO_2 recovery processes from biogas, analysing efficient biomethane purification. This investigation highlights CO_2's multifaceted applications and signifies its potential for inventive solutions in the Australian red meat sector.

Material and Methods

The approach utilised for the comparative study involved systematic searches in academic databases, employing appropriate keywords and filters to gather an extensive array of scholarly materials. Once these materials were obtained, a screening process was applied to choose those aligned with the research's scope.

Subsequently, the literature underwent a thorough examination, involving the summarisation of significant discoveries and limitations.

Results and Conclusions

Various methodologies have emerged, to enhance biogas quality by effectively removing CO_2 impurities. Absorption techniques represent an integral facet of CO_2 removal from biogas. These methods involve subjecting untreated biogas to specialised columns laden with absorbents like water or chemical solutions. Through this meticulous process, CO_2 dissolves, allowing for a gas stream enriched with methane, thus laying the groundwork for a more refined biogas product.

Complementing absorption techniques, Pressure Swing Adsorption (PSA) surfaces as a promising alternative. Here, materials such as activated carbon or zeolite selectively trap CO_2 molecules while permitting the passage of methane. PSA excels in its high adsorption efficiency and capacity, holding potential for significant strides in CO_2 removal from biogas.

Further expanding the repertoire of approaches, membrane separation operates on the premise of differential gas permeability. Specialised membranes permit the passage of CO_2 while retaining methane. However, the efficiency of this method heavily relies on membrane material performance, making its efficacy variable based on membrane quality.

In parallel, biological techniques, notably microalgae cultivation leveraging photosynthesis, offer an eco-friendly avenue. By harnessing CO_2 from biogas for organic compound production, these techniques exhibit minimal energy consumption. Yet, challenges persist in scaling up this method for larger-scale applications and improving carbon sequestration efficiency.

Beyond these, cryogenic separation and the hydrate method emerge as formidable contenders. Cryogenic separation involves the cooling of gas to extremely low temperatures to condense and separate CO_2 from methane, albeit demanding significant energy inputs. Conversely, the innovative hydrate method forms solid structures to selectively capture CO_2 and H_2S under controlled conditions, offering efficient CO_2 removal with relatively lower energy consumption.

Each method embodies unique advantages and challenges, shaping the selection based on operational requirements and desired outcomes. These methodologies, while diverse in their approach, collectively propel the efforts towards cleaner and more efficient CO_2 recovery from biogas. Their continual refinement and deployment hold promise in reshaping the energy landscape, contributing significantly to sustainable energy practices and global environmental initiatives.

The red meat industry heavily relies on CO_2 in the form of dry ice to preserve and transport products. Dry ice, made from solidifying carbon dioxide gas, maintains a consistent -78.5°C temperature, preserving meat's freshness without leaving residue as it transitions directly from solid to gas. This slows bacteria growth, extending meat's shelf life. However, Australia's CO_2 market challenges various industries due to disrupted supply chains, increased demand, and temporary production closures. Due to COVID-19 pandemic, the Australian CO_2 cost increased from $400 to $2,000, prompting investment in CO_2 recovery projects. Efforts to address this include seeking alternative sources and optimising production to ease the strain on CO_2-dependent industries. Recognising the possibility that CO_2 generation within red meat processing sites would eliminate their reliance on external CO_2 supply chains, Table 1 shows the potential of CO_2 production in the red meat industry in Australia.

Table 1. The estimation of CO_2 from biogas in different regions of Australia in 2018–2019.

Region	Manure CO_2 Content (Million m³/year)	Blood CO_2 Content (Million m³/year)	Rumen Content CO_2 Content (Million m³/year)
NSW	1,823,038	684	1,021
VIC	1,414,623	742	1,449
QLD	5,052,337	1,245	1,247
SA	427,083	118	321
WA	880,929	187	391
TAS	255,682	81	99
Total	9,853,692	3,057	4,528

References

Andriani, D., Wresta, A., Atmaja, T. D., & Saepudin, A. (2014). A Review on Optimization Production and Upgrading Biogas Through CO2 Removal Using Various Techniques. Appl Biochem Biotechnol, 172, 1909–1928. https://doi.org/10.1007/s12010-013-0652-x

Fu, L., Ren, Z., Si, W., Ma, Q., Huang, W., Liao, K., Huang, Z., Wang, Y., Li, J., & Xu, P. (2022). Research progress on CO2 capture and utilization technology. Journal of CO2 Utilization, 66, 102260. https://doi.org/10.1016/j.jcou.2022.102260