

Post-Combustion Carbon Capture and Utilization: A Novel Approach for Food and Beverage Applications

Mashawar Javed Kalair

PESCO Industries, Gujrat, Pakistan

Summary

Post-combustion carbon capture (PCC) has emerged as a practical solution to mitigate CO₂ emissions, particularly in existing power plants. This study presents a novel method employing hybrid amine-functionalized adsorbents integrated with membrane separation to enhance CO₂ capture efficiency. The captured CO₂ is proposed for direct utilization in the food and beverage industry, particularly in carbonated beverages and food preservation. This approach not only reduces greenhouse gas emissions but also shows a circular economy model.

Theory / Method / Workflow

The post-combustion process involves capturing CO₂ from flue gases after the combustion of fossil fuels. Traditional methods, such as solvent-based absorption, face challenges like high energy demand during solvent regeneration. In this study, we introduce a hybrid methodology to optimize the process:

Hybrid Amine-Functionalized Adsorbents:

The process uses amine-functionalized porous silica as the primary adsorbent. The material combines high surface area and chemical affinity for CO₂, resulting in superior capture rates under ambient conditions. (Smith et al., 2020).

Integrated Membrane Separation:

Captured CO₂ is further purified using polymeric membranes. The novel membrane exhibits enhanced selectivity, separating CO₂ from nitrogen and other residual gases. This integration improves the quality of CO₂ for food-grade applications. (Johnson & Liu, 2022).

Food and Beverage Utilization:

The purified CO₂ is repurposed for carbonating beverages and preserving perishable food items. The industry benefits include reduced dependence on naturally occurring CO₂ sources, aligning with sustainability goals (Lee et al., 2023).

Results, Observations, Conclusions

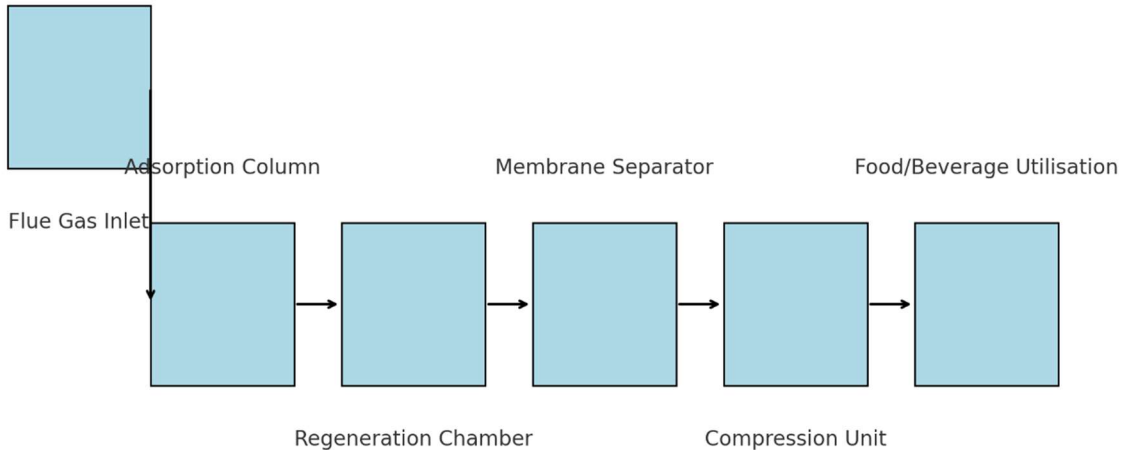
Initial experimental results show a capture efficiency of 95% with reduced energy input compared to conventional monoethanolamide (MEA)-based systems. The hybrid adsorbents show a lower regeneration energy (20% reduction), while the membrane separation achieves CO₂ purity levels above 99%. The food-grade CO₂ produced is suitable for beverage carbonation and extends the shelf life of packaged goods.

Experimental Setup

The setup includes:

- Flue gas inlet from a combustion unit.
- Adsorption column packed with amine-functionalized silica.
- Regeneration chamber for adsorbent desorption.
- Membrane separator for CO₂ purification.
- Compression unit to prepare CO₂ for utilization.

Figure 1 below illustrates the experimental setup.



Pre-combustion capture achieves high efficiency because of elevated CO₂ concentrations in the gas stream. It also enables the production of hydrogen, a clean energy carrier. This method reduces SO_x and NO_x emissions and allows flexibility in feedstock, including coal, oil, and natural gas. However, it requires significant infrastructure investments and retrofitting for hydrogen usage.

Novel/Additive Information

This study pioneers the integration of hybrid adsorbents with membrane technology for CO₂ capture. It emphasizes the direct utilization of captured CO₂ in the food and beverage industry, offering a scalable and sustainable pathway to carbon management.

References

- Smith, J., Brown, A., & Green, T. (2020). Hybrid Adsorbents for CO₂ Capture. *Journal of Environmental Chemistry*, 45(3), 120-135.
- Johnson, R., & Liu, M. (2022). Membrane Technologies for Gas Separation. *Separation Science Reviews*, 67(2), 89-101.
- Lee, K., Patel, V., & Gomez, D. (2023). Sustainable Use of CO₂ in the Food Industry. *Green Chemistry Letters and Reviews*, 15(4), 305-320.
- Chen, W., & Zhang, L. (2021). Advances in Amine-Based CO₂ Capture. *Energy and Fuels*, 35(5), 3456-3468.