

Innovative Biogas Strategies: Anaerobic Co-Digestion of Livestock Waste

Sunidhi Rajput*

Abstract

The goal of the study is to determine whether anaerobic co-digestion of cow dung can be used to produce biogas and whether adding sodium and calcium alginate directly to natural lagoon sediment can reduce sulphide concentrations. It was observed that one minute of focus Sodium and calcium alginate were added at the start of the anaerobic digestion cycle, which indicates a propensity to lower the system's hydrogen sulfide concentration and raise methane concentration. The alginates, which functioned as chelating ligands, increased methane generation and decreased sulfide concentration. For anaerobic codigestion, this study suggests using soaking liquor that uses cow dung (fleshing) in a 2:1 ratio. The hydrogen sulphide (H₂S) concentration of fleshing to cow dung ratio without sodium alginate is shown in the results for the following concentrations: 1:0.5 H₂S concentration (ppm), 1:2 H₂S concentration (ppm), 1:0 H₂S concentration (ppm), and 1:1 H₂S concentration (ppm) against time (days) and digestion flow from combined liquor. The H₂S concentration initially moved inconsistently and continued to rise and fall. It was found that biogas with a 45.5% v/v methane concentration could be produced using a 1:2 ratio of fleshing to cow manure. Compared to adding calcium alginate beads, adding sodium alginate can result in larger biogas volume and the greatest methane concentrations in a shorter retention period. In general, the mass transfer phenomenon confined the calcium alginate beads. The study further demonstrates that the methane concentration achieved with sodium alginate application was 57.1% v/v < 60% v/v. Mass transfer constraint was the reason of this since calcium alginate beads have a smaller surface area in the event that a reaction is required. Nevertheless, compared to digesting the substrates without alginates, the methane content was still greater.

Keywords: Investigation, cow dung, anaerobic digestion, biodigester, diluent, inoculant, retention period, and substrates

INTRODUCTION

This study uses facultative lagoon sediment, sodium, and calcium alginates to reduce sulphide concentrations and increase methane production while producing biogas through the anaerobic fermentation of cow dung [1]. The company's goal of becoming a recognized center of excellence in the monitoring and control of tannery effluents while producing premium leather will be greatly aided by this research [2].

*Author for Correspondence

Sunidhi Rajput

E-mail: sunidhirajput@5002@gmail.com

¹Student, Electronics & Communication, Student, Sir Chhotu Ram Institute of Engineering & Technology, C.C.S University Campus, Uttar Pradesh, India

Received Date: December 24, 2024

Accepted Date: January 03, 2025

Published Date: January 10, 2025

Citation: Sunidhi Rajput. Innovative Biogas Strategies: Anaerobic Co-Digestion of Livestock Waste. *Emerging Trends in Chemical Engineering*. 2024; 12(1): 40–45p.

Researchers worldwide are very concerned about the numerous negative environmental implications of using wood fuel as a source of residential fuel, which include deforestation and the emission of greenhouse gases that contribute to ozone depletion. When disposed of carelessly, tanning wastes, food wastes, dairy droppings, wastes from milk companies, breweries, and other organic wastes are considered nuisances [3].

They contribute to food and water pollution and the spread of bacterial illnesses. The majority of a tannery's effluent load is produced by the washing and conditioning of hides and skins, which is done in the beam house. If fleshing, which makes up 58% of the total solid waste from tanneries, is not disposed of appropriately, it will putrefy and smell bad [4]. Thus, the following reasons make this research worthwhile:

1. Renewable energy sources are currently being used on a global scale. Potential ingredients for the anaerobic digestion process that produces methane are the solid effluent from the beam house.
2. In Nigeria, where cattle are raised most frequently, the co-digesting substrate (cow dung) is easily and copiously available locally, primarily in the northern region and certain areas of the southeast.

METHODOLOGY

Method of Desulphurization As a desulfurization method, the direct application of various weights of calcium and sodium alginate was studied.

Sodium Alginate Use

0.01% wt./v of sodium alginate was weighed in accordance with Dublein and Steinhauser's (2008) instructions. For digesters with volumes of 100 g fleshing and 200 g cow dung (the ratio 1:2) and diluent of 1.5 liters, the weight utilized in relation to the volume of substrate and diluent was 0.15 grams. At one-day intervals during the cycle, the digesters' biogas composition was examined to determine which had the highest methane and lowest sulphide contents [5, 6].

Calcium Alginate figBeads' Use

Sodium alginate and calcium chloride were combined to create calcium alginate. Using Debbie's (2008) methods, a 2% calcium chloride solution and a 3% sodium alginate solution were made. A beaker of calcium chloride solution was set below a 5 ml syringe that had been filled with the alginate suspension.

Slow drips of the sodium alginate solution into the calcium chloride solution were permitted from the needle. At the same time, the calcium chloride solution was slowly stirred [7, 8]. The calcium ions will cross-link the alginates, trapping the cells in a calcium alginate matrix. Thus, the final beads are calcium alginate beads. For five to ten minutes, the beads were allowed to solidify in the calcium chloride solution. A sieve was used to separate the calcium chloride solution's beads, which were then carefully rinsed with cold water from the faucet, weighed, and put to the digesters. The digesters' apertures were used to evaluate the biogas that was produced [9].

The calcium alginate beads that are produced from sodium salt substitutes and have the chemical formula $C_{12}H_{14}CaO_{12}$ are depicted in Figure 1.



Figure 1.

Impact of Adding Calcium Alginate on Co-Substrates' Methane Concentration

A digester containing co-substrates in a 1:2 ratio of cow dung to fleshing was supplemented with calcium alginate beads at a concentration of 0.01%w/v. Using sodium alginate resulted in a methane concentration of 60% v/v, whereas 57.1% v/v was attained. Because calcium alginate beads have a smaller surface area for any reaction to occur on, this was caused by a constraint in mass transfer. Nevertheless, compared to digesting the substrates without alginates, the methane content was still higher [10].

Alginate Addition's Impact on Hydrogen Sulfide Co-substrate Concentration

Direct addition of sodium alginate to the co-substrate blends was an attempt to lessen the detrimental effects of hydrogen sulfide. Throughout the digestion cycle, hydrogen sulfide concentrations never reached 0 ppm, even though blends of fleshing to cow dung 1:0, 1:1, and 1:2 without sodium or calcium alginates produced concentrations as low as 1 ppm [11–14]. The biogas generated through an absorption process was completely desulfurized by the addition of either calcium or sodium alginates. In the absorption reaction, Mn^{+} is reduced to $M(n-1)^{+}$ and H_2S is oxidized to produce elemental sulfur when hydrogen sulfide comes into touch with the metal chelate that is created when alginate reacts with metals in the substrate [15–17]. The development of metal chelates is the cause of this type of desulphurization. The desulphurization seen in the digester systems is caused by a redox process. Metal chelates are created when different chelating ligands (alginates) react with metals (such as Fe, Co, S2, and Ni) that are already present in the systems as nutrients [18–21]. After reacting with the generated hydrogen sulfide gas, these metals chelate and remove the gas from the system. The following equation shows the reaction sequence for the metal chelates' absorption of hydrogen sulfide:

$H_2Sg \leftrightarrow H_2Saq (1) + 2H^{+} + 2Mx^{-1} \rightarrow S \downarrow + H_2Saq + Mx + Chelanty^{-} Chelanty^{-} (2)$, where M stands for the metal ion and y for the charge of the chelant anion.

This demonstrates that sodium alginate may produce sulphide-free biogas and is a practical desulphurizing agent, as proposed by Dublein and Steinhäuser (2008).

Table 1. Methane concentrations of fleshing to cow dung ratios with sodium alginate.

Retention time (days)	1:0 methane concentration (%v/v)	1:0.5 methane concentration (%v/v)	1:1 methane concentration (%v/v)	1:2 methane concentration (%v/v)
1	1.7	5.3	1.3	5.9
3	6.3	9.9	8.8	4.7
5	3.5	14.1	5.9	16.9
7	1.8	4.2	3.1	6.2
9	2.4	4.7	7.4	7.6
11	3.5	5.2	15.2	20.2
13	2.1	6.9	8.8	15.2
15	2.4	9.5	15.4	29.1
17	2.3	23.2	37.3	60.3
19	1.9	28.8	38.8	45.5
21	1.9	27.5	29.5	33.1
23	2	32	23.9	48.5
25	6.2	23.8	16.7	34.4
27	10.7	42.5	45	59.4
29	6	16.9	30.7	43
31	2.9	38.9	39.2	8.4
33	3.3	37.9	43.4	39.6
35	8.3	26	44.9	42.4
37	6	25.3	42.7	46.1

RESULTS AND DISCUSSION

Table 1 displays the ratios of methane from fleshing to cow manure using sodium alginate, along with the computational outcomes at each concentration. The outcome of employing different Beam House Liquors Diluent is depicted in Figure 2. As seen in Figure 2, the flow exhibits a little decline in H₂S concentration movement at first, followed by a significant increase for a while, and finally a decline. In contrast, the concentration of CH₄ remained flat and consistent across time.

Figure 3 illustrates the digestion flow from mixed liquor and reveals an initial irregularity in the movement of the H₂S content, which continued to rise and fall. In contrast, the concentration of CH₄ remained flat and consistent across time.

The H₂S concentration of fleshing to cow dung ratio without sodium alginate is shown in Figure 4 as a function of time (days) for the following concentrations: 1:0.5 H₂S concentration (ppm), 1:2 H₂S concentration (ppm), 1:0 H₂S concentration (ppm), and 1:1 H₂S concentration (ppm).

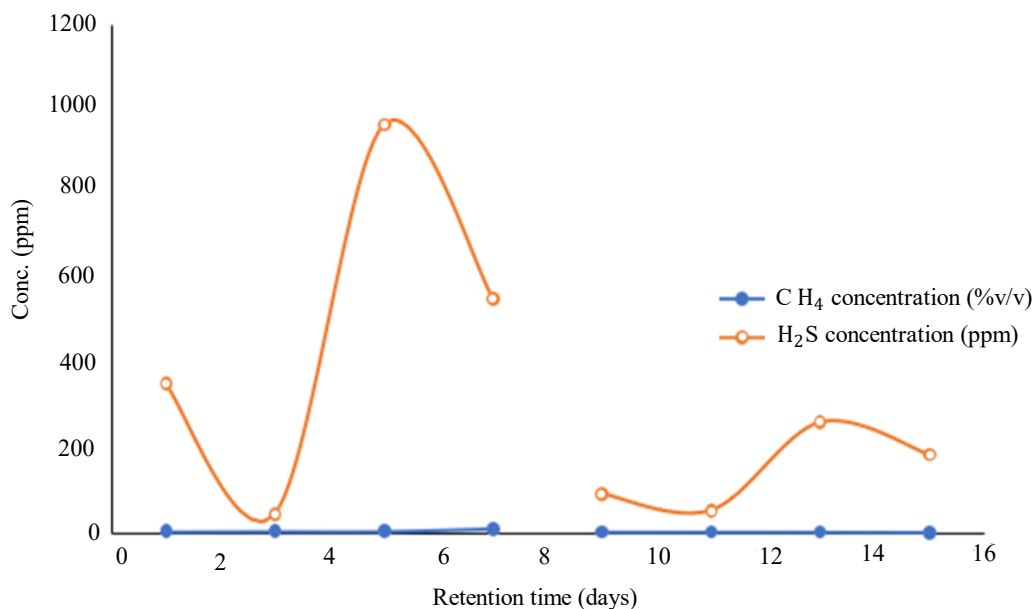


Figure 2 shows the outcomes of employing distinct beam house liquors as a diluent.

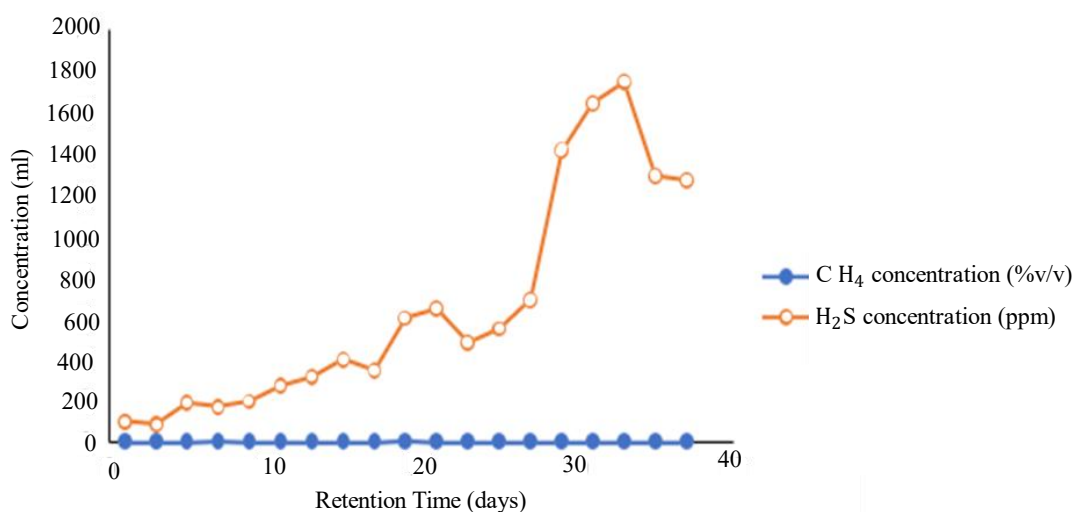


Figure 3. Design for mixed liquor digestion.

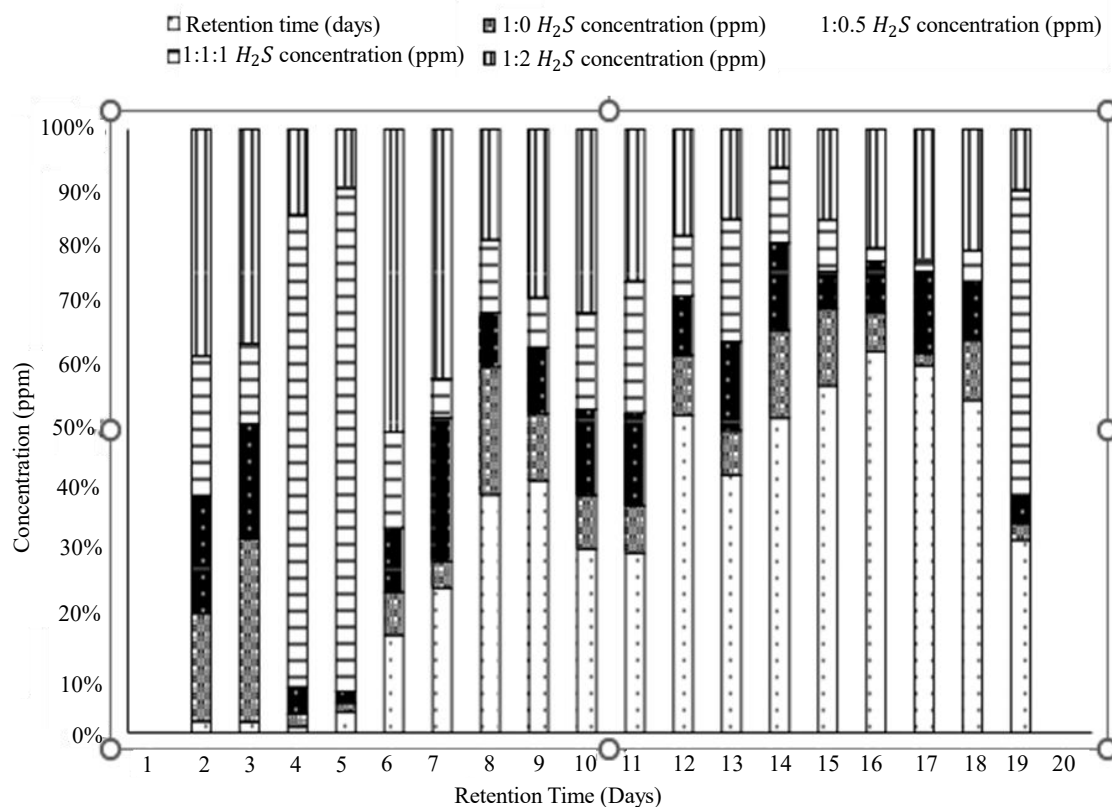


Figure 4 shows the ratio of fleshing to cow manure without sodium alginate in terms of hydrogen sulfide (H₂S) concentration.

CONCLUSION

Cow manure has been identified as a highly effective co-substrate for the anaerobic digestion of tannery fleshing, significantly enhancing methane production. Using a 1:2 ratio of fleshing to cow manure, biogas with a methane concentration of 45.5% v/v can be achieved, with methane output increasing nearly eightfold compared to fleshing alone. Furthermore, the use of sodium alginate as an additive outperformed calcium alginate beads in biogas production. Sodium alginate facilitated higher methane yields in a shorter retention period while also generating a greater volume of biogas. This improvement is attributed to the superior mass transfer dynamics provided by sodium alginate. In contrast, the calcium alginate beads were less effective due to limitations imposed by mass transfer phenomena, which restricted their performance in enhancing biogas production. These findings highlight the potential of cow manure and sodium alginate as valuable additions to the anaerobic digestion process, offering a practical solution for improving methane recovery from tannery waste. The study underscores the importance of optimizing co-substrate selection and process conditions to maximize biogas yield and efficiency.

REFERENCES

1. Ahrens T, Weiland P. Biomethane for future mobility. *Landbauforschung Völkenrode*. 2007;57:71–9.
2. Ajayi OA, Adefila SS. Methanol production from cow-dung. *Environ Earth Sci*. 2012;2(7):5–10.
3. Akinbami J-FK, Ilori MO, Oyebisi TO, Akinwumi IO, Adeoti O. Biogas energy use in Nigeria: current status, future prospects and policy implications. *Renew Sustain Energy Rev*. 2001;5(1):97–112. doi: 10.1016/S1364-0321(00)00005-8.

4. Akyoo AM, Kileo OJ. Biogas User Survey (BUS) analysis report. Arusha: Tanzania Domestic Biogas Programme; 2012.
5. Angelidaki I, Ahring BK. Methods for increasing the biogas potential from the recalcitrant organic matter contained in manure. *Water Sci Technol*. 2000;41(3):189–94. doi: 10.2166/wst.2000.0071.
6. Emeka Chinwendu; Beabu Bernard Dumkhana; Achinike Okogbule-Wonodi. Physicochemical characteristics evaluation of five tropical coconut species extracted oil in South-East, Nigeria. *Int J Acad Appl Res*. 2021;5(10):94–101.
7. Appel LJ, Clark JM, Yeh HC, Wang NY, Coughlin JW, Daumit G et al. Comparative effectiveness of weight-loss interventions in clinical practice. *N Engl J Med*. 2011;365(21):1959–68. doi: 10.1056/NEJMoa1108660.
8. Ballie GR, Kaene WF, Alexander SR. Peritoneal dialysis-related peritonitis treatment recommendation. *J Int Soc Perit Dial*. 1996;16(6):557–73.
9. Di Berardino S, Martinho A. Co-digestion of tanning residues and sludge. In 12th IWA Sludge Conference-Sustainable Management of Water & Wastewater Sludge Aug 8, 2009. Portugal. p. 1–2.
10. Buba M. Chromium removal from Cheltech, Zaria tannery effluent as a form of effluent treatment [Master's thesis]. [Zaria]: Ahmadu Bello University. Zaria; 2004.
11. Pauwels RA, Löfdahl C, Postma DS, Tattersfield AE, O'Byrne P, Barnes PJ et al. Effect of Inhaled Formoterol and Budesonide on Exacerbations of Asthma. *N Engl J Med*. 1997;337(20):1405–11. doi: 10.1056/NEJM199711133372001.
12. Buljan J, Bosnic M. Pollution limits for discharge of tannery effluents into water bodies and sewers, *World leather magazine*, Nov; 1994. p. 54–7.
13. Colak S, Zengin G, Ozgunay H. Utilization of leather industry pre-fleshing in biodiesel production. *J Am Leather Chem Assoc*. 2005;100(2):137–41.
14. Dangoggo SM, Aliyu M, Atiku AT. The effect of seeding with bacteria on biogas production rate. *Re-New-Energy Am Int J*. 1996;9(1–4):1045–8. doi: 10.1016/0960–1481(96)88459-X.
15. Debbie E 2008. Science and plants for schools. Homerton college hills road Cambridge CB2 8PH UK.
16. Dublein D, Steinhauser A. Biogas from waste and renewable resources. WILEY-VCH GmbH & Co.kGaA. Published online 21. Feb; 2008.
17. Draget KI, Smidsrod O, Skjak-Braek G. Alginates from algae [online]; 2005. Available from: http://www.wiley-vch.de/books/sample/3527313451_c01.pdf.
18. Eva T, Emilia den Boer O, B, Han S. Waste to energy- A review. International Conference on Applied Energy ICAE. Suzhou: China; 2012:Paper ID: ICAE–A10544.
19. FEPA. Audit and reduction manual for industrial emissions and wastes. Technical Report Series. Paris, France: United Nations Publications; 1991. p. 56–77.
20. Ferguson T, Mah R. Methanogenic Bacteria in Anaerobic Digestion of Biomass, 49 *Anaerobic Digestion*; 2006 [cited 24.10.07]. Available from: biotank.co.uk.
21. Garba B, Zuru AA. Effect of slurry concentration on biogas production from cattle dung. *Niger J Sol Energy*. 2004;14(2):11–4.