ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar2005

Assessment of Biogas Potential of Codigested Cow Manure with Soymilk Dreg

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Publication Date: 2025/04/19

Abstract: The use of amendment of Soymilk Dreg (SMd) substrate to improved biogas yield from Cow Manure (Cm) substrate was investigated and duplicate batch experiments were carried out at 4 g VS/L, in eight 2 L volume polyethylene biodigester, with 1.8 L working volume using 144 mL of inoculum throughout the experiments, for 30 days at a fixed temperature of 33 °C. The substrates were divided to three ratios (Cm: SMd (%)); 2:1(50 %), 3:1(33 %) and 4:1(25 %) and a control with only Cm in biodigesters labelled A, B, C and Control. The results shows that biodigesters A, B and C recorded biogas volumes of 25.96, 23.51 and 18.46 % above the control and the bioCH_4 composition of biodigesters A, B and C were 50.48, 47.08 and 40.00 % higher than the control. It was concluded that the presence of SMd provided a balanced substrate composition, supporting a stable methanogenic activity across treatments and higher biogas and bioCH_4 yields. It is recommended that 25 % SMd (volatile solid) amendment should be codigested with Cm for optimal biogas production.

***Keywords**: Anaerobic-Codigestion, Soymilk Dreg Amendment, Cow Manure, Biogas Production.*

How to Cite: Orkuma J.G.; Samuel, D.A.; Eziefula B.I.; Yakubu, D.K. (2025). Assessment of Biogas Potential of Codigested Cow Manure with Soymilk Dreg. *International Journal of Innovative Science and Research Technology*, 10(3), 3188-3196. https://doi.org/10.38124/ijisrt/25mar2005.

I. INTRODUCTION

Biogas production is becoming an attractive renewable energy technology in the quest for sustainable energy alternatives. This is due to the ease with which the technology can be deployed and the massive energy content of methane (CH_4) available in biogas which can be utilised for the production of heat, energy and power. Biogas production can also sustainably alleviate environmental problem of turning waste to wealth and minimise the impact of Greenhouse Gas (GHG) associated with global temperature inversions.

Cow manure (Cm) has become an attractive substrate for the production of biogas in the Anaerobic Digestion (AD) ecosystem in the past decades. This is due to its widespread availability throughout the globe and the presence of viable hydrolytic, acidogenic, acetogenic and methanogenic microorganisms in the manure. These organisms can easily inoculate a feedstock and trigger biogas production seamlessly, without extra inputs, at a significantly cheaper rate than other renewable energy technologies (Itodo *et al*., 2022). The Cm is linked with buffering the AD system with bicarbonate, ammonia and phosphate, within the neutral pH range, when mixed with high energy crops, which together prevents the acidification of the system and improves biogas production (Acosta *et al*., 2021). Cow manure also has high nitrogen content which is considered crucial in the AD process by helping to balance the Carbon (C) to Nitrogen (N) (C: N) ratio of the system and providing the essential nutrients, needed for microbial synthesis of enzymes, nucleic acids and proteins, which are critical for biogas production (Ward *et al*., 2008).

Cow manure is readily available throughout Nigeria, where in most instances, it constitutes environmental challenges but can sustainably reduce the electricity energy deficit of the country if properly harnessed. According to Itodo *et al* (2022), about 122 billion kg of livestock waste is generated annually in Nigeria. This can be biologically converted to biogas for the generation of 100 MW of electricity to supply grid and off-grid electricity, amongst other applications.

Although, there are some drawbacks associated with the stand-alone digestion of Cm for biogas production, especially its low biogas and CH_4 yields when compared to other substrates, such as fats, vegetables and food waste (Surra *et al*., 2019). The low biogas yield from the mono-digestion of Cm is attributable to its substrate characteristics such as its; moderate Volatile Solids (VS) contents (≤ 80 %), low C:N ratios (≤ 20), lignocellulosic and fibre fraction contents and the low carbohydrate, fats and protein contents (Li *et a*l.,

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar2005

2021). The VS, which is the organic portion of the manure that is converted to biogas, is low to moderate in cow manure because, most of the organic matter rich portions, derivable from the feeds eaten by the cows, has being thorough digested in their multi-chamber stomach and used up for their wellbeing and milk production, leaving behind the hard-to-digest lignin, cellulose and hemicellulose in the manure (Li *et al*., 2021). The lignin content of Cm structurally degrades at a slower rate and is resistant to microbial enzymatic degradation (Wang *et al*., 2018), thereby, limiting the amount of VS that can be converted to biogas, such that it becomes commercially unattractive to invest in medium to large scale systems using Cm only for biogas production in a country like Nigeria (Itodo *et al*., 2022).

Anaerobic Codigestion (ACoD) entails the digestion of two or more organic materials in one digester, at the same time, in order to increase the biogas and bioCH_4 contents potential derivable from low-yielding or difficult to hydrolyse feedstocks combined with synergetic substrate(s) (Achina and Euverink, 2019). Several high energy crops have been codigested with Cm to determine their viability as co-substrate and the results indicate positive prospects (Orkuma *et al*., 2024; Iweka and Owuama, 2020; Achina and Euverink, 2019; Owamah and Izinyon, 2015; Sturmer *et al*., 2021).

Caruso *et al*. (2017) highlighted the difficulty of finding an ideal raw substrate, or a combination of substrates, that is an all-fits, for the operational parameters of an AD system. Surra *et al*. (2019), acknowledge the fact that ACoD of substrates is a topic needing continuous further research in order to gain useful insights, as the optimal substrates for ACoD are difficult to find. They advocated a continuous assessment of available organic substrates within a country, so as to evaluate their compatibility and synergetic effect in the ACoD process, for economic viability and sustainable bioCH_4 production (Surra *et al*., 2019).

Soymilk dreg (SMd) is the insoluble residue emanating from the processing of soybeans that is hulled, soaked in water, grounded and boiled at a temperature of about 90 – 100 ^{O}C for 30 - 60 min. After cooling, the solution is filtered in a cloth sieve and the milk is strained out as filtrate and the retentate, which is the dregs are usually discarded. Foraminifera Market Research ([FMR], 2021) indicates that about 150 million L of soymilk is produced in Nigeria, by small scale holders, annually. Szulc et al. (2023) projected that an average of 1.2 kg of wet dregs can be gotten from each litre of soymilk produced from soybean, and thus, a residue potential of 180 million kg of dregs per annum is achievable in Nigeria. This SMd is found to be rich in fibre (cellulose, hemicellulose, and lignin; 53 - 58 %), fat (9 - 11 %), protein (25 - 29 %) and non-fibre carbohydrate (4 -5.5%) with very high VS concentration of (~98 %) (Gupta et al.,2018). It putrefies at an extremely fast rate than most organic residues (Gau and Yang, 2015) and may be a good co-substrate with Cm in the ACoD process of biogas production.

Although, the fibrous content of unprocessed soybean is also capable of limiting its biogas yield potentials. Zhang *et al*. (2019) codigested raw soybean processing waste with cow manure and reported ammonia inhabitation at high proportion of soybean waste due to its high protein content. However, SMd usually undergo some pretreatment, such as grinding, which increases its surface area and thermal treatment, which would have solubilized the fibres in the substrate to soluble sugars that can easily be degraded, thereby creating the ideal condition for biogas production without pretreatment (Surra *et al*. 2019).

The literature however suggests that, most research on ACoD of soybean byproducts has been on the use of raw sludge or tofu waste water (Wang *et al*., 2018: Zhang et al, .2019: Li et al., 2020; Okorie and Ibrahim., 2021). Tofu waste water is produced almost in a similar manner like SMd, but fermented for a longer duration of time which increases its potential adverse effect on the AD process, if not properly tended to. Satyanarayan *et al*. (2010) investigated biogas production enhancement by codigesting soy sludge (SS) generated from soymilk production with cattle dung in India at 10, 20 and 25 % of SS using the volatile solids organic loading of 2.4 kg/m^{-1}d^{-1} in 6 L continuous digesters for 30 days. Their result showed higher yields at 20 to 25 % of amendment.

Given the dearth of studies on the codigestion on Cm with SMd, especially in Nigeria, where these wastes are in abundance for sustainable energy production, there is a need to fill the gap. This study therefore, is aimed at evaluating the biogas potential of codigesting Cm with SMd. The specific objectives are to; produce biogas by codigesting Cm with SMd and evaluate their biogas and CH_4 potentials.

II. MATERIALS AND METHODS

A. Substrates Characteristics

The Cm was collected fresh from a pen at the Livestock Teaching and Research Farm, Joseph Sarwuan Tarka University, Makurdi (JOSTUM)-Nigeria in a 20 L plastic bucket. The manure was sorted for contaminants such as twigs, plastics and stones and used on the same day for the experiments. The SMd was previously purchased, fresh, from a soymilk producer in Wurukum area of Makurdi, Benue State Nigeria and refrigerated at 4 °C. The inoculum was withdrawn from an active 0.1 m^3 polyethylene digester at the Department of Agriculture and Biosystems Engineering (DABE), Jostum using a 100 mL syringe. Distilled water was used throughout in the experiments.

One hundred grams each, of the Cm and SMd, were taken to the Central Analytical Chemistry Laboratory, Department of Chemistry, JOSTUM for the determination of the Total Solids (TS), Volatile Solids (VS), carbon (C) and nitrogen (N) contents of the substrates using standard procedures (ASTM-D2974, 2020; APHA-5310B, 2017). The result of the characterisation of the substrates is in Table 1.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar2005

Table 1: Characteristics of Influents used for Biogas Production

Parameter	Cow Manure (Cm)	Soymilk Dreg (SMd)	2:1	3:1	4:1
C content (%)	36.16	48.02			
N content (%)	1.44	4.32			
C:N Ratio	25.13	12.00	20.75	21.85	22.50
TS (%)	18.47	28.42			
VS (%)	15.89	27.82			
VS as % TS	68.02	97.90			
pH	7.01	6.91	7.52 (7.74)*	7.41(7.81)	7.40 (7.98)

*(final pH)

B. Analytical Methods

➢ *Operational Factors*

The organic loading rate (OLR) is defined as the mass of volatile solids (VS) added per unit volume of the digester per day (Holliger *et a*l., 2016). Since the experiment was in batch, a time of 30 days was assumed being the typical duration for the completion of biogas production (Hafner *et al*., 2018). The substrates were divided to three ratios (Cm: SMd (%)); 2:1(50 %), 3:1(33 %) and 4:1(25 %) and a control with only Cm. The OLR was calculated based on the recommendation of Angelidakis *et al*. (2018) that it should be between 1 - 4 g VS/L and an OLR of 4 g VS/L was chosen in order to increase the biogas yield without the system souring.

The Total Volatile Solids (TVS) was computed using the following function;

$$OLR = \frac{\text{TVS (g)}}{\text{V}_d(L)}$$

Where:

- OLR (g VS/L/day), 4 g VS/L
- TVS (Total Volatile Solids), is the organic fraction of Total Solids (TS) 4 g.
- V_d -Digester working volume (m^3), $= 0.9 \times 0.002 = 0.0018\, m^3$(1.8 L)

$$\text{TVS} = \text{OLR} \times \text{V}_d = 4 \times 1.8 = 7.2\ \text{g} \frac{\text{VS}}{\text{L}}$$

➢ *Substrate Mass*

The total mass of substrate represented by M was calculated for each mass ratio according to their proportions, as;

- 2:1 ratio: $\text{Cm} = \frac{2}{3}M$, $\text{SMd} = \frac{1}{3}M$,
- 3:1 ratio: $\text{Cm} = \frac{3}{4}M$, $\text{SMd} = \frac{1}{4}M$,
- 4:1 ratio: $\text{Cm} = \frac{4}{5}M$, $\text{SMd} = \frac{1}{5}M$,

For the substrate mass for ratio 2:1 for 7.2 g is; $\text{Cm} = \frac{2}{3}M$, $\text{SMd} = \frac{1}{3}M$

$$\text{Cm} = \frac{7.2\times2}{3} = 4.80\ g,\ \ \text{SMd} = \frac{7.2}{3} = 2.4\ g$$

- VS in Cm = 4.80/68.02% = 5.58 g
- VS in SMd= 2.4/97.90 % = 2.45 g
- 2:1 Total VS = 5.58 g + 2.45 g = 8.03 g

For the total substrate mass at ratio 3:1 for 5.4 g is; CM $= \frac{3}{4}M$, $\text{SMd} = \frac{1}{4}M$,

$$\text{CM} = \frac{7.2\times3}{4} = 5.40\ g,\ \ \text{SMd} = \frac{7.2}{4} = 1.80\ g$$

- VS in Cm = 5.40/68.02% =7.06g
- VS in SMd= 1.35/97.90 % = 1.84 g
- 3:1 Total VS = 7.06 g + 1.84 g = 8.90 g

For the total substrate mass at ratio 4:1 for 5.4 g is; CM $= \frac{4}{5}M$; $\text{SMd} = \frac{1}{5}M$,

$$\text{CM} = \frac{7.2\times4}{5} = 5.76g,\ \ \text{SMd} = \frac{7.2}{5} = 1.44g$$

- VS in Cm = 5.76/68.02% = 8.47 g
- VS in SMd= 1.44/97.90 % = 1.47 g
- 4:1 Total VS = 8.47 g + 1.47 g = 9.94g

For the Control sample too;

$$\text{TVS} = \text{OLR} \times \text{V}_d = 4 \times 1.8 = 7.20\ \text{g} \frac{\text{VS}}{\text{L}}$$

$$\text{VS} = \frac{7.20}{68.02\%} = 10.59\ \text{g}$$

➢ *Calculating Inoculum and Water Volumes*

- *Inoculum Volume*

Common inoculum-to-substrate ratio (ISR) is 2:1 (VS basis, Angelidaki, 2019). So, Inoculum VS required becomes;

2×7.2 =14.40 g VS.

It was assumed that the inoculum contained 10 % VS and so the fresh inoculum mass became;

14.40/0.10= 144 g

Substrate and inoculum were assumed to have similar densities with water (1kg/L), so 144 g was considered as 0.144 L of inoculum.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar2005

- *Water Volume*

The remaining volume after adding inoculum and substrate was filled with water. The water volume was computed as;

2:1 = 1.8 – 0.144 - 0.00803(8.03 g) = 1.65L
3:1 = 1.8 – 0.144 - 0.00890 (8.90 g) = 1.65 L
4:1 = 1.8 – 0.144 - 0.00994 (9.94 g) = 1.65 L
Control = 1.8-0.144 - 0.01059 (10.59 g) = 1.65

Table 2: Biodigester Feedstock

Parameter	**Substrate Ratio (Cm :SMd)**			
	A – A_r (2:1)	B – B_r (3:1)	C – C_r (4:1)	Control
Cm VS (g)	5.58	7.06	8.47	10.59
SMd VS (g)	2.45	1.84	1.47	
TVS (g)	8.03	8.90	9.94	10.59
Total substrate volume (L)	0.00803	0.00890	0.00994	0.01059
Inoculum (L)	0.144	0.144	0.144	0.144
Water (L)	1.65	1.65	1.65	1.65
Working volume (L)	1.80	1.80	1.80	1.80

C. Description and Operation of the Biodigester System

The biodigester (Plate 1) is a 2 L transparent polyethylene bottle with a round cone-shape screwcap. The tip of the cone has a 4 mm opening for inserting flexible tubing for delivering biogas into a two channels Tedlar gasbag (2 L). Biogas mass was determined by measuring the weights of two empty gasbags before and after biogas and CH_2 was delivered to the gasbags. In order to measure biogas and bioCH_4 mass, the inlet of a weighed Tedlar gasbag was connected to a biodigester and the outlet was linked to a 2 L graduated 500 mm long eudiometers, containing a barrier solution of spent carbide residue (pH ≥12).

Plate 1: Biodigester Setup

For the measurement of biogas, the inlets of the gasbags connected to the biodigester were opened and biogas generated in the digesters was allowed to flow into the gasbags and the weights were recorded using an Eosphorus digital mass scale (0.00 – 1000 g; 0.01 g accuracy China). The inlet channels of these gasbags were closed at 9:00 am and 5:00 pm daily, from the second day of the experiment, and the weights were recorded and logged up to the end of the experiment.

For the measurement of bioCH_4, the outlet valves of these gasbags were then opened to allow biogas flow from the gasbags through the eudiometers, where the biogas was scrubbed and CO_2 and H_2S were removed. The pH of the barrier solution in the eudiometer was monitored fortnightly and replaced when it was 13. The top open ends of the eudiometers were connected to second Tedlar gasbags for the collection bioCH_4 after scrabbing. The bioCH_4 gasbags were also weighted and logged. The recorded masses were used to calculate the average daily biogas/ bioCH_4 volume and to compute the cumulative yields using the mass- density relation corrected and normalised at STP according to the methods of Angelidaki *et al.* (2018); Holliger *et al*. (2016).

D. Experimental Procedure

Duplicate experiments were carried out in eight 2 L volume polyethylene biodigester with 1.8 L working volume using 144 mL of inoculum in each biodigester throughout the experiments. The biodigesters were cleaned with distilled water before the loading of substrates. Two biodigesters each, labelled A, A_{R1}(A), B, B_{R1}(B), C-C_{R1}(C) and Control were used in the experiment. The combinations of substrates, inoculum and water used in the experiments are in Table 2. In the Biodigesters A-A_{R1}, 5.58 g of Cm was weighed and mixed with 2.45 g of SMd in the digesters and a measuring cylinder was used to apportioned 1.65 L of distilled water which was poured into each of the biodigesters and mixed thoroughly by shaking and swirling into a homogeneous volume. A syringe was used to withdraw 144 mL of inoculum and used to seed each bioreactor. The procedure was repeated using 7.06 g of Cm and 1.84 g of SMd in Biodigesters B-B_{R1} and 8.47 g of Cm and 1.47 g of SMd in Biodigesters C-C_{R1}. In the control, 10.59 g of Cm only was used. All the six experimental and the two control biodigesters were placed inside a laboratory incubator (Temp range: 26 ~36 ºC,) at 33 ºC for 30 days The biodigesters were swirled once a day and pH was measured and recorded at the beginning and the end of the experiments.

III. RESULTS

The characteristics of the substrates (Table 1) show that C, N, TS, VS contents (%) and C:N ratios of the Cm were 36.16, 1.44, 18.47, 15.89 and 25.13, and 48.02, 4.32, 27.82 , 28.42 and 12.00 for the SMd. The C:N ratio of the SMd was below the optimal range for AD but after it was amended to the Cm, the C:N ratios became 20.75, 21.85 and 22.50 in

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar2005

biodigesters A(2:1-Cm:SMd), B(3:1-Cm:SMd), C (4:1-Cm:SMd) and the control(Cm). The C:N ratio of the control was and 25.13 and were within the ideal range of 20-30:1 for optimal AD performance. The results of the daily biogas yields and the cumulative biogas yields for the various combinations and control are Tables 3 and 4 with plots in Figures 3 and 4. The average daily biogas yield (mL) was 101.96, 96.99, 94.5 and 78.53 in biodigesters A, B, and C and Control. The cumulative biogas yield (mL) over the 30 days hydraulic retention period were 3058.80, 2983.50, 2835.00 and 2355.90 in biodigesters A, B, and C and Control.

Similarly, the mean daily bioCH_4 yields were 72.08, 70.45, 67.06 and 47.90 while the cumulative yields (mL) were 2162.45, 2113.39, 2011.90 and 1437.07 from in biodigesters A, B, and C and Control.

The production of biogas was initially low from day 1 to day 2, especially in the control. However, the amended treatments (Biodigesters A, B, and C) started yielding biogas earlier, indicating that the addition of SMd provided a more readily available carbon source for biogas production. The inoculum added may have eliminated the lag phase in the amended treatments as well but the hydrolytic microbes required more time to decompose the complex organic matter of the control.

Table 3: Daily Biogas and BioCH_4 Yields

Daily Yield	**Biogas (mL)**				**BioCH4 (mL)**			
Day	**A (2:1)**	**B (3:1)**	**C (4:1)**	**Control**	**A (2:1)**	**B (3:1)**	**C (4:1)**	**Control**
1	12.36	0.00	0.00	0.00	8.78	0.00	0.00	0.00
2	48.77	47.14	46.52	0.00	34.62	33.47	33.03	0.00
3	73.97	101.00	103.00	0.02	52.52	71.71	73.13	0.00
4	106.15	102.61	101.37	56.00	75.36	72.85	71.97	34.16
5	144.08	139.28	136.88	58.00	102.30	98.89	97.18	35.38
6	135.00	178.84	130.04	69.00	95.85	126.97	92.33	42.09
7	224.71	217.22	213.47	67.00	159.54	154.23	151.57	40.87
8	258.19	249.58	245.28	70.00	183.32	177.21	174.15	42.70
9	280.63	240.00	255.00	66.00	199.25	170.40	181.05	40.26
10	308.53	278.92	274.11	72.00	219.06	198.03	194.62	43.92
11	300.63	271.27	266.60	76.00	213.45	192.61	189.28	46.36
12	258.19	249.58	239.69	70.00	183.32	177.21	170.18	42.70
13	185.71	217.22	178.84	63.69	131.85	154.23	126.98	38.85
14	224.00	220.34	175.75	86.45	159.04	156.44	124.78	52.73
15	139.98	139.28	136.88	111.00	99.39	98.89	97.18	67.71
16	142.15	131.04	139.66	134.83	100.92	93.04	99.16	82.24
17	73.97	71.51	70.27	86.45	52.52	50.77	49.89	52.73
18	48.77	47.14	46.33	63.69	34.62	33.47	32.89	38.85
19	30.41	29.40	28.89	154.91	21.59	20.87	20.51	94.50
20	17.94	17.34	18.00	168.38	12.74	12.31	12.78	102.71
21	10.01	9.68	9.51	173.12	7.11	6.87	6.75	105.60
22	5.28	5.11	5.02	168.38	3.75	3.63	3.56	102.71
23	10.36	6.30	2.51	154.91	1.87	1.81	1.78	94.50
24	6.50	4.36	1.18	166.39	0.89	0.86	0.84	101.50
25	12.00	9.00	8.56	111.00	8.52	6.39	6.08	67.71
26	0.24	0.23	0.22	44.38	0.17	0.16	0.16	27.07
27	0.09	0.09	1.23	29.26	0.07	0.06	0.03	17.85
28	0.04	0.03	0.03	18.25	0.03	0.02	0.02	11.13
29	0.01	0.01	0.01	10.76	0.01	0.01	0.01	6.57
30	0.00	0.00	0.00	6.01	0.00	0.00	0.00	3.66
Mean	**101.96**	**99.45**	**94.50**	**78.53**	**72.08**	**70.45**	**67.06**	**47.90**

The exponential phase of biogas/bioCH_4 production was between day 7-12 and the biogas volume of the amended treatments increased significantly from day 7 with the highest peaks observed between days 9-11. The stationary phase of biogas production among the amended treatments started from day 13 – 20 possibly due to substrate depletion or inhibitory byproducts as in the case of biodigester C. Biodigester C exhibited an earlier decline in biogas production, suggesting that excessive Cm might have led to some level of inhibition or imbalance in the microbial community. Considering the high proportion of lignocellulosic material that might be available in biodigester C, due to is high Cm content, it is expected to decompose more slowly, leading to a reduction in biogas production efficiency as well. The control continued producing biogas at a lower rate, likely due to the slower degradation of Cm alone. From day 21-30, biogas/bioCH_4 production sharply declined among the amended treatments, indicating the exhaustion of readily biodegradable organic matter. However, the control continued to produce small volumes of biogas longer than the

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar2005

amended treatments, possibly due to the slow degradation of more recalcitrant organic matter in Cm and peaked around day 17-24.

Table 4: Cumulative Biogas and BioCH_4 Yields

Cum. Yield	Biogas (mL)				BioCH4 (mL)			
Day	A (2:1)	B (3:1)	C (4:1)	Control	A (2:1)	B (3:1)	C (4:1)	Control-Cm
1	12.36	0.00	0.00	0.00	8.78	0.00	0.00	0.00
2	61.13	47.14	46.52	0.00	43.40	33.47	33.03	0.00
3	135.10	148.14	149.52	0.20	95.92	105.18	106.16	0.00
4	241.24	250.75	250.89	56.00	171.28	178.03	178.13	34.16
5	385.32	390.03	387.76	114.00	273.58	276.92	275.31	69.54
6	520.33	568.86	517.80	183.00	369.43	403.89	367.64	111.63
7	745.04	786.08	731.27	250.00	528.98	558.12	519.20	152.50
8	1003.23	1035.67	976.55	320.00	712.29	735.32	693.35	195.20
9	1283.86	1275.66	1231.55	386.00	911.54	905.72	874.40	235.46
10	1592.39	1554.58	1505.66	458.00	1130.60	1103.75	1069.02	279.38
11	1893.02	1825.85	1772.26	534.00	1344.04	1296.35	1258.30	325.74
12	2151.21	2075.44	2011.95	604.00	1527.36	1473.56	1428.48	368.44
13	2336.92	2292.66	2190.79	667.69	1659.21	1627.79	1555.46	407.29
14	2560.92	2513.00	2366.54	754.14	1818.26	1784.23	1680.24	460.02
15	2700.90	2652.27	2503.42	865.14	1917.64	1883.11	1777.43	527.73
16	2843.05	2783.31	2643.07	999.96	2018.56	1976.15	1876.58	609.98
17	2917.02	2854.82	2713.35	1086.41	2071.09	2026.92	1926.48	662.71
18	2965.79	2901.96	2759.68	1150.10	2105.71	2060.39	1959.37	701.56
19	2996.20	2931.35	2788.57	1305.01	2127.30	2081.26	1979.88	796.06
20	3014.14	2948.70	2806.57	1473.39	2140.04	2093.57	1992.66	898.77
21	3024.15	2958.37	2816.08	1646.51	2147.15	2100.45	1999.42	1004.37
22	3029.44	2963.48	2821.10	1814.89	2150.90	2104.07	2002.98	1107.08
23	3032.07	2966.03	2823.60	1969.80	2152.77	2105.88	2004.76	1201.58
24	3033.32	2967.24	2824.79	2136.19	2153.66	2106.74	2005.60	1303.08
25	3045.32	2976.24	2833.35	2247.19	2162.18	2113.13	2011.68	1370.79
26	3045.56	2976.47	2833.57	2291.58	2162.34	2113.29	2011.84	1397.86
27	3045.65	2976.56	2833.62	2320.84	2162.41	2113.36	2011.87	1415.71
28	3045.69	2976.59	2833.65	2339.08	2162.44	2113.38	2011.89	1426.84
29	3045.70	2976.60	2833.66	2349.85	2162.45	2113.39	2011.90	1433.41
30	3045.70	2976.61	2833.67	2355.85	2162.45	2113.39	2011.90	1437.07
					70.69 %	70.84 %	70.93 %	60.99 %

Biodigester A recorded the highest mean biogas volume which was 2.49 %, 7.59 % and 25.96 % higher than biodigesters B, C and the control. The mean biogas volume of biodigester B was also 5.11 % and 23.51 % higher than biodigester C and the control and that of biodigester C was 18.46 % higher than the control. Comparably, the mean bioCH_4 volume of biodigesters A, B and C were 50.48, 47.08 and 40.00 % higher than the control. It was 2.26 and 6.96 % higher in biodigester A than B and C and also higher by 4.81 % in B than in C. The result of the increase in biogas yield is similar to the 27 % increases reported by Satyanarayan *et al.* (2010).

The bioCH_4 compositions of biogas were 70.69, 70.84, 70.93 and 60.99 % in biodigesters A, B, C and the control and suggests that all amended treatment has similar CH_4 contents of ~ 71% while the control had a significantly lower percentage of ~ 61 %. This implies that that the presence of SMd provided a balanced substrate composition, supporting a stable methanogenic activity across treatments. The insignificant variations of the bioCH_4 content among amended treatments may be due to differences in substrate composition, C:N ratio, or microbial activity. The high Cm content of biodigester C may have impeded the rate of hydrolysis, limiting the readily available carbon, and may have possibly disrupted the optimal C:N ratio, leading to poorer performance compared to the other amended treatments. On the other hand, the control with only Cm, could not provide an optimal nutrient balance for efficient methanogenesis with the less efficient conversion resulting in the increased formation of CO_2 and other non-methane gases in the biogas as was noticeable in its lag phase, where there was delayed microbial adaptation which is cable of affecting overall CH_4 yield.

IV. CONCLUSION

Higher biogas/bioCH_4 yields in amended treatments suggests that SMd improved substrate availability and microbial activity. Optimal C:N ratio in biodigesters A (2:1) and B (3:1) showed the highest biogas and methane yields, indicating a balanced nutrient composition. High levels of

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar2005

Cm in biodigester C (4:1) led to a slightly lower yield. It can be concluded that at all levels of amendments, the biogas/bioCH_4 yields were higher that the control but was optimal at 25 % of VS of SMd and therefore, it is recommended that Cm should be codigested with 25% SMd for maximum biogas yield.

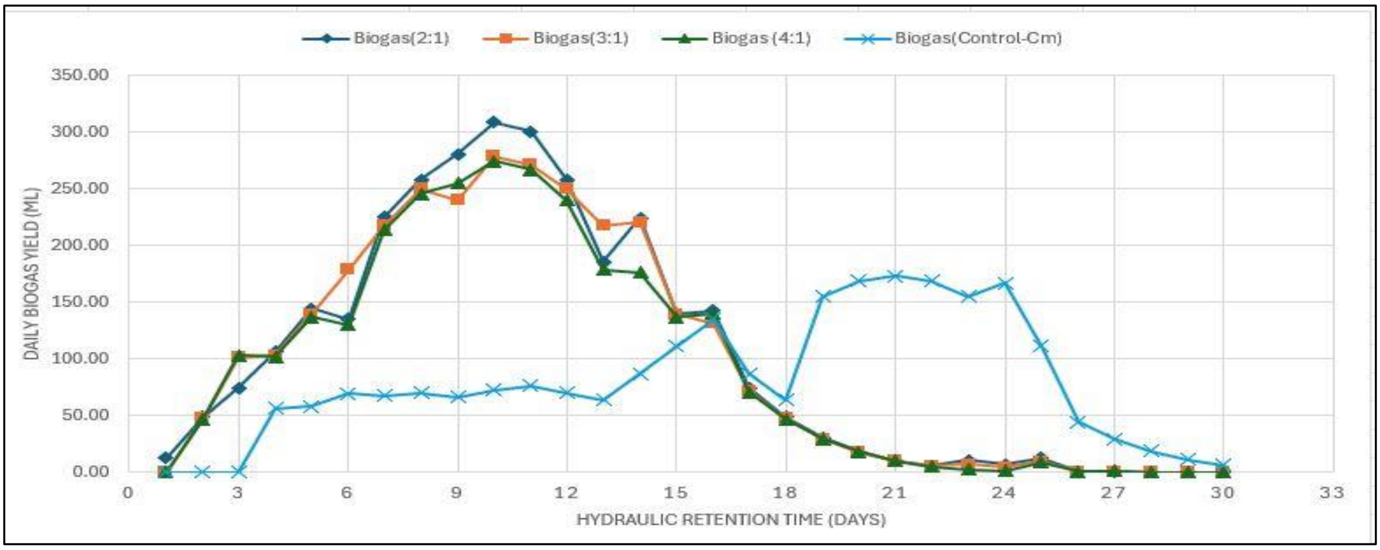

Fig 2: Plot of Daily Biogas Yields

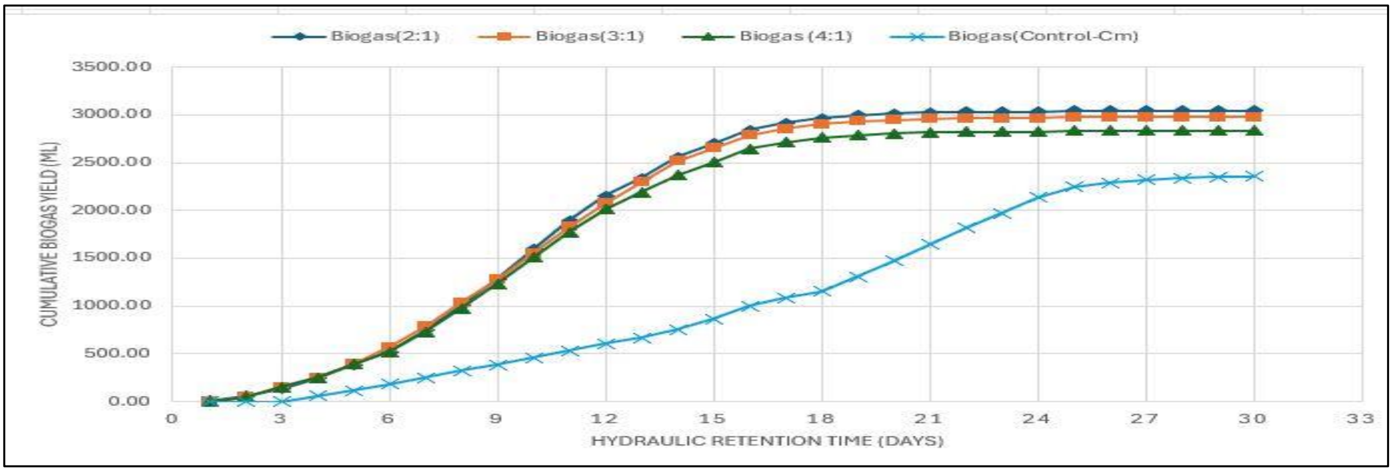

Fig 3: Plot of Cumulative Biogas Yields

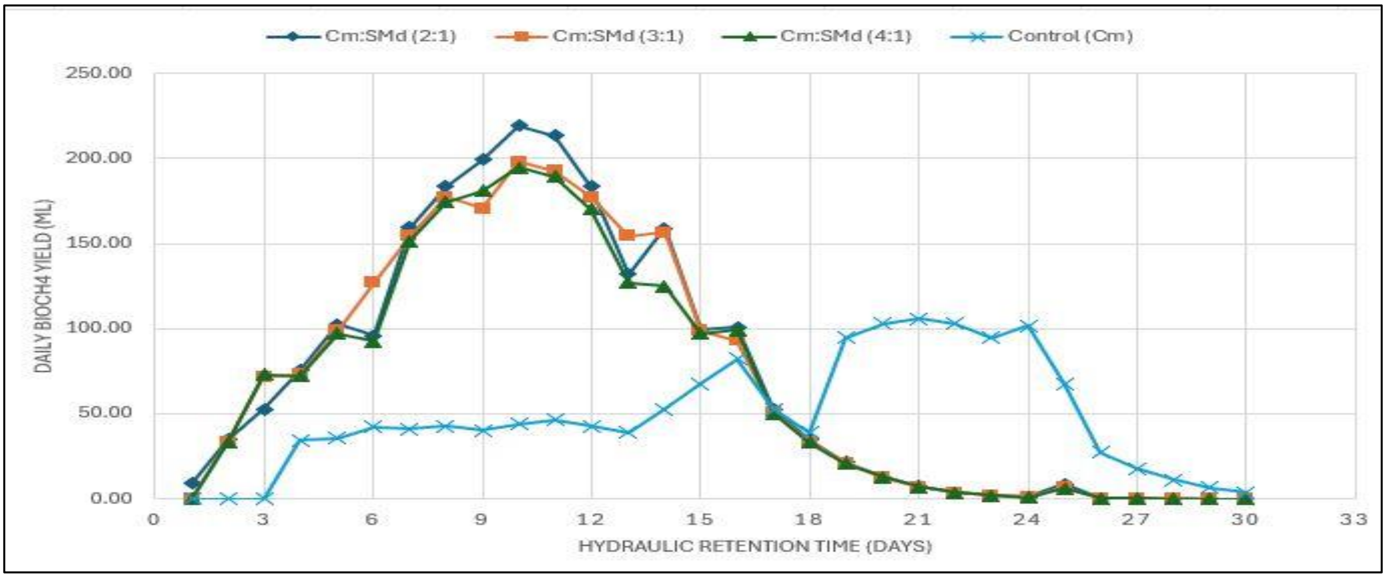

Fig 4: Plot of Daily BioCH_4 Yields

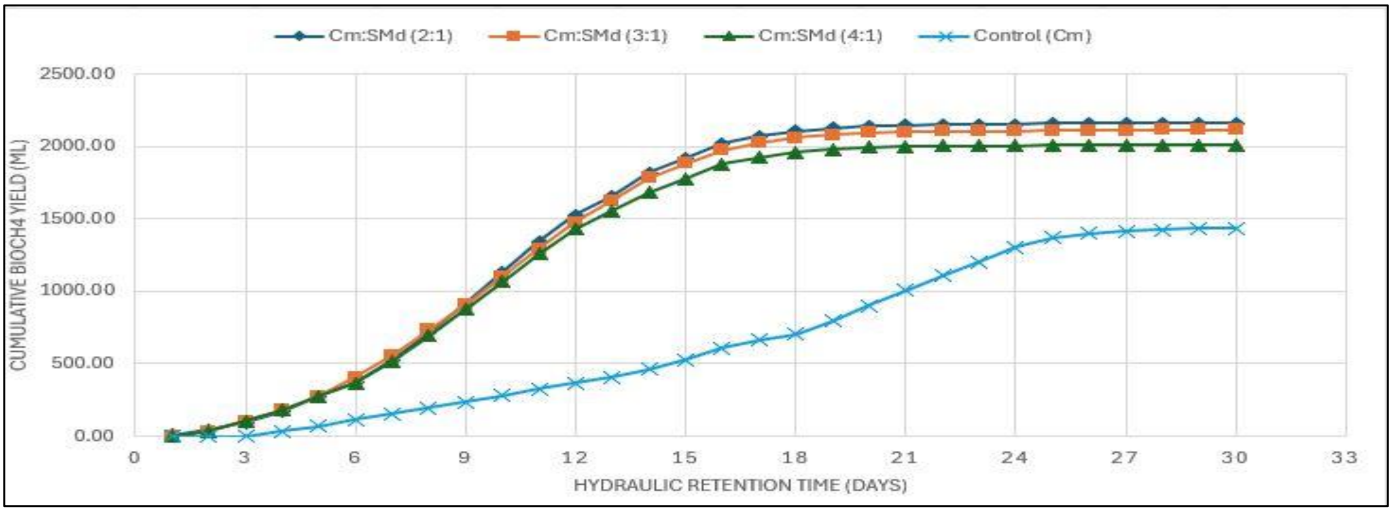

Fig 5: Plot of Cumulative BioCH_4 Yields

REFERENCES

[1]. Achinas, S., and Euverink, G. J. W. (2020). Rambling facets of manure-based biogas production in Europe: A briefing. *Renewable and Sustainable Energy Reviews*, *119*, 109566.

[2]. Acosta, N., Kang, I. D., Rabaey, K., and De Vrieze, J. (2021). Cow manure stabilizes anaerobic digestion of cocoa waste. *Waste management*, *126*, 508-516.

[3]. Angelidaki, I., Treu, L., Tsapekos P., Luo, G., Campanaro, S., Wenzel, H., and Kougias, P.G. (2018). Biogas production and purification processes. *Biotechnology Advances*, 36: 452—466.

[4]. APHA (2017). Standard Methods: 5310B -Total organic carbon by High-Temperature Combustion. American Public Health Association (APHA) Standard Methods for the Examination of Water and Wastewater.

[5]. ASTM (2020). Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils. American Society of Testing Materials (ASTM) International, West Conshohocken.

[6]. Caruso, M. C., Braghieri, A., Capece, A., Napolitano, F., Romano, P., Galgano, F., ... & Genovese, F. (2019). Recent updates on the use of agro-food waste for biogas production. *Applied Sciences*, *9*(6), 1217.

[7]. FMR (2021) Soya Beans Export in Nigeria: The Feasibility Report. Foraminifera Market Research. Pp. 26.

[8]. Guo, J. and Yang, X, Q. (2015). *11-Texture modification of soy-based products*, Editors; Jianshe Chen and Andrew Rosenthal. In Woodhead Publishing Series in Food Science Technology and Nutrition, Modifying Food Texture. Pp. 237-255.

[9]. Hafner, S. D., Madsen, J. T., Pedersen, J. M., & Rennuit, C. (2018). Inter-stage thermophilic aerobic digestion may increase organic matter removal from wastewater sludge without decreasing biogas production. *Water Science and Technology*, *77*(3), 721-726.

[10]. Itodo, I.N., Bala, E.J., and Sambo, A.S. (2022). Biogas Technology in Nigeria. 1st Edition, CRC Press, Taylor and Francis Group, LLC. 2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN. 33 pp.

[11]. Iweka, S.C. and Owuama, K. C. (2020). Biogas Yielding Potential of Maize Chaff Inoculated with Cattle Rumen and Its Characterization. *Journal of Energy Research and Reviews* 6*(*3): 34-50.

[12]. Li, Y., Zhao, J., Krooneman, J., & Euverink, G. J. W. (2021). Strategies to boost anaerobic digestion performance of cow manure: Laboratory achievements and their full-scale application potential. *Science of The Total Environment*, *755*, 142940.

[13]. Okorie, E. E., and Ibrahim, A. (2021). Detoxification of soybean oil mill effluent using anaerobic digestion and the suitability of the digestate for fertigation. *International Journal of Recycling of Organic Waste in Agriculture*, *10*(1).

[14]. Orkuma, J. G., Samuel, D. A., Eziefula, B. I., & Okoro, O. M. Enhancing Biogas Yield by Co-Digestion of Cattle Dung and Acha (Digitaria Exilis) Hulls (2023). *International Journal of Innovative Science and Research Technology*, 9 (12): 2291-2298. https://doi.org/10.5281/zenodo.14603613

[15]. Owamah, H.I. and Izinyon, O.C. (2015). Development of simple-to-apply biogas kinetic models for the co-digestion of food waste and maize husk. *Bioresource Technology*, 194: 83–90. http://dx.doi.org/ 10.1016/j.biortech.2015.06.136

[16]. Satyanarayana, B., Muslim, A. M., Horsali, N. A. I., Zauki, N. A. M., Otero, V., Nadzri, M. I., ... & Dahdouh-Guebas, F. (2018). Status of the undisturbed mangroves at Brunei Bay, East Malaysia: a preliminary assessment based on remote sensing and ground-truth observations. *PeerJ*, *6*, e4397.

[17]. Sturmer, B., Leiers, D., Anspach, V., Brügging, E., Scharfy, D., and Wissel, T. (2021). Agricultural biogas production: A regional comparison of technical parameters. *Renewable Energy*, *164*, 171-182.

[18]. Surra, E., Bernardo, M., Lapa, N., Esteves, I., Fonseca, I., Mota, J.P., (2019). Biomethane production through anaerobic co-digestion with Maize Cob Waste based on a biorefinery concept: A review. *Journal of*

Environmental Management, 249: 1-21. https://doi.org/10.1016/j.jenvman.2019.109351

[19]. Szulc, J., Błaszak, B., Wenda-Piesik, A., Gozdecka, G., Żary-Sikorska, E., Bąk, M., & Bauza-Kaszewska, J. (2023). Zero waste technology of soybeans processing. *Sustainability*, *15*(20), 14873.

[20]. Wang, Y., Li, G., Chi, M., Sun, Y., Zhang, J., Jiang, S., & Cui, Z. (2018). Effects of co-digestion of cucumber residues to corn stover and pig manure ratio on methane production in solid state anaerobic digestion. *Bioresource technology*, *250*, 328-336.

[21]. Ward, A. J., Hobbs, P. J., Holliman, P. J., & Jones, D. L. (2008). Optimisation of the anaerobic digestion of agricultural resources. *Bioresource technology*, *99*(17), 7928-7940.

[22]. Zhang, L., Loh, K. C., Sarvanantharajah, S., Tong, Y. W., Wang, C. H., & Dai, Y. (2019). Mesophilic and thermophilic anaerobic digestion of soybean curd residue for methane production: Characterizing bacterial and methanogen communities and their correlations with organic loading rate and operating temperature. *Bioresource Technology*, *288*, 121597.