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Evaluation of Methane Potential of Slaughterhouse Waste in the Urban Municipality of N'Zérékoré, Guinea Republic

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Abstract

This study focuses on optimizing biogas production from biodegradable waste from the slaughterhouse in the urban commune of N'Zérékoré, Guinea. To achieve this objective, we rigorously identified and quantified three main types of waste: rumen contents, blood, and wastewater. Next, an in-depth physicochemical characterization of these substrates was carried out. The results reveal high moisture content (56 to 87%), a high carbon/nitrogen (C/N) ratio ranging from 24 to 32, and a high proportion of degradable organic matter. These results indicate conditions conducive to anaerobic digestion. In addition, an experiment was conducted over a period of 39 days in 4.5-liter laboratory digesters at a controlled mesophilic temperature (29 to 36°C) to evaluate the methanogenic potential of waste at different dilution ratios. The rumen content produced up to 2.493 ml of biogas per kilogram of dry matter with an optimal dilution ratio of 1/1.5, while blood reached a maximum volume of 3.415 ml/kg under similar conditions. Co-digestion with pig manure showed lower potential, suggesting the need for specific optimizations for this mixture. These findings demonstrate the energy value of local slaughterhouse waste for biogas production, offering a renewable and decentralized solution in rural areas. This recovery promotes sustainable management of organic residues while contributing to energy independence and reducing the environmental impacts of animal waste in Guinea.

Keywords: Biogas, Slaughterhouse waste, Renewable energy, N'Zérékoré, Optimization, Anaerobic digestion.

Introduction

Scientifically is known that slaughterhouses are among the meat industries that produce the most biodegradable effluents[1]. Indeed, slaughterhouses produce solid waste including manurehorns hooves and bones and liquid waste namely blood and stomach contents[2]. Thus, it is argued that slaughterhouses produce effluent because it exposes the physiological fluids (bloodsaliva) of slaughtered animals to the external environment[3].

In Guinean slaughterhouses one hundred and fifty (150) to two hundred and fifty (250) cattles and an average of three hundred (300) sheep are slaughtered daily which increases during the Tabaski and Ramadan celebrations. Thus, these slaughterhouses generate a large quantity of wastes which are primarily of an organic nature. These wastes can create serious environment pollution problems if they are improperly managed or untreated[4-6]. However, many abattoirs in Guinea are not designed to take advantage of their wastes or do not have a management plan to reduce the polluting way of their waste[7]. The slaughterhouses in N'Zérékoré, Forest Guinea are not exempt from this situation related to the deficient management of slaughterhouse waste[8], hence the interest in the N'Zérékoré slaughterhouse.

In West African context, the best way to take advantage from slaughterhouse wastes and overcome the improperly managed wastes from the slaughterhouse is to convert these slaughter house wastes to biogas and therefore to produce energy from these wastes[1,9-13]. The first step to reach these goals is to evaluate the methane potential of each kind of slaughterhouse wastein West African cities[14,2].

Thus, the evaluation of methane potential of slaughterhouse waste has been investigated in several African cities for instance in Dakar by Adannou et al.[15]; in Abidjan by Kone et al.[16]; in N'Djamena by Adannou et al.[15]; in Lagos by Audu et al.[3]; in Acrra by Nana[17].

To help the BIOGAZ project[18-20] in its goal of installing biodigesters in Guinea mainly in Nzérékoré, this study aims to evaluate methanogenic potential from slaughterhouse wastes and to identify the best combination of slaughterhouse waste that can produce a large quantity of biogas in the urban municipality of Nzérékoré in Guinea republic. In the following section we describe and present the materials and methods. The subsequent section deals with the results analysis and discussion and finally the conclusions are drawn.

Materials and Methods

Study site and targeted waste: The slaughterhouse considered in this study is located in N'zérékoré mainly in the urban municipality of N'zérékoré (UMZ). N'zérékoré is located in Southeastern Guinea and characterized by a humid equatorial climate with annual rainfall between 1.500 and 2.000 mm and average. N'Zérékoré slaughterhouse in Loulé is one of the main animal processing centers in the municipality. It plays a strategic role in supplying meat to the urban population and surrounding prefectures, notably Lola, Beyla, Yomou and Macenta. Cattle from these breeding areas are mainly of the Zebu and N'dama breeds which are adapted to hot climates and local conditions respectively[21]. The Horoya slaughterhouse generates a significant volume of organic waste such as rumens contents, blood, trimmings and intestines which have significant methan ogenic potential for biogas production. The diversity of breeds and the proximity of the livestock farming areas provide a representative sample for assessing the physicochemical characteristics of the waste. Figure-1 shows the location of the slaughterhouse and the main prefectures supplying it.

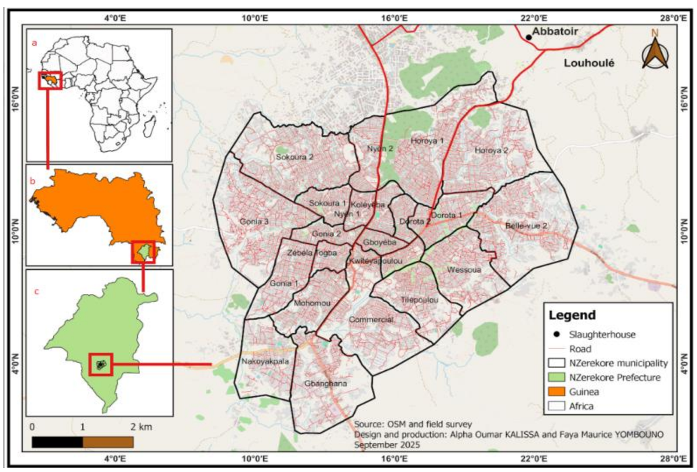

Figure-1: Geographic location (a) Guinea within Africa, (b) forested Guinea within Guinea, (c) Loulé within forested Guinea, (d) Map of the urban municipality of N'Zérékoré.

Quantification of waste from cattle slaughter: Animal waste was quantified by estimating daily production based on the contents of the rumen of slaughtered cattle. Each morning five rumens of different volumes were collected and weighed using a scale with a capacity of 100 kg. The average of these weights was considered to represent the average individual production per cattle for all animals slaughtered during the day. The total amount of rumen content produced per day was calculated as:

$$M = M_j \times N \quad (1)$$

M: Quantity of rumen contents produced per day in kg; M_j: Average daily production of rumen contents per oxen; N: Total number of oxen slaughtered per day. For wastewater the daily volume was measured using a 20-liter container placed at the collection basin and the total volume at the end of each day is determined.

Physical-chemical characterization: The slaughterhouse waste collected has been analysis by the laboratory of the Guinean Palm Oil and Rubber Tree Company (SOGUIPAH). The physical and chemical parameters based on the essential parameters for anaerobic digestion are determined. These parameters are:

Moisture content (H%) an indicator of water content that promotes or limits microbial activity;

$$\text{H (\%)} = \left(\frac{P_1 - P_2}{P_1 - P_0}\right) \times 100 \quad (2)$$

Dry matter (DM %) important for defining concentrated organic load;

$$\text{DM (\%)} = \left(\frac{P_2 - P_0}{P_1 - P_0}\right) \times 100 \quad (3)$$

Volatile organic matter (VOM%) an essential biodegradable component;

$$\text{VOM (\%)} = \left(\frac{P_1 - P_2}{P_1}\right) \times 100 \quad (4)$$

Organic carbon total (OCT %) and total nitrogen content (N %) essential for calculating the carbon/nitrogen ratio (C/N) a key indicator of microbial nutrient balance[22].

$$\text{C (\%)} = \left[\frac{(P_c + E) - P_{500}}{(P_c + E) - P_{cv}} \times 100\right] \times \frac{1}{1.724} \quad (5)$$

$$N = V_{acide} \times 0.195 \times m_{pe} \quad (6)$$

Experimental digesters and operating conditions: The experimental setup comprises twelve polypropylene bottles 4.5-liter (Figure-2) divided into 4 experiments each using 3 bottles connected by pipes. The first bottle serves as a digester the second as a gasometer filled with water and the third which is empty collects the water displaced by the biogas produced. The amount of biogas is determined by weighing the displaced water using an electric scale.

Loading of the devices: The digester (D_1) was loaded with a mixture of 1kg of rumen content diluted with 1.5 liters of tap water. The second digester (D_2) contained 1.5 liters of blood while in the third digester we made a mixture of 500g of rumen content and 500g of pig manure diluted in 1.5 liters (co-digestion) and finally the fourth device is loaded with 1.5 kg of rumen content diluted in 1.5 liters of tap water.

The digesters were placed in a thermostatic chamber to maintain a controlled temperature corresponding to the mesophilic regime as following: 35-36°C for rumen content; 33°C for blood; 29°C for pig manure. These temperatures promote optimal activity of methan ogenic microbiological communities, particularly methan ogenic archaea which are involved in the final stage of methanogenesis[21].

The pH was measured regularly (using a calibrated pH meter) and maintained ideally within the neutral to slightly alkaline range[23-25,7] to prevent excessive acidification that could inhibit fermentation[26]. The composition of the biogas produced was analyzed using an Optima 7-Biogas gas phase biogas analyzer equipped with a detector to quantify the methane (CH_4) and carbon dioxide (CO_2) content as well as any traces of hydrogen sulfide (H_2S) and other gases. The quality of the biogas (CH_4/CO_2 ratio) is a key indicator of the energy value and performance of the digestion process[27]. The different stages of the investigation methodology are summarized in the Figure-4.

Figure-2: Experimental setups built at the electricity and electonics Laboratory at the University of the N'Zerekore (experiment duration April 6th to May 14th, 2025.

Figure-3: Biogas analyzer to determine the composition of the biogas produced during the experiment.

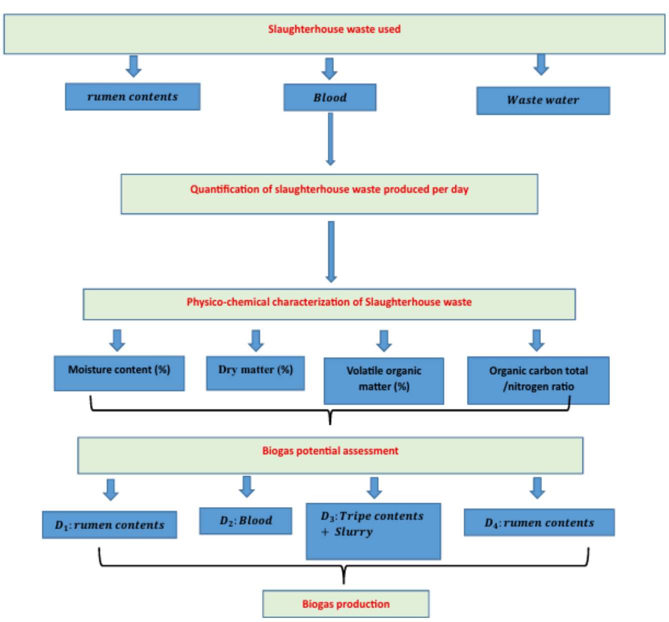

Figure-4: Stages of the investigation methodology.

Results and Discussion

Daily production and variability of rumen content wastes at the Urban Municipality of N'Zérékorés laughter house: Table-1 shows the daily production of rumens contents. The daily assessment of waste deposits from rumen contents collected at the slaughterhouse in the Urban Municipality of N'zérékoré revealed a significant average production of rumen contents during the study period.

The quantities recorded were ranged from 377.4 kg to 713.4 kg per day with a daily average of 521 kg. Data analysis highlights daily fluctuations of rumen content wastes marked by significant peaks observed on February, 8 2025 with a volume of 713.4kg of rumen content collected. This variability is directly related to the number of animals slaughtered each day as well as the specific characteristics of the animal batches, particularly their weight and fatness.

Overall, the results indicate that production remains relatively stable most of the time with an estimated average of 24.42kg per animal slaughtered while recording occasional increases corresponding to periods of intensified slaughtering activity.

Dynamics of daily wastewater production from cattle slaughter in the Urban Municipality of N'Zérékoré slaughterhouse: Table-2 depicts the daily wastewater production. Analysis of data on daily wastewater production from cattle slaughter in the Urban Municipality of N'zérékoré shows a significant variation in the number of animals slaughtered and the volumes of effluent generated (Table-2).

Table-2 shows that during the study period the number of cattle slaughtered daily fluctuated between 15 and 26, with an average of 20 head per day. The highest number was recorded on March 1. 2025 (26 head) while the lowest numbers were observed on March 17 and April 26. 2025 (15 head each).

Furthermore, the total volume of wastewater generated per day followed the same trend varying between 1.875m³ and 3.172m³ with an average of 2.465m³/day. The maximum volume corresponds to the day when the number of animals slaughtered was highest, while the minimum volume was recorded on the day when the number of animals slaughtered was lowest.

This trend shows a positive correlation between slaughtering activity and the amount of wastewater produced. On the other hand, the average volume of wastewater per head remained relatively stable ranging from 0.119 to 0.129 m³/animal/day (approximately 124 liters per animal) with an average of 0.124m³/animal/day.

This low variability indicates that the amount of water used per animal follows a relatively standardized process.

Table-1: Daily collection of rumen contents from February 2nd to March 16th, 2025, at the N'Zerekore slaughterhouse, Loule.

Date of production	Number of cattle slaughtered per day	Rumen content per head (kg/day)	Average rumen content per head (kg/day)
02.02.2025	20	456	22.8
04.02.2025	21	592.2	28.2
06.02.2025	23	676.2	29.4
08.02.2025	29	713.4	24.6
09.02.2025	22	576.4	26.2
11.02.2025	21	457.8	21.8
13.02.2025	20	580	29
15.02.2025	29	690.2	23.8
17.02.2025	22	594	27
18.02.2025	20	420	21.5
19.02.2025	17	377.4	22.2
21.02.2025	19	385.7	20.3
24.02.2025	22	587.4	26.7
26.02.2025	16	403.2	25.2
27.02.2025	21	554.4	26.4
28.02.2025	23	538.2	23.4
02.03.2025	21	514.5	24.5
04.03.2025	22	429	19.5
06.03.2025	23	494.5	21.5
07.03.2025	18	480.6	26.7
09.03.2025	25	532.5	21.3
12.03.2025	19	480.7	25.3
14.03.2025	18	491.4	27.3
15.03.2025	25	617.5	24.7
16.03.2025	18	381.6	21.2
Average	21	521	24.42

Table-2: Daily collection of wastewater from February 25th to April 30th, 2025, at the N'Zerekoreurban commune slaughterhouse, Loule district.

Date of production	Cattle slaughtered per day	Wastewater volume per head (in m³/day)	Average wastewater volume per head (in m³/day)
25.02.2025	20	2.500	0.125
26.02.2025	17	2.176	0.128
27.02.2025	21	2.667	0.127
28.02.2025	20	2.480	0.124
01.03.2025	26	3.172	0.122
02.03.2025	19	2.261	0.119
03.03.2025	22	2.640	0.120
11.03.2025	21	2.625	0.125
17.03.2025	16	2.032	0.127
20.03.2025	15	1.940	0.129
28.03.2025	20	2.520	0.126
02.03.2025	21	2.709	0.129
11.04.2025	19	2.342	0.123
17.04.2025	15	1.928	0.128
19.04.2025	23	2.740	0.120
21.04.2025	25	3.050	0.120
24.04.2025	18	2.196	0.122
26.04.2025	15	1.875	0.125
27.04.2025	22	2.706	0.123
30.04.2025	23	2.737	0.119
Average	20	2.465	0.124

Physico-chemical characteristics of waste produced at the slaughterhouse in the Urban Commune of N'Zérékoré: Figure-5 presents the physicochemical parameters of the waste produced at the slaughterhouse in the Urban Commune of N'Zérékoré during the studied period.

Analysis of the physicochemical parameters of waste generated at the UMZ slaughterhouse reveals significant variability depending on the type of substrate. Figure-5 shows that rumen content has very high moisture content (86.80%) and low dry matter (13.19%) while its organic matter content is 84.64% with total carbon of 47.14%. Its C/N ratio of 24.17 indicates a predominance of carbon over nitrogen. Blood has moderate moisture content (74.32%), higher dry matter (25.67%) almost total organic matter (96.69%) and total carbon of 55.97% (with a C/N ratio of 32.46). Manure is characterized by the lowest moisture content (56.11%) and the highest dry matter content (43.88%) with organic matter at 76.36% and a C/N ratio of 30.05. These results highlight the diversity of the waste's physicochemical characteristics emphasizing the distinct compositions of each type of substrate.

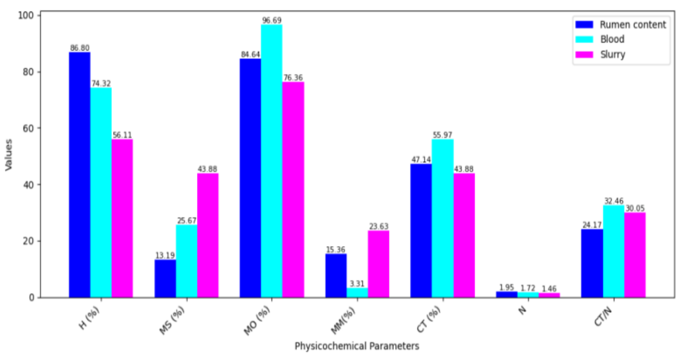

Figure-5: Characteristics of the physicochemical parameters of the waste produced at the slaughterhouse in the Urban Commune of N'zérékoré during the studied period. H (Moisture content), MO (organic matter content), CT (total carbon), N (nitrogen), CT/N (carbon/nitrogen ratio).

Biogas production kinetics in mesophilic digesters: Figure-6 presents the daily biogas production. Biogas production was measured daily for thirsty nine (39) days, which corresponding to a complete mesophilic anaerobic digestion cycle for these substrates. The gas produced was collected via a water displacement system allowing accurate measurement of the volume generated in milliliters. Analysis of daily biogas production (Figure-6) highlights distinct dynamics depending on the digester with rumen content alone (ratio 1/1.5) maximum production (646ml/kg) is observed on the first day followed by a rapid decline a stable phase between days 5 and 16 and then a gradual decline until day 39. Blood shows slower production peaking on day 13 with a marked increase between days 8 and 16 indicating progressive methan ogenic activity. Rumen-slurry co-digestion shows a late start (day 17) and overall low production indicating an initial imbalance in microbial biomass. Finally, rumen content at a ratio of 1.5/1.5 peaks on day 16 (156 ml) before slowing down due to substrate depletion. These results confirm the influence of substrate type and substrate/ inoculum ratio on methan ogenesis kinetics. These results highlight biogas production in mesophilic digesters at 36°C.

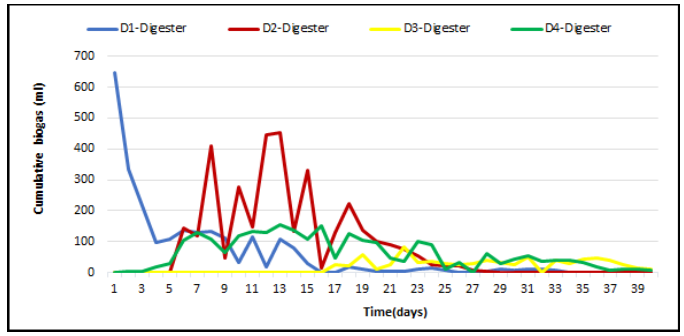

Figure-6: Daily biogas production for each biogas digester.

Cumulative biogas production according to substrate type and digester ratio: Table-3 presents the cumulative biogas production according to substrate type and digester ratio. The results show that cumulative biogas production varies significantly according to the type of substrate and the ratio applied in the digesters. Analysis of Table-3 shows that rumen content alone produced relatively high volumes (2.493m³ for D_1 and 2.432m³ for D_4). This indicates that the load ratio has a moderate effect on methane yield. Blood alone generated the highest volume (3415m³) reflecting its richness in easily biodegradable nutrients and its high energy potential. On the other hand, co-digestion of rumen content with pig manure (D_3) led to significantly lower production (795m³) probably due to a carbon/nitrogen imbalance or partial inhibition of microbial activity.

Table-3: Cumulative biogas production according to substrate type and digester ratio.

Subrates	Digesters	Ratio	Production time	Volume in m³
Pans contents	(D1)	1/1.5	39	2493
Blood (only)	(D2)	Alone		3415
Pans contents + Pigmanure	(D3)	Co-digestion		795
Pans contents	(D4)	1.5/1.5		2432

Characteristics of the composition of the biogas produced: Table-4 shows the characteristics of the composition of the biogas produced. The study of the composition of biogas from the three selected substrates (rumen content, blood and pig manure) highlights significant variations in the proportions of methane (CH_4), carbon dioxide (CO_2) and hydrogen sulfide (H_2S) (Table-4). Analysis of the biogas composition shows that methane (CH_4) content varies from 57.08% to 68.27% confirming good energy potential. Blood has the highest proportion (68.27%) followed by rumen content (65.84%) reflecting their excellent suitability for biogas production. Pig manure with the lowest value (57.08%) is characterized by a high proportion of CO_2 (42.52%) indicating less efficient conversion to CH_4 and a lower calorific value.

The H_2S concentration varies from 0.40% to 1.80% with a maximum recorded in rumen content which requires a desulfurization step before energy recovery. The temperatures observed (29°C to 30.8°C) are within the optimal mesophilic range promoting good methan ogenic activity.

Table-4: Characteristics of the composition of the biogas produced.

Substrates	Temperatures	CH_4 (%)	CO_2 (%)	H_2S (%)
Cow rumen contents	30.8°C	65.84	32.36	1.80
Blood	30°C	68. 27	30.55	1.18
Pigmanure	29°C	57.08	42.52	0.40

Analysis of waste deposits produced at the slaughterhouse in the urban commune of N'Zérékoré shows a regular and relatively high availability with a daily average of 521kg of rumen content and 20 cattle slaughtered per day. Our results corroborate those of Sakouvogui, A., & Kamano, M.[7] who reported a significant accumulation of animal residues. Mainly rumen contents and blood in the forest region of Guinea with no sustainable treatment system in place.

This availability is a major asset for supplying substrates to a methanization unit. In terms of physical and chemical properties rumen content has high moisture content (86.80%), low dry matter content (13.19%) and a C/N ratio of 24.17 while blood is characterized by very high organic matter content (96.69%) and a C/N ratio of 32.46. These characteristics directly influence the methan ogenic potential of the substrates.

According to Angelidako[21] and Chen[26] the optimal C/N ratio for anaerobic digestion is between 20 and 30 and above this an excess of carbon slows down degradation while an excess of nitrogen promotes the accumulation of toxic ammonia. Our results show that rumen content alone is close to equilibrium while blood which is richer in carbon has high energy potential but requires co-digestion with a nitrogenous substrate to optimize methane production. These findings are consistent with those of Mokhles[27] who have demonstrated the benefits of a balanced mixture of slaughterhouse waste to maximize biogas production and limit microbial inhibition. Daily biogas production showed variable performance depending on the substrate. Blood alone generated the highest volume (3.415m³) reflecting its richness in easily biodegradable soluble compounds confirming the results of Ait-Brahim[28] and Wang[20] who have reported that higher methan ogenic yields can be obtained with liquid substrates rich in proteins and lipids. Rumen content alone also showed interesting production (2.493m³ for D_1 and 2.432m³ for D_4) with a moderate effect of the loading ratio. In contrast co-digestion with pig manure (D_3) produced a significantly lower volume (795m³). This result could be explained by an imbalance in the C/N ratio or by the presence of inhibitory compounds as described by Zongo[29] in Burkina Faso and[24] in Senegal in similar studies. According to Greenexia[23] optimizing mixtures is essential to maintain effective microbial activity and prevent the accumulation of volatile fatty acids which are responsible for reduced yield. Finally, analysis of the biogas composition revealed a methane (CH_4) content ranging from 57.08% to 68.27% indicating that the biogas produced is of good energy quality. Blood had the highest methane content (68.27%) followed by rumen content (65.84%). These values are similar to those reported by Oua[30] and Yankyera[31] who observed CH_4 contents of between 60 and 70% in slaughterhouse methanization units in West Africa. SciDev. Net (2015) and the European program[32] emphasize that levels above 50% allow for direct use of biogas for cooking electricity generation or heating. These results therefore confirm the project's energy and environmental viability while offering a sustainable alternative to current slaughterhouse waste management practices.

Conclusion

This study has demonstrated that slaughterhouse waste from the Urban Muncipality of N'Zérékoré represents a significant resource for biogas production. Rumen content and blood proved to be effective methanogenic substrates with respective volumes of 2.493m³ and 3.415m³ and methane contents of up to 68.27%. However, co-digestion with pig manure showed limitations. Suggesting the need to adjust mixing ratios to optimize production and prevent microbial inhibition. These results highlight the technical feasibility of a local methanization unit while reducing the environmental impacts associated with direct waste disposal. From a socio-economic perspective the energy recovery of these animal residues would help reduce dependence on fossil fuels improve hygiene conditions and create job opportunities in the green sector. This project could therefore form part of local energy transition strategies in Guinea while inspiring other municipalities facing similar issues in sub-Saharan Africa.

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