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Evaluation of Biogas Production Potential from Organic Waste from the Yaoundé Industrial Slaughterhouse and Sizing of a Biomethanation Unit

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Abstract. The purpose of this work is to propose a method for recovering organic slaughterhouse waste from the industrial slaughterhouse in Yaoundé. Biogas production is the basis of this, which can be utilized as a source of energy, either thermal or electrical. In this study which has the Industrial Slaughterhouse of Yaoundé as a site of study, the overall organic slaughterhouse waste production potential, biogas production potential, and energy (thermal and electricity) were assessed and the values obtained are respectively 4 616 298 kg/year, 373.6 x 10^3 m^3 CH_4/year, 6 455.6 x 10^3 MJ/year, and 560.4 MW/year. The anaerobic fermentation of 25 kilograms of organic matter, comprising 15 kilograms of rumen waste and 10 kilograms of manure, in combination with 25 liters of water in a 60-liter cask utilized as a digester, was also carried out. The total volume of biogas collected after 30 days of anaerobic digestion is 223.4 L. One of the major expenses at the Industrial Slaughterhouse of Yaoundé is related to electricity need, which is about 16,302 kWh/month. Based on the daily potential flow of effluent produced at the ISHY, we could size a digester with a volume of 910 m^3. Biogas production is thus proving to be a solution with a multifunctional advantage, as it is not only reducing the organic waste to be managed, but also produces an energy source that can be used for several purposes, including electrical energy.

Key words: Biogas, Biomethanation, Slaughterhouse, Waste, Sizing

Introduction

The environmental concern under climate change is due to the progressive need of energy actually mainly provided by fossil fuels (Budiyono et al., 2010; Budiyono et al., 2014; Omondi et al., 2019). Facing the climate change and the fact that the fossil fuels will come to an end, researchers, and scientists have all been looking to green energy sources which leads to the serious consideration of biomass as a source of renewable energy. In this sense, crops of short cycle of production have been commonly used; but the limit of this is the challenge of the availability of arable land for their production (Omondi et al., 2019). Industrial development and rapid demographic pressure – which all needs energy – are responsible for the large-scale production of waste (radioactive waste, household waste, agricultural waste, animal waste) (Diallo, 1999)**.** Nowadays observation of human health problems (Budiyono et al., 2010), environmental deterioration is presumed mainly to be caused by the mismanagement of biodegradable liquid and solid wastes, the excessive use of fossil fuel, and agricultural activities (Musa et al., 2019). Among the human activities that produce biomass from which biofuel (biogas) can be produced, slaughterhouses are to be considered. Effluents from slaughterhouses are urine, blood, and large intestines and stomach residues have to be treated and disposed of in order to protect the environment and to prevent human health (Kabeyi & Olanrewaju, 2021). Wastewater from a commercial cattle slaughterhouse is considered to be high-strength

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industrial wastewater due to high biological oxygen demand (BOD), total suspended solids (TSS), chemical oxygen demand (COD), and fats, oil, and grease (FOG) (Musa & Idrus, 2020). Slaughterhouse wastewater studied by Budiyono et al. (2011) presented BOD = 1,873 ± 421 mg/L, COD = 3,756 ± 687 mg/L, and TSS = 1,171 ± 311 mg/L while Rajab et al. (2017) had the following characteristics: COD = 3,102 ± 688 mg/L, FOG = 375 ± 151 mg/L, and suspended solids of 872 ± 178 mg/L. Kabeyi & Olanrewaju (2020, 2021) stated that bovines generate about 27.5 % of the weight of solid waste per live animal. It has been shown that the slaughterhouse waste conversion into biogas and electricity inactivates pathogens, reduces the cost of waste treatment, and produces fertilizers (Kabeyi & Olanrewaju, 2021). Taking other renewable energy forms into account, many advantages in terms of environment, health, energy and waste management are offered by biogas technology (Budiyono et al., 2011; Roopnarain & Adeleke, 2017; Sarteshnizi et al., 2018; Ali et al., 2020). The biogas produced is constituted of about 25–50% carbon dioxide, 50–70% methane, nitrogen, water vapor, hydrogen sulfide, etc. When the gases accompanying the methane are separated from methane, this results in a gas with a higher heating value, named biomethane (Kabeyi, 2019). The biomass (liquids, dung, and rumen digest) from the slaughterhouse is converted into biogas through biomethanation process which is an anaerobic process where methanogen bacteria are used. These methanogen bacteria are of three types, cryophiles (12–24 °C), mesophiles (22–48 °C), and thermophiles (50–70 °C) in respect to the optimum operating temperature range (Kabeyi & Olanrewaju, 2021).

Biogas production from slaughterhouse wastes can be conducted from one substrate through the process named anaerobic digestion, as well as from its combination with other biomass that has low content of lipids and/or nitrogen through the process named co-digestion (Castellucci et al., 201). In this regard, Callaghan et al. (1999), Kumar & Sharma (2017) have shown that correlating process parameters in co-digestion of a biomass with other substrates in a simple and inexpensive technology enhanced microbial degradation of the biomass. Also; Li et al. (2011), Rao and Baral (2011), and Dias et al. (2014) demonstrated that the digestion of individual substrates leads to a poor performance in comparison to the co-digestion of substrates in which the simultaneous processing has a synergy effect leading to a better performance. The reduction of the concentration of toxic compounds, the improvement in substrate loading, the increase of the concentration of ingredients, the hygienic stabilization of enzymes are some of the numerous advantages of the microbial digestion through co-digestion (Tufaner & Avsar, 2016; Musa et al., 2019; Kabeyi & Olanrewaju, 2021). The performance and the stability of the anaerobic process are all of important benefits (Esposito et al., 2012) with potential consequences of the increase of the yield of the biogas and the reduction of the hydraulic retention time (Callaghan et al., 1999). Zhang et al. (2012) previous studies found that the methane yield in batch and semi-continuous reactors for a ratio of 2:1 of food waste and cattle manure as substrates is 41.1% and 55.2% respectively.

Due to the demographic growing, the demand for meat for the human feed also keeps growing, leading to the increase of the meat production industry which finally became a fast industry worldwide (Pagés-Díaz, 2015) including Cameroon. The industrial slaughterhouse in Yaoundé (Cameroon) is no exception, as it is tasked with providing meat for human consumption. From the most recent data available, 106 599 bovines were slaughtered in 2017 (SODEPA, 2018). Since high amounts of wastes are produced from the industrial slaughterhouse of Yaoundé (ISHY) and considering the energy deficiency that is recorded in this city, the potential biogas production from this biomass is to be evaluated. The general objective of this research is to improve the overall management of organic waste from the ISHY by producing Biogas that can be used as a source of electrical energy.

Materials and Methods

Materials

The ISHY wastes used for this study are essentially made of solid wastes constituted of rumen waste and manure from cattle. Their physicochemical characteristics were assumed to be within the average of published research on wastes from bovine slaughterhouses. The rumen waste was collected directly from the cleaning shop where the intestines are washed and manure from the barn to reduce the risk of contamination with chemicals and toxic agents such as cleaning products, grease, and oil. In order to prepare of the organic matter for the potentiality assessment, rumen waste (15 kg) was mixed with manure (10 kg) in a container into which water was added (25 L). This mixture is practically constituted of 50% water, 30% rumen waste, and 20% manure.

Methods

Evaluation of biogas production and energy potential from waste at the ISHY

Estimation of organic waste production rate

With the aim of evaluating the waste production rate, it was decided to make a daily follow-up during twelve months (February 2022 – January 2023) of operation of the ISHY. The data analysis on daily and monthly basis allows determining the day of the week with high demand and the average monthly demand.

Simultaneously with the previous data collection, rumen waste was also collected on 30 animals chosen randomly. The weight of the animal and the amount of rumen waste were recorded As far as manure is concerned, it was collected after a stalling period of 3 hours/day during 30 days. The ISHY counts 15 stalls and one was selected each day for manure collection.

Biogas production potential

The determination of the production of biogas potential from ISHY waste is done by using the following Eq. 1 (Ali et al., 2020):

$$P = M * TS * AC * B_{TS} \qquad \text{Eq. 1}$$

Where:
P is the biogas potential (m^3 $year^{-1}$);
M denotes the total amount of waste (kg $year^{-1}$);
TS represents the content of total solid (%);
AC is the availability factor; and
B_{TS} is the experimental biogas production (m^3 kg^{-1} TS).

The same as what Ali et al. (2020) did in their study and based literature, in this research work, since the animal excreta and rumen waste are always available because collected at the slaughterhouse, the *AC* was considered to be equal to 100 %. The total solids (*TS*) contents were moreover considered to be 25 % since it is the value retained for large ruminants, being for excreta or for the rumen. For B_{TS}, the chosen value is 0.8 m^3 kg^{-1} TS for the excreta of large ruminants, and 0.3 m^3 kg^{-1} TS rumen waste.

Biogas energy potential

The energy potential evaluation of the biomass is based on its calorific value, amount of available biogas, and the conversion system (Ali et al., 2020). It has been reported that cattle manure produces biogas with methane content ranged between 50 and 70 % (Nasir et al., 2012), while slaughterhouse waste biogas content is 60 % (Garcia, 2014).

$$E_{biogas} = C * CH_4 * P * \eta \qquad \text{Eq. 2}$$

Where:
E_{biogas} is the quantity of electricity or heat energy produced (kWh $year^{-1}$);
η represents the overall efficiency of the conversion of biogas (%). It is noted that the η values (η_e or η_c) were considered as η_c = 80% (efficiency of the combustion process) and η_e = 25%

(efficiency of heat-to-electricity conversion), respectively, for thermal and electric energies (Ali et al., 2020);
P is the amount of biogas produced per year or the biogas potential as described in the above Eq. 1 and expressed in m^3 $year^{-1}$;
CH_4 represents the methane content that we are going to be considered to be 60% in our study;
C represents the lower calorific value of methane, which was considered as 36 MJ (or 10 kWh) per cubic meter of methane (1 m^3 CH_4 = 36 MJ; 1 kWh = 3.6 MJ; 1 m^3 CH_4 = 10 kWh) (Garcia, 2014; Abdeshahian et al., 2016).

Experimental biogas production

Having the aim to assess the potentiality of biogas production from ISHY wastes, a laboratory scale digester had to be constructed based on information available in literature. The designed laboratory size production system is illustrated by Figure 1 below.

Construction of the laboratory size production system

Important equipment, materials, and tools needed based on their use are the preparation tank (1), the digester (2), the purification tank (3), and the storage tank (4). The preparation tank is constituted of a container of 60 L to have the role of the vessel where all prepared materials are mixed before being sent to the digester through piping containing a valve. The digester is where the anaerobic digestion of the organic material takes place. The digester used for this work is constituted of a container of 60 L equipped with an agitator which the function is to keep the reaction medium well mixed. The gaseous phase is sent to the purification tank, while the organic solid residues is recovered is evacuated and disposed accordingly. The purification tank which the function is to clean the biogas produced, since it is usually constituted of CH_4 (60–70 %), CO_2 (20 – 30 %) and other trace elements. Absorption by bubbling, which consists of allowing the produced biogas to go through water from the bottom to the surface. During this ascension of the biogas, CO_2 and other trace elements are dissolved in the water. This is how the biogas purification is conducted. The purified gas is then stored in a cylindrical container that was previously used to store the frigorific gas, R22. A flow meter is placed in the piping connecting the purification tank to the storage tank in order to master the biogas production rate. A pressure gauge was placed on the storage tank for the monitoring of the pressure in the storage tank.

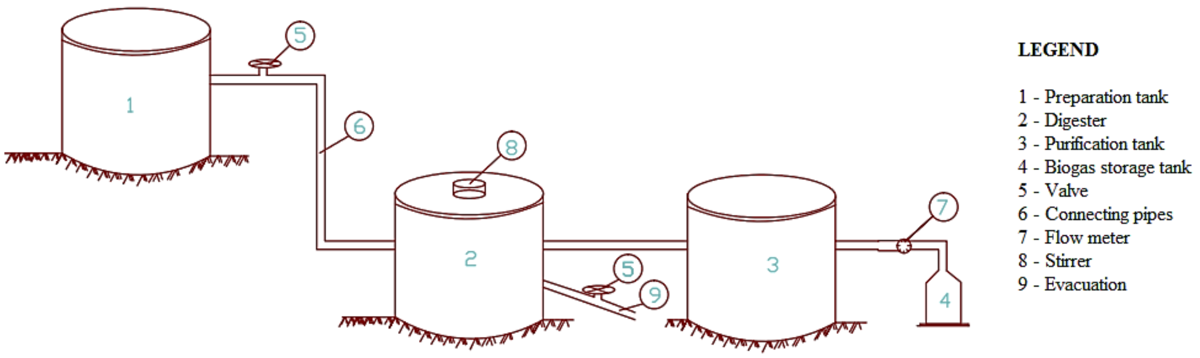

Figure 1. Schematic representation of the experimental set-up for biogas production

Biogas production and inflammability test

The prepared biomass is introduced in the digester and the system was observed for 30 days, during which the variation of the volume of gas produced was registered on a daily basis at the same time: 4 pm. There was no need to set particular temperature for anaerobic digestion condition since we intended to favor mesophile bacteria which optimal development temperature ranges between 22 °C and 48 °C. This range happens to include the ambient temperature, allowing us not to seek extra means of heat transfer.

The produced and treated biogas went through inflammability test to appreciate the quality of the biogas produced in regards with impurities such as carbon monoxide, hydrogen sulfide and other trace elements. Through this test, we will find out if it has the ability to burn and produce heat, which can be transformed into electricity.

Sizing of a biomethanation unit at the scale of ISHY

A biogas production unit has several compartments as we saw during our experience at the Slaughterhouse (preparation tank, digester, purification tank, storage tank). In this part, we will just focus on the basic formulas of the sizing of a digester at the scale of ISHY.

The volume of the digester

The volume of the digester is the volume of the assembly formed by the gasometer (G), which is the maximum daily volume of biogas that can be produced and the volume of the effluent V.

$$V_D = G + V \qquad \text{Eq. 3}$$

To find the volume of the digester, we will use the most applied formulas in the sizing of tanks, as illustrated by Eq. 4. **(**Widodo et al., 2009).

$$V_D = Q\ [\ HRT + B_0 * S\left(1 - \left(\frac{K}{HRT * U_m - 1 + K}\right)\right)] \qquad \text{Eq. 4}$$

Where:

Q is the quantity of effluent;

HRT is the hydraulic retention time;

B_0 is the potential for methane production;

S is the volume load of the effluent;

U_m is the maximum specific daily growth rate of microorganisms;

K is the inhibition constant.

Q is equal to the daily mass of belly content produced at the slaughterhouse added to that of manure. In this study, in order to facilitate the hydrolysis of our substrate, we diluted it in the proportions 1:1, that is to say 1 kg of organic matter for 1 liter of water. Q is then determined following the Eq. 5.

$$Q = \frac{\mathrm{M}(1+1)}{1000} \qquad \text{Eq. 5}$$

Based on the stable methane production as observed by Musa and Idrus (2020), the hydraulic retention time (*HRT*) was fixed for 30 days in this study.

B_0 is determined by analysis in a laboratory. It is actually equal to 0.2 $m^{3/}$ kg for organic waste from oxen (Widodo et al., 2009).

Knowing that the percentage of organic matter for rumen waste and manure is 68% (SODEPA, 2018), *S* can be calculated according to the Eq. 6 (Widodo et al., 2009):

$$S = \frac{\boldsymbol{\%Mo * 1000}}{\mathbf{TRH\ (1+1)}} \qquad \text{Eq. 6}$$

K is obtained according to the Eq. 7 (Widodo et al., 2009):

$$K = 0.8 + 0.0016 \times e^{0.06\ S} \qquad \text{Eq. 7}$$

U_m, the maximum specific growth rate of microorganisms is determined based on the below Eq. 8 (Widodo et al., 2009):

$$U_m = 0.013\ (T) - 0.129 \qquad \text{Eq. 8}$$

The volume of effluent V is a function of the daily flow rate of the effluent and the hydraulic retention time. So we can write:

$$V = Q \times HRT \qquad \text{Eq. 9}$$

The volume of Gasometer G, which is the maximum daily volume of biogas produced, is then deduced from the Eq. 3:

$$G = V_D - V \qquad \text{Eq. 10}$$

Results and Discussion

Evaluation of the Waste Production Rate in the ISHY

An average amount of cattle slaughtered daily, weekly, monthly, and yearly was necessary to estimate the rate of waste production. The statistical recording included random recording of the amount of rumen waste and manure.

Slaughtering Statistics in the ISHY

The follow-up of the activities in the slaughterhouse allowed us to have precise information on the rate of slaughtering daily, weekly, monthly, and yearly. Figure 2 below illustrates the amount of oxen slaughtered on a specific day over a week during four weeks.

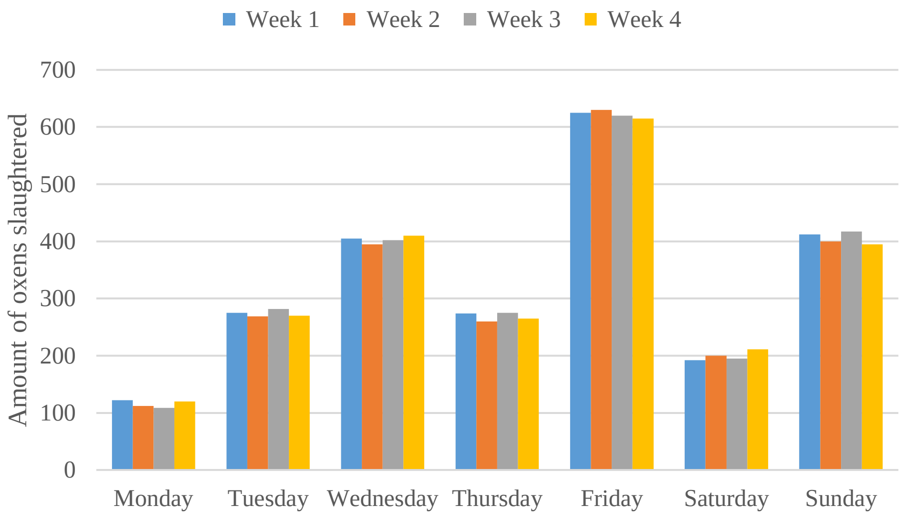

Figure 2. Daily slaughtering statistics at the ISHY during 4 weeks

From the above Figure 2, it can clearly be seen that for each day, the amount of slaughtered oxen stayed slightly constant during four weeks since small variations are noted for a specific day during four weeks. This shows a relatively constant demand of the population for meat in respect to the day.

It is apparent that the quantity of slaughtered oxen fluctuates from day to day. The day of Monday is recorded as the day that meat is less consumed (116 ± 6 slaughtered oxen) comparatively to Friday with 623 ± 6 slaughtered oxen, which is the day that meat is highly demanded. The daily average 327 while the weekly average is 2 289 slaughtered animals. The high demand in meat on Fridays can be justified by the fact that it is the day before the weekend, during which festivities (celebrations and parties) are mostly organized all around the city.

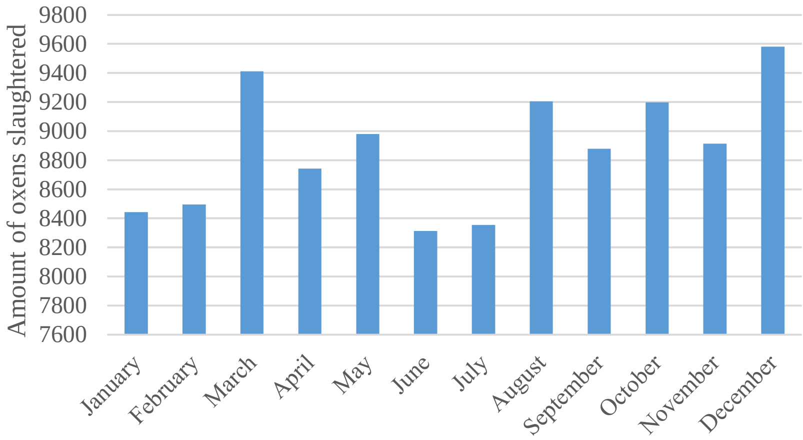

Figure 3. Monthly slaughtering statistics at the ISHY during 12 months

The histogram in Figure 3 is a representation of the variation in the amount of slaughtered oxen per month throughout a year. The statistics on a monthly basis throughout the year reveals a distribution where the month of June exhibit the least amount of slaughtered oxen (8 314) while December shows the highest value of 9 582 slaughtered oxen. The whole year gives the value of 106 518 slaughtered oxen, with a monthly average of 8 877 ± 421.

Evaluation of Biogas Production Potential from Organic Waste at the ISHY

The ISHY produces organic waste that includes rumen waste, blood, and manure. Our focus was on biomass that is composed of rumen waste and manure. Because of not being able to collect all the biomass produced, the selection of the animal from which the rumen waste was to be collected was chosen randomly, the same as the choice of the stall from which manure was to be collected.

Rumen Waste Production Rate

The selected animals, after being weighted and killed, the waste from the rumen was completely collected and weighted. Figure 4 below shows the variation of the mass of the rumen waste collected in relation to the weight of the animal from which it was collected. It is observed that, the amount of rumen waste collected is somehow proportional to the weight of the animal till 210 kg, after which the amount of rumen waste stays slightly constant despite the increase of the animal weight.

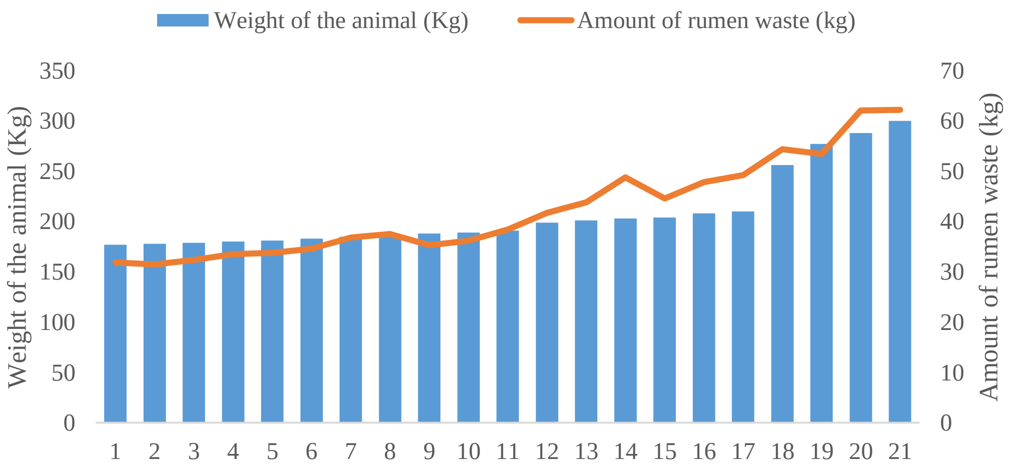

Figure 4. Variation of the mass of the rumen waste as a function of the animal weight

The average weight of the sample of animals is 205 ± 38 kg, while the average weight of rumen waste is 41.3 ± 9.6 kg. The latest is found to be far away greater the value of 27.5 kg per living animal published by Kabeyi and Olanrewaju (2020, 2021). From this average rumen waste produced by an animal, the amounts corresponding to daily, weekly, monthly, and yearly rumen waste production by ISHY are 13 500 kg, 94 498 kg, 366 472 kg, and 4 397 418 kg respectively. The production rate came out not to be negligible with high potentiality of exploitation as organic fertilizer or as source of energy (heat and electricity).

Manure Production Rate

Using the statistical analysis of recorded data, we were able to establish the average manure production rate of 2.03 0.24 kg per living animal. The ISHY's daily, weekly, monthly, and yearly average of slaughtered animals can be used to calculate the amount of manure accordingly. The manure production for daily, weekly, monthly, and yearly production was calculated to be 608 kg, 4 256 kg, 18 240 kg, and 218 880 kg respectively.
As a summary for the appreciation of the rate of biomass waste production by the ISHY, the Table 1 below shows the variation of organic waste production in relation with the amount of animals slaughtered on daily, weekly, monthly, and yearly basis.

Table 1. Potential production rate of organic waste in ISHY

	Slaughtered animals	Rumen waste (kg)	Manure (kg)	Total organic waste (kg)
Daily	327	13 500	608	14 108
Weekly	2 289	94 498	4 256	98 754
Monthly	8 877	366 472	18 240	384 712
Yearly	106 518	4 397 418	218 880	4 616 298

The slaughterhouse volume keeps growing due to the rapid changes in the national demand for beef. The latest reported number of heads slaughtered for national consumption in 2018 was 882 503 heads (Tsapi et al., 2022). The performance of ISHY in 2018 is actually 12 % of the average annual amount of heads slaughtered.

Biogas Production and Energy Potentials

Eq. 1 was used to determine the yearly biogas production potential, while Eq. 2 was used to determine the biogas energy potential for both manure and rumen waste. The below Table 2 gives the energy potential of ISHY.

Table 2. Energy potential of ISHY

	Biogas (10^3 m^3 CH_4/year)	Thermal energy (10^3 MJ/year	Electrical energy (MW/year)
Rumen waste	329.8	5 699.1	494.7
Manure	43.8	756.5	65.7
Total	**373.6**	**6 455.6**	**560.4**

It is appearing that the wastes from ISHY have a great energy potential, being electrical or thermal energy. These values are in accordance with the results obtained by Ali et al. (2020).

Experimental Production of Biogas from ISHY Organic Wastes

Biogas production

Daily measurements were taken of the volume of produced biogas after the prepared biomass was introduced into the constructed digester as shown in Figure 1. A digital thermometer was utilized to monitor the temperature fluctuation within the digester, despite there being no special setting for temperature regulation. Batch-processed biogas production was used in this study, and the volume of biogas produced was recorded daily for a period of 30 days. The cumulative volume representation curve and the variation in the volume of biogas produced daily are illustrated in figure 5 below.

After 30 days of anaerobic digestion, our constructed system could produce a total of 223.4 L of biogas from 25 kg of slaughterhouse waste. Regarding the variation of the cumulative volume produced, it can be observed that the overall production of biogas can be divided into three stages which were also observed by Rouf et al. (2016) and which are:

- ***Latent stage***: observed for 5 days, with a total production of 1.8 L of biogas on the fifth day. The beginning of microbial growth can be observed during this period. According to Marder et al. (2019), microorganisms require a period of adjustment before activating their anaerobic metabolism in a new environment. As the anaerobic metabolism is activated, with a fixed amount of organic matter to be degraded, the amount of biogas produced if proportional to the amount of microorganism in presence which is a function of its multiplication rate. The availability of nutrients is a factor in the multiplication rate.
- ***Exponential production stage***: observed from the 6th to the 15th day of the biogas production period of 30 days. The rapid increase of the biogas production rate in this stage is justified by the fact that the degradation of the organic matter is increasing, since it is from this organic matter that the microorganisms are finding the nutrients needed for their growth. The more they grow, the faster the organic matter will be degraded, and the more biogas will be produced. The cumulative volume of biogas produced gives 117.5 L in 9 days.
- ***Progressive decreasing stage***: from the 16th to the 30th day of biogas production, the daily production started decreasing progressively. During these 15 days, the total volume of produced biogas is 104.1 L; which lesser than the amount produced in 9 days of exponential production stage. By this, it is obvious to understand that the biogas production has reduced. The gradual reduction of biogas production is the result of depletion of the organic matter, leading to the dead of microorganisms responsible for methanation.

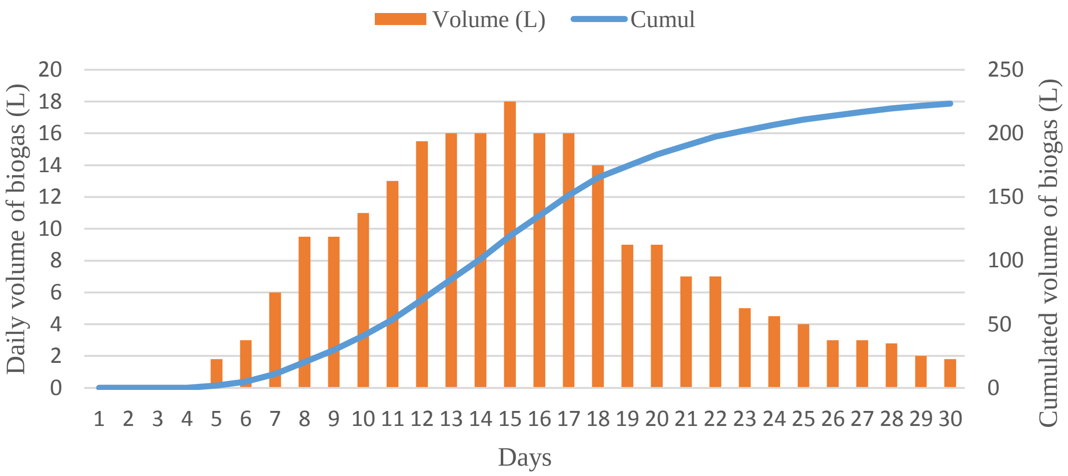

Figure 5. Variation of the volume of biogas produced daily and the cumulative volume

The three stages described above have been similar to experiments conducted by other researchers such as Rouf et al. (2016), Marder et al. (2019), and Rhee et al. (2021), but it is understandable that the biogas production patterns are very different. The bacteria involved and the physicochemical characteristics of the biomass can be responsible for these differences.

Produced biogas inflammability test

Lighting a flame from the produced biogas is how the test is conducted. The color of a flame is determined by the burned constituent's content, as is known. As shown in Figure 6 below, a sky-blue flame was observed in this inflammability test. By using this test, we were able to confirm that the biogas produced does not contain any other elements, such as carbon dioxide and hydrogen sulfide, from methane. The purification tank where the biogas was bubbling could be the cause of this. The absorption of unwanted compounds took place in this area.

Blue flame

Figure 6. Inflammability test of the produced biogas

The volume of the digester

In order to determine the volume of the digester as indicated by the above Eq. 4, we need to know the quantity of effluent (Q), the volume load of effluent (S), the maximum specific daily growth rate of microorganism (U_m), and the inhibition constant (K). The potential for methane production (B_0) and the hydraulic retention time (HRT) are 0.2 m^3/Kg and 30 days respectively.

- **Quantity of effluent (*Q*)**

  Q is determined following the above Eq. 5.

$$Q = \frac{(13\,500 + 608) * (1 + 1)}{1000} = 28.2\ m^3/day$$

The quantity of effluent out of the ISHY is found to be about 28.2 m^3/day.

- **Volume load of effluent (*S*)**

  Given that the percentage of organic matter for rumen waste and manure is 68%, S can be calculated according to the above Eq. 6.

$$S = \frac{0.68 * 1000}{30\ (1 + 1)} = 11.3\ m^3/day$$

The calculation of the volume load of effluent out of the ISHY is to be about 11.3 m^3/day.

- **Inhibition constant (*K*)**

  The inhibition constant (K) is obtained according to the above Eq. 7

$$K = 0.8 + 0.0016 * e^{0.06*11.3} = 0.0025$$

- **Maximum specific growth rate of microorganism (U_m)**

  The maximum specific growth rate of microorganisms is determined based on the above Eq. 8 with a mean temperature of 40 °C.

$$U_m = 0.013 * 40 - 0.129 = 0.391$$

- **Volume of the digester (V_D)**

The application of the above Eq. 4 gives the total volume of the digester.

$$V_D = 28.2\left[30 + 0.2 * 11.3 * \left(1 - \left(\frac{0.0025}{30 * 0.391 - 1 + 0.0025}\right)\right)\right] = 909.88\,m^3$$

Then, the total volume of the digester can be said to be equal to 910 m^3. The digester being occupied by the effluent and the produced biogas, let determine the volume occupied by each. The volume of effluent V is a function of the daily flow rate of the effluent and the hydraulic retention time, as stated by the above Eq. 9. So we can calculate:

$$V = 28.2 \text{ x } 30 = 846\,m^3$$

The volume to be occupied by the produced gas (G) or Gasometer can then be deduced following the above Eq. 10

$$G = 910 - 846 = 64\,m^3$$

For the organic wastes from the ISHY to be used as sources of energy (heat or electricity), an important space will be needed for the construction of the biogas production unit.

Conclusion

The energy potential of organic slaughterhouse waste is excellent. In this study which has the Industrial Slaughterhouse of Yaoundé (ISHY) as a site of study, the overall organic slaughterhouse waste production potential, biogas production potential, and energy (thermal and electricity) were assessed. The results were obtained at a rate of 4 616 298 kg/year, 373.6 x 10^3 m^3 CH_4/year, 6 455.6 x 10^3 MJ/year, and 560.4 MW/year. The production of biogas was also the subject of a trial. The total volume of Biogas collected is 223.4 L. Based on the daily potential flow of effluent produced at the ISHY, we could size a digester with a volume of 910 m^3.

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Declarations

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• *Conflict of interest/Competing interests* – The authors have no competing interests to declare that are relevant to the content of this article.
• *Ethics approval* – Not applicable
• *Consent to participate* – All authors are favorable
• *Consent for publication* – All authors are favorable
• *Availability of data and materials* – Data and materials are available under regular requirement
• *Code availability* – Not applicable
• *Authors' contributions* – All the authors contributed in various ways

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