INTERNATIONAL JOURNAL OF APPLIED SCIENCE AND RESEARCH

www.ijasr.org

2018 V0L.-1 ISSU.-3

CHARACTERIZATION OF WASTE FROM "ATTIÉKÉ" (*CASSAVA SEMOLINA*) PROCESS FOR THE DIMENSIONING OF BIO-METHANE's DIGESTER

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ABSTRACT

Anaerobic digestion is a natural process by which organic matter is transformed into a biogas that contains about 2/3 methane and 1/3 carbon dioxide. It results from the activity of a complex anaerobic microbial ecosystem. Biogas is a source of energy that can be used directly to replace natural gas, to produce heat and electricity by cogeneration or as fuel for motors. Thus, the domestication by man of this natural process makes it possible to treat wastewater and waste while recovering a source of renewable energy. The recovery of this biogas, which can be emitted during the natural degradation of organic matter, also contributes to reducing the greenhouse gas emissions to which methane contributes significantly. After a presentation of household waste, general principles of anaerobic digestion and the main operating parameters, this study has characterized some components of the DMA (household waste and assimilated) that are leftover food, peeled cassava pressing juices, Cassava peels and allowed to know their ability to be methanized.

Key words: cassava, household waste, anaerobic digestion, biogas, digester, methanation, *Manihot utilissima, methanation, dimensioning, characterization,*

INTRODUCTION

The programmed depletion of fossil energy resources and global warming have pushed the scientific world to research bioenergetics processes in recent years. Among these processes, the anaerobic digestion (AD) of waste has many interests:

- Anaerobic digestion can become a structuring element of the territory by the fact that AD projects can be multi-stakeholder, involving farmers, communities and industries [2];
- The biogas formed from the organic matter (OM) makes it possible to produce electricity and / or renewable heat;
- This method of waste recovery reduces the environmental impacts of waste and allows the reduction of greenhouse gases such as methane (CH_4) whose global warming potential (GWP) over a century is 23 times greater than that of carbon dioxide (CO_2) [3];
- Energy production from DMA (household waste and assimilated) can be a source of income for households or communities.

It is all of the above that this article proposes the recovery of household waste by anaerobic digestion. The work presents the materials and methods used as well as the experimental protocols adopted for gravimetric analyzes and leachate.
The results of experimental measurements concerning the gravimetric analyzes and the leachate of certain organic waste chosen on the basis of the availability of their deposit. These data are interpreted to highlight the natural ability of this waste to undergo anaerobic digestion.

MATERIALS AND METHODS

1.MATERIALS

1.1**Substrate characterized and methanized**

For this study, our attention focused on food leftovers consisting mainly of 30% “attieke” (cassava semolina), 30% rice, 30% pasta, 5% fish and 5% vegetables (Figure 1a) from the refectory of Yamoussoukro Scientific High School, a city in central Côte d'Ivoire, cassava peel (*Manihot utilissima*: Figure 1.b) and juice from the pressing of pulp peeled cassava (Figure 1.c) from a small cassava processing unit to its derivatives in the N'Zuessy district of the same city. These organic wastes were mainly selected because of their high availability in the city of Yamoussoukro.

(a) (b) (c)

Figure 1: Food leftovers (a), cassava peel (b), pressed juice of the peeled cassava paste (Le Bi amateur photo)

1.1 Laboratory equipment

Laboratory equipment consists of:

- - SARTORIUS brand analytical balance of sensitivity 1 mg;
- - Oven (0 to 200 ° C) brand MEMMERT;
- - KARTELL Brand Silica Gel Dehydrated Dryer;
- - Oven (30 ° C to 3000 ° C) brand NABERTHER;
- - HANNA HI 8424 brand pH meter;
- - HEIDOLPH brand magnetic stirrer;
- - NASCO brand mixer;

- - distillation assembly brand VAPODEST;
- - Laboratory glassware (50 ml test tube, 100 mL flask, 250 mL flask, 250 mL beaker, porcelain crucible).

1.2 Chemical Reagents Needed
The reagents mainly used are the suspension of ground crushed material, concentrated sulfuric acid, potassium sulphate, copper sulphate and some pumice grains.

2. METHODS

2.1 Pretreatment and physical and chemical characterization of substrates

2.1.1 Pretreatment of substrates before physicochemical characterization

Only cassava peels have been washed in order to extract unrecoverable inert such as mainly grains of sand. To make the washing task easier, it was done before peeling the cassava tubers. Peels and food scraps were ground in a blender before being subjected to leachate analysis.

2.1.2 Physical and chemical characterization

The analyzes for the physical and chemical characterization of the substrates were carried out in the laboratory of the industrial processes of synthesis of the environment and new energies, abbreviated LAPISEN, in National Polytechnic Institute Houphouët Boigny (INP-HB) of Yamoussoukro. Some analyzes were done three times.

a) Gravimetric analyzes

- Method for determination of dry matter content (% DM) and moisture content (% H)
The determination of the content of MS was carried out as quickly as possible after obtaining the substrates, according to the French standard NF ISO 11465 AFNOR X 90-029 (1994). About 10 g of fresh unmilled substrate was taken, placed in dry porcelain crucibles and placed in an oven at 105 ° C. for 24 hours. The DM content was obtained by weighing before and after drying in an oven (equation E.1).

$$\boldsymbol{MS}(\%) = \left(\frac{\boldsymbol{m_2 - m_0}}{\boldsymbol{m_1}}\right) \times \boldsymbol{100} \qquad (\mathbf{E.1})$$

The moisture content has been deduced from that of dry matter by the following relation:

$$\boldsymbol{H}(\%) = \left(\frac{\boldsymbol{m_0 + m_1 - m_2}}{\boldsymbol{m_1}}\right) \times \boldsymbol{100} \qquad (\mathbf{E.2})$$

Where m_0 (g) is the mass of the empty dry crucible, m_1 (g) the mass of the fresh substrate sample, m_2 (g) the mass of the crucible containing the sample after drying.

- ✓ Method for the determination of the volatile dry matter content (% MSV) and the mineral content (% MM).

- The volatile dry matter content

The determination of the volatile dry matter content (% MSV) was carried out by the method of loss on ignition (PAF) according to the French standard for the analysis of culture media (AFNOR NF U 44-160, (1985). Substrate samples previously dried in an oven at 105 ° C. for 24 hours are calcined in an oven at 600 ° C. for 4 hours. The loss of mass, relative to the amount of dry matter, corresponds to the MSV content (equation E.3).

$$\boldsymbol{MSV}(\%) = \left(\frac{\boldsymbol{m_2 - m_c}}{\boldsymbol{m_2 - m_0}}\right) \times \mathbf{100} \qquad (\mathrm{E.3})$$

Where m0 (g) is the mass of the empty dry crucible, m2 (g) the mass of the crucible containing the sample after drying in the oven, mc (g) is the mass of the crucible containing the calcined sample.

- ✓ The mineral content

After 4 hours in the incinerator, an inorganic residue is obtained: this is the mineral matter or ash [94]. Measurement mc (g) of the mass of the crucible containing the calcined sample made it possible to determine the mineral content of the waste (equation E.4).

$$\boldsymbol{MM}(\%) = \left(\frac{\boldsymbol{m_c - m_0}}{\boldsymbol{m_2 - m_0}}\right) \times \mathbf{100} \qquad (\boldsymbol{E.4})$$

- Method for determining the total organic carbon content (% TOC)

Once the content of volatile matter determined, that of organic carbon was calculated from equation E.5, equation valid in the French standard relating to the analysis of culture media (AFNOR NF U U 44-160, (1985)).

$$\boldsymbol{COT}(\%) = \frac{\boldsymbol{MSV}(\%)}{\mathbf{1,725}} \qquad (\mathbf{E.5})$$

b) *Leachate Analyzes*

- Method for pH measurement

The pH of the solid substrates (cassava peels and food residues) was measured after dissolving a crushed material of approximately 5 g in 50 ml of distilled water. The diluted mixture thus obtained was stirred for 10 minutes. The pH of this aqueous suspension was then measured at a temperature of 25 ° C.

As for the liquid substrate (cassava pressing juice), its pH was measured under the same conditions of temperature and pressure as previously after sampling a volume of 50 ml.

- Method for determination of nitrogen content (% N) and protein content (% Protein)

It was done using the Kjeldahl method. This method makes it possible to determine the total Kjeldahl nitrogen in the solid and liquid samples. This procedure consists of an analysis in 3 successive steps: (i) the mineralization of the organic nitrogen with 1N sulfuric acid boiled at 300 ° C, in the presence of pumice, producing ammonium; (ii) the ammonium is then distilled in the presence of an excess of caustic soda to give ammonia recovered by condensation; (iii)

the condensed ammonia is then titrated with 0.1N hydrochloric acid in the presence of colored indicator.
The total protein content is deduced from that of the total nitrogen (% N) by the use of the following relation:

Proteins (%) = 6.25 ×% N ***(E.6)***

The factor 6.25 is based on the assumption that proteins contain 16% nitrogen and that the total nitrogen content comes exclusively from proteins [88].

- Method for the determination of the density

A 100 mL test tube is filled with cassava juice and weighed on a scale. As for the cassava food remains and peels, the determination of the volume of a mass of about 10 g was carried out by the technique of displacement of water.
Densities are calculated from the following equation E.7:

$$\varphi = \frac{m}{v} \qquad (E.7)$$

Where φ ($kg.m^{-3}$) is the density, m (Kg) is the mass and V (m3) is the volume of the container

3. RESULT AND DISCUSSION

3.1 Density (ρ), moisture content (% H) and dry matter (% DM)

Parameters	**food leftovers**	**Manioc pressing juice peeled**	**Cassava peels**
Density (kg/m^3)	1033,1	1024,7	1042,4
H(%)	61,10 ± 1,23	92,81 ± 0,01	64,17 ± 0,38
MS(%)	38,90 ± 1,23	7,19 ± 0,01	35,83 ± 0,38

Table 1: Density (ρ), dry matter content (% DM) and moisture content (% H) of characterized organic waste

The moisture content (64.17%) and dry matter (35.83%) of cassava peels are different from the results of Braun [18] (80% moisture content and 20% DM content). This difference in content of about ± 15% can be explained by the existence of several varieties of cassava and by the quality of the peels. As for the pressing juice of peeled cassava, its moisture content (92.81%) and MS (7.19%) are comparable to those reported by OSVALDO KUCZMAN [20] which are 92.10% H and 7, 90 for% MS.
Table 1 shows that the density agrees well with the humidity since the more it is wet, the lower the density. The moisture content (% H) of the peeled cassava juice sample is estimated

to be 92.81%. This very high level compared to other substrate samples, is partly due to its viscous texture, even liquid. The moisture contents of the other two substrates are as high (% H greater than 60%). This finding makes this waste, hardly combustible waste. Methane fermentation remains one of the best techniques for their valorization. They also have a high dry matter content (% DM greater than 35%), which makes them available for dry methanation (15-40% DM) [75].

3.2 Content of volatile dry matter (% MSV) and mineral matter (% MM)

Parameters	food leftovers	Manioc pressing juice peeled	Cassava peels
MSV(%)	95,29 ± 4,17	82,07 ± 0,37	96,41 ± 0,06
MM (%)	4,71 ± 4,17	17,93 ± 4,17	3,59 ± 0,06

Table 2: Volatile dry matter content (% MSV) and mineral content (% MM) of organic waste characterized

The volatile dry matter content (% MSV) of cassava peels (96.41%) is about 20% higher than that reported by Braun [18]. As for their mineral content, it is relatively low, compared to that of samples characterized by Braun [18]. The reasons for these differences are identical to those mentioned above, namely the existence of several varieties of cassava and the quality of the peels. The MSV content of the cassava pressing juice is 82.07%. This value is quite close to that reported by Osvaldo Kuczman (86.83% of MSV) [20]. Slight differences are still noted. They can be related to the size of the mesh of tissues or bags of pressing.

From the analysis in Table 2, it appears that the organic waste characterized in this study consists essentially of MO (% MSV greater than 80%), which predisposes them to a good rate of biodegradation. It also reveals a poverty of this organic waste in mineral matter. The totality of the mineral matter contained in the organic waste, being conserved after the methanation, these results presage of a poverty of digestate in mineral salts. In spite of this, the valorization of the residual product of the anaerobic digestion as a compost will have to follow a much more complete determination of its composition. Also, a field study and the comparison of this compost with other fertilizer products can be useful.

3.3 Content of total organic carbon (% TOC), nitrogen (% N), protein (% Protein) and C / N ratio

Parameters	food leftovers	Manioc pressing juice peeled	Cassava peels
COT (%)	55,24 ± 2,41	47,57 ± 0,21	55,89 ± 0,04
N (%)	0,85	0,24	0,31

C/N	64,99	198,23	180,29
Protéines (%)	5,31	1,50	1,94

Table 3: Total organic carbon (% TOC), nitrogen (% N), protein (% Protein) and C / N ratio of organic waste characterized

The respective values of the protein and nitrogen contents of the cassava juice are 1.50% and 0.24%. These values are quite close to those reported by OSVALDO KUCZMAN (2.18% protein and 0.35% nitrogen) [20]. These results will have to be supplemented by those of the ions and heavy metals contained in the ashes (MM), the content of lipids, celluloses ... Indeed, the more detailed composition of the biomethanizable waste brings more information as to estimating their biogas potential. Moreover, although the components mainly nitrogen, phosphorus, potassium, calcium, magnesium, chlorine and sulfur, to which must be added some trace metal elements such as iron, copper, zinc, nickel, molybdenum, selenium, cobalt ..., are nutrients necessary for the development of anaerobic bacteria, they can be toxic at excessive concentrations [62].
From the analysis of the values in Table 3, it should be noted that these organic wastes are rich in organic carbon (% TOC greater than 47%) but very low in organic nitrogen (% N less than 1%). This nitrogen deficiency implies risks of inhibition of microbial growth [65]. These organic wastes have very high C / N ratios, indicating a generally high content of sugars [63] and therefore a relatively low methanogenic potential of the order of that of glucose. On the other hand, the high C / N ratio implies slow degradation [24], which results in a long residence time. It will therefore be necessary to carry out methanation of these substrates either mesophilic (25 ° C to 35 ° C) or thermophilic (49 ° C to 60 ° C) [77] to reduce their anaerobic digestion time. The C / N ratios are well above the optimum for bio-methanation, which is between 20 and 30 [54]. In order to lower this ratio and adapt it to the conditions required for the anaerobic digestion process, it is necessary to perform co-methanation with other waste such as cattle dung, which in addition to being rich in nitrogen (26% N) [90], already contains the various populations of microorganisms involved in the four stages of AD [47].

3.4 pH of substrates before methanation

Parameters	**food leftovers**	**manioc pressing juice peeled**	**Cassava peels**
pH	4,67 ± 0,02	4,14 ± 0,00	5,76 ± 0,02

Table 4: pH before methanation of the characterized organic waste

The pH of the cassava pressing juice peeled (pH = 4.14) before methanation is compatible with the range indicated by KPATA (pH between 3 and 4.20) [89]. The lack of pH value in the literature for cassava peels does not allow for comparison.

With regard to the values in Table 4, the starting pH of the organic waste studied is acidic (pH less than 7), which can accelerate the first two steps of the DA namely hydrolysis and acidogenesis whose pH range Optimum is 4 to 6 [53] and then allow a relatively fast passage to the acetogenesis and methanogenesis phases. However, the zone favorable to the realization of these two last phases in terms of pH being between 6.8 and 7.5 [53], an increased monitoring of this parameter must be carried out during the digestion, if necessary, the adjust to 7 to allow an optimal realization of the DA. pH adjustment to neutrality must be made as soon as biogas is started using human urine in consideration of its basic character [85].

4. DIMENSIONING OF THE DIGESTER

In consideration of its availability, it’s high relative to food residues, with respect to the liquid texture and almost zero methanogenic power [49] of peeled cassava juice, cassava peels are the main substrate for methanised. The cassava juice should be used as a water supply to lower the DM content inside the digester. As for food residues, in consideration of their good methanogenic power of the order of 500 mL / g MSV [39], they will be associated with cow dung to form a kind of microbial leaven that will have to be introduced into the digester from its first use and in the event of a decrease in biogas production. Based on these choices, the determination of the type of digester and its characteristics will be based on the physicochemical characteristics of the manioc peels.

4.1. Type of digester and its characteristics

The physicochemical analysis of manioc peels and the bibliographical synthesis, orient their methanation towards a type of digester with definite characteristics

The comparison of the performance of the Indian and Chinese model digesters [55] makes us choose an Indian-inspired digester " ARTI " as a physical model of bio-digester. It consists of two main parts: a digester and a gasometer floating in a water seal, provided respectively with pipes (supply, drain, overflow) and gas line. To this model we added a mechanical stirring system for the homogenization of the reaction medium as shown in the attached figure (Appendix H). This agitator also serves as a counterweight to the biogas pressure.

4.2. Dimensioning of the digester

An anaerobic digestion plant usually consists of a digester, purification equipment, equipment for use and connection accessories. As part of this work, the facility is intended to produce raw biogas used for cooking. It will therefore not include purification equipment. Under these conditions, the size of this domestic installation comes down to the sizing of its main element (the digester) and is based on the daily energy demand of a typical household of developing countries which is about 3 m3 biogas. -1 for a family of six [47]. The other three parameters of its design are the daily input flow Q, the hydraulic retention time TRH and the ratio x of the cassava peel-cassava juice mixture.

4.2.1. Sizing parameters

$$\boldsymbol{Daily\ input\ flow: Q(g/j) = m.\frac{\%H(digester)}{\%H(peel)}} \quad (E.8)$$

$$\boldsymbol{Mass\ of\ peelings\ to\ be\ mathanised:\ m\ (cubic\ meter\ biogas/day) = \frac{P}{B_1(biogas)}} \quad E.9)$$

$$\boldsymbol{biomass\ production/day\ :\ B_1(biogaz) = \frac{100.C.B_0(CH_4)}{50} = 2.C.B_0(CH_4)} \quad (E.10)$$

$$\boldsymbol{Content\ of\ M.O:\quad C(\%) = \frac{MSV}{MF} = \frac{MS}{MF}.\frac{MSV}{MS}} \quad (E.11)$$

$$\boldsymbol{(biogas\ production) = 2.\frac{MS}{MF}.\frac{MSV}{MS}.B_0(CH_4)} \quad (E.12)$$

$$\boldsymbol{Mas\ of\ peelings\ to\ be\ methanised: m\ (cubic\ meter\ biogas\ /\ day) = \frac{P}{2.\frac{MS}{MF}.\frac{MSV}{MS}.B_0(CH_4)}} \quad (E.13)$$

$$\boldsymbol{daily\ flow\ \ Q(kg/jour) = \frac{P}{2.\frac{MS}{MF}.\frac{MSV}{MS}.B_0(CH_4)}.\frac{\%H(digester)}{\%H(peels)}} \quad (E.14)$$

$$\boldsymbol{Ratio\ melange\ peel - cassava\ juice: x = \frac{Q-m}{m}} \quad (E.15)$$

$$\boldsymbol{useful\ Volume\ of the\ digester:\ V(cubic\ meter) = \frac{TRH.(1+x).P}{2.\varphi_S.\frac{MS}{MF}.\frac{MSV}{MS}.B_0(CH_4)}} \quad (E.16)$$

$$\boldsymbol{Volume\ of\ the\ digester:\ V_d(cubic\ meter) = 1,1V = 1,1.\frac{TRH.(1+x).P}{2\varphi_S.\frac{MS}{MF}.\frac{MSV}{MS}.B_0(CH_4)}} \quad (E.17)$$

$$Volume\ of\ the\ gasometer: V_g = \frac{1}{5}V_d = \frac{1}{5}\frac{1,1.TRH.(1+x).P}{2\varphi_S.\frac{MS}{MF}.\frac{MSV}{MS}.B_0(CH_4)} \quad (E.18)$$

$$Volume\ of\ biogas\ produced/day: \ G = V_s.V = \frac{V_s.TRH.(1+x).P}{2\varphi_S.\frac{MS}{MF}.\frac{MSV}{MS}.B_0(CH_4)} \quad (E.19$$

4.2.2. Digital applications

The different calculations were carried out using the following data (Table 5) either from the experiments carried out within the framework of this work, or from the bibliographic synthesis, or set for the reasons mentioned above.

Parameters	**measure Source**	**measure Source**
Average MS content of cassava peels	35,83%	Expérimentation(*)
Mean MSV content of cassava peel	96,41 %	Expérimentation(*)
Bio-methanogenic potential (B0) in CH4 peels	0,267 m^3.kg/MSV	[40]
Moisture content of cassava peel	64,17%	Expérimentation(*)
Moisture content inside the digester	90%	Fixed (**)
Density (φ_S) of fresh manioc peels	1042,5 kg/m^3	Expérimentation(*)
Volume production of biogas per m3 of digester	3 m^3 biogas/m^3digester.j	[83]
Daily biogas demand	3 m^3 de biogas/j	[47]

(*)value from experiments carried out as part of this work, (**) value from justified choices

Table 5: Data used for calculations

Parameters	Values
Mass cassava peels to methanised m (kg / d)	16.26
Daily input flow (kg / d)	25.24
Ratio x of peel / cassava juice mixture	0.40
Useful volume of the digester (m3)	1.55
Volume of the digester (m3)	1.70
Volume of the gasometer (m3)	0.34

Table 6: Calculation Results

The amount of peels thus calculated is underestimated compared to the production of 3 m3 biogas.day-1. Indeed, the entire MO is not converted to methane or biogas. Some is used by microorganisms for their maintenance and growth [42]. The amount of fresh peels must be increased to reach the daily target set, ie to estimate m at 18 kg.

Cassava juice with a non-zero MS content and considering the likely water loss of the peels when grinding, x must be increased by the unit. The mixture of fresh manioc peels and cassava juice will be 1: 1 (1 kg of fresh manioc peels is mixed and diluted in 1 kg of cassava juice) which leads to a daily withdrawal Q (corrected) 36 Kg / d.

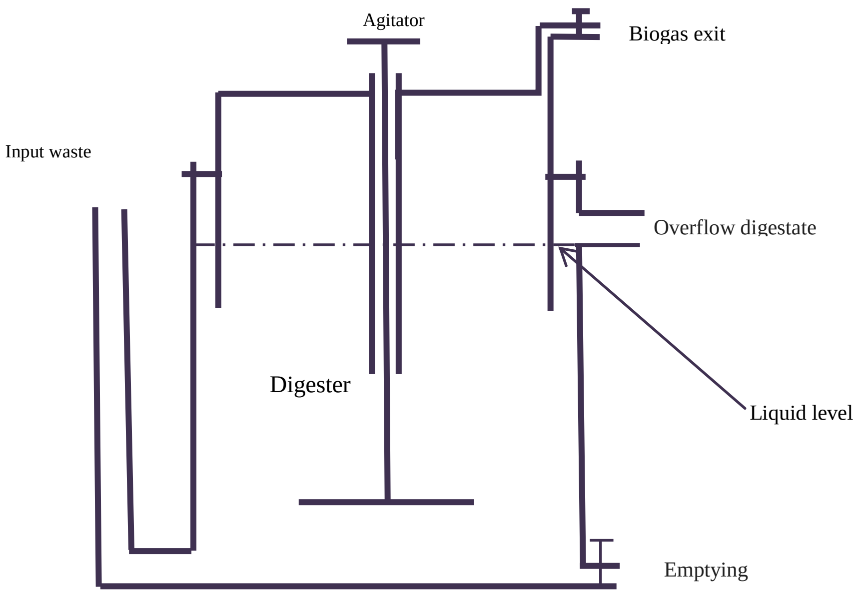
The volume of the gasometer (Vg) is also affected by possible accumulations of mosses. Vg must be increased. Vg (corrected) is then 0.4 m3. The volume G of biogas produced per day is therefore: G = 4.65 m^3, a surplus of 1.65 m^3 compared to domestic demand.

4.2.3 Geometry of the digester and the gasometer

The digester and its gasometer are both of cylindrical shape respectively respecting the diameter to height ratios equal to 4/5 and 2/1. The pipes at the inlet and at the outlet are also cylindrical. Table 7 shows the different measurements of the pilot digester.

Component of the digestion unit	Diameter (m)	Height (m)	Volume (m^3)
Digester	1,2	1,5	1,7
gasometer	1	0,5	0,39
Supply pipe	0,11	1,5	-
Drain hose	0,11	0,5	-

Table 7: Dimensions and volumetric capacities available for the solid, liquid and / or gaseous phases at the different compartments of the digester.



CONCLUSION

The characterization of some organic waste (leftover food, peeled manioc pressing juice, cassava peel) allowed us to know that they are more suitable for energy recovery by methanation than by incineration, and to size a digester for their methanation. . From the bibliographic synthesis it emerged that anaerobic digestion is an efficient and easily exploitable organic waste treatment method. This process makes it possible to produce biogas which is a renewable energy; reduce the use of fossil fuels; to contribute to the depollution of the organic charges; and to produce fertilizers that can be provided as an organic amendment to mineral-poor agricultural soils.

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