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Biogas Production from waste of carrots

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Abstract—This research focuses on the experimental study of the anaerobic digestion of waste of carrots). In particular, it studies the behavior of organic matters contained in the sludge under mesophilic condition, in order to clean up and stabilize them biologically, thereafter to valorize them in the form of a renewable energy, and fertilizer matters as well that could be exploited by farmers. The results obtained, through the recorded pH values and the collected biogas volume, clearly indicate a smooth digestion.
Keywords: Bioenergy, Environmental protection, Méthanisation, Organic Matters, biogas.

I. INTRODUCTION

Anaerobic digestion, also known as methanisation appears as a technology of choice because it is first of all a natural process [1]-[2] for the degradation of organic materials of all kinds through the action of microorganisms [3, 4]. This operation takes place in reactors called digesters under asphyxia conditions [5].

It is well admitted world widely that anaerobic digestion is one of the best effective technologies allowing for the treatment of the organic fraction contained in wastes and for transforming environmental pollutants into sources of wealth [6]-[7]. Thanks to this method it is possible to clean and stabilize the waste, to reduce their volumes to simultaneously produce high-energy fuels and fertilizers for agricultural activities [8]-[9].

The substrates that can be subject to anaerobic digestion are varied and cover all types of waste that have an organic fraction of either animal or vegetable origin. As such we can cite the urban sewage and sludge, food processing industry waste (candy, cheese ...), agricultural residues (manure, liquid manure), etc [10]-[11].

In our conditions, anaerobic digestion is oriented to principally study the transformation mechanisms of organic waste into biogas, a gas mixture consisting mainly of methane (CH_4) and carbon dioxide (CO_2) [12]-[13].

As a renewable source of energy, biogas could be valued in several ways. Finally, digestion residues (digestates) are of a particular agricultural interest to farmers because of their wealth in various fertilizers elements [14]-[16].

II. MATERIALS AND METHODS

A. Substrate used

In this study, the substrate used for the digestion consists mainly of potato peelings. It is considered rich in organic matter.
To optimize the kinetics of biogas production and reduce the residence time, the substrate is subjected to a drying and a mechanical pre-treatment (milling) [17]-[18] [19].

B. Description of the digester and the experimental device

The tests were conducted in batch digesters. These digesters glass vessels are laboratories models, to ensure culture medium anaerobic conditions. Digesters are provided with two openings, one for the collection of liquid samples using a syringe, and the other to ensure the exhaust gas for measuring the

volume of biogas produced. The effective volume of the reactors is 1 l. A little volume of gas is left above the liquid level to protect the gas outlet, and maintain anaerobiosis.
The digesters used are fed with diluted slurry to obtain a dry matter volume of about:

- 200 ml of substrate for the first digester ;
- 400 ml of substrate for the first digester.

The digesters are hermetically sealed and kept in mesophilic conditions (35 ° C ± 2 ° C) [20]-[21] in a water bath heated and thermostatically controlled, the simplified diagram of the device used is shown in Figure 1. The reactors are agitated manually through shaking once or twice per day to increase the production yield [22].

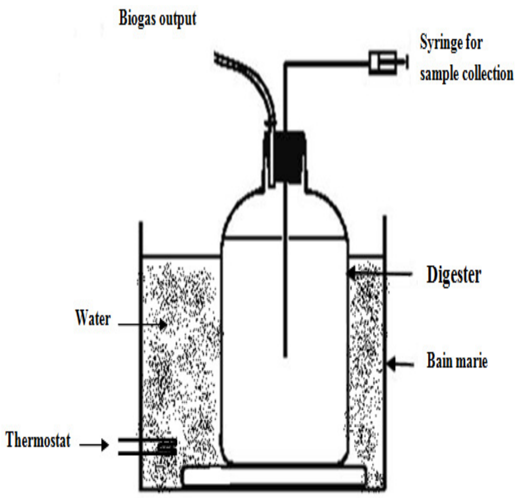

Figure 1: *Simplified diagram of the fermentation device used.*

C. characterization of the substrate

C.1 Dry matter determination

To determine the dry matter, a mass of any sample taken, is poured into a cleaned and dried capsule, then the assembly is placed in a stove at 105 °C for 24 hours until obtaining a constant weight. The capsule is weighed after cooling in a desiccator. The dry matter (DM) is calculated according to the following expression [19].

$$\% \, DM = \frac{M_1 - [(M + M_1) - (M + M_2)]}{M_1} \times 100$$

M: mass of the capsule ;
M_1: mass of the sample before drying ;
M_2: mass of the sample after drying.

C.2 Determination of the content of organic matter (OM)

When the sample, previously dried, is subjected to an incineration at 550 °C, the organic matter is consumed and the residual matter is the mineral.

To determine the organic matter (OM), any sample weight after drying, is introduced into a cleaned and dried capsule having a mass,the assembly is placed in a muffle furnace calcination at 550 °C for 12-18 hours. After cooling, the capsule containing the inorganic matter is weighed again. The mass of organic matter is obtained by difference between the dry matter weight and the weight of inorganic material.

$$\%\,OM = \frac{(M + M_1) - (M + M_2)}{M_1} \times 100$$

M : mass of the capsule;
M_1 : mass of the sample after drying ;
M_2 : mass of the sample after calcination.

D. The followed parameters

During digestion, we conducted follow-up parameters as of below:

D.1 The pH

The pH is an easily measurable factor and the most important for the anaerobic digestion process, it gives an idea about the acidity or alkalinity of the environment, in addition, microorganisms cannot grow operate within a specific range of pH. pH values were measured using a pH meter BASIC 20.

D.2 Volume of biogas

Gas production is the main purpose of anaerobic digestion. Biogas volume is measured 2-3 times per week. Biogas volume is measured by means of a hydraulic system(Charnay) [23] and (Moletta) [24], or the product gas outlet of the digester, passes into a graduated cylinder immersed in a liquid, which will move the liquid level in the test tube and indicates thus the volume of gas produced. In these conditions it is preferable to use potassium sulfate acid solution to avoid the solubilization of carbon dioxide.

D.3 oxygen chemical demand (COD)

The measurement of the COD makes it possible to consider the load organic polluting of an effluent. Its measurement before and after a physical, chemical or biological processing also makes it possible to control the good performance of purification or to evaluate the activity of anaerobic micro-organisms in a digester. Anaerobic digestion is advantageous for the effluents strongly charged with organic matter, with concentrations higher than 50-100 mg COD/l.

The follow-up of the degradation of the COD is necessary to show the degree of the depollution obtained by the adopted method. Oxygen chemical demand COD is retained universally like criterion of evaluation and appears in all the studies concerning the rejections.

It is useful to note that the chemical oxygen demand is accepted worldwide as an important criterion for assessing the degree of pollution release and appears in all the studies [25].

The chemical oxygen demand (COD), measured according to the AFNOR method (T90 -101). The dosage is carried out by the use of the method potassium bichromate. The organic matters contained in the sample are oxidized, in acid medium (H_2SO_4), in the presence of silver sulphate (Ag_2SO_4) like catalyst, and of mercury sulphate ($HgSO_4$) to avoid the interference of chlorides, by potassium bichromate ($K_2Cr_2O_7$), introduced in excess, under the heating with 150°C, during 2 hours in a thermo reactor. After cooling, the COD is determined by back titration: the potassium bichromate excess is proportioned using an iron ammonium sulphate solution [salt of Mohr Fe (NH_4) 2 (SO_4) $6H_2O$] 0.25 NR, after the determination of their titter, in the presence of some drops of ferroïne like indicator. The oxidation of the matter produces ions Cr3+, giving a purplish red coloring.
The COD is expressed by the following relation:

$$COD = \frac{(V_T - V_E) \times 8000 \times T \times d}{V_e} \quad (g\ O_2/l)$$

III. RESULTS AND DISCUSSIONS

A. Substrate characteristics

A.1 Dry matter

Table 1 : les résultats de matière sèche.

Sample	DM weight (g)	DM (%)	Average (%)
1	1.055	24.12	35.209
2	2.311	39.62	
3	2.254	41.87	

A.2. Organic matter (OM)

Table 2 : les résultats de matière organique.

Sample	OM weight (g)	OM (%)	Average (%)
1	0.039	96.30	97.44
2	0.0473	97.95	
3	0.0431	98.08	

B. The followed parameters

B.1 pH evolution

The pH is an important parameter because it informs about the demarcation of the different phases of digestion and conditions the metabolism of the microbial species responsible for the other phases of digestion, namely the acetogenic and the methanogenic phases [26]. In their sets, anaerobic processes are strongly influenced by pH. Indeed, anaerobic digestion takes place optimally at around neutral pH (pH = 7) [27]. pH is an interesting indicator for the stabilization and the smooth running of anaerobic digestion. In addition, the monitoring of changes in pH allows to accurately locate the various stages of degradation of organic matter.

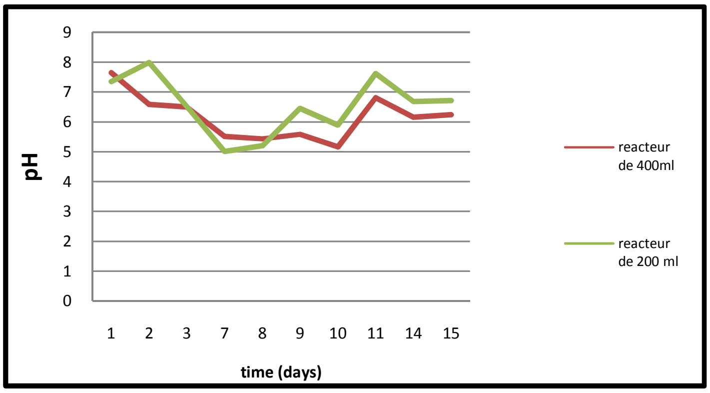

Figure 2: *Changes in pH during anaerobic for both digesters.*

The pH evolution curves for the both digesters can be divided into three main parts:

- **The first part**

In this first part, there is a rapid drop in pH to acidic values, i.e. acidification of the environment. This phenomenon takes place starting from 1st up to the 8th day: (7.35 to 5.20) for the first digester ; (7.65 to 5.43) for the second digester.

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This drop can be explained by the decomposition of organic matter and the production of volatile fatty acids (VFA) and their accumulation in the environment.

- **The second part**

In the second part, the pH values increase gradually; it is the alkalizing process which starts to settle into the culture milieu. This is observed from the 8th day and continues until the 11th : for the first digester (5.20 to 7,63); for the second digester (5.43 to 7).
The phenomenon can be accounted for through the beginning of the consumption of volatile fatty acids (VFA) by other bacteria on the one hand, and by increasing the alkalinity of the other culture milieu on the other hand.

- **The third part**

In this part, we can see that there is stabilization of pH values starting from the 11th day until the end of the process: (between 7.63 and 6.72) for the first digester; (between 7 and 6.24) for the second digester
This stabilization can be explained by the stability of the process in general, that is to say, that there is a simultaneous production of AGV on the one hand, and their consumption on the other.

B.2 Daily production of biogas

The production of biogas is the surest criterion for a good running of anaerobic digestion. With a 15 days residence time, the amount of biogas produced is estimated to 500 ml for the first digester, and 800 ml for the second digester. Biogas accumulation kinetics is shown in Figure 3.

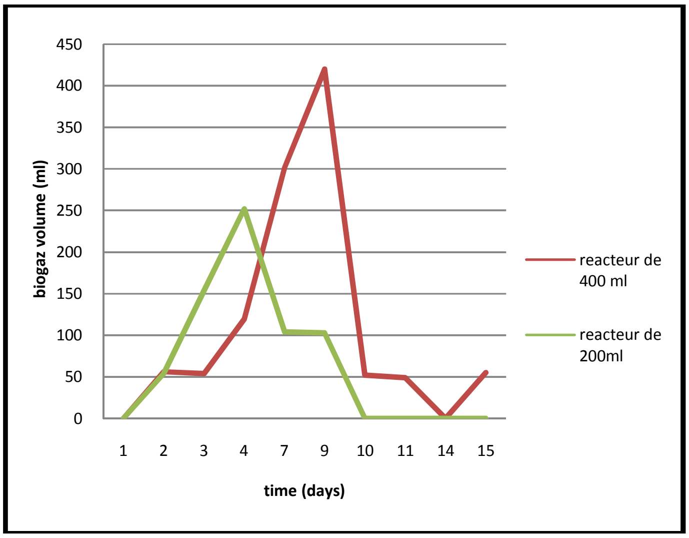

***Figure 3 :** Daily production kinetics of biogas for both digesters.*

B.3 The variation of the chemical oxygen demand (COD)

The chemical oxygen demand (COD) (figure 4) expresses the substrate pollution levels, which encompasses the pollution load of organic matter as well as that of mineral matter. We clearly observe that the rate of reduction of COD is more complete and important when the milieu is seeded.

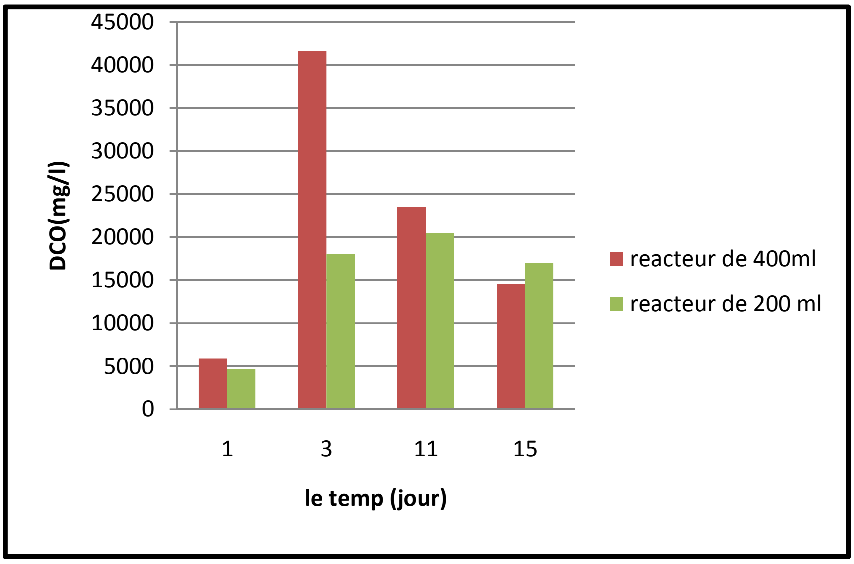

Figure 4: The variation in COD for both digesters.

IV. CONCLUSION

In the context of the treatment of waste including sludge from wastewater treatment plants, anaerobic digestion seems like the best solution for treating such a waste on the one hand, and to value it on the other. The first objective of this study is to give an energy value using as substrate waste of carrots. To achieve this aim, a series of experiments is undertaken.

The results of the analysis of the substrate showed that it contains a significant organic fraction (over 90 %) and is therefore a suitable substrate for biogas.

The results obtained in the complete seeding show a clear improvement of the production of biogas The tests of the production of biogas from the anaerobic digestion of the waste of carrots showed the feasibility of the biotechnological process to value such a substrate. Yet, the results attained need more details and improvement. Indeed, for several times a flammable biogas with good removal efficiency was obtained.

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