International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 4 No. 2 Oct. 2013, pp. 343-352

http://www.issr-journals.org/ijias/

Energy, environmental and agronomic valorizations of the rural biomethanisation of the bovine biomass

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ABSTRACT: This work consists in studying various possible valorizations of the rural biomethanisation applied to the bovine dejections. The follow-up of the adopted digester related to: the estimate of the qualitative productivity (% CH_4, % CO_2, % H_2S and % H_2; LCV and HCV) before and after conditioning. For the analysis of the gas composition and the estimation of the calorific values, we had recourse to the technique of chromatography in gaseous phase (CGP); analysis of certain environmental parameters (SM and BDO_5), in order to establish the corresponding assessments of depollution; possibilities of agronomic valorization except ground of the residues of the biométhanisation (the methacompost as full or partial substitute for peat and / or compost and juice process plants gardeners as fertilizer).
The significant preliminary results rising from this work are the following: the conditioning of rural biogas product made it possible to improve the energy performances; the process of rural biomethanisation allowed an insufficient reduction of the polluting load as for SM as for BDO_5; the use of the methacompost as a partial substrate of culture gives encouraging results for the growth in height of the pepper seedlings; the juice of process diluted at a rate of 75% showed an interesting power fertilizing.
Ultimately, the current trend towards the agrobiologic practices encourages the agronomic use of these digestats, because of the importante depollution generated.

KEYWORDS: Rural digester, bovine dejections, assessment of depollution, quality of biogas, methacompost, juice of process.

1 INTRODUCTION

Face to the very fluctuating economic situation of the energy prices and to appreciably reduce local pollution and the greenhouse effect. References [1, 2] shows that the prospection and the development of the new energy sources were undertaken for a long time [3, 4].

Many measures taken by the public authorities to protect the environment and the natural resources. Among the adopted solutions, the recourse to the use of renewable energies, which arouse an interest growing in particular those resulting from the biomass [5,6] and particularly, biogas coming from the biomethanisation of the agricultural effluents [7,8, 9].

The valorization of organic waste and mainly the animal manure for the production of biogas could be regarded as an ecological and economic solutions to these problems. The biomethanisation constitutes, today, a source of diversification for agriculture.

The biomethanisation having thus like principal vocation the production of biogas, showed lately other interests [1, 10]. It constitutes, today, one of sources of diversification for agriculture [2].

In the absence of oxygen (O_2), bacteria degrade partially the organic matter (OM) [11, 12], which leads to the formation on the one hand, of a biogas mainly made up of the methane and developed in energy [13, 14, 15], and on the other hand, residues called digestates [16, 17, 18, 19]. These secondary by-products can be used in a solid state (Methacompost) like

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integral part of the substrates of culture or be spread [20, 1, 11, 21, 22, 2], as they can be used directly in the liquid state (Juice of Process) like fertilizer of the arable lands, even, except ground [4, 23].

The present study proposes to look further into the analysis of certain determining parameters in the appraisal of energy performance of the rural biogas produced on the qualitative level (gas composition and calorific value), environmental level (polluting load in SM and BDO_5 of the dejections before and after fermentation) and agronomic except ground (use of the methacompost like substrate of growth and the juice of process like fertilizer in market-gardening seedbed) of the bovine biomass digested in a rural digester of farm.

2 MATERIALS AND METHODS

2.1 EXPERIMENTAL SITE

It is the experimentation of the biomethanisation of the bovine dungs on the level of the digester installed in the farm attached to the Agricultural Professional Training Center in Bovine Breeding (A.P.T.C.B.B.) in Sidi Thabet, Tunisia. This rural digester of farm was built around the years 2000. It is a buried pilot digester (Figure 1) with manual uninterrupted feed and having a capacity about 6 m³.

Fig. 1. The rural pilot digester

2.2 EXPERIMENTAL MATERIAL

It is the biomethanisation of the fresh dungs produced by the cows available (like substrate) and of the black bovine dungs extracted from the adopted septic tank (like inoculum). The characteristics of these two dungs are illustrated in table 1 hereafter.

Table 1. Physical and chemical characteristics of the bovine inputs put at the test

Nature of the bovine dungs	% DM	pH
Fresh dungs (substrate)	31.5	6.5
Black bovine dungs (inoculum)	9.4	7.2

2.3 TESTS OF EVALUATION IMPLEMENTED

The qualitative analyzes of produced biogas were carried out in the test laboratory of the Tunisian Company of Industries of Refining (T.C.I.R.), located in Bizerte, whereas the environmental analyzes were carried out at the laboratory "Biogas" of the APTCBB.

2.3.1 EVALUATION OF THE QUALITATIVE ENERGY PERFORMANCE OF THE DIGESTER

The analysis of the qualitative productivity of biogas understands a determination of the composition of biogas produces and its calorific value (CV) with its lower and higher limits (LCV and HCV).

For the analysis of the gas composition, we had recourse to the technique of chromatography in gaseous phase (CGP). This technique is suitable for the compounds gas or likely to be vaporized by heating without decomposition. The components determined by this method (Figure 2) are the following: % CH_4, % CO_2, % H_2S and % H_2.

Fig. 2. The chromatography for the estimation of the composition of gas

Moreover, we were also interested in the natural energy (Figure 3), by considering the values lower and higher of the calorific value (LCV and HCV), expressed in kWh/m³, kcal/m³ or kcal/kg and which are linked by expression 1 following:

$$\mathrm{HCV} = \mathrm{LCV} + \text{heat of vaporization} \qquad (1)$$

Fig. 3. The chromatography for the estimation of the calorific values

2.3.2 EVALUATION OF THE ENVIRONMENTAL PERFORMANCE OF THE DIGESTER

The environmental parameters in which we were interested are relating to the polluting load (SM and BDO_5) of the digested matter coming from various mixtures.

For SM, they correspond to the whole of mineral and/or organic particles present in a natural or polluted water [24]. Their determination makes it possible to consider the bacterial biomass in the digester [25]. The analysis is based on the principle of quantifying all the matters being able to be decantable after elimination of the major part of water by filtration and vaporation in the drying oven with 105 °C.

Concerning the BDO_5, this parameter constitutes a good indicator of the biodegradable OM content in water during processes of purification. The principle of the measurement of the BDO_5 rests on the quantification of O_2 consumed after a sample incubation during five days.

2.3.3 EVALUATION OF THE AGRONOMIC PERFORMANCE OF THE SOLID AND LIQUID DIGESTATES

For the case of the bovine methacompost (BMC), the evaluation in a direct way, by appreciating its maturity and its physical properties (total porosities, of ventilation and of retention) and indirect evaluation, by the follow-up of morphological parameterized of the seedlings (germination, growth in height,…) is necessary, in order to develop a suitable substrate allowing an optimum conditions for growth of the seedlings.

For the bovine juice of process (BJP), its evaluation is limited to an indirect characterization carried out, following a follow-up of the vegetative behavior (growth in height) of the pepper seedlings with respect to integral and partial watering with this product.

Concerning the evaluation of the maturity of the BMC, it is a question of carrying out a biotest of germination on lettuce seeds [26]. The aim of the biotest is to evaluate the maturity of the BMC [27], to envisage the possible existence of some phytotoxic elements [28, 29], while putting in consideration the photosensitivity of the lettuce seeds used like Plant-test[30].

The followed method consists in putting, under favorable conditions of germination, the seeds of lettuce [26]. For that, we used small pots out of transparent plastic, impermeable and hermetically closed. The BMC underwent a light humidification. We put in each pot 20 seeds of lettuce and one took as witness sand with three repetitions for the BMC. Let us announce that maturity can be evaluated, according to the percentage of germination, even, according to germinative energy. The determination of the rate and the germinative energy of the lettuce seedlings was carried out starting from regular countings of the germinated seedlings.

The determination of the porosity of the studied substrates of growth, it is based on the control and the comprehension of the microscopic structures. On a microscopic scale, the substrate is in the form of a microsystem with three phases; a solid phase composed by organic particles containing water, a liquid phase composed by absorbed water and a gas phase composed by the vacuum called lacunar space containing of gases and steam [31].

It is thus comprehensible that the porosity of the substrates is defined as being the sum of the gas phase and the liquid phase [31].The total porosity (Pt) is determined by the relationship between the volume poured with the saturation of the substrate and total volume.

The porosity of ventilation (Pv) is determined by the relationship between dried volume through the holes of drainage under the effect of the forces of gravity and total volume. The porosity of retention (Pr) is determined by difference between total porosity and porosity in ventilation. The total porosity of the substrates is generally higher than that of the ground (soil), which is about 40 to 50% of total volume [32].

The Tunisian conditions require the following proportions of porosity: Pt ≥ 50%, Pa ≥ 20% and Pr ≥ 30%. These rules to be applied were inspired by the Canadian standards [33], by supporting the retention on ventilation, because of the dry climate of Tunisia.

The evaluation of porosities was carried out, using a standard test of porosity, on pure substrates: peat and compost like substrates of reference and BMC. It should be noted that each test of porosity was carried out with three repetitions.

About the evaluation of the agronomic value of the BMC and its operating requirement like substrate of culture in a pure state or in mixture, it appeared using a bearing test on the sowing of seeds of pepper. The BMC used during this test was taken after a residence time of 15 days in the rural digester, then dried for a period of four days.

Three types of substrates were tested which are a pure peat (pilot), a pure BMC and a mixture made up of 60% peat and 40% BMC. The follow-up related to the behavior of the pepper seedlings installed in alveolate plates, from growth point of view in height, while taking the heights cumulated with regular intervals (four days).

Concerning the evaluation of the fertilizing capacity of the BJP, it is appreciated by using it to sprinkle pepper seedlings already prepared in advance (sown in alveolate plates on the same support of reference which is the compost), while selecting 24 seedlings having homogeneous heights which were useful like support of the experimentation. Then, we began the watering of the seedlings selected with the solutions prepared, at a rate of a watering every 48 hours during 20 days, while taking the levellings cumulated with regular intervals (some of four days). The solutions used are: water (pilot), juice of concentrated process, then respectively diluted, at a rate of 25% or of 75%.

3 RESULTS AND DISCUSSION

3.1 QUALITATIVE CHARACTERIZATION OF PRODUCED BIOGAS

3.1.1 GAS COMPOSITION

The biogas produced by the rural digester underwent a conditioning (filtration and reduction of moisture). In this respect, the follow-up was carried out before and after conditioning to appreciate its importance qualitatively. The evaluation of the performance of the conditioning implemented is interpreted starting from the results of analyzes of the composition of the biogas produced reported in table 2.

Table 2. Results of the analyzes of the gas composition

	% CH_4	**% CO_2**
Before treatment	58.1	40.9
After treatment	66.1	32.7

According to the results obtained of the composition of the biogas produced, the percentage of methane (CH_4) before conditioning is close to the reality of the treated bovine biomass (58%). This percentage increased by 8% after conditioning thus recording an output of purification of 13.8%, which shows the importance of the treatment of biogas, since it ensures more reduction in polluting elements (CO_2…) while increasing the concentration in CH_4.

3.1.2 CALORIFIC VALUE

Concerning the values obtained for the calorific value of produced biogas, they give a full satisfaction on the energy performances of the rural biomethanisation (Table 3). They are understood in the whole in the fork given by [34]. According to this author, the calorific value of biogas is proportional to its content of CH_4 and it varies between 5000 and 8500 kcal/m^3.

This post-processing makes it possible to have an output of purification which is about 4.8%. This output is weak because especially of the ineffective process of conditioning implemented. Ultimately, it is advisable to more improve the output of purification of biogas to reach the theoretical maximum equal to 8500 kcal/Nm^3 [34].

Table 3. Results of the calorific values

	LCV (kcal /Nm^3)	**HCV (kcal /Nm^3)**
Before treatment	4973	5532
After treatment	5210	5932

3.2 ESTABLISHMENT OF THE ASSESSMENTS OF DEPOLLUTION

The analyzes as of the SM and of the BDO_5 were carried out on the two mixtures initially and later introduced. The results are given in table 4.

Table 4. Follow-up of principal environmental parameters

Parameters	**Mixture initially introduced**	**Mixture introduced later**
SM before fermentation (mg/l)	13.9	20.5
SM after fermentation (mg/l)	12.3	12.2
Assessment of depollution of SM (%)	11.5	40.4
BDO_5 :beginning of fermentation (mg O_2/l)	406.7	573.5
BDO_5 : end of fermentation (mg O_2/l)	323.7	354.2
Assessment of depollution of BDO_5 (%)	20.4	38.1

The assessment of depollution as of the SM as that of the BDO_5 increases according to the concentration of DM introduced into the digester (from the first to the second mixture). The assessments of depollution obtained are regarded as non satisfactory as well while being based on SM as on the BDO_5 and deserve to be improved more especially for the case of the mixture initially introduced (substrate without inoculum).

3.3 Results of the agronomic evaluation of the digestates

3.3.1 Appreciation of the maturity of the methacompost

The experimental results of germination of the bio-test on the BMC are mentioned in table 5.

The values obtained of the biogermination of the lettuce seeds on the BMC tested give a full satisfaction, since the rate of germination is even higher than that obtained on sand, which proves its good maturity. So the BMC produces by the rural digester, considered as wall, could thus be used like substrate as culture in seedbed except ground (breeding-ground).

Table 5. Results of the bio-test of germination

Substrate	Rate of germination (%)
Sand (proof)	82
Methacompost	95

3.3.2 Appreciation of the porosity of the substrates of growth tested

Figure 4 gives an idea about the physical characteristics, in terms of porosity of the pure substrates employed during the standard test implemented.

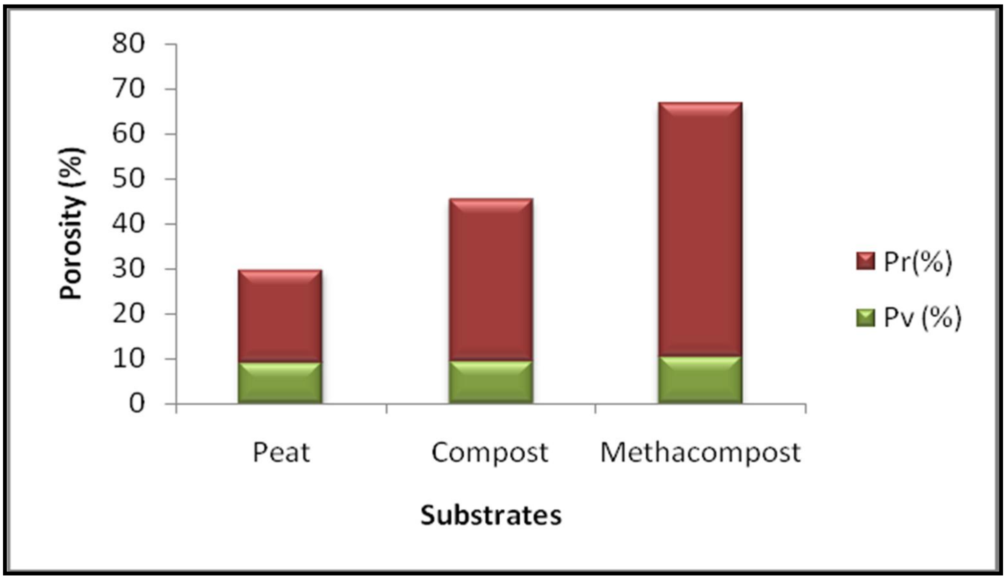

Fig. 4. Results raised of porosity of various pure substrates tested

To guarantee a good production of the seedlings, we must make sure especially of the physical characters of the substrate of growth used which must be satisfied, because they play a big role in the water supply of the plant and the operation of the roots: ventilation and temperature. The physical properties relate primarily to the porosity of the substrate and the evaluation of the water contents and of air available for the roots [31].

Concerning the results obtained, we can note that the witnesses are far from being acceptable from point of view total, ventilation and retention porosities. Only the compost shows an acceptable porosity of retention. Such results are in contradiction with the literature, which regards the peat as the ideal substrate for the breeding of the seedlings, especially from point of view Pv. Such a situation could be due particularly to the handling errors and/or to the drying during the carrying out of the standard test of porosity.

Concerning the BMC, it meets the standards of total and of retention porosities, however, its Pv is unacceptable. In front of such situation, this substrate can be considered as retaining substrate and could be partially built-in with a substrate aerator (compost). The optimal ratio of mixture remains to be determined.

Water can act directly by its reactions of degradation and its reactions of hydrolysis. These last relatively reduce granulometric dimensions of the BMC. The retention capacity can increase and the porosity of ventilation can decrease when the granulometric components of the BMC are fine. The BMC resulting from the biomethanisation of the bovine dungs can be only a partial substitute of the peat and/or the compost.

3.3.3 Operating requirement agronomic of the methacompost like substrate of culture

The results of the follow-up of the growth in height of the pepper seedlings cultivated on BMC in a pure state or mixed with the peat are configured on figure 5.

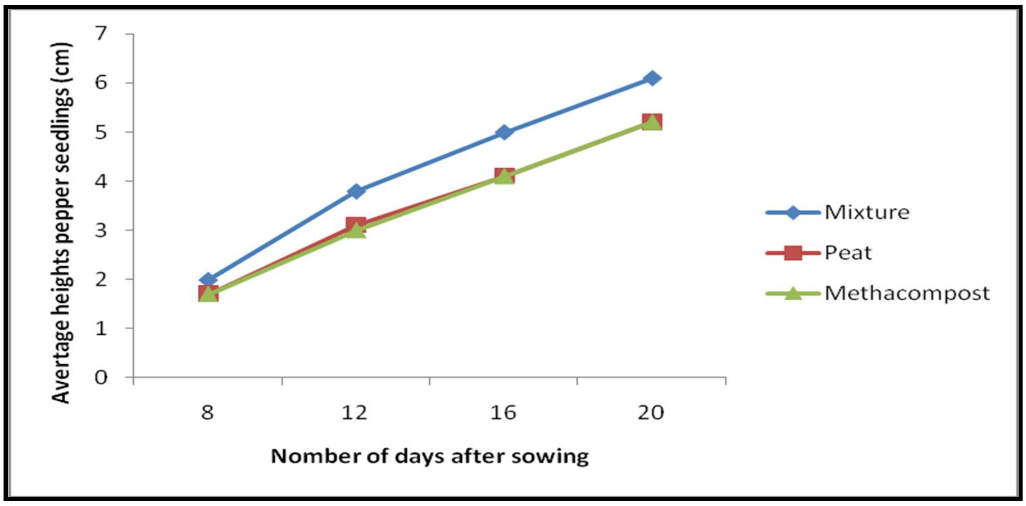

Fig. 5. Growth in height of the pepper seedlings installed on various substrates

By comparison between the various substrates of culture (pure or in mixture), the growth in height of the seedlings of pepper is almost identical for the seedlings installed on peat and BMC at the pure state. But, the seedlings installed on BMC presented hails stems, sensitive and some were burned and end up fading. The peat incorporated with BMC at a rate of 60% gives a faster growth and higher heights of seedlings without presenting any vegetative anomalies. These preliminary results are extremely interesting (being given the possibility of incorporation of the BMC at a rate of 40% with the peat) and deserve other investigations before being applied.

3.3.4 Operating requirement agronomic of the juice of process like fertilizer

The results of the follow-up of the growth in height of the pepper seedlings sprinkled with the BJP, in a concentrated state or diluted with water in various proportions are reported on figure 6.

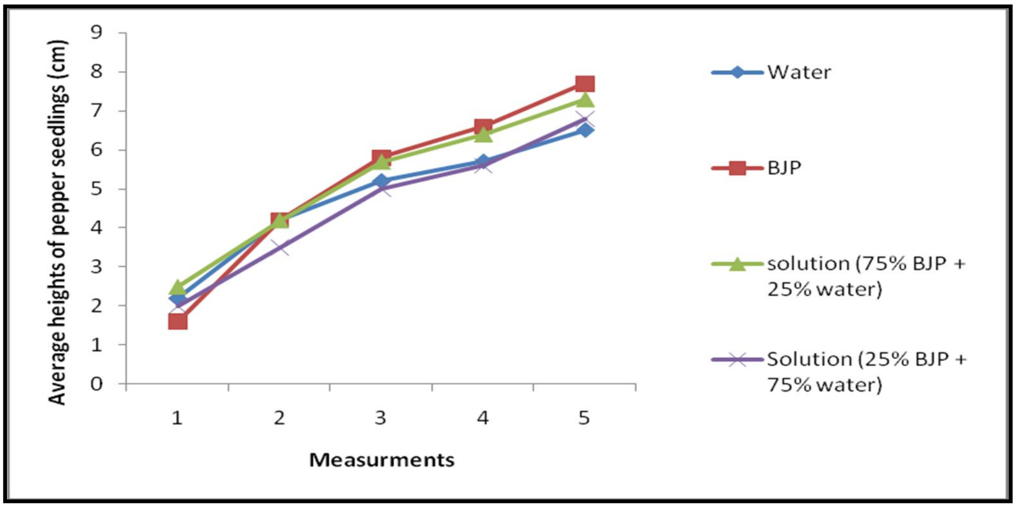

Fig. 6. Test of growth of the pepper seedlings sprinkled with various fertigations

The juice of process used in a concentrated state allowed a considerable growth in height reaching 8cm in 20 days, but it is necessary to evoke that several seedlings finished by fading suddenly. The same observations were raised for the solution made up of 75% BJP and 25% Water, as well from growth point of view of the seedlings as sudden fading. On the other hand, a solution made up of 25% BJP and 75% Water, allows a good growth without presence of anomalies of fading. Such results deserve to be confirmed by testing in parallel the report of dilution 1/2, to study the possibility of fertigation of the seedlings with this last report.

4 CONCLUSION

The animal manure is particularly interesting to use, when they are produced in significant amounts and regular and especially when they are treated biologically by biomethanisation before use.

In the light of the results obtained at the time of this study referring to energy, environmental and agronomic valorization of the bovine biomass treated in a rural digester, we could learn the verifications hereafter.

- The qualitative characterization of rural biogas shows an unquestionable interest of post-processing by conditioning and an acceptable quality on the plans composition and calorific value. It makes it possible, indeed, to more improve its potentialities energy (% CH_4 and PC).

- The follow-ups as of SM and of the BDO_5 showed that the biomethanisation allows a reduction of the polluting load which takes more importance with the increase of the concentration in DM of the matter to be fermented, proving thus that the biomethanisation is a very beneficial process in terms of energy valorization and recycling of OM for the safeguarding of the environment. This reduction is regarded as reduced and requires an improvement, considering the assessments of depollution obtained are weak with relatively acceptable.

- The bovine methacompost tested cannot be regarded as a good substrate of growth because of its insufficient porosity of ventilation, which justifies its mixture, according to adequate proportions, with the peat which has a porosity of ventilation normally more raised, for a correction of the physical balance of the substrates of growth.

- The tests carried out showed that the use of the peat in mixture with methacompost at a rate of 40% like substrate of culture, proves very encouraging and powerful with respect to the growth in height of the seedlings of pepper. The recourse to the bovine methacompost like partial substitute of the peat or the compost could constitute an interesting alternative to limit the imports, and consequently, the hemorrhage of the currencies.

- The juices of process showed an interesting fertilizing powers, in particular, that diluted to water at the rate of 75%. However, the results obtained are only preliminary and they deserve to be considered with prudence, because of certain vegetative anomalies raised in the case of the concentrated juices (from 75 to 100%).

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