International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 11 Issue 11, November 2024

ISSN: 2394-4404

# Experimental Study And Modeling Of Jatropha Curcas Cake In Biogas

**Novy Flavie**

**TOMBOZARA Marcellio**

**Dr NORBERT Tovondrainy, Ecole**

**Pr RAMINOSOA Chrysostôme**

Ecole Doctoral Thematique et son Environnemental

***Abstract:** Jatropha is a genus of dicotyledonous flowering plants of the Euphorbiaceae family. It is a tree with toxic seeds and leaves, resistant to the most extreme conditions. The valorization of jatropha cake as a substrate for the transformation of cake into biogas is a promising strategy in the context of the search for renewable energy sources. In this study, we carried out experiments on the anaerobic fermentation of jatropha cake to valorize its potential in biogas produced. The experimental results showed that with a digestion temperature of 35 ° C and a C / N ratio of 16.5, jatropha cake could be efficiently converted into biogas, with a good profit. The mathematical model developed made it possible to accurately predict the biogas production according to the digestion parameters. Our results suggest that jatropha meal could be a viable source as a substrate, and generated competitive energy yields compared to other organic substrates. Further studies are needed to optimize digestion conditions and enhance yield on a large scale.*

***Keywords:** Jatropha meal, Biogas, Anaerobic digestion, Modeling, Renewable energy.*



## I. INTRODUCTION

The search for renewable energy sources has become a global priority due to the increasing concerns about greenhouse gas emissions and dependence on fossil fuels [Shivani]. In this context, the valorization of agricultural and agro-industrial by-products for biogas production is of considerable interest. Jatropha cake, a residue from jatropha oil production, is one such by-product that has attracted attention as a potential substrate for anaerobic digestion. In this study, we aimed to evaluate the biogas production potential of jatropha cake and develop a mathematical model to predict the biogas production as a function of digestion parameters. This paper is organized as follows: methods and materials, results, and discussions.

## II. MATERIALS AND METHODS

Anaerobic digestion experiments were carried out using a batch biodigester. Jatropha cake was mixed with water in specific mixing ratios, and the biodigester was incubated at different temperatures (25°C, 35°C, and 45°C) for defined periods. Biogas production was measured regularly during the incubation period. Characteristic analyses of substrates and fermentation parameters were developed to find the biogas production as a function of initial substrate concentrations and digestion conditions.

### A. SUBSTRATE CHARACTERIZATION

It is necessary to know the following parameters in order to optimize anaerobic digestion conditions and improve biogas production in an efficient and sustainable manner.

#### *a. MOISTURE CONTENT TMH*

The following steps were followed:

-Dry a crushed and sieved sample at a temperature of 105°C 2°C.

-Keep this temperature for 24 hours.

TMH is calculated as follows:

$$T_{MH}=\frac{(m_1-m_2)}{(m_1-m_0)}\times 100 \qquad (1)$$

TMH: moisture content

$m_0$:mass of the empty cup in g

$m_1$: mass of the cup with the sample before heating

$m_2$: mass of the cup with the sample after heating

*b. VOLATILE MATTER CONTENT*

The same sample that was used during the moisture content determination is heated to 550°C. It is calculated as follows:

$$T_{mv}=\frac{(m_1-m_2)}{(m_1-m_0)}\times 100 \qquad (2)$$

$T_{mv}$: volatile matter content

$m_0$: mass of the empty crucible with its lid in g

$m_1$: mass of the crucible with its lid with the sample before heating

$m_2$: mass of the crucible with its lid with the sample after heating

*c. CARBON CONTENT*

According to [afilal et al., 2014], the carbon content is calculated as follows:

$$T_{Ca}=\frac{T_{mv}}{1{,}74} \qquad (3)$$

TCa: Carbon content

$T_{mv}$: volatile matter content

*d. NITROGEN CONTENT*

It is calculated as follows from data found by the Kjelddahl method:

$$T_N=\frac{(V_1-V_0)\times T\times M_N}{1000\times m}\times 100 \qquad (4)$$

$V_0$: volume used for the experiment

$V_1$: volume used for the blank assay

$M_N$: molar mass of nitrogen in grams per mole

m :: mass of the sample

T: titer of the hydrochloric acid solution (HCl), with T=0.1mol/l

*e. pH*

The pH was measured using a pH meter.

## III. EXPERIMENT

### A. ADDITION OF COW DUNG RATE

The test was done according to the cow dung rates added to the weight of the cake. We tested on the cow dung rate of 5, 15, 20 and 100%. The experiment aims to know the uncertainties of the physico-chemical conditions and to know the effects of the addition of cow dung rate.

### B. VARIATION OF THE SUBSTRATE CONCENTRATION RATE

According to [LeLe S., 2005] and [Billaud et al., 1983], in order to pump the semi-liquid substrate, the methanization must be carried out at 10% dry matter. [Billaud et al., 1983] also states that the significant production of biogas in m3 depends on the high solids content. The concentration rate of 6, 12, and 31% in dry matter was tested in relation to the useful volume of the digester.

### C. USE OF LIMING RATES

According to [Billaud et al, 1983], throughout the fermentation the pH must vary between 6.6 and 8.

In our case, 4.5 and 8 g of liming rate per liter of useful volume were tested.



## IV. RESULTS

The experimental results showed that the jatropha cake could be efficiently converted into biogas by anaerobic digestion. The production was optimal at a digestion temperature of 35 ° C and a C / N ratio of 16.5. The mathematical model developed was able to accurately give the biogas production according to the digestion parameters.

### A. EFFICIENCY OF COW DUNG ADDITION

With the two curves below, the anaerobic fermentation was done by respective additions of cow dung of 5, 15, 20 and 100%. It can be seen that, from the first day of fermentation, their yields differ according to the speed of volume production but the onset of gas flammability is the same for all substrates.

✓ *on the volume of biogas produced*

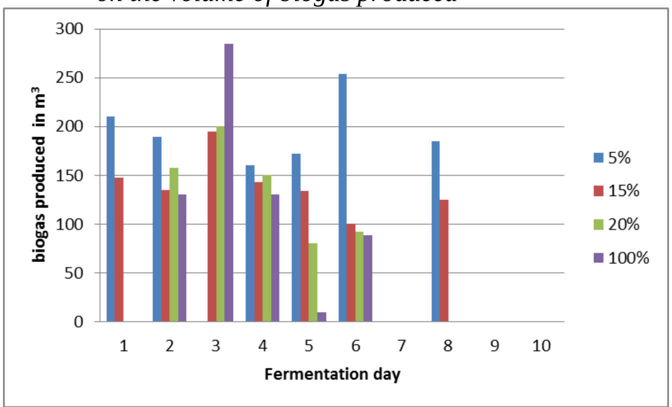


*Figure 1: Biogas produced in $m^3$/kg of cake/d according to cow dung*

The addition of cow dung can generally increase biogas production per kilogram of jatropha cake per day by providing more organic matter, balancing nutrients, influencing the C/N ratio, improving microbiological diversity and stabilizing pH. However, specific results may vary depending on specific substrate characteristics and digestion conditions. Experimental testing and adjustments are often necessary to optimize biogas production in a given facility.

✓ *on the variation of pH*

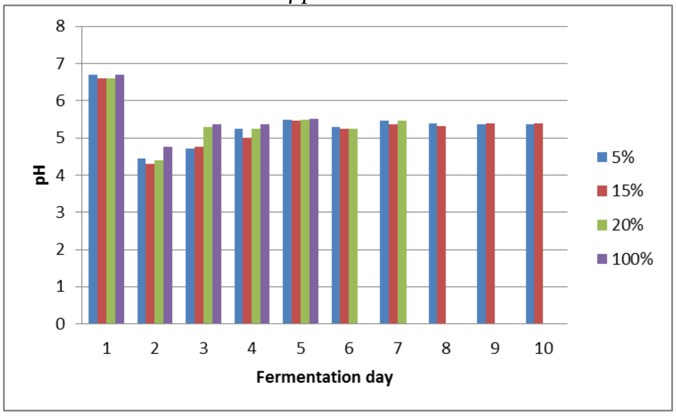


*Figure 2: PH variation according to the rate of cow dung added in the cake*

According to this curve, from the first day of fermentation the pH decreases and on the second day, it begins to increase but the pH does not exceed the value 6 which is the lower limit of pH. We can say that this situation corresponds to acidogenesis and hydrogenesis.

Cow dung contains compounds that act as natural buffers, thus stabilizing the pH of the digestion system. This can help prevent extreme fluctuations in pH that could inhibit the microbial activity responsible for biogas production.

✓ *on temperature*

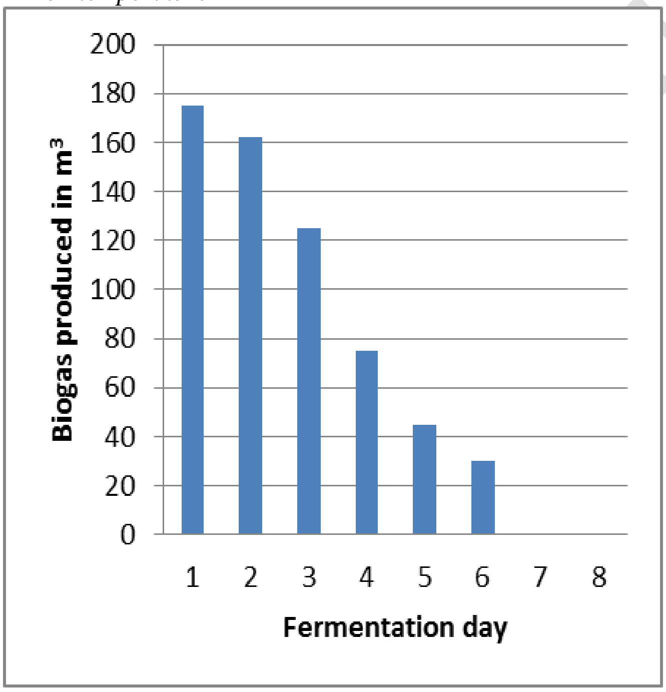


*Figure 3: The variation of temperature on biogas production in m3/kg of cake per day*

Cow dung, rich in organic matter, provides more substrates for methanogenic microorganisms. Increased methanogenic activity can generate heat as microorganisms metabolize substrates. Therefore, the addition of cow dung can increase the temperature of the anaerobic digester.

B. EFFICIENCY OF DRYING RATE OF JATROPHA CURCAS CAKE

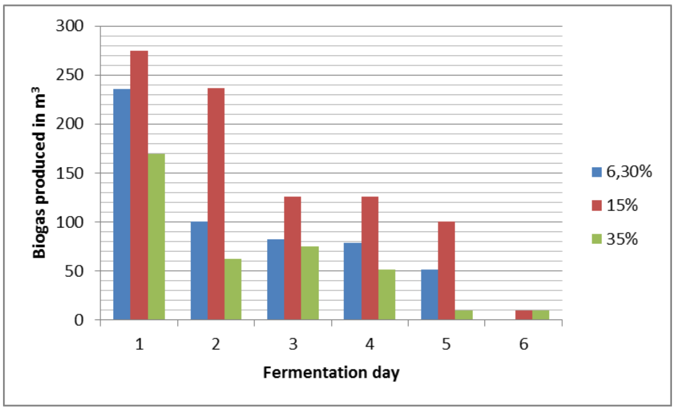


*Figure 4: Effect of cake drying rate on biogas production in $m^3$/kg cake per day*

A higher drying rate of jatropha cake can generally contribute to higher biogas production per kilogram of jatropha cake per day by promoting better accessibility of substrates to methanogenic microorganisms, improved energy efficiency, reduced competing reactions, and increased substrate density. However, it is important to carefully monitor the drying conditions to avoid excessive nutrient loss or undesirable change in substrate composition, which could negatively affect the anaerobic digestion process.

C. LIMING EFFECT

✓ *on pH*

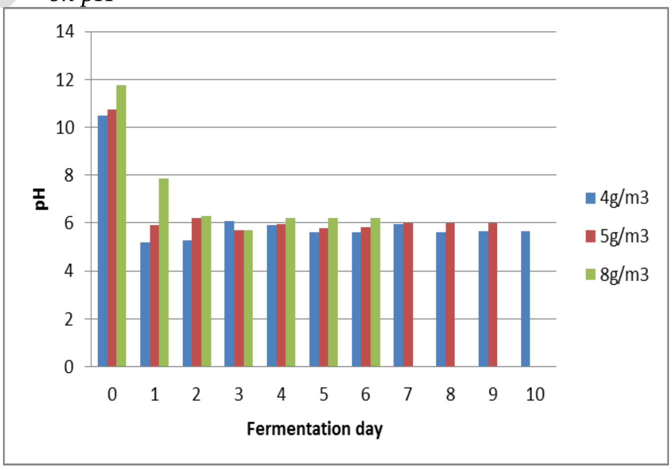


*Figure 5: Liming rate effect on pH*

Lime is an alkaline agent, meaning that it has the ability to increase the pH of the substrate. By adding lime, the pH of the anaerobic digestion system can be raised. This can be beneficial because many methanogenic microorganisms prefer an alkaline environment for optimal activity. In addition to increasing pH, lime can also act as a buffer, meaning that it can help stabilize the pH of the system. This can be important in maintaining stable environmental conditions that are favorable for methanogenic activity.

✓ *on biogas production*

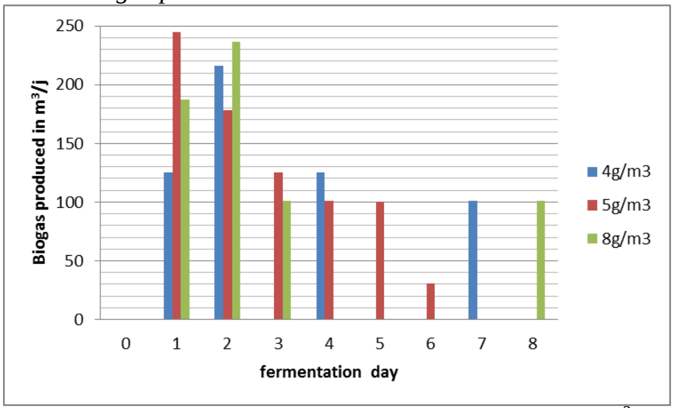


*Figure 6: Effect of liming rate on biogas production in $m^3$/kg of cake per day*

The addition of lime in the production of biogas from jatropha cake can have several beneficial effects, including pH control, reduction of acidification, improvement of nutrient availability and reduction of heavy metal toxicity. These effects can contribute to improving the efficiency of anaerobic digestion and thus increase the biogas production per kilogram of jatropha cake per day. However, it is important to carefully monitor the amount of lime added to avoid adverse effects on the anaerobic digestion process.

### D. SUBSTRATE CHARACTERISTICS

| Substrates | $T_{MV}$[%] | $T_{Ca}$[%] | $T_N$[%] | C/N | TMS (%) |
|---|---|---|---|---|---|
| Cow dung | 72,8 | 52,13 | 2,03 | 25,6 | 23,95 |
| Jatropha cake | 79.26 | 51,2 | 3,06 | 16,73 | 94,1 |

*Table 1: Moisture, dry matter, ash and volatile matter content*

Considering the dry matter content of jatropha cake of value 94.1%, it is a dehydrated solid substrate according to its characteristic. The respective C/N ratio result determines the mixing rate between jatropha cake and cow dung. And our results of the respective C/N ratio are 25.6 and 16.73 and this was confirmed by JLAIDI M. et al in 1995 which is of value 15 to 30.

## V. DISCUSSIONS

Our results indicate that jatropha cake has promising potential as a substrate for biogas production. However, further studies are needed to optimize digestion conditions and assess the potential for large-scale production. Economic and environmental considerations should also be taken into account to determine the long-term viability of this approach. With an anaerobic filter reactor, [Ruth Staubmann, 1997] obtained the best biogas production of 0.35$m^3$/kg DM. [Chandra & al., 2006], also uses a filter reactor but with a biogas yield of 250l/kg DM. According to [Domergue, 2008], a gas production yield of 50 to 60% methane can be obtained on a conversion rate of 0.5 to 0.6$m^3$/kg of organic matter, and a calorific value between 18 and 22 MJ/kg.

## VI. CONCLUSION

The experimental and modeling study on the potential of biogas production from jatropha hulls demonstrated promising results regarding the use of this agricultural by-product as a renewable biogas source. Initial analyses revealed that jatropha hulls have a favorable chemical composition for anaerobic digestion, with adequate organic matter content and satisfactory biodegradability.

Anaerobic digestion tests confirmed the ability of jatropha hulls to produce biogas efficiently, with significant methane yields. Anaerobic digestion parameters, such as temperature, pH and hydraulic retention time, were optimized to maximize biogas production.

In parallel, kinetic and reactor modeling allowed to mathematically describe the biogas production process from jatropha hulls. The developed models provided valuable information on biogas production kinetics and predicted reactor performance under different operational conditions.

## REFERENCES

[1] Afilal, M.E., Elsari, O. et Merzak, Z. (2014). Caractérisations des déchets organiques et évaluation du potentiel Biogaz (organic waste characterization and evaluation of its potential biogaz), J. Mater. Environ. Sci., 5(4), pp 1160-1169.

[2] Billaud D., Vara F., 1983, La fermentation méthanique. Paris: GRET, Dossier A.71p.

[3] CHANDRA, Ram, Vijay, Virendra K., et Subbarao, Parchuri M. V. A Study on biogas generation from no-edible oil seed Cakes: Potentiel and prospects in India. Inde: The 2nd joint International conference on « Sustainable Energy and environment (SEE 2006) » November 2006, Bangkok, Thailand.

[4] Domergue, M., & Pirot, R. (2008). Jatropha curces L. Rapport de synthèse bibliographique. CIRAD, AGR Ogeneration.

[5] LeLe S., 2005, Bio-gas plant [En ligne], consulté le 12 Mars 2022, disponible sur http://www.jatropha.de

[6] Nafisa Ali, A.K.K.A.S.B., Bio-mthanisation of jatropha curcas deatted waste.2010.

[7] NBE EN 13342:2000, caractérisation des boues- Détermination de l'azote Kjeldahl, 1e éd., octobre 2000.

[8] Mohamed JLAIDI, AMAHROUCH A., Maintenance des biodigesteurs à biogaz, volume 4, publié par l'UNESCO et CDER en 1995

[9] Ruth Staubmann, G.F., Nikolaus foidl, Georg M. GOsitz, ROSERr M.LAFFERrY, Victoria M. Valencia Arbizu, and walter Steiner, Biogas production from Jatropha curcas Press-Cake 1997.

[10] Shivani P., Khushbu P., Faldu N., Thakkar V., Shubramanian R. B. Extraction and analysis of Jatropha curcas L.seed oil. Afr. J. Biotechnol. 10 (2011) 18210–18213.