Euphorbia tirucalli biogas

Anaerobic digestion of different Euphorbia tirucalli samples

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1 INTRODUCTION

Euphorbia tirucalli (petroleum plant) is a tropical plant with a high potential biomass production. Past research in the energy applications of the crop have focused mainly on extraction and use of its latex. This latex can be used for rubber production and it contains gasoline-like hydrocarbons. Extraction and refining of the latex for these purposes has been extensively studied and was found to be unprofitable. Dried Euphorbia tirucalli (chopped pieces or briquetted) has also been tested as feedstock for gasification. Current research focuses on its use as feedstock for biogas.

This report describes the results of a short desk study and experiments on the biogas yield of *Euphorbia tirucalli* (ET) in anaerobic digestion. The desk study was carried out by FACT staff, and the experiments were conducted by Ingenia from 16 November 2010 until 12 December 2010. On the right is a picture of a Euphorbia tirucalli plantation in Colombia (2010).

2 BIO-ENERGY POTENTIAL

Under optimal conditions, Euphorbia tirucalli (ET) produces between 200 and 500 MT of fresh biomass per hectare per year (22 – 55 MT of dry matter)(Van Damme 1999, Kumar 2000, Orwa 2009). Advantages are that only vegetative material is needed and there is no need to wait for flowering and fruit production; when cut back, the plant rapidly grows back by itself, and plantation can easily be established by vegetative propagation. The gross energy content of dry ET is 17,600 kJ/kg (Orwa *et al*. 2009).

There are also several unknowns, such as:

- The optimal plantation style of ET;
- The number of years that sustainable continuous yield is possible;
- Diseases that might develop (not found now in hedges of the plant);
- Number of times the plant can be coppiced before yield reduction will push for replanting.

2.1 Hydrocarbons

The latex hydrocarbon is largely a C30 triterpenoid which, after cracking, yields high octane gasoline (Orwa *et al*. 2009). The costs for extraction are enormous and oil quality will be low; upgrading to fuel quality leads to considerable losses. Taking this into consideration, about 2,200 liters of fuel oil equivalent could be harvested per hectare per year requiring advanced chemical technology against very high costs. When used to generate electricity through a gasoline generator, this amount could generate 6,600 kWh (at 3 kWh/ liter) per ha per year.

2.2 Gasification

Dried ET can be compressed into pellets or briquettes or be used directly for gasification. Experiments by Mr. John Loke in Colombia have shown that 200 liters (about 100kg) of dried and cut ET pieces produce about 10kWh, equivalent to energy yields of 100kWh per ton dry ET. At 30 ton DS/ ha/ year this would lead to 3,000 kWh. This can be a bit higher with more advanced gasification systems.

2.3 Biogas

The entire plant contains latex, sugars, cellulose, which can all be converted to biogas through anaerobic digestion. Estimated production is 275 m3 of biogas (60% methane) per ton dry matter of ET. At a production of 30 MT/ha/year this results in 8,250 m3 biogas. In smaller systems (biogas engine gensets) 1 m3 of biogas yields 1.44 kWh/m3. This results in a total output of 11,880 kWh per hectare per year.

2.4 Comparison

A tentative first order comparison of the energy yields of ET is made with Jatropha curcas (JCL) and oil palm. For jatropha, a yield for semi-arid conditions is taken and electricity from oil and biogas from presscake is included. For oil palm, a low yield is taken (under semi arid conditions) with low extraction efficiency in small scale technology. For oil Palm, electricity output is higher when biogas from residues is included.

Table: Annual energy yields after conversion to electricity of Euphorbia tirucalli (Et), Jatropha curcas (JCL), Oil palm (considering small scale communal electrification technology)

	Et – oil	Et gasifier	Et - biogas	JCL (oil + biogas from presscake	Oil Palm (only oil taken)
yield/ ha/yr	2 MT dry	30 MT dry	8,250 m^3	1,500 kg dry seeds /ha	1,950 liter/ha
electricity	6,600 kWh	3,000 kWh	11,880 kWh	2,330 kWh	5,850 kWh
level technology	very high[1]	high	low	medium	medium
production cost	very high	medium	medium	high	medium

The first indication is that ET is attractive through a biogas conversion route. Secondly, it seems that under good conditions (precipitation, temperature and soils) it can surpass the energy yields of jatropha and even oil palm. Therefore, FACT Foundation decided to test the biogas yields that were demonstrated in a laboratory experiment by Sow et al. (1989).

3 EXPERIMENTAL SET-UP

3.1 Samples

Samples were collected by FACT staff in Colombia and Tanzania. The material from Colombia was collected in October 2010 from a plantation, 1 year and 8 months old. Part of a plant was taken and cut into small pieces and subsequently sun dried. With a grinder the pieces were made into powder. The material, from Tanzania, was collected from a hedge and kept fresh

[1] Oil from latex is included to give an indication of yields but the technology is too complicated to apply in communal bio-energy systems

under cool conditions. It is clear that it already dried out a little because it was processed 2 months after being cut off of the plant. Right before the experiment, is was cut into smaller pieces (of 3 centimetres length and 4-5 mm diameter) that fit in the biogas reactor.

3.2 Method

The samples were tested for biogas production with an adapted DIN 38414 test at the ALGE (Analytisches Labor Gelsenkirchen) laboratory in Germany, and the results were analyzed together with Ingenia. The exact dry matter content of the samples was determined.

Of each sample about 50 grams were tested in twofold with a control batch fed with cellulose. Anaerobic digestion took place in the dark under mesophilic conditions (35 °C). The samples were put in 500 ml glass bottles with a standard bacteria culture from an UASB system for domestic wastewater treatment. The digesting samples were not stirred. Biogas production was measured with a eudiometer during 21 days. Biogas composition (CH_4 and CO_2) was measured as well.

4 RESULTS

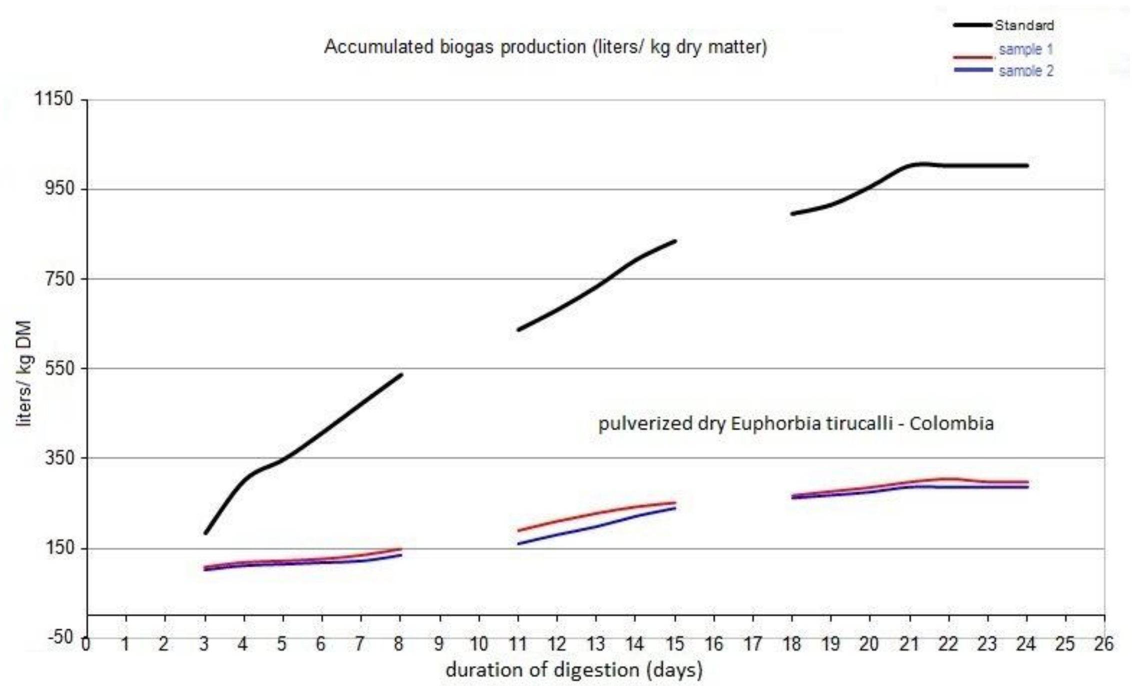
4.1 Dry matter content

The dry matter content of the dry powdered Euphorbia tirucalli was 89.0%.
The dry matter content of the 'fresh' Euhporbia tirucalli was 18.6%.

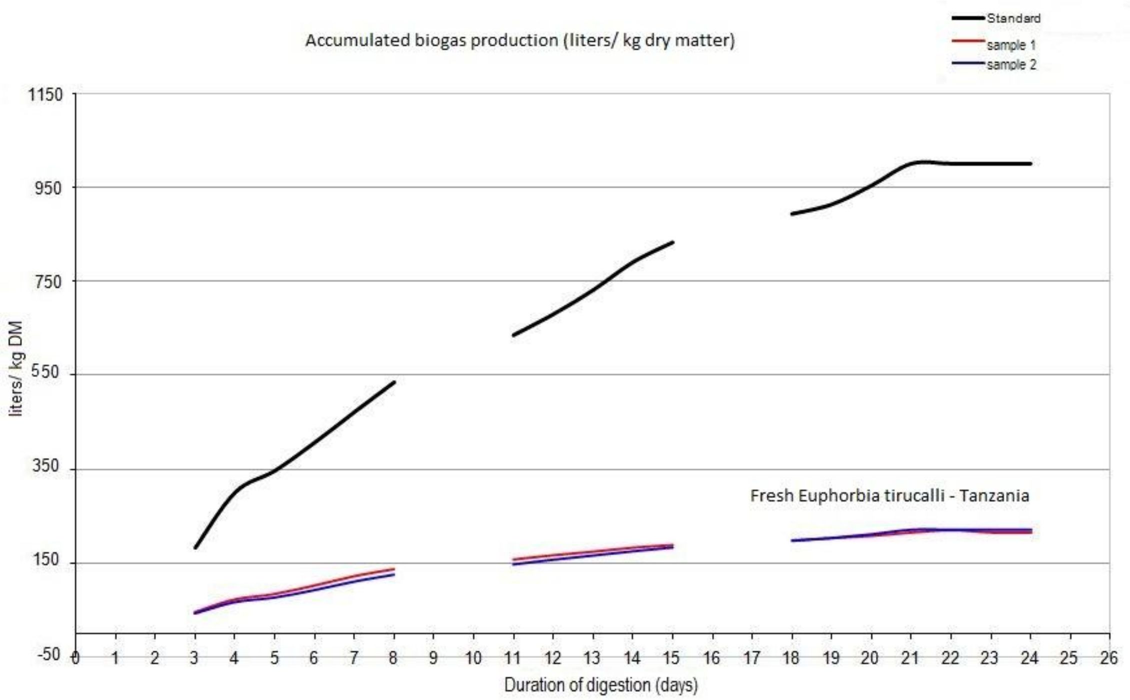
4.2 Biogas yield

The pH from the digesting matter of both samples was 7.4 in the beginning and 7.0 on the final day.

The biogas production for dried pulverized Euphorbia tirucalli from Colombia was 293 liters/kg on average.



The biogas production for ‘fresh’ Euphorbia tirucalli stems from Tanzania was 218 liters/kg on average.



4.3 Biogas composition

For the dry and pulverized sample from Colombia a methane content of 75% was found which is reasonably high. For the ‘fresh’ stems from Tanzania the methane content was 60%.

5 CONCLUSION AND DISCUSSION

Euphorbia tirucalli is a good feedstock for biogas production under laboratory conditions, with biogas production ranging from 218 to 293 liters/kg dry matter. Because the lab tests were done under mesophilic conditions, without stirring, gas production was constant over the total digestion period and because no acidification took place it is likely that in larger unstirred biogas digester systems at ambient temperature biogas production will be successful. Under project conditions at a larger scale biogas production the hydraulic retention time will be more than 21 days.

A combination of factors makes ET a very interesting potential source of bioenergy in tropical countries:

- It is able to grow and produce with low levels of water. Since it is a succulent plant with a cactus-like photosynthetic metabolism, it has a very high water use efficiency (Calvin 1980);
- It has a high yearly production of biomass;
- It is a suitable feedstock for biogas in anaerobic digesters;
- The whole plant can be harvested and used, making harvesting easy and cheap;
- The plant can be harvested at all ages until 2 years old, after which stems turn into wood;
- It can be harvested all year long;
- It grows back after harvesting and doesn’t need replanting;
- It is cheap and easy to set up a plantation;

- Little labour is needed in plantation management as the crop is tolerant to pests and diseases.

Various experienced Euphorbia growers mention it is highly resistant against pests and diseases (John Loke 2010,pers. comm, Kees 2010 -professional grower at Fachjan project plants, pers. comm.). During a visit to a plantation in Colombia no pests or diseases, only few mosquitoes, were found. Only one reference to pests on E. tirucalli was found, namely that Meloidogyne incognita infests the plant in India (Orwa et al 2009).

A drawback is that the latex is mildly toxic and protective clothing is needed when harvesting and processing the crop. There is no problem walking through a plantation without protective clothing (personal observation 2010).

Biogas production per kg DM is not exceptionally high, grass species yield up to 400 liters/kg) compared to 298 liter/kg for ET). Biomass production is high compared to other crops leading to a high bioenergy output per hectare per year. Because of its high water use efficiency due to its cactus like metabolism it performs very well in semi-arid environments. Management of the crop is minimal. The crop provides feedstock all year round and the crop can be harvested at any time until the crop is 2 years old and it starts to lignify. Harvesting is easy and little to no pretreatment (solely chopping to the right size) is needed before feeding it into the digester. It easily digests. Altogether the crop is a low cost, low input bioenergy feedstock that compares well to other energy crops for semi arid conditions.

6 FOLLOW UP

FACT Foundation intends to start a pilot project to test Euphorbia tirucalli biogas production and use under project conditions. The project will include the issue of plantation management, harvesting and processing the crop.

7 REFERENCES

1. Calvin, M. 1980. Hydrocarbons from plants: Analytical methods and observations. Naturwissenschaften 67:525-533.
2. Damme, 1999. Euphorbia tirucalli for high biomass production in semi-arid zones.
3. Kumar, A. 2000. Hydrocarbon yielding plants and future prospects: Biotechnological approach. In: Plant Biotechnology- recent advances (P.C. Trivedi, ed.), Panima Publishing Company, New Delhi. pp 194-212;
4. Sow, D., B. Ollivier, P. Viaud and J. L. Garcia. 1989. Mesophilic and thermophilic methane fermentation of *Euphorbia tirucalli.* MIRCEN Journal, 1989, 5, 547-55º.
5. Orwa C, Mutua A, Kindt R, Jamnadass R, Simons A,.2009. Agroforestree Database: a tree reference and selection guide version 4.0 (http://www.worldagroforestry.org/af/treedb/)