(05-020) - PROPOSAL FOR THE USE OF BIOGAS OBTAINED FROM THE BIODIGESTION SARGASSUM: AN ALTERNATIVE TO CONVENTIONAL FUELS IN THE DOMINICAN REPUBLIC

Ramos Ciprián , Rubén Darío [1]; Villanueva Rosario, Junior Alexis [1]; Körner, Ina [2]; Deipster, Anna [3]; Salavert Fernández, José Miguel [4]

[1] Universidad Central del Este, [2] Hamburg University of Technology, [3] Institute of Wastewater and Water Protection, [4] Universitat Politècnica de València

In the production of renewable energy, one of the most abundant sources is organic matter, known as Biomass. One of the best ways to generate renewable energy is through residual biomass such as Sargassum. This source of biomass has several advantages over terrestrial crops, as it does not compete for land use and does not consume the amount of water necessary to grow food. Considering that in 2022 18 tons of Sargassum invaded Dominican beaches, this biomass is presented as an alternative with great potential to produce biofuels. Life cycle analyzes (LCA) confirmed the environmental benefits of the biogas production system.

The organic waste from the biodigester can be used as organic fertilizer, while the biogas can be used for combined heat and power production.

After collecting all the data on the input variables, the simulation began. The simulation was carried out using 18.09 kg of dry matter or total solids as input material. Taking the organic dry matter content of 27.49% from laboratory results and with an incubation temperature of 30 degrees Celsius, for a simulated time of 90 days.

Keywords: Renewable energy; Sargasso; Biodigestion

PROPUESTA DE APROVECHAMIENTO DE BIOGÁS OBTENIDO DE LA BIODIGESTIÓN DEL SARGAZO: UNA ALTERNATIVA A LOS COMBUSTIBLES CONVENCIONALES EN REPÚBLICA DOMINICANA

En la producción de energías renovables, una de las fuentes más abundantes es la materia orgánica, conocida como Biomasa. Una de las mejores formas de generación de energía renovable es mediante biomasa residual como Sargazo. Esta fuente de biomasa tiene varias ventajas sobre los cultivos terrestres, ya que no compite por el uso de la tierra y no consume la cantidad de agua necesaria para cultivar alimentos. Considerando que en 2022 18 toneladas de Sargazo invadieron las playas dominicanas, esta biomasa, se presenta como una alternativa con gran potencial para producir biocombustibles. Los análisis del ciclo de vida (ACV) confirmaron los beneficios medioambientales del sistema de producción de biogás.

Los residuos orgánicos del biodigestor se pueden utilizar como fertilizante orgánico, mientras que el biogás se puede utilizar para la producción combinada de calor y energía.

Luego de recolectar todos los datos de las variables de entrada, se inició la simulación. La simulación se realizó utilizando como material de entrada 18,09 kg de materia seca o sólidos totales. Tomando el contenido de materia seca orgánica de 27,49% a partir de resultados de laboratorio y con una temperatura de incubación de 30 grados centígrados, durante un tiempo simulado de 90 días.

Palabras clave: Energías Renovables; Sargazo; Biodigestión

Correspondencia: Ruben Dario Ramos Ciprian, rubenramos@uce.edu.do

1. Introduction

Currently, the Dominican Republic faces a difficulty that directly affects the country's tourism industry and the quality of life of the inhabitants of the coasts. This problem is known as the invasion of sargassum algae, and theories related to its proliferation indicate that it is due to the increase in temperature in the oceans that produces the death of these algae, which are then dragged by the currents to the coasts of the Dominican Republic, among other localities of the Caribbean (Suarez & Martinez-Daranas, 2017).

Although almost a decade has passed since the first event was reported, it has not yet been possible to implement a coherent strategy for managing and adapting to this phenomenon in most of the affected countries, with environmental, economic and social effects, aggravated by the continuous growth of the amounts that they arrive year after year (Liranzo & Jauregui 2021). In 2013, from satellite observations it was determined that the sargassum affecting the Caribbean does not come from the Sargasso Sea as previously thought, but from northern Brazil (Széchy et al., 2012). Every year, in the period between March and August, large quantities of sargassum sail near the shores of the Caribbean islands. The species that make up this family of brown macroalgae are Sargassum Fluitans and Sargassum Natans (Rodríguez-Martínez et al., 2017).

Today humanity faces three acute problems: rising fuel prices due to rising energy consumption, climate change and air pollution. Industry and transport are two industries that demand the most energy, we know that most of the energy used today in the transport sector comes from fossil fuels, an industry that is very well positioned in the energy sector and that has served the industry for more than a century (Hernandez, 2017).

Sargassum in recent years has become a topic of interest in all areas of life in countries that have coasts and how much more in the islands such as the Dominican Republic where their coasts in many ways are extremely relevant since much of the economy depends on it either in terms of tourism and even logistics with the entry and exit of exports and imports.

Figure 1. Sargassum in Dominican beach. Source: Diario libre.

But, for the benefit of the development and expansion of the biofuel's portfolio in the Dominican Republic, Sargassum can be used as biomass from which both the solid matter and the biogas that is obtained through the biodigestion of the same could be used, which leads us to the reason for carrying out this degree project.

We must keep in mind that, although sargassum has been occurring on the Dominican coasts during all these years regardless of the date or season, the largest amounts of Sargassum arrive in the summer seasons.

This work aims to characterize the biogas produced by the biodigestion of sargassum for energy applications and simulations with SimuCF software.

So, it is proposed to take the sargassum and valorize energy through the process of anaerobic biodigestion within a digester, obtaining biogas of renewable origin and its possibility of application as a biofuel helping to eliminate this recidivist problem in a sustainable way.

2. Main Section

Sargassum is a threat to the economy of Caribbean countries that, like the Dominican Republic, are heavily dependent on tourism. The arrival of sargassum is one of the great problems that affects things in the Dominican Republic, a challenge that they say must be solved immediately to prevent both marine life and beach activities from being affected by this species of macroalgae, which has no mercy with the ecosystems of the sea. The main affectation that the beach has in all its territorial extension by the accumulation of this type of algae, is the bad image that presents in the periods of February-April and August-November, which are the dates of greatest appearance of this ficus. "I think we have to adapt to the situation, we cannot change it, because we would have to change the Ocean or the climate," says Yolanda León, a researcher at the Technological Institute of Santo Domingo (Intec) who has monitored the issue at the local level. (Mejia and Molina). In past years, 49 national beaches were impacted by the arrival of sargassum whose accumulation volume reached 2,424,800 cubic meters, according to Environment estimates. (Devesa, 2014)

This sector is one of the largest emitters of CO2 causing this compound to increase its concentration in the Earth's atmosphere and therefore have a great impact on climate change on the planet. Considering the above, we understand the importance of developing and creating energy sources that are in principle efficient at a competitive cost with the industry and therefore that their generation and use do not negatively affect the climate balance of the planet. (Devesa, 2014)

The other explanation is that Sahara dust contains iron and phosphorus that fertilize the sea, and this is partly positive as it absorbs carbon dioxide and feeds fish. But, in turn, it nourishes and feeds the sargassum; which is also related to the El Niño climate phenomenon, which has increased its periodicity due to climate change. From periods of three to seven years, it can now be presented every two years or in less time. (Hernandez, 2017)

All these uncontrolled processes of pollution are having an important point of affectation on our beach, since the current production of the sargassum type algae that exists, has been increasing in recent years, and that is being alarming. One of the options is to collect the sargassum in time to prevent it from crowding, since when it rots it releases toxic gases and affects the development of ecosystems composed of corals.

Considering the information previously reviewed, the questions that arise in relation to the problems raised are:

1. How can the biogas produced by anaerobic biodigestion be obtained?
2. What is the chemical composition of sargassum that determines the presence of biogas?
3. Could biogas be presented as a source of biofuel?
4. Which tool is effective in demonstrating the energy obtained from sargassum?

3. Materials and Methods

The software used in this investigation is the SimuCF, a Waste management Simulation of biological degradation processes software created and developed by Dr. Anna Deipser and Dr. Ina Körner in 2014 in the Hamburg University of Technology (TUHH) and used in the Institute of Wastewater Management and Water Protection of Hamburg (AWW) for plant a better planed and optimized operation and emission and biogas production protection.

The software processes in anaerobic fermentation and composting systems can be predicted.

The Software works as follows:

Input: The substrate type can be selected from a specified list. However, the specific chemical composition can also be entered directly. Further input values describe the reactor and the process operation: Fats, proteins, carbohydrates, lignocellulosic organics, minerals, and water.

Simulation: In the software, the essential aerobic and anaerobic microbiological, chemical, biochemical, and physical processes are merged. The programming was implemented with the graphic programming system LabVIEW™ 7.0 from National Instruments. The developed complex simulation software, with more than 50 iteration loops, allows for expansions and integrations of additional special objectives up to measurement and control tasks.

Output: The output of the simulation results is implemented in the form of diagrams and data tables. The user can select output parameters as well as units and scales and store simulated variants and data for: Solid phase, Substrate water phase, Exhaust gases, Condensate and Leachate.

The Sargassum samples to be analyzed were extracted from Juan Dolio beach, in the province of San Pedro de Macorís, located in the Eastern Zone of the Dominican Republic.

After the algae was collected, it was dried in the sun for 1 day. Since this way, this would help the sargassum lose a little of the seawater and in turn when analyzing the reflected results of this algae are the results of the algae by itself without any external intervention that could compromise the results of the research.

Figure 2. Sargassum samples in homemade biodigester

After the drying process, Sargassum was introduced into our home digester created for the biodigestion process, where the algae were retained for a period of 1 month (30 days) to complete the fermentation process and be analyzed in the laboratory. A closed container was used as a home biodigester. Then the digester was delivered to the laboratory of the Dominican Agribusiness Board (JAD). to continue the analysis process at their facilities, where the followed analysis was made to meet the software input requirement in table 1:

Table 1. Laboratory measured parameters. Source: Authors.

PH	Copper
Electrical conductivity	Manganese
Organic matter	Iron
Organic Carbon	Zinc
Nitrogen	Humidity
C/N	Carbohydrates
Phosphorus	Proteins
Calcium	Ashes
Magnesium	Fats
Potassium	

The results were obtained using the following methodology and equipment:

For the equipment: MW150MAX, Soxtec 8000, Fibertec 8000 and Kjeltec8200.

Methodology: Potentiometer Method, Kjeldahl's method, Molybdo-Vanadate Method (Spectrophotometry), Atomic Absorption Spectrophotometry Method and Walkley and Black method (Spectrophotometry).

Table 2. Results of laboratory analysis. Source: Authors based on laboratory analysis results.

Parameters	Results (% w /w)
pH	6.65
Electrical Conductivity (µmhos/cm)	33,100.00
Calcium (Ca)	5.451
Manganese (Mn)	0.0073
Magnesium (Mg)	0.489
Potassium (K)	9.17
Zinc (Zn)	0.003
Nitrogen (N)	0.78
Phosphorus (P)	0.07
Iron (Fe)	0.0158
C/N	20.47
Fats	0.38
Humidity	81.91
Proteins	4.37
Carbohydrates	80.92
Carbon	15.92
Ashes	35.93
Organic Matter	27.46

4. Simulation Results

After collecting all the data of the input variables, the simulation was started. The simulation was performed using 18.09 kg of dry matter or total solids as input material. Taking the organic dry matter content of 27.49% from laboratory results and with an incubation temperature of 30 degrees Celsius, for a simulated time of 90 days.

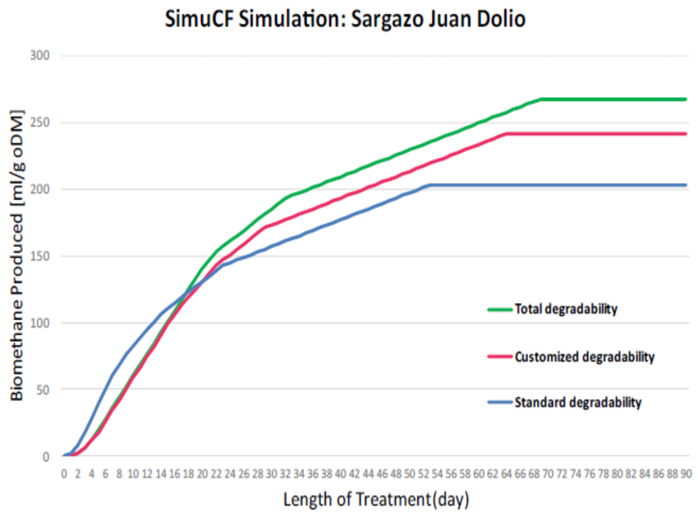
Table 3. Output values from simulation. Source: Authors based on SimuCF software simulation.

Parameters	Results (% w /w)
Copper (Cu)	0.21
Biogas	55-70
Calorific Value (Mj/m3)	35.8
Methane (CH4)	218
Energy (Kcal/g)	1.95-2.12

In figure 3 are represented the result using three different scenarios:

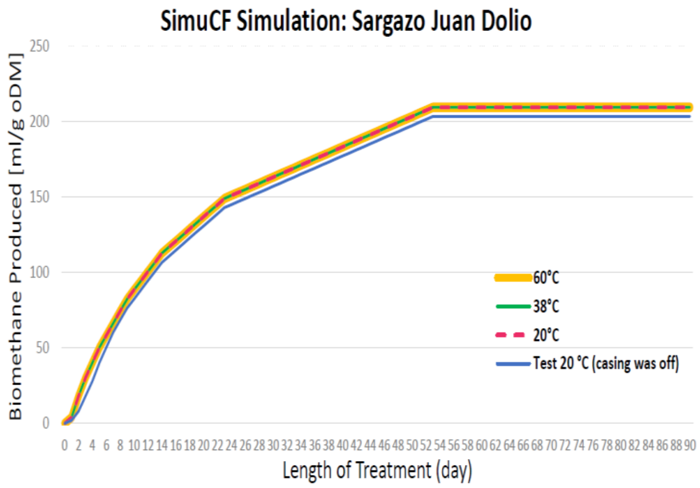
- Standard Degradability (Blue line), taking the results of the bibliography revision (Carb. 70%, fats 45%, prot. 50%).
- Custom Degradability (Red line), taking the parameters from the laboratory (Carb. 90%, fats 45%, prot. 80%).
- Total Degradability (Green line), a hypothetical ideal case of 100% of degradability of all components (Carb. 100%, ats 100%, prot. 100%).

Figure 3. Simulation of biogas production. Source: SimuCF Software.



Another simulation was carried out by varying only the temperature to observe the role played by the incubation temperature in the degradability process of the sample, it was set at 20, 38 and 60 ° C respectively.

Figure 4. Comparison of biodigestion with variation of temperature. Source: SimuCF Software.



Where judging by the simulation results, temperature has little or no influence on the behavior in the analyzed sargassum sample and its degradability process.

In addition to yielding data with reference to the amount of methane with reference to the solid material and how much temperature affects degradability, we also receive results and graphs of how the different gases, water, and other components of sargassum behave, which allows us to know and learn from the behavior of the degradation of this substrate over time and helps us to see more clearly opportunities to take advantage of it.

Figure 5. Gases and water behavior. Source: SimuCF Software

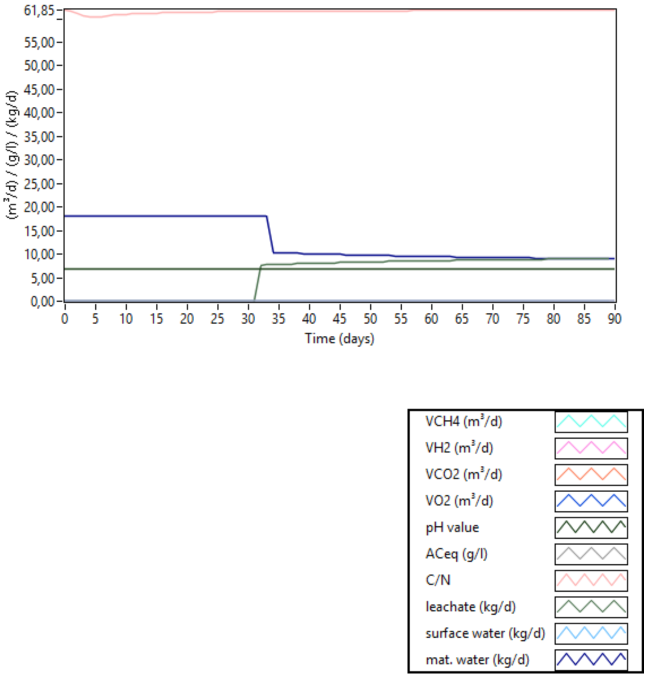


Figure 6. S-N behavior during simulation. Source: SimuC Software

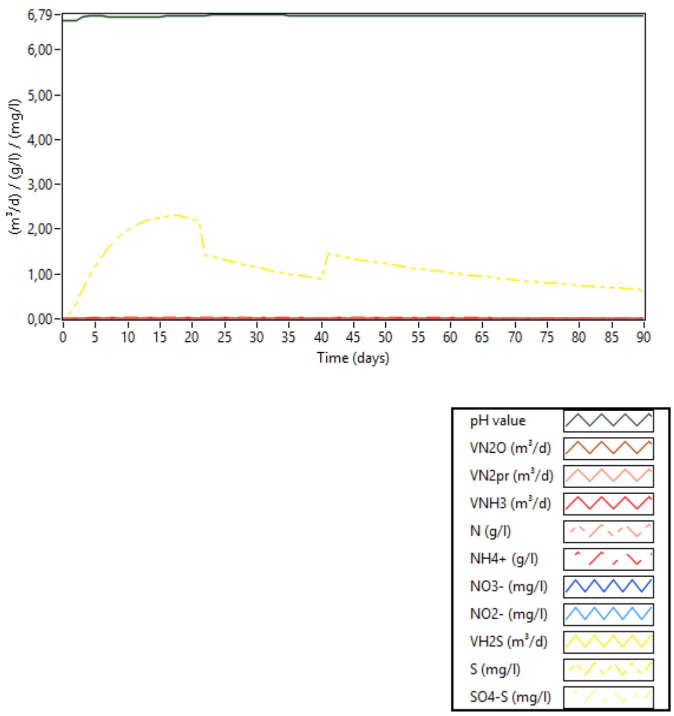


Figure 7. Nitrogen based compounds behavior. Source: SimuCF Software

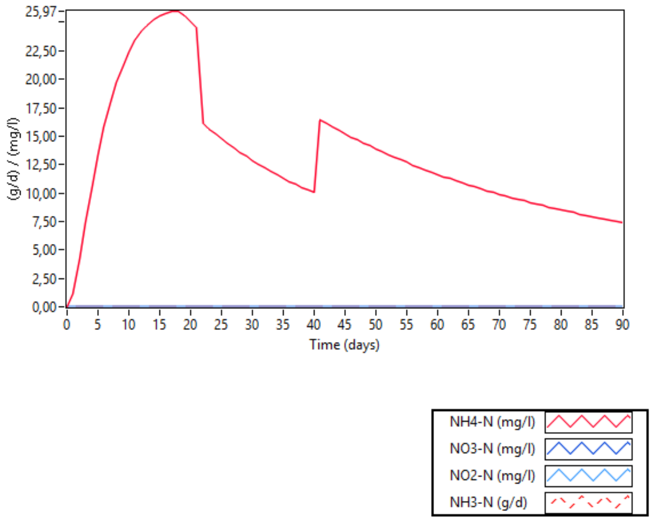


Figure 8. N-S-C balances. Source: SimuCF Software

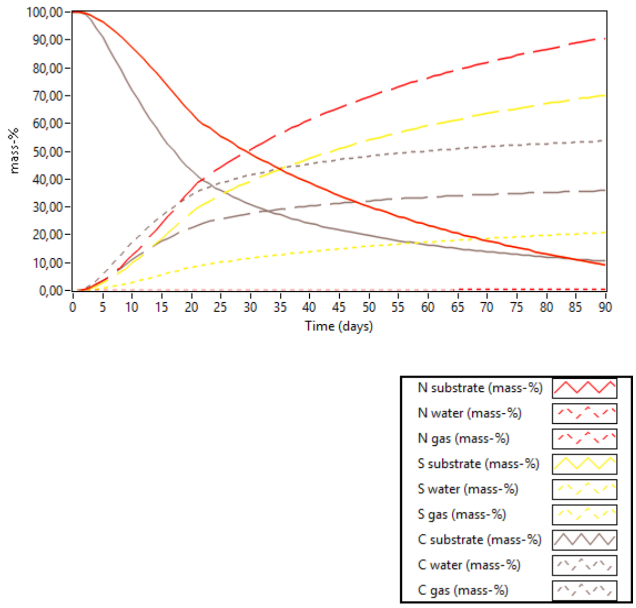


Figure 9. Physics parameters behavior. Source: SimuCF Software

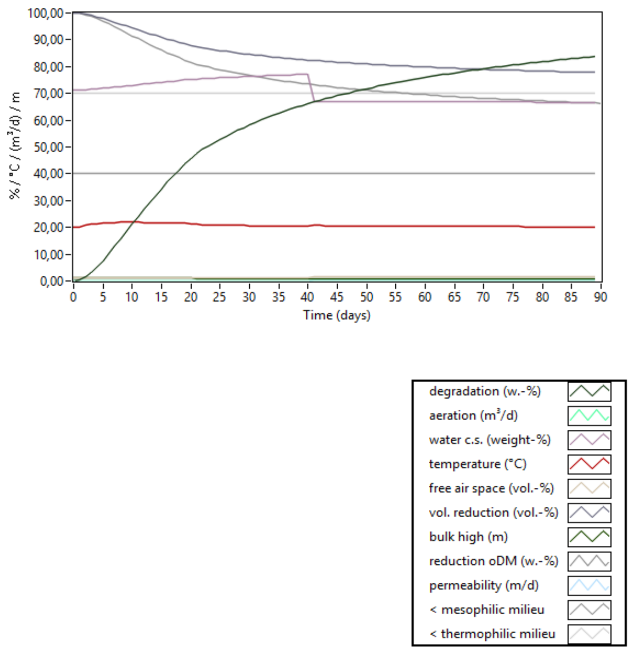
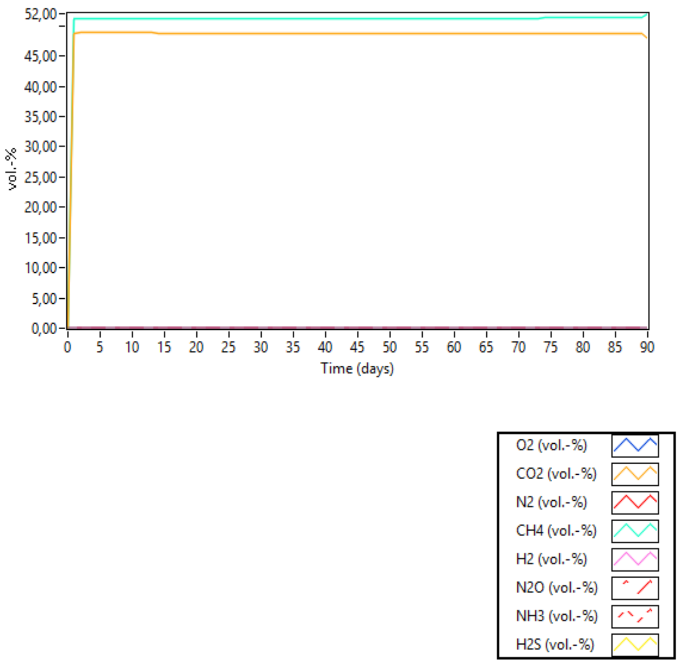


Figure 10. Gas production. Source: SimuCF Software



5. Technical Proposal

Considering that sargassum affects the coastal areas of the Dominican Republic, and these areas tend to be the most vulnerable in terms of socioeconomic conditions and electricity poverty, the following proposal aims to illustrate the use that sargassum biodigestion can have to meet the thermal and electrical energy needs of a lower-class family in the Dominican Republic.

The proposal consists of changing the fuel of both a standard 1kW stove with a flow in the burner of 0.08 m3 that uses LPG and a small electric generator of 1-25kW supplying this energy need with the biogas produced from the biodigestion of sargassum.

Assuming the following parameters for the calculation and its monetary equivalent of Dominican Pesos (DOP) to US Dollars, the current exchange rate being 56.20DOP x 1USD shown in table 4.

Table 4. Base parameters for calculation. Source: Authors.

Item	Value	Unit
η motor	0.4	-
η Biogas stove	0.37	-
η LPG stove	0.49	-
Stove	1	Kw
ρ (LPG)	0.49	g/cm^3
ρ (LPG)	493	kg/m^3
PCI Biogas (50-70% CH4)	5.81	kWh/m3
PCI (gasoline)	0	kWh/kg
PCI GASOLINE	44000	kJ/kg
PCI GLP	12.88	kWh/kg
Kitchen consumption	0.28	m^3
Gasoline price	5.21	USD
LPG Price (USD Gallon)	2.26	USD
GN Price (M3)	0.52	USD
Electricity price (0-200 kWhP	0.08	USD

Using these parameters, we can calculate the actual cost of using the electric grid (that is not always available) as energy source in table 5.

Table 5. Actual cost of electric grid for 0-200kWhP. Source: Authors based on Dominican Republic electricity prices.

Startup data		Cost of Electric Grid Use		
HP	Kw	Energy (kWh/month)	Cost (USD$/month)	Cost (USD$/year)
1	0.7	30.4	5.7	68.2
2	1.5	45.6	7.3	87.6
5	3.7	60.8	8.9	106.9
13	9.7	91.3	12.1	145.7
20	14.9	121.7	15.4	184.5
25	18.7	182.5	30.4	365.3

Table 6. Actual cost of gasoline use in a 1-25HP electric generator. Source: Authors based on gasoline price.

Startup data			Gasoline Cost		
HP	Kw	V(L)	Energy (kWh/month)	Cost (USD$/month)	Cost (USD$/year)
1	0.7	1	30.4	5.7	68.2
2	1.5	1.5	45.6	7.3	87.6
5	3.7	2	60.8	8.9	106.9
13	9.7	3	91.3	12.1	145.7
20	14.9	4	121.7	15.4	184.5
25	18.7	6	182.5	30.4	365.3

Using the information obtained in the simulation and estimating 0.031 USD/kwh in maintenance and operation, considering that the installation is self-operated by householders Table 7 shows the cost of using biogas from sargassum.

Table 7. Actual cost of LPG use for cooking in a 1kW stove. Source: Authors based on LPG price.

Startup data			GLP COST		
HP	Kw	V(m^3)	Volume GLP (US GL)	Cost (US$/month)	Cost (US$/year)
1	0.75	1	0.155	$10.67	$128
2	1.49	1.5	0.310	$21	$256
5	3.73	2	0.775	$53	$640
13	9.70	3	2.0173	$139	$1,665
20	14.92	4	3.103	$213	$2,562
25	18.65	6	3.879	$267	$3,202

Table 8. Cost of using biogas produced by biodigestion of sargassum. Source: Authors based in the results of SimuCF simulation.

Startup data			Biogas Calculation (including maintenance and operation)	
HP	Kw	Biogas volume (m3)	Cost (USD$/month)	Cost (USD$/year)
1	0.75	0.4652	$0.93	$11.125
2	1.49	0.6978	$1,391	$16.688
5	3.73	0.9304	$1,854	$22.251
13	9.70	1.3955	$2,781	$33.376
20	14.92	1.8607	$3,709	$44.501
25	18.65	2.7911	$5,563	$66.752

6. Conclusion

This work has evaluated the possibility of using the sargassum obtained from the beach Juan Dolio as an energy source from obtaining biogas through the process of anaerobic biodigestion for domestic use in communities of scarce economic resources and energy poverty through simulation using SimuCF software.

The sargassum sample was collected directly from the beach of Juan Dolio, 18.09kg of sargassum sample, which was analyzed in its composition by different laboratory methods to obtain the input variables of the SimuCF software. The simulation was carried out under controlled temperature conditions for a period of 90 days, obtaining a biogas composed mostly of methane (CH_4) with 51% and carbon dioxide (CO_2) 49% with a methane potential of 203.22 ml / g, maintaining a pH in the range of 6.70 to 6.79 which is correct for anaerobic biodigestion and matching in range with other values reviewed in the literature, which gives us values very close to reality.

Based on this methane potential, a use of this biogas is proposed to replace conventional fuels such as gasoline in small electric generators or liquefied petroleum gas (LPG) in conventional stoves for cooking food, which considering the current cost of such fuels would be a considerable saving in energy costs and energy independence for these people.

The intermittency in the arrival of sargassum could indeed affect the optimal functioning of a biodigester solely reliant on this material for operation. Biodigesters necessitate a consistent feedstock to maintain an efficient process of decomposition and biogas production. In cases where the arrival of sargassum is irregular, there might be periods where the biodigester lacks sufficient material to operate, consequently impacting its performance.

To mitigate this issue, strategies such as the possibility of blending sargassum with other organic substrates to maintain a more consistent feed to the biodigester should be explored, considering that The Dominican Republic is a purely agricultural and livestock country so in the seasons of low influx of sargassum this biodigester can be fed with organic waste from animal production, agriculture and organic waste from human food. Moreover, designing the biodigester with adaptability to fluctuations in sargassum availability would be crucial for its functionality in the Caribbean context, where the arrival of this seaweed can be unpredictable.

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Comunicación alineada con los Objetivos de Desarrollo Sostenible