Study of the Viability of Sargassum as a Substrate to Produce Biofuel

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Abstract: Sargassum is an indicator of progressive pollution in the seas because it causes lack of light and lack of oxygenation. It arrives in the Mexican Caribbean between the months of April and September, causing a bad smell that it has after its decomposition, a heavy load of heavy metals, as well as being an inconvenience for the inhabitants because it causes losses for tourism in that region. There are several ways to take advantage of these algae and one of them is to generate biomass to obtain a biofuel. The objective of this study was to determine the viability of sargassum (two varieties) as a substrate to obtain biogas in anaerobic co-digestion with sludge from a WWTP (Wastewater Treatment Plant). Two forms of drying were also applied to the two varieties of algae. It was obtained that sargassum is a good component to co-digest because it does not destabilize the process and good biogas production is achieved.

Key words: Sargassum, co-digestion, biogas.

1. Introduction

Sargassum is a set of marine macroalgae, of the genus Sargassum, which have brown, black and green colors, have different textures (curly, laminated, lined) and can occupy large surfaces in a wide variety of habitats. Some species of sargassum have gas vesicles that allow them to stay afloat in the ocean and grow. The most representative species of sargassum that make up the floating mantles are: Sargassum natans (Linnaeus) and S. fluitans (Børgesen). Sargassum in the ocean functions as a habitat, shelter, and feeding or spawning site for several marine species that use these macroalgae as a means of food, protection, and transportation. It has been observed that the biomass of the floating mantles can reach up to 20 million tons of live weight in 8,850 km in the Atlantic. This phenomenon of massive accumulation of sargassum has been given the name of the Great Sargassum Belt of the Atlantic [1].

Since 2011 there has been an annual stationary growth in the amount of sargassum in the Atlantic [2]. Between March and July 2021, the SEMAR (Secretary of the Navy) collected 26,558 tons of sargassum in the waters of the Mexican Caribbean, 7,504 tons more than those collected from the sea last year, almost 40% upward. Massive sargassum stranding events are a completely new phenomenon for many countries. This unprecedented phenomenon is linked to climate change and various anthropogenic environmental alterations at the global level. Seaweeds have caused many negative effects, but at the same time they can also provide raw materials for various uses and be an important habitat and refuge for many marine organisms in the open ocean environment [3, 4].
There are various energy generation processes that use biomass as a raw material, which can consist of municipal waste: food scraps, garden scraps, orchards, vegetables from markets and sludge from WWTPs (Wastewater Treatment Plants). One of these processes is based on the anaerobic digestion, from which biogas and a by-product called biol, rich in nutrients, are obtained. However, to evaluate the potential of sargassum as a biogas generator, it is necessary to study the presence of multiple components, such as sulfates, sodium chloride and heavy metals, as well as the nutritional content, since they could act as inhibitors of anaerobic digestion [5, 6].

However, they have some disadvantages, such as the presence of high-water content, seasonal chemical composition, and the occurrence of some inhibitory phenomena during anaerobic digestion [7, 8]. In this work, the results obtained from the use of sargassum as a substrate in anaerobic codigestion are presented, providing a possible solution to the problems previously raised.

2. Material and Methods

Different tests were developed for its conservation and storage of sargassum, as well as the assembly of an anaerobic digestion, inoculation, adaptation, and evaluation system.

2.1 Sargassum Sampling

A sample of two different types of sargassum was taken: brown and green from the coasts of Quintana Roo. They are shown in Figs.1 and 2.

2.2 Treatment of Samples

Due to the massive arrivals of sargassum on the Mexican Caribbean coast, it is important to find a way to conserve and store this macroalgae so that it can be co-digested and obtained as a biofuel. In such a way that a treatment was carried out on each variety of sargassum, it is shown in Fig. 3.

Fig. 1  Brown sargassum from the coast of Quintana Roo.

Fig. 2  Green sargassum from the coast of Quintana Roo.

Fig. 3  Sample treatment.
2.2.1 Drying in the Sun of Brown Sargassum

In each aluminum tray, 50 g of sample was placed; three of them contained sargassum previously washed with drinking water to remove excess sand and three other trays without washing. All were left in the sun for 72 h, at room temperature (32 °C). In Fig. 4, the samples are observed, which were weighed every 24 h.

2.2.2 Oven Drying of Green Sargassum

For oven drying, 50 g of the sample was placed in aluminum trays in the same way (Fig. 5), as in the previous case, some samples were washed, and others were not. Subsequently, the trays were left for 72 h in the drying oven at a temperature of 50 ± 2 °C. The samples were weighed every 24 h.

2.3 Assembly of the Digesters

For the assembly of the anaerobic digestion system, four heating plates were placed, as the temperature is required to be homogeneous and indirect, since the required regimen is mesophilic (32 ± 2 °C), a metal tray was placed which functioned as a water bath. In this tray, three digesters (Erlenmeyer flasks) of 1,000 mL were introduced (one would serve as a control). The temperature of the plates was set at 35 °C.

Three holes were made in the plugs of the digesters, the first served to feed the digester, the second was connected to the biogas collection system and the third to adapt a thermometer to monitor the temperature, see Fig. 6.

The measurement of the biogas produced in the system was carried out by the water displacement method, for which a plastic container was placed, with water up to a considerable level and inside it, a wooden support was placed where the 4,500 mL test tubes filled with water as shown in Fig. 7, taking care not to have air bubbles inside them.

2.4 Inoculation and Stabilization of Anaerobic Digesters

The inoculation of the anaerobic digestion system (Fig. 8 shown the anaerobic digestion system) was carried
To verify that the system had reached stabilization, temperature (°C), biogas (mL/d), pH and VFA’s/alkalinity were determined and maintained for 23 days, under those conditions, that is, an HRT (Hydraulic Retention Time).

2.5 Feeding with Mud-Sargassum

The sludge required for feeding had to have a concentration of 25%, to reach that concentration, the fresh sludge taken from a domestic wastewater treatment plant was thickened. The amount of total volatile solids contained was determined and the value obtained was used to establish the necessary dilution to obtain the desired concentration.

To feed the system, a mixture of fresh sludge-dry sargassum (brown or green) was used in codigestion, a term used for the anaerobic digestion of two or more substrates to take advantage of the synergy of the mixture [9]. The mixture was prepared with a concentration of 25%, that is, 12.5% of fresh and 12.5% mud from each of the dry sargassum varieties. The control flask was fed with fresh mud only. It was fed during an HRT for system stabilization and then the system was evaluated using the parameters shown in Table 1.

3. Results and Discussion

3.1 Sargassum Drying and Storage

When analyzing the drying results of the two varieties of sargassum, it was obtained that the best option is to wash the sargassum since the remains of sand, snails and salt that can be found are eliminated and thus reduce its weight and obtain better drying. The most effective option was conventional oven drying. The values are observed in Table 2.
Table 2  Drying of sargassum during 72 h.

<table>
<thead>
<tr>
<th></th>
<th>Sargassum red</th>
<th>Sargassum green</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>Don’t wash</td>
<td>12.8 g</td>
</tr>
<tr>
<td></td>
<td>Wash</td>
<td>6.5 g</td>
</tr>
<tr>
<td>Oven dry</td>
<td>Sun</td>
<td>8.2 g</td>
</tr>
<tr>
<td></td>
<td>Oven drying</td>
<td>5.5 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.5 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.0 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16.2 g</td>
</tr>
</tbody>
</table>

Fig. 9  Sargassum storage.

At the end of the drying process, the storage of the sargassum continued for future tests. Each type of sargassum was crushed and stored in labeled glass containers. The sargassum was kept in storage throughout the investigation and remained in good condition as shown in Fig. 9.

3.2 Evaluation of the System in Anaerobic Co-digestion

Regarding the operating parameters, the temperature and pH ranges remained optimal, as can be seen in Table 3.

During the stabilization of the systems that were installed for co-digestion and that were only fed with fresh sludge, in Fig. 10, it is observed that there is biogas production, however, with many fluctuations during the 23 days that the measurement was made. On average, a production of 299 mL, 199 mL and 267 mL was obtained for reactor 1, 2 and 3, respectively. The deviations are due to the variability in the composition of the fresh sludge (shown in Fig. 10).

Table 3  pH values and average temperature in the systems in anaerobic co-digestion.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Maximum value</th>
<th>Minimum value</th>
<th>Average</th>
</tr>
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<tbody>
<tr>
<td>pH</td>
<td>8.42</td>
<td>6.98</td>
<td>7.5</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>36</td>
<td>29</td>
<td>33.5</td>
</tr>
</tbody>
</table>

Fig. 10  Evolution of the stabilization of the digesters, fed with sludge.
3.2.1 Biogas Measurement

Once the feeding with the mud-sargassum mixture began, the VFA’s/Alkalinity ratio was determined, finding that the average values were 0.22 for green sargassum and 0.10 for brown sargassum, which are in the range that the bibliography mentions that it is 0.1-0.5 [9], which indicates that the relationship is optimal for the generation of biogas.

During a Hydraulic Retention Time (23 days) the biogas production of each of the co-digestion reactors, as well as the control reactor, was determined, finding that on average the brown sargassum digester had a production of 253 mL, the green sargassum digester had a average of 336 mL and the control digester 325 mL. It is also observed that it remained more stable compared to the same systems fed only with sludge, possibly because the sargassum provided nutrients to the co-digestion system. The values obtained from the same systems with only sludge show a noticeable increase in production when the feed is supplemented with brown sargassum, see Fig. 11.

4. Conclusion

The oven drying process is efficient since it is faster, however, due to the amount of sargassum that reaches Mexican beaches on a large scale, it would not be as efficient. Drying the algae in the sun also provides adequate drying, although with longer exposure times. On the other hand, dry sargassum storage was successful, it is odorless, does not decompose and can be stored for a long time for later use.

When comparing the values of the VFA’s/Alkalinity ratio, as well as the biogas production, it is concluded that the mixture of sludge-sargassum in co-digestion is a feasible substrate for the generation of biogas and an effective option for the disposal of sargassum.

References


