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USE OF BIODIGESTERS AS A SUSTAINABLE ALTERNATIVE FOR THE STEAM PRODUCTION IN A DISTILLERY INDUSTRY

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Abstract. A distillery is an industrial facility dedicated to the production of alcoholic beverages through the distillation process. Many of these use firewood as fuel, generating high CO_2 emissions and particulate pollutants, which negatively affect the environment. Historically, this issue has driven the search for more sustainable alternatives, such as the use of biogas. The implementation of biodigesters powered by biodegradable substrates is a workable choice to significantly reduce conventional fuel consumption, minimize environmental impact, and keep an energy output comparable to that generated with firewood. This study analyzes the technical and economic feasibility of implementing biodigesters in distillery boilers, using waste generated in the production process as raw material. To this end, a biodigester system was designed to meet the specific needs of a distillery in Paraguay, considering variables such as daily waste volume, retention time, and biogas production. Currently, this industry consumes 72,000 kilograms of firewood per day to fuel its boilers. However, the results show that by implementing a biodigester with 30% bagasse as a substrate, firewood consumption can be reduced to 10,940 kilograms per day. The incorporation of biodigesters powered by bagasse offers a sustainable solution for energy generation in the distillery industry, contributing to environmental conservation and the efficient use of natural resources.

Keywords. *Biodigesters, Biogas, Boilers, bagasse, biomass, saturated steam.*

Introduction. Biodigesters, which decompose organic materials to produce biogas, can serve as a sustainable alternative to traditional fuels by mitigating negative environmental impacts (Pérez Medel, 2010). The global trend in biodigester development focuses on reducing costs, extending the lifespan of these systems, and making this technology accessible to a larger user base (Jaramillo Ludeña, 2012). The hypothesis posits that implementing biodigesters powered by biodegradable substrates will significantly decrease the use of conventional fuels while generating energy output comparable to that of firewood.

In this work, the general goal of this study is to assess the technical and economic feasibility of integrating biodigesters into steam boilers to replace conventional fuels in a distillery.

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Main text. A biodigester system was designed to meet the specific requirements of the case study. Key variables considered included the daily amount of waste, retention time, and daily biogas production. To estimate the required biogas production, the reference value used was the thermal energy demand of a boiler in a Paraguayan distillery. The boiler, a pyrotubular model manufactured by Termeco, produces 1,500 kg/h of steam at a pressure of 7 kg/cm² of saturated steam, assuming the water temperature is at 20°C (room temperature) with an efficiency of 90% (Aquino, 2008).

The heating value of biogas ranges between 18.8 and 23.4 MJ/m³, depending on the reference source (Fundación, 2023), and varies according to the methane and carbon dioxide content in the biogas at the time of production. For steam production, some variables were considered, including the daily amount of waste needed to feed the biodigester, retention time, daily biogas production, the biogas volume needed, and fermentation process parameters.

The proposed system was compared to the currently used system, focusing on biodigester construction costs and the amount of waste needed, without factoring in energy performance or a comprehensive economic analysis. The costs of firewood and biodigester implementation were assessed through consultation of books, scientific documents, technical operational data, and user manuals. To find the operating principles of a biodigester applied to the industry, a thorough analysis was conducted that involved the preparation of an operating flowchart, illustrated in figure 1.

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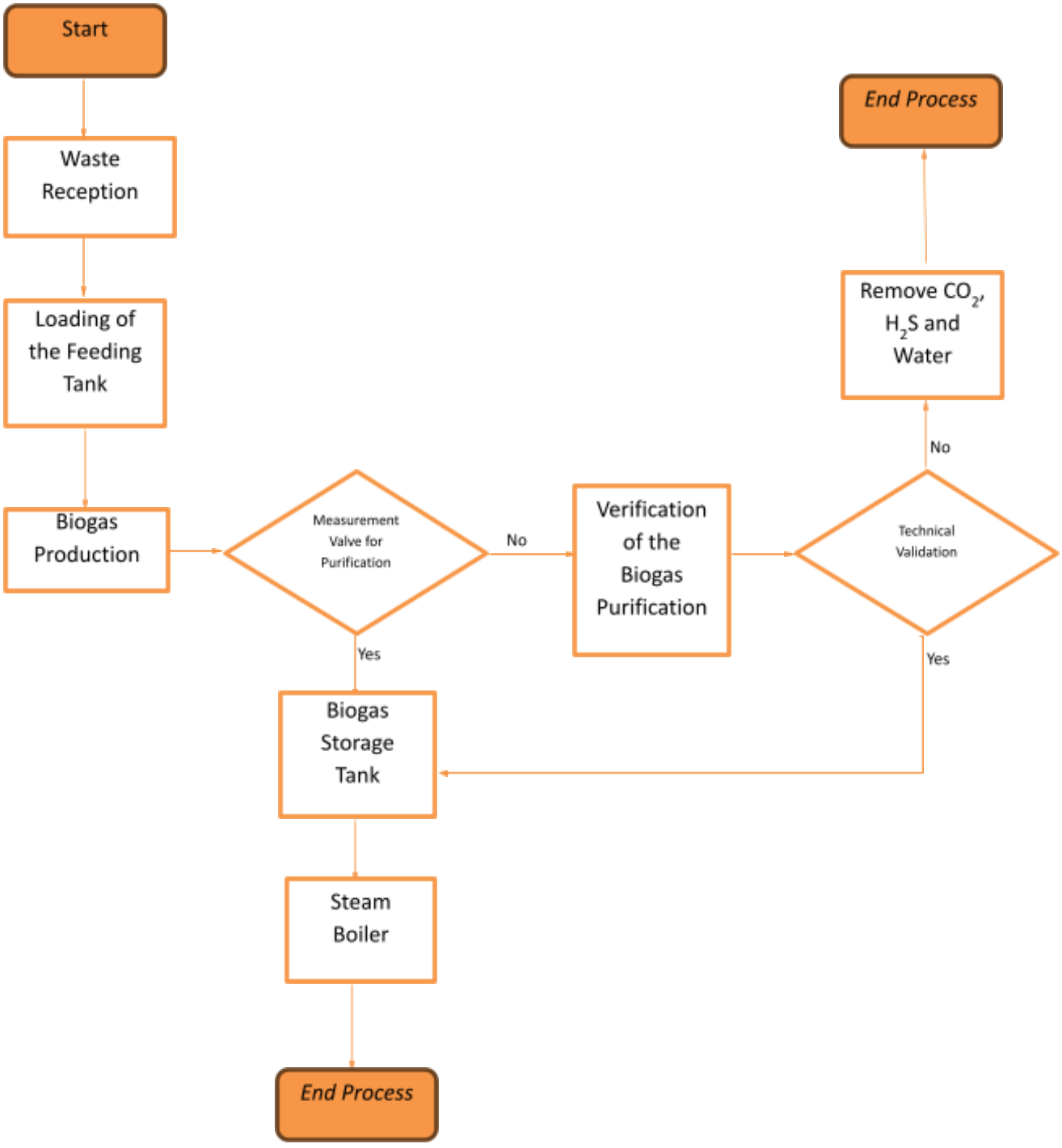

Figure 1. Flowchart of the biodigester operation.

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Subsequently, we calculated the heat needed to meet the boiler's demands over a specified period, using data obtained from a reference distillery in Paraguay. The energy needed for the boiler to sustain the production levels required by the distillery is 194,400 kcal/h.

To calculate the biodigester load, fixed parameters are considered, which vary depending on the case, such as the amount of waste to treat, the amount of biogas to generate, or the size of the tank used. In this case, it is assumed that the biodigester will be fed with FORSU (organic fraction of municipal solid waste), utilizing the residue from sugarcane after the juice extraction (Argentina, 2019). The volume of the tank is taken as a fixed value, but the amount of biogas to be generated or the waste to be treated can also be considered, adjusting as needed (Lorenzo Acosta & Obaya Abreu, 2005). By mixing various organic substrates with bagasse, such as FORSU, a production of 615,000 liters of biogas per day would be achieved. To meet the total demand of the industry's boilers, 30% of FORSU would be needed, generating 10,256 kg and reaching a total production of 1,025,000 liters of biogas per day. The total biogas demand of the industry would be 1,027 m³ (1,027,000 liters) per day.

Table 1 presents the daily input necessary for the current boiler to achieve this calorific value of 194,400 kcal/hour, enabling a production rate of 1500 kg of steam per hour.

Table 1. Result obtained with conventional fuel.

STEAM BOILER WITH CONVENTIONAL FUEL	
Quantity of firewood and bagasse (kg/day)	72.000
Amount of steam generated (kg/hour)	Data not provided
Degree of heat achieved (kcal/hour)	194.400
Volume of firewood used (m^3/hour)	1,17

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Table 2. Result obtained with 18% bagasse as fuel.

STEAM BOILER WITH BIODIGESTOR (18% bagasse)	
Amount of bagasse (kg/day)	6.150
Amount of steam generated (kg/hour)	1.500
Amount of heat achieved (kcal/hour)	194.400
Waste volume used(m^3/hour)	0,72
Volume of biogas obtained (m^3)	513,5

An anaerobic biodigester was designed with a volume of 87 m³, using the distillery's bagasse as raw material. To match the heat energy output of the wood-burning boiler, the biodigester would need to produce 42.8 m³ of biogas per hour.

Table 2 shows the results for the heat production required by the boiler using a biodigester with 18% bagasse. This amount of biogas would allow the boiler to run only for 12 hours a day, which is insufficient since the demand requires the boiler to run 24 hours.

Therefore, to meet the demand, it was found that the best configuration for meeting the boiler's demand is to use a biodigester fueled by 30% bagasse. The results of this analysis are described in table 3.

Table 3. Estimated result with 30% bagasse as fuel to cover demand**.**

STEAM BOILER WITH BIODIGESTOR (30% bagasse needed to cover total demand)	
Amount of bagasse (kg/day)	10.940
Amount of steam generated (kg/h)	1.500
Amount of heat achieved (kcal/h)	194.400
Waste volume used(m3/h)	1,30
Volume of biogas obtained (m3)	1.027

In the distillery found in Paraguay, the annual expenditure on buying firewood to meet the required production levels is approximately 61.895 American dollars. In contrast, the estimated cost for constructing a biodigester is around 68.290 American dollars. (S.A., s.f.)

This financial comparison highlights the initial investment needed for transitioning from firewood to biogas production through a biodigester. While the construction cost of the biodigester is higher upfront, it may offer long-term savings and sustainability benefits by reducing reliance on firewood and its associated costs over time.

Conclusion. To meet the energy requirements of the distillery, a daily biomass input of 72,000 kg is currently needed for the boiler. However, by implementing a steam boiler combined with a biodigester that uses 30% bagasse, the daily biomass requirement can be significantly reduced to just 10,940 kg.

This change not only guarantees a consistent supply of steam throughout operations but also there is a decrease in overall biomass consumption. The integration of bagasse-fed biodigesters thus presents an effective technical solution for fulfilling the energy demands of the distillery.

To follow up on this research, the following recommendations are suggested: study the efficiency and energy performance of the biodigesters, evaluate the environmental impact, and conduct a thorough study of pre-existing biodigesters.

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