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Feasibility of the energy use of residual sludge from the wastewater treatment plant of the poultry slaughter plant.

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Residual sludge from wastewater treatment plants is difficult to handle in Colombia, especially that produced in poultry slaughter plants in the department of Santander, because it is the largest producer of chicken meat in the country; The sludge is the result of wastewater treatment processes by physical and chemical methods, with

coagulation, flocculation, and sedimentation operations, especially using ferric chloride.

This treatment generates large amounts of sludge, which are difficult to manage, since many of them are taken to thermal processes to be dried and reduced, but this has high energy and economic costs, another form of treatment is final disposal in sanitary landfills, but transportation and final disposal costs are high; alternatively,

another approach was carried out, considering the treatment of sludge through anaerobic digestion, to determine the quantity and quality of biogas that can be generated in these bioreactors, which shows a good production of this biofuel, which can be used in the energy needs of poultry slaughter plants, this can reduce energy demand, reducing the use of fossil fuel used in boilers, also producing a sludge with a high concentration of nutrients to be used in agricultural fertilizer, this to improve performance environmental performance of this industry, the viability that we show shows the possibility of carrying out this strategy and having better energy and environmental performance. Residual sludge from wastewater treatment plants is difficult to handle in Colombia, especially that produced in poultry slaughter plants in the department of Santander, because it is the largest producer of chicken meat in the country; The sludge is the result of wastewater treatment processes by physical and chemical methods, with coagulation, flocculation, and sedimentation operations, especially using ferric chloride.

* 1. Introduction

The implementation of technologies and studies already developed of alternative energies, envisions a promising horizon in the Colombian industry, although these must be accompanied by policies and regulations that regulate and motivate their use in the industrial processes of the sector. Poultry farms have an outstanding presence in the country and in the department of Santander.

In the processes of the poultry sector, waste with an organic load is produced, which can be treated and used for energy generation, through the production of biogas through anaerobic digestion achieved in a reactor. Avinsa SAS, is the company in which this project will be developed, with the support of the University of Santander, within the support policies for industrial development in the department, this company produces 18 m3 of residual sludge daily from the industrial wastewater treatment plant (PTARI). Waste that must go through a subsequent drying process for its reuse as fertilizer or for its final disposal, natural gas is used as energy in the process for drying, highlighting that this fossil fuel is a priority use for the residential sector, and as will be evidenced later in the planning of the problem, the current state and the projection of demand for natural gas will gradually increase in the country, while the offer will decrease, due to the lack of discoveries of gas sources.

In this project, the use of residual sludge is proposed, this being characterized for the possible estimation of biogas generation through anaerobic digestion. To then carry out the design of a reactor that carries out the biological and physical-chemical processes of the reactions inside the device, where the working conditions, the kinetics of the reactions in anaerobic digestion, as well as the production and response will be simulated. in the generation of methane. To finally determine if the sludge drying process can be carried out from the production of energy that complements or replaces the use of natural gas.

* 1. Materials and methods

The technology proposed in this project includes the instrumentation for the control systems in the anaerobic digestion process, for which the availability of the same in the current market and the adequate use of these must be determined, since the conditions of the compound and the reactor are particular and not any instrumentation could be assigned to this project.

Temperature control: The sensor proposed for this control is a type J thermocouple reference 123610, which has a length of 12 inches, in addition to a protection head. Due to the contact of the sensor with the mud, a protection must be chosen, since the fluid is corrosive and would deteriorate it, for this reason a thermowell is selected. The temperature sensor must take the measurement to a controller that at the same time indicates the controlled temperature range, in addition to activating the passage of energy to the heating resistance.

As mentioned, the control includes a heating resistance that delivers energy to the mixture, to maintain the working temperature, for this an L-shaped device is selected, this due to the conditions of the sludge, and of the reactor, since this one has a mixer inside it.

pH control: For this controller, a sensor is defined that can meet the residual sludge, for this the reference HI1001 is selected, which resists the working temperature and the conditions of the sludge. This sensor is selected due to its working characteristics, which allow contact with organic compounds, proteins, and heavy metals. In addition, the probe has a glass body for use with aggressive chemical products and is also easy to clean (Hanna Instruments, “Characteristics Sonda de pH)

The sensor is compatible with the BL981411-1 controller, since it is from the same manufacturer, with a pH measurement range of 0-14 and contact for pump dosing, this controller is easy to install and manage for configuration and programming of the same (Hanna Instruments, “Characteristics Controlled de pH).

Agitation control: The device to be controlled in this segment comprises a vertical propeller agitator, which helps the mixture to be homogeneous and the temperature added to it to be distributed evenly in the sludge.

This system has a speed variator, according to the needs of the process, suggested to the manufacturer, in addition to a timer to adjust the work and rest times of the agitator, as well as the length of the shaft and the size of the propellers are given to the manufacturer. depending on the dimensions of the tank.

Gas pressure gauge: To carry out the measurement of the methane gas produced inside the reactor, it is proposed to use a sensor, which in turn is a pressure indicator, which allows activating the passage of gas towards the corresponding pipe, it also has signal outputs of 4 -20 mA and digital Modus as standard. Those that allow to connect it with a computerized system. All this previous instrumentation, proposed for the control systems of the CSTR reactor's own variables, are devices found in the national market, therefore there is the possibility of articulating these systems for the use of residual sludge in the production of methane, being the implementation of these is feasible from the technological point of view, since the reactor design part according to capacity will be proposed later.

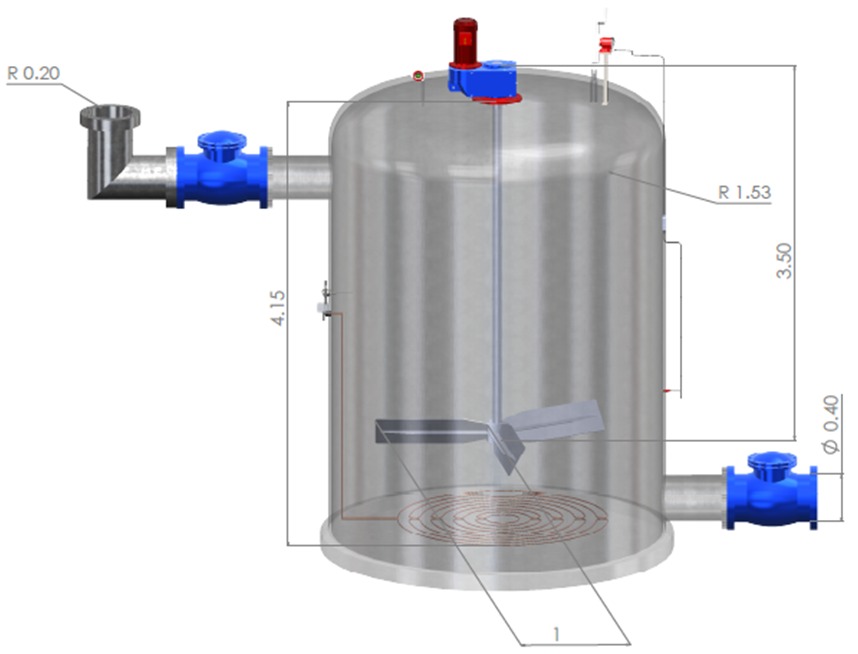
Carrying out the technical feasibility study of the bioreactor. Once the devices for the control of the digestion process have been selected, their cost will be determined, to be proposed in the implementation in a reactor, in addition to the cost of the tank arranged for said purpose. The values proposed in the construction of the reactor will be compared with the current final disposal cost, for which the BIO 0028-0119 proposal presented by the company Biodolos S.A. is presented. E.S.P. In which the cost of transport in a suction vehicle of 8 tons for treatment and disposal is manifested for a value of 570 pesos per kilogram of sludge.

Table 1: Final Sludge Disposal Colombian pesos

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| --- | --- | --- | --- | --- |
| Cost | Unit cost | Total cost |  |  |
| Daily Cost | 8000\*570 $/kg | 4’560.000.00 |  |  |
| Monthly cost | 8000\*30\*570 $/kg | 136’800.000.00 |  |  |
| Annual cost | 8000\*30\*12\*570 $/kg | 1.641’600.000.00 |  |  |

Once the fixed cost for the disposal of the residual sludge has been estimated, it is compared with the cost of construction and operation of the reactor, for which the cost of construction of the tank and of the instrumentation will be taken into account, for the first one a device is considered built in fiberglass reinforced polyester or metal covered inside with fiberglass, cylindrical 32,000,000 million pesos placed in Bogotá, + 7 million pesos in crane transportation for final location. On the other hand, the necessary instrumentation for the control of the process in the reactor, the meter and transmitter of methane gas, the pH controller, the temperature controller, and the agitation control will be considered.

To determine the design of the reactor, the amount of sludge from the PTARI will be considered, corresponding to 8 cubic meters of sludge per day. For the volume of the reactor, it is considered to propose a Volume of 24m3, with a hydraulic retention time of 3 days.



*Figure 1: Reactor*

The total costs of the construction of the reactor are estimated at a total of 91,462,181.

* 1. Results and discussion.
     1. Comparative analysis of the selected alternatives.

Initially, the comparative analysis of the selected alternatives for the residual sludge utilization process was proposed, where the reactors were categorized in a general way, based on the parameters defined by the type of flow and the operating criteria for the sludge control. of the variables of temperature, pH level and stirring time to homogenize the mixture. The reactors that were discarded at the beginning of the study were the RTDA and the RSCTA. The decision is made because both reactors do not allow the handling of a continuous flow, as required by the process.

As for the RFP, there is no longitudinal mixing, which prevents the process from performing anaerobic digestion adequately, lowering the level of efficiency in terms of methane production.

Once the previous reactors have been discarded, the CSTR is the one indicated to carry out the process, since it allows a continuous flow of the mixture in the process, although initially it works in a stationary process, while it performs a hydraulic retention that allows the mixture to activate the microorganisms present. This reactor also allows its automation, to control the process improving the active production of methane under recommended conditions, which were mentioned above. Regarding the continuous flow, it is considered that 8 cubic meters of sludge per day come from the PTARI, this parameter must be considered when calculating the reactor.

* + 1. Determination of the final design for the bioreactor construction according to its mechanical, electrical, variable control and automation composition.

From the volume of the tank for the previously calculated reactor, its composition is established considering the distribution of the parts that compose it for its correct operation, it should be noted that the following proposal is flexible to modifications for its possible construction, pretending suggest a proposal regarding the volume, instrumentation and attached devices to produce methane. A reactor with a sludge capacity equal to 24 cubic meters is proposed, made of carbon fibre with a stainless-steel alloy, with an upper inlet for the substrate in a pipe with a radius of 20 cm, coming from the PTARI and a lower outlet for the residue, said pipe allows the

passage of the sludge through solenoid valves activated manually or by level control arranged in the subsequent programming.

* + 1. Determine the energy potential of the generated biogas using Labview.

This must be established once all the information on the volume and conditions of the liquid present in the reactor has been determined. The device and its control variables are established from the instrumentation to be used:

•Temperature control.

• pH control.

• Agitation control.

•Pressure gauge.

In addition to the simulation that is proposed to be worked under the Labview platform, in which the control variables will be established, as well as the kinetics of the anaerobic digestion process, in its biological and physical-chemical reactions, to show the changes that have occurred with the variation of temperature, pH, agitation and COD.

To quantify the gas potential produced by the residual sludge, an experimental reactor from the Udes Environmental Engineering laboratories was used, in which the anaerobic digestion process was simulated. Mud was initially added with a hydraulic hold from September 20 to October 5. The experiment lasted a month, in which the device worked with the previously exposed control variables, with a capacity of 10 litters of sludge, the reactor has a mixer, which was activated for 20 minutes and left at rest for 40 minutes at through a timer. In the instrumentation it also had a temperature controller, to provide heat and maintain the mixture in a range of 50 to 55 ° Celsius. Finally, for the pH control, samples were taken manually to maintain the desired range. Figure 43 shows the device.

The production of Biogas and Methane resulting from the mixture can be seen in the following table, considering that the sludge was changed twice, for which a total of 30 litres was used. A total production of 107, 293 litters of methane and 168,290 litres of Biogas is indicated, which shows a high viability for the use of sludge. Considering an average production of 8 cubic meters of sludge, it can be stated that the daily production at similar conditions proposed in the reactor. In this way, it is established that for every 8 m3 of sludge, 85,834 m3 of CH4 would be produced at the proposed working conditions, that is, 10,729 times of the total sludge.

For every 8 m3 of sludge per day, 134,632 m3 of Biogas can be produced, that is, 16.8 times the amount of sludge, considering the capacity for both calculations, of a 10 L reactor, while for the proposed design they would be 8 m3 per day with a hydraulic retention of 2 days. Finally, a CH4 production of 10 m3 per m3 of sludge is estimated, which can be optimized by adjusting the work variables of the reactor.

Biogas and biofertilizer are considered final products for anaerobic digestion in systems with a high organic load and complete mixture. For the first, a mixture with two main compounds, methane, and carbon dioxide, in addition to other impurities, is proposed. It should be noted that if the biogas has a content greater than 45% methane, it is considered flammable (MINENERGIA/PNUD/FAO/GEF, “Manual de Biogás.” Santiago de Chile, 2011).

The harnessed energy potential of the residual sludge treated in the reactor has been determined previously, since the LabView platform does not allow such work to be carried out, therefore it has been used to create a simulation of the process carried out, controlling the following variables:

• Mix temperature.

• pH level

• Agitator working time.

In addition to the sludge level, as well as the control of the inlet and outlet valves to the reactor, an image of the process is shown below.

In the simulation, the control of variables can be evidenced on the left side, which can be adjusted according to its requirement, evidencing the temperature in a range between 50 and 54 ° Celsius, as well as a pH of 7 and finally the working time on and off the mixer.

The following figure shows the block diagram of the programming carried out in LabView, where the inputs are marked as valves, green inputs, these can be articulated to a data acquisition card, which communicates the instrumentation with the simulation to have control of it.

In the same way, the outputs can be connected through the acquisition card to control the proposed instrumentation of the system. Therefore, the simulation will serve to understand process control and as a proposal to be articulated with the instrumentation of the Bioreactor, having a complementary control of the variables that allow the production of methane.



*Figure 2: Simulation*

* 1. Conclusions

The variables of the residual sludge need a series of adjustments, due to the values ​​of pH, alkalinity, which are decisive to produce biogas with a high concentration of methane; For this, it is necessary to carry out a neutralization with low concentration NaOH, and an increase in temperature up to 50°C helps the generation of biogas.

Methane production is projected at 4664ml for 10 litres of sludge per day, considering the adjustments mentioned, considering the high COD of the residual sludge.

A versatile design was presented, proposed from the characterization of the residual sludge and the volume produced periodically, where a device with a capacity of 24 m3 was established, with a hydraulic retention time of two days for a CSTR Reactor, since it is necessary to evacuate the continuous flow of waste from the treated process.

The energy potential of the biogas generated, the experimentation was carried out in a scale reactor with a capacity of 10 litres, using the study sludge, a production of 10,729 times of CH4 was established on the amount of residual sludge treated. In other words, for every 8 m3 of sludge, 85,834 m3 of CH4 would be produced. For biogas, for every 8 m3 of sludge per day, 134,632 m3 of Biogas can be produced, that is, 16.8 times, obtaining for methane 807.8 – 875.1 kWh on monthly average, proposing an energy balance with the elements that consume the most energy. in the reactor processes, for which the agitator motor with 4 hp of power, which works for 20 minutes per hour, a consumption of 0.97 KW h is estimated.

The heating resistance can vary its behaviour due to environmental conditions, so the maximum consumption of 1 KW h is proposed, in this way the balance for methane, removing the most significant consumption of control of reactor variables, would be 805.83 - 873.13 kW h.

Useful for the use in the drying of the sludge for its final disposal since the annual cost of its treatment is 1,641,600,000 COP according to the Biosludge company.

While the cost of construction of the Bioreactor with the respective instrumentation would be 91,462,181COP, being a viable project since it would take advantage of the energy potential of a waste that currently has a high cost for its final disposal, in addition to allowing another uses to the treated substrate in the production of energy from energy use, as well as the reduction of energy consumption for drying the sludge and in the generation of a raw material for bio fertilizer and, most importantly, the contribution to the reduction of the carbon footprint left in industrial poultry production.

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