CHEMICAL ENGINEERING TRANSACTIONS

VOL. 79, 2020

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Enrico Bardone, Antonio Marzocchella, Marco Bravi

ISBN 978-88-95608-77-8; **ISSN** 2283-9216

DOI: 10.3303/CET2079081

Design and Simulation of Anaerobic Bioreactor, for the Energetic Use of the Residual Mud of the Wastewater treatment Plant of a Chicken Slaughterhouse

Epalza Jesús, Caro Oscar, Palomino Orlando

Universidad de Santander (UDES), Environmental Engineering, Bucaramanga, Colombia.
je.epalza@mail.udes.edu.co - manuelepalza@gmail.com

The poultry industry has the most formal employment in the region of Santander, Colombia and presents different challenges, especially in the energy part, because the prices of energy and fuels have high prices; In addition to this, it is a generator of residual sludge, especially in the processes of slaughtering birds for national consumption and export. This study shows the possibilities of the energetic use of residual sludge, by means of the implementation of an anaerobic bioreactor, which can generate biogas with high concentrations of methane, which can be used in boilers and other industrial uses.
This study analyses the flow of waste sludge from a slaughterhouse of chickens in the Bucaramanga metropolitan area, which slaughters sixty thousand chickens a day and has a wastewater treatment plant that operates with coagulation, flocculation, sedimentation and filtering using ferric chloride; According to the sludge flow, the bioreactor is designed and an operative simulation is made with the LabVIEW software, which allows to determine all the electronic control devices of the bioreactor, which will allow to maintain a constant temperature, a control on the income and expenses of the bioreactor and an operation very similar to reality, taking into account that this residual sludge has already been characterized and tested in a laboratory pilot reactor at the University of Santander.
This work deals with the implementation of an exploitation of biogas, derived from the microbiological activity of anaerobic microorganisms, to supply part of the fuel necessary for chicken slaughtering operations, besides this is a technological option for this industrial sector. The entire food industry in Santander, Colombia, has problems with sludge from wastewater treatment plants, but the use of this biologically derived fuel as part of its energy consumption has not been seriously explored. The methodology addressed gives us a clear vision of the true possibilities of the use of biogas in Colombia, because if you have different sources, but have not implemented plants that produce biogas for industrial use.

1. Introduction

The production of sludge from the waste water of the slaughter of the chickens, is a waste little used, different technological applications have already been made, for the use of this material, but generally they are expensive and not very friendly with the environment; for this work it was based on the production of residual sludge from a slaughter plant in the metropolitan area of Bucaramanga, because this area has several chicken slaughterhouses, and in this region of the country is where this industry has its highest production (FENAVI - FOUND AVICOLA, 2010).
In the normal processes of the poultry sector, a large amount of organic waste is produced (FENAVI - FOUND AVICOLA, 2010), which can be treated and used for the generation of energy, through the production of biogas through anaerobic digestion carried out in a reactor The companies of the sector have the support of the University of Santander, within the policies of support for industrial development in the department, said company produces approximately 8 m3 of residual sludge daily, from the industrial wastewater treatment plant.

Paper Received: 14 July 2019; Revised: 17 November 2019; Accepted: 17 February 2020
Please cite this article as: Epalza J., Caro O., Palomino O., 2020, Design and Simulation of Anaerobic Bioreactor, for the Energetic Use of the Residual Mud of the Wastewater Treatment Plant of a Chicken Slaughterhouse, Chemical Engineering Transactions, 79, 481-486 DOI:10.3303/CET2079081

This waste must go through a drying process to be reused as a fertilizer or to make the final disposal (MI Alfa, 2014), for the drying process natural gas is used as energy in the process, highlighting that this fossil fuel is of use priority for the residential sector, and as will be justified later in the planning of the problem, the current moment and the projection of demand for natural gas will gradually increase in the country (UPME Energy Mining Planning Unit, 2010), while the supply It will decrease, due to the lack of findings of gas sources.
This project proposes the use of residual sludge, being characterized for the potential assessment of biogas generation, through anaerobic digestion. And then carry out the design of a reactor that performs the biological and physical-chemical processes of the reactions inside the device, in which the working conditions, the kinetics of the reactions in anaerobic digestion (Batstone. DJ, 2002), as well as the production and response in the generation of methane gas, and finally establish whether the sludge drying process is achieved from the production of energy that complements or replaces the use of natural gas; The main objective of the present study is to be able to project a possible use of biogas and if possible a transformation towards biomethane, such as a biofuel (Scholz, 2013) (S.M. Ashekuzzaman, 2011) (Naja, 2011) (Naik, 2010).

2. Materials and methods

To perform a survey and simulation of the reactor, specialized software will be used, where the anaerobic digestion process will be visualized, as well as the entry and exit of fluids to the system, the production of gas and the control systems used in the production of biogas , this software will allow the management of a graphical interface, allowing visualization in the gasification process, for which LabVIEW has been determined to be used. Being a tool With a graphical programming syntax that makes it easy to visualize, create and code engineering systems, LabVIEW, being able to reduce test times and offer analysis of situations caused in the reactor from simulation from a state machine, In graphic programming language, it allows controlling the proposed process (National Instruments, 2016).

STAGE 1: Analyse the flow of residual sludge from the industrial wastewater treatment plant, determined daily volume and flow.

At this stage, an analysis and quantification of the waste produced by the treatment plant will be carried out, the mud will also be characterized, that is, the components of said sludge will be determined in order to determine the capacity of this to produce biogas.
A suitable solution to reuse sludge, among these are the quantification of the different gases generated by anaerobic digestion (Hamed M. El-Mashad, 2004), this is a multi-step bioprocess, where organic matter is converted into compounds simpler without the intervention of an acceptor of external electrons, such as oxygen or nitrates, produced in the bioreactor. In an anaerobic digestion system that aims to have a biologically active environment (Cantrell, 2008), taking advantage of residual sludge to produce methane gas. The information for the development of the project will be extracted from the measurement of the kinetic and operational conditions of the sludge bioreactor (Kayhanian, 1996). In the development of this item, a series of analytical methodologies must be implemented, which need the measurements of the COD, BOD, Volatile Suspended Solids, Alkalinity, pH, Methane, Biogas Volume, Temperature variables, these measurements are made with appropriate methodologies (American Public Health Association, 1995).

Table 1: Parameters of residual sludge.

Parameter	Method	Value	Unity
Total solids	AWWA 2540	92,7	%
pH	HACH 8156	5,73	
Alkalinity	HACH 8203	36.800	mg/l
Volatile Fatty Acids (VFA)	HACH 8196	28.000	mg/l
Chemical Oxygen Demand (COD)	HACH 8000	102.000	mg/l
Chloride	HACH 8207	24.266	mg/l
Sulphide	HACH 8131	60	mg/l

(Vanessa Suarez, 2018)

Table 1 presents the variables evaluated and the techniques used in their analysis.

STAGE 2: Design the anaerobic bioreactor for biogas production, according to the characteristics of the residual sludge.

A reactor is a vessel or system that is designed and used to produce chemical and biological reactions, which involves biochemically active organisms or substances derived from these organisms (Diaz Baez María, 2002).
For this project a mechanism is needed, which can constantly receive waste sludge from the industrial wastewater treatment plant, for this the digester is composed of a fermentation tank, a temperature control system, a system of homogenization of the mixture (stirring), a pH control system, a waste outlet system and a biogas outlet system. Anaerobic digestion of organic matter is a process of decomposition in total absence of oxygen, where CH_4 methane gas is produced, with concentrations greater than 60% that can have a calorific potential below 5500 Kcal / m^3 (MIAlfa, 2014) (Mbatia, 2011). One of the most important criteria that must be considered for the design of the reactor is determined from the type of waste and its composition, which in this case is mud (Kato, 1997).
The reactors are classified in a general way in two systems, according to the phases of operation and the simultaneous or sequential form of operation, which can be classified as continuous, semi-continuous and discontinuous (Bruce Rittman, 2001) (Barba Juan, 2014). The former work initially in a stationary regime, later when they level the mixture, biomass can be added continuously, and they can carry out large-scale reactions, while discontinuous ones handle small-scale reactions. They are also classified according to the flow model and the contact with the mixture, called full-mix or stirred tank reactors and continuous tubular reactors.
In this case, we will work with the Continuous-Stirred Tank Reactor (CSTR), since it is the most suitable because it works with mud, while the others work with mixtures such as wastewater and dry mixtures (Bruce Rittman, 2001) (Beard Juan, 2014). The CSTR reactor consists of an excellent agitation tank that ensures a uniform mixture throughout the system, initially a steady state must be reached, that is, the flow rate entering the reactor must be equal to the flow rate leaving and thus prevent the tank from being empty or overflowed. To measure the residence time of the mixture, the volume of the tank must be divided by the average volumetric flow rate. For example, if the inflow is 8 m^3 / d and the volume of the tank is 2 m^3, the residence time is 2days.

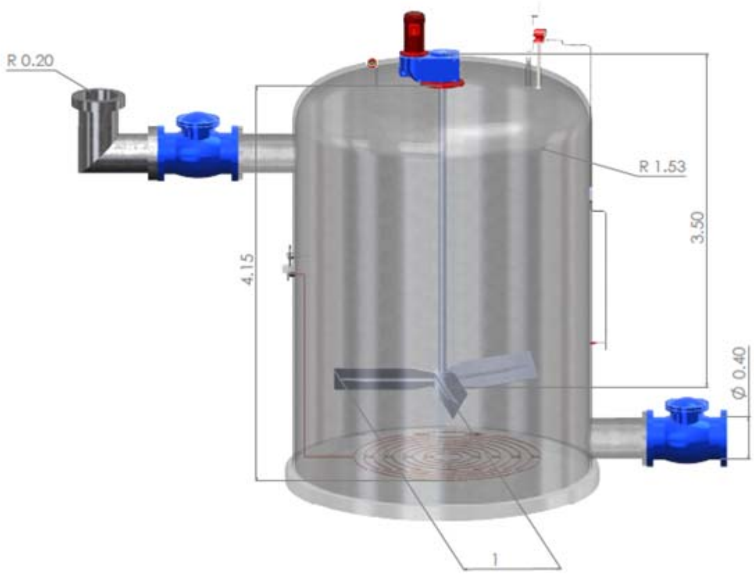

Figure 1: Reactor

Reactor Volume: The current tank residue is 8 m^3 and the hydraulic ratio is 2 days for this process; for the calculation of the reactor volume.

$$Rv = Hrt * Q \quad (1)$$

Hrt = Hydraulic retention time [days]
Q = Flow rate [m^3 / s]

$$Q = 8m^3/d \quad (2)$$

$$Hrt = 2\ d \tag{3}$$
$$Rv = 8m^3/d * 2d = 16m^3 \tag{4}$$

Reactor volume total = Rv*Bf
biogas factor (Bf) = 1,5

$$Rvt = \ 16m^3 * 1{,}5 = 24m^3 \tag{5}$$

With the previous calculations it is decided to make a 24 m^3 tank, cylindrical, suitable with a main stirrer, which will receive power from an engine, with 80 to 120 revolutions per minute, together with a spiral resistance for heat exchange.
To perform the simulation, it is necessary to control different variables; in this case we determine to measure temperature, pH, Agitation and Pressure; To perform this task, different sensors are determined, which are:

Temperature: Temperature sensor, Temperature controller.
pH: pH sensor.
Agitation: Engine, agitator, speed meter.
Pressure: Pressure gauge.

When stirring the residual sludge, the mixture becomes homogeneous, optimizing the digestion of organic waste, which helps to generate the gas inside the empty cavity of the bioreactor, which is more or less than 30% of the total volume of the tank Due to this, the gas does not have to expand, therefore, the pressure increases as it is produced, for this reason a monitoring and analysis of the volume of production must be carried out from the increase in the pressure within the reactor.
To obtain pressure data it is recommended to use a PT124B210 reference ZHYQ sensor, which handles a range from -1 to 2000 bar (-14.5 to 29,007.55 psi), and with a temperature range between -20 ° C and 80 ° C. All are loaded for the LabVIEW system to detect and read, interpreting and controlling.

STEP 3: Create the simulation of the bioreactor gasification process.

At this stage it will be shown graphically and through simulation through the labVIEW program, which shows the process step by step of the process that will be performed to obtain natural gas in the treatment plant.

3. Results and discussion

The process begins by opening the valve that allows the sludge to enter the reactor tank, having as a parameter the level of sludge that is in the tank since this can have residues from previous processes or is completely empty, this valve will allow filling At a level previously established on the control board, when the mud level reaches the stipulated level, the mixer is immediately started, which in this case is an electric motor which will be in charge of homogenizing the mixture (mud).
By measuring the internal temperature of the reactor and taking into account the ideal temperature in the process, it is usually necessary that the temperature of the mud increases, a heating resistance will be activated that will cause the mixture to increase in heat causing an acceleration of the composition of the sludge and subsequently reach the generation of methane gas which is the purpose of the project.
Throughout the process, the gas pressure sensor will be censoring to be able to control the volume of gas generated, in order to maintain the maximum pressure, set on the control board. Additionally, the pH sensor will be responsible for maintaining the mixture with the appropriate alkalinity levels controlled by a peristaltic pump that is responsible for adding alkaline agents to keep the mud mixture at its ideal point which will lead to the generation of biogas.
If the mixture had a low PH level, the control system would trigger an electro valve that adds alkaline agents (AGV, sulfates, sulphides, chlorides) to the mixture to obtain the established levels. The process ends when the moisture in the mud is reduced; The mixer is turned off together with the heating resistance and the evacuation gate opens to extract the residue which could be used in different activities than the company to which the study is being carried out, which in this case is have previously established.

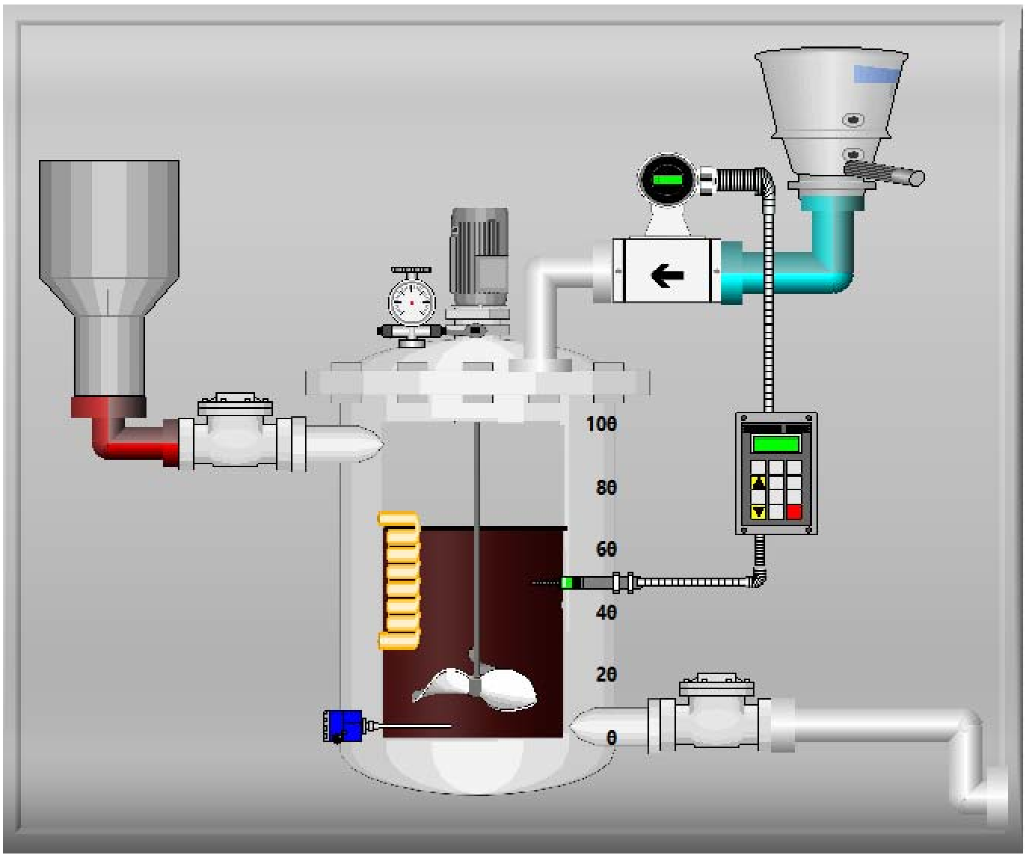

Figure 2: Reactor viewer in labVIEW software

4. Conclusions

The bioreactor's conceptual design is aimed at having an anaerobic digestion process, controlling the main variables of biogas generation.
The simulation was carried out to have a software writing in LabVIEW, which can receive the data from the sensors and manage substances and heat, that maintain the conditions of biogas generation in a stable way.
For this project, LabVIEW was selected as a simulation tool, because it allows visualizing the process through a graphical interface, in addition to being proposed the simulation to be interconnected with the instrumentation selected in the project through signal acquisition cards, remaining this project as a sustainable alternative of energy production for the Colombian poultry industry.

Acknowledgments

We thank the University of Santander for supporting our research and the company Avinsa SAS, for helping us with the necessary samples and teaching us about the chicken slaughtering process

References

American Public Health Association. (1995). Standard Methods. Whashinton, D.C.: American Public Health Association.
Barba Juan, C.T.(2014).Reactores Químicos y Bioquímicos. Castellón: Publicacions de la Universitat Jaume I.
Batstone. D. J., K. J. (2002). The IWA Anaerobic Digestion Model No 1 (ADM1). Water Science and Technology, 65-73.
Bruce Rittman, E. M. (2001). Biotecnología del Medio Ambiente, Principios y Aplicaciones. Madrid: Mc Graw Hill/Interamericana.
Cantrell, K. B. (2008). Livestock waste-to-bioenergy generation opportunities. Bioresource Technology, 7941-7953.
Diaz Baez María, E. S. (2002). Digestión Anaerobia. Bogotá: Universidad Nacional de Colombia.

Fenavi - Fondo Avicola, N. (2010). Estrategia Competitiva y Sostenible de la Industria Avícola en Santander. Bucaramanga: Cámara de Comercio de Bucaramanga.
Hamed M.El-Mashad, G. W. (2004). Effect of temperature and temperature fluctuation on thermophilic anaerobic digestion of cattle manure. Bioresource Technology, 919-201.
Kantachote, D. C. (2008). Selection of sulfur oxidizing bacterium for sulfide removal in sulfate rich wastewater to enhance biogas production. Electronic Journal of Biotechnology, 225-233.
Kato, M. T. (1997). Anaerobe Tolerance to Oxygen and the Potentials of Anaerobic and Aerobic Cocultures for Wastewater Treatment. Brazilian Journal of Chemical Engineering, 590-598.
Kayhanian, M. &. (1996). Development of a Mathematical Model for the Simulaiion of the Biodegradation of Organic Substrates in a High-Solids Anaerobic Digestion Process. Water, 312-322.
M.I.Alfa, D. S. (2014). Assessment of biofertilizer quality and health implications of anaerobic digestion effluent of cow dung and chicken droppings. Renewable Energy, 681-686.
Mbatia, B. N. (2011). Valorisation of fish waste biomass through recovery of nutritional lipids and biogas. Biotechnology., 123-131.
Mohd.Yusof Hj.Othman, B. M. (1996). Chicken dung biogas power generating system in Malaysia. Renewable Energy, 930-933.
Naik, S. N. (2010). Production of first and second generation biofuels. A comprehensive review, 578-597.
Naja, G. M.-J.-P. (2011). Assessment of biogas potential hazards. Renewable Energy. Renewable Energy, 3445-3451.
National Instruments. (2016). LabVIEW 2016. New York: National Instruments.
S.M.Ashekuzzaman, T. G. (2011). Optimizing feed composition for improved methane yield during anaerobic digestion of cow manure based waste mixtures. Bioresource Technology, 2213-2218.
Scholz, M. M. (2013). Transforming biogas into biomethane using membrane technology. Renewable and Sustainable Energy Reviews, 199-212.
Unidad de Planeación Minero Energética UPME. (2010). PLAN INDICATIVO DE EXPANSIÓN DE COBERTURA DE ENERGÍA ELÉCTRICA 2010-2014 . Bogotá: UPME.
Vanessa Suárez, L. A. (2018). Study of the energy use of biosolids from a chicken slaughterhouse wastewater treatment plant. CHEMICAL ENGINEERING TRANSACTIONS, 1-6.
Ziemiński, K. &. (2012). Methane fermentation process as anaerobic digestion of biomass: Transformations, stages and microorganisms. African Journal of Biotechnology, 4127-4139.