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Study of the Energy Use of Biosolids from a Chicken Slaughterhouse Wastewater Treatment Plant

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The poultry industry in Colombia faces operational and environmental challenges, one of these is the integration of residual biosolids in other processes, which may generate a direct or indirect benefit within their production. This study shows the results obtained in the anaerobic treatment of the residual biosolid of the wastewater treatment plant of a chicken slaughtering plant; This biosolid is the result of the coagulation, flocculation and sedimentation process with ferric chloride, as main coagulant and possible flocculating substances in the process. The anaerobic treatment of biosolids is carried out in a CSTR bioreactor, with a capacity of 10 litres, inside the bioreactor the system is started, and different variables are monitored, such as pH, volatile fatty acids, alkalinity, sulphates , chlorides and chemical oxygen demand, which will determine the transformations of organic matter within the bioreactor, additionally biogas measurements resulting from anaerobic digestion are made, the gases analysed are methane, hydrogen sulphide, carbon monoxide and oxygen, which determine the quality of the biogas produced, together with the volume produced of biogas with respect to the volume of biosolids deposited in the bioreactor. This seeks to determine the productive capacity of the biosolids, to be stabilized and exploited energetically, considering that biogas is a usable biofuel and the resulting biosolid is a good raw material to produce organic fertilizers, destined to the agricultural production of animal feed.

1. Introduction

Poultry production in Colombia has a high participation in the economy, especially in the Santander region, where it is the first employer in this region of the country (Cámara de comercio de Bogotá, 2009). This economic activity has different stages, which are divided into raising and fattening the chickens, slaughtering animals and then distributing and selling raw chicken to supply the domestic and industrial needs of the country, with export capacity to neighbouring countries (NATIONAL, 2010). In this study emphasis is placed on the chicken slaughter process, because this activity produces a high amount of wastewater, from which high amounts of residual sludge are derived (NACIONAL, 2010), which are disposed in landfills, producing a high expense in its collection, transportation and final disposal of this material (GSDTAA.Superintendencia delegada para acueducto, alcantarillado y aseo, 2012). The residual sludge generated from the wastewater treatment processes of chicken slaughtering plants has a high contaminant load, in terms of COD and BOD, which are not used efficiently, due to their disposal in landfills; this is why the anaerobic treatment of sludge is carried out in a reactor, to establish parameters for the consumption behaviour of the organic matter of the residual sludge, also called biosolids; in Colombia there is legislation for biosolids (Decree 1287 Ministry of Housing, City and Territory, 2014), which allows them to be used in different ways, with processes that can transform them into new raw materials for other economic activities, such as agricultural use and other uses, according to their composition and origin (Environmental Protection Agency EPA, 2000). In this study, a prefect mixing reactor is fed with the biosolids, to perform a start in batch, which will allow observing the behaviour of the biosolids to produce biogas, and to monitor different control parameters, which will determine their kinetics. consumption of organic matter and its subsequent need to be fed continuously, to establish the operational behaviour of the reactor (Mbatia, 2011).

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The residual biosolids we use are the result of wastewater treatment, with a coagulation, flocculation and sedimentation method, carried out with ferric chloride, in the wastewater treatment plant of the chicken slaughtering plant; This wastewater comes from the slaughter, evisceration, discard and chiller stages, from which wash water comes out with detergents and the use of some disinfectants. The proposal that is made in the study is to propose an energetic use for the residual mud, and consists of transforming the organic matter of the biosolid into biogas, which can be used as fuel (Cantrell, 2008), additionally the digestion of the biosolids provides biological improvements to biosolids, to be used in agricultural work (Naik, 2010), changing the traditional final disposal in sanitary landfills, for two uses for the same raw material, energy use (Dublein Dieter, 2008) and a possible agricultural use.

2. Materials and Methods

The research lasted eighteen weeks, during which daily samples of pH, alkalinity and volatile fatty acids were taken in triplicate; weekly samples of chemical oxygen demand; and a single sample of total suspended solids from the wet mud and the drained mud on the first day. In order to carry out the analysis of the control parameters, their incidence within the anaerobic digestion process was considered, and the processes from which the biosolids are derived.

Table 1: Parameters analysed.

Parameter	Method	Periodicity
Total solids	AWWA 2540	One
pH	HACH 8156	Daily
Alkalinity	HACH 8203	Daily
Volatile Fatty Acids (VFA)	HACH 8196	Daily
Chemical Oxygen Demand (COD)	HACH 8000	Weekly

The essays were done with HACH methodologies, following the methodologies validated with Standard Methods (HACH, 2000) (American Public Health Association, 1995). Experimentation with biosolids was carried out, with a high humidity biosolid, it can be said that the input essays were performed on two types of biosolids, the first one a high humidity sludge, which was used to feed the reactor, the other biosolid corresponds to a drained sludge with less humidity, produced by a filter press, in the chicken slaughtering plant. The monitoring times of variables are determined by what is suggested in the anaerobic digestion process (María Díaz Báez, 2000) (Ertola R., 1994), both in the hydrolysis, acidogenesis, acetogenesis and methanogenesis phases (Bruce Rittman, 2001), and taking into account what is suggested in the ADM1 model (Batstone, DJ, 2002). The reactor was conditioned, to contain 10 litres of biosolids, with 5 litres of space for biogas, with a temperature control, which was programmed at 50 ° C, to take advantage of the capacity of the thermophilic bacteria and a good desorption of the biogas , the agitation of the reactor was programmed in one hour of activity for one hour of rest, the reactor has internal deflectors to increase the level of mixture, with a speed of 170 revolutions per minute. The reactor was fed after measuring a very low amount of COD, with significant differences in pH, alkalinity and volatile fatty acids. In addition to the monitoring of biosolid control variables, biogas measurements were taken, in which biogas was considered, the percentage of methane measured with a GK-2009 RKI gas meter and the approximate percentage of CO2, these measurements were carried out in week 5 after the start of the reactor, when checking in the manometers a slight positive pressure of biogas.

3. Results

The results obtained from the monitoring of the anaerobic reactor are shown in several stages, in the first stage the analytical conditions of the wet sludge and the drained sludge are shown, making it clear that the biosolid used corresponds to the wet one. The initial conditions of the mud show a very humid biosolid, with high concentrations of COD, high volatile fatty acids and an alkalinity that allow a good anaerobic digestion (Schomaker, 2000), with high chlorides derived from the use of the coagulation process with ferric chloride. The pH shows an initial behaviour of values between 5 and 6, which are normal under reactor starting conditions, since a large amount of hydrolysis of the organic matter is being carried out. In the behaviour of the graph we can see a pH stability over 7 and in its last part a pH fluctuation is observed, after some injections of bicarbonate and NaOH, to maintain a neutral pH, and it is also related to the feeds of the reactor with new mud in the last phase of the monitoring, the average pH throughout the experiment was 6.4.

Table 2: Mud data at the beginning.

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

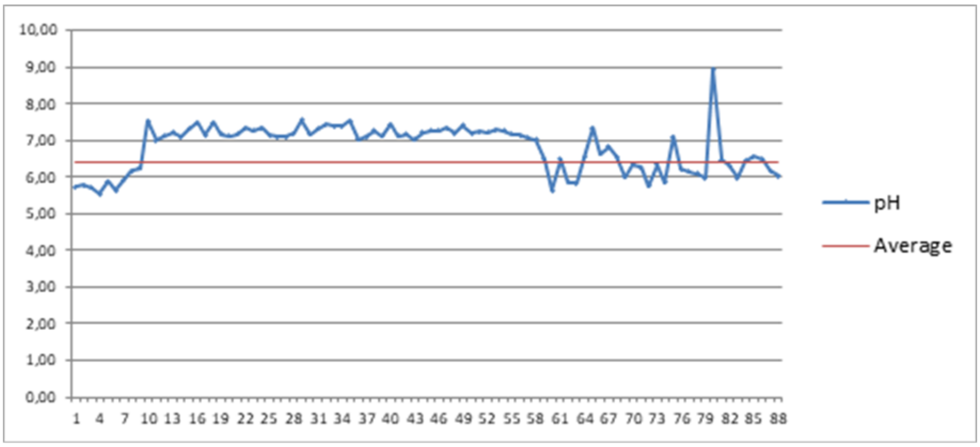

Figure 1: pH

The behaviour of the COD was carried out weekly, and it was established that the initial load of more than 100,000 mg / l of O2 and began to decrease, reaching levels below 10,000 mg / l of O2, after this was carried out a feeding with mud of high content of organic matter as observed in the last measurement, the average COD was 59,098 mg / l of O2.

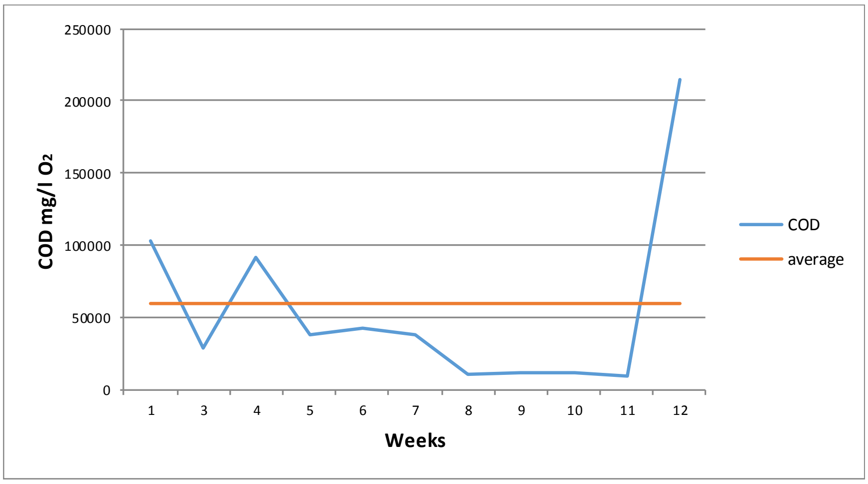

Figure 2: Behaviour of chemical oxygen demand COD

The volatile fatty acids show a decrease and then recover when the phases of acidogenesis and acetogenesis are activated in the metabolism of the bacteria involved in anaerobic digestion (Ziemiński, 2012), then there is a new decrease, which is restored with the addition of new sludge with high amounts of organic matter, the average of volatile fatty acids is 19,100 throughout the process.

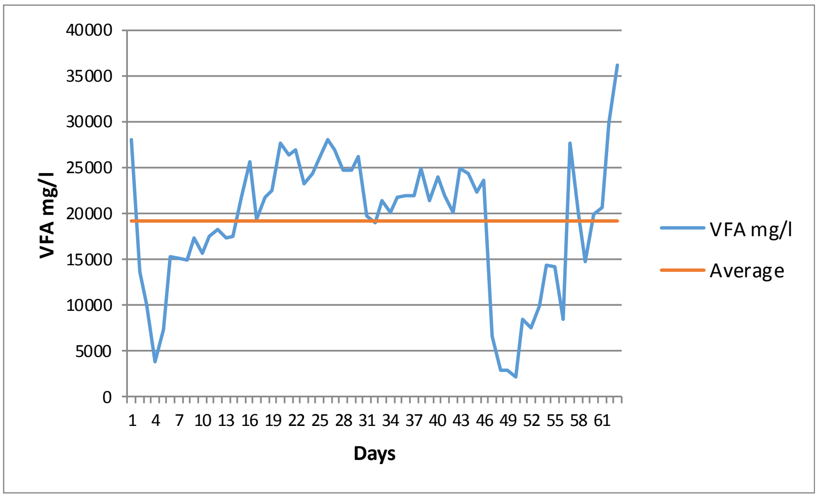

Figure 3: Behaviour of volatile fatty acids VFA

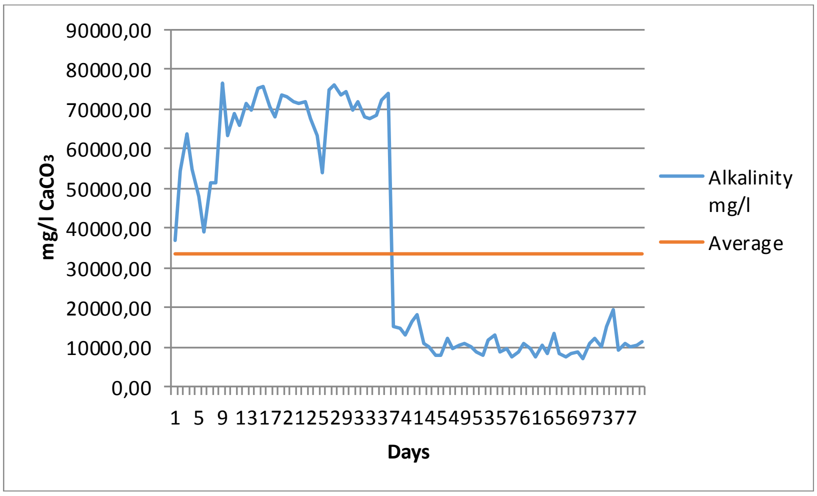

Figure 4: Behaviour of alkalinity

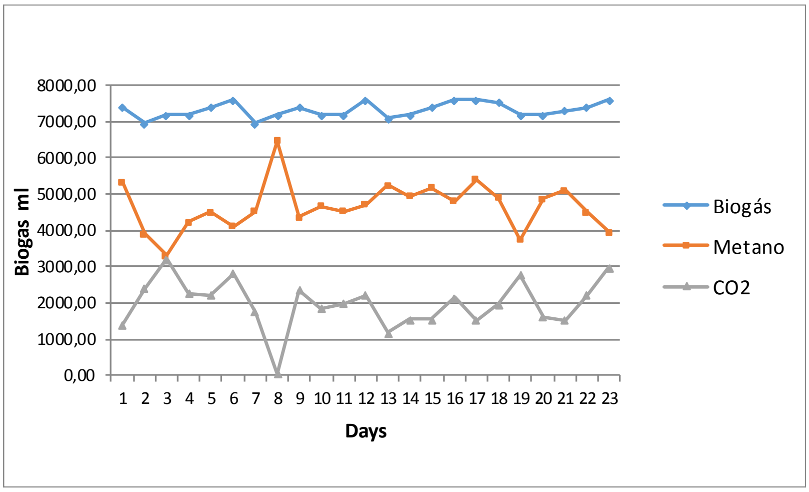

Figure 5: The production of biogas

The alkalinity shows an ascending behaviour, in the first part of the process, but it does not reach to recover significantly, with the additions of bicarbonate and NaOH made after the decrease of alkalinity (Kayhanian, 1996).
The production of biogas is shown throughout the monitoring period, during which a production between 5900 ml and 7800 ml was maintained, derived from different reactor conditions; this monitoring was carried out after the start-up and stabilization of the variables of pH, alkalinity and volatile fatty acids; the amounts of methane in the biogas fluctuated between 52% and 90%, with an average of 63.7% of methane present in the biogas, the other majority gas CO2 fluctuated in an antagonistic manner, and there were H2S concentrations, which they did not reach 500 parts per million inside the biogas.
The behaviour of the reactor with the biosolid shows a start behaviour in batch and after variations in the measured variables, a stability is presented, as can be presented in reactors that are fed with cattle or swine manure (Anja, 2011) (Schomaker, 2000).

4. Conclusions

The biosolids derived from the slaughter of chickens is a good raw material to produce biogas with high concentrations of methane, which makes it possible to use it as a biofuel.
The consumption of organic matter in the mud is sustained and the mineralization of pollutant compounds from the mud is carried out, this makes possible a new use for this sludge digested in anaerobic digestion.
The production of biogas with good concentrations of methane, can provide an alternative for the energy use of this residual biosolid (Osorio, 2009) l, for this it is necessary a gas cleaning process that eliminates the accompanying gases, to improve its heat capacity of biogas (Naja, 2011) (Lansing, 2007).
The biosolids of chicken slaughtering plants can be considered within the options of energy use (Scholz, 2013), by anaerobic digestion, but additional studies are needed, which consider the quantities of biosolids produced in the Santander region and their potential energetic.

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