

MODELING, SIMULATION AND CONTROL OF ANAEROBIC FERMENTATION OF WASTEWATER

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ABSTRACT

This research work was carried out for the purpose of modeling and simulation of temperature control in the anaerobic fermentation of waste water in a bioreactor or controlled fermentation reactor. Research carried out at the Professional School of Agroindustrial Engineering of the National University of Moquegua, Peru. It consists of using the LabVIEW software from National Instrument that allows graphic programming without the need for a programming specialist. Temperature control is applied in the on/off mode, which has control of the minimum and maximum temperature based on a Set point, where if the Set point value is modified, the minimum and maximum temperature is automatically modified. . For this, an analog temperature sensor is used, which is Lm35, which in this case is simulated and is an input variable and the output variable is the system cooler. In the block panel, a While Loop cycle is created for the installed indicators, the voltage to temperature converters are created. A SubVI is opened for the Lm35 to temperature converter. Using all this instrumentation, it was possible to carry out the modeling, simulation and temperature control in the bioreactor for the anaerobic fermentation of waste water, obtaining the results expected by this research using the LabVIEW software.

KEYWORD

Modeling, Simulation, Bioreactor, Fermentation, Programming.

I. INTRODUCTION

In works carried out by [1], they are concerned that companies should do research for efficient and productive production without contaminating the environment, that is, with automated controls. Improvements must be made in waste treatment by implementing recycling and reuse strategies adapted to the company's specific operations. They must include the reuse of treated wastewater in secondary processes or the reuse of key materials within their production chain.

Nomenclature**Abbreviations**

Set point ; It is the desired value of a control variable, such as temperature, pressure, or speed, that the system attempts to keep constant by regulating the energy input.

LabVIEW ; Laboratory Virtual Instrument Engineering Workbench

pH ; Hydrogen ion concentrations

mg/L ; Milligrams per liter

mV ; Milli volts

w/w ; Weight to weight ratio

Shift registers; Type of digital circuit using a cascade of flip-flops

While Loop ; Repeats a code for the duration of a certain condition.

SubVI ; Subroutine in text-based programming languages.

CO₂ ; Carbon dioxide

In a research carried out by the authors[2], in "Optimization of the anaerobic fermentation process for phosphate release using food waste" where experimenting with domestic sludge and others, they achieved high performance with the addition of 10% of food waste and working at a temperature of 45°C, reaching a pH of 5.30, and where releasing 371 mg/L P in 10 days. This offers benefits in cost reduction and respect for the environment.

In the anaerobic fermentation at a temperature of 55°C, greater efficiency is obtained in the product than when working at a temperature of 25°C, giving the fermentation of carbohydrates, where fatty acids predominated and in the efficiency of the bioconversion of waste from foods with greater than 77% w/w of carbohydrates, greater than or equal to 10 in the carbohydrate/protein ratio and high content of soluble matter with which the anaerobic fermentation of specific fatty acids in the composition of the foods could be predicted. food waste, these results are presented in the research work carried out by the authors[3], [4], [5]. So we can say that it is important to control the temperature in anaerobic fermentation.

In work carried out by[6], they were able to maintain a constant temperature in anaerobic digestion (37 ± 0.5°C) in the experiment system or module with circuit installations with feedback adjustment and reception signals, with which they control the release of cold or hot water to the experiment system to maintain the desired temperature in the process. Where they also demonstrated the variation and stability of pH in the anaerobic digestion system as seen in Figure 1.

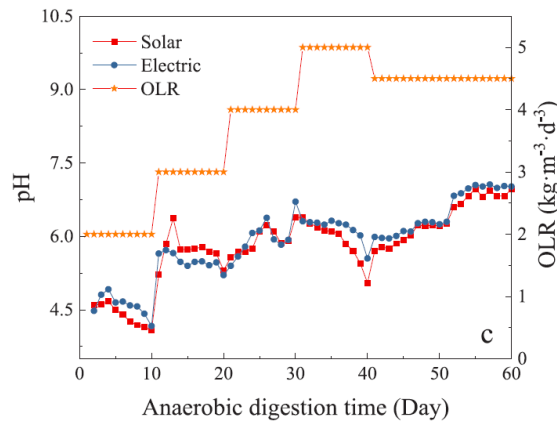


Figure 1. pH change of the fermentation liquid in the whole AD. Source: [6]

In research work of "Two-stage anaerobic digestion of food waste: Enhanced bioenergy production rate by steering lactate-type fermentation during hydrolysis-acidogenesis" carried out by the authors [7], where they used a bioreactor system controlling the temperature ($36 \pm 1^\circ\text{C}$) of anaerobic digestion, in which they obtained expected results in the production of energy with the use of food waste, and in which it can be concluded that the temperature control of the process is very important in any anaerobic fermentation process.

The researchers [8], in their research work "Modeling and simulation of anaerobic wastewater treatment and its application to control design: case whey", developed a model using five different groups of components for one- and two-stage fluidized bed anaerobic fermenters, with pH as the main variable, the model studied was to describe the dynamic behavior and steady state of the fermenters considering system control schemes. They conclude that the simulation helped them in reducing experimental efforts for the configuration and evaluation of the controller in the fermentation system.

A new approach is used to control an alcoholic fermentation system and this is with the in-depth application of the analysis of the acoustic emissions product: A preliminary assessment" carried out by the authors [9], they demonstrated good results to characterize and describe the control of temperature and CO_2 production in a laboratory scale reactor for 8 liters using *Saccharomyces cerevisiae* as inoculum, to carry out automatic control and process results simultaneously they used LabVIEW and Matlab software.

In the Production of fermentative hydrogen through a real-time fuzzy logic controller, work that was carried out by researchers[10], they use LabVIEW software for real-time monitoring and control in hydrogen production fermenters, where the fermenters controlled with fuzzy logic in LabVIEW presented an increase of 13.44 liters per day purchased with another fermenter not controlled with fuzzy logic and whose production was 3.12 liters per day, much lower in relation to the previous system,[11].

In "Design and simulation of a greenhouse in a computational environment (ANSYS/FLUENT) and an automatic control system in a LABVIEW environment" research work carried out by[12], they use fuzzy logic in LabVIEW software and Arduino hardware to control the temperature of a greenhouse with expected results in terms of real meteorological data in which they tested Four different controllers simulated thinking.

In the research work “Simulation in the temperature parameters control in the yogurt manufacturing process” carried out by [13], using LabVIEW software from National Instruments for the simulation and control of temperature parameters in the process of yogurt production, pasteurization, cooling to 45°C, fermentation, coagulation and cooling, thereby obtaining numerical and graphical data of the process. In this work he showed that modeling and simulation was possible in the control of temperature and time in the yogurt coagulation process.

In a simulation of parabolic solar panels for the purpose of generating thermal and electrical energy, they used the National Instrument LabVIEW software with the NI6009, where they predicted the generation of solar energy, the need for electricity and simulated the energy to heat water, for air conditioning and electricity for 20 rooms of a hotel, obtaining the expected results according to the authors of the research [14].

The LabVIEW software was used by researchers [15] to control an acceptable number of devices with different hardware and show the ease of additional modifications of any hybrid system, since block programming in LabVIEW facilitates its development without the need from a specialized programming expert.

II. Objectives

Modeling, simulation and temperature control in the anaerobic fermentation of waste water in a bioreactor and using LabVIEW from the National Instrument.

III. Material and Methodology

The research work has been carried out in the Laboratory or computer workshop of the Professional School of Agroindustrial Engineering of the National University of Moquegua, in the country of Peru.

Using the recommendations found in the works of researchers [16], first a bibliographic review is carried out on the anaerobic fermentation of waste water in an anaerobic bioreactor with the controllable variable of temperature and time, for which the software is used of LabVIEW from National Instrument for being a software that is easy to program in graphics without the need for a programming specialist.

In our research work, temperature control is applied in the on-off mode, recommended based on the author's work [17], which has the control of minimum temperature and maximum temperature based on a Set point, in where if the Set point value is modified, the values of the minimum and maximum temperature are automatically modified. The Lm35 was used as a temperature sensor that, with recorded values, was considered as the input variable and as an output variable in the system, the operation of the cooler that must regulate the desired temperature in the system for the control of coagulation.

For this, a program is created on the LabVIEW front panel installing the cooler, the Lm25 temperature sensor that delivers the value of 10mV for each degree Celsius (GC) and it can be expressed that 1GC is equal to 10mV, 10GC equal to 100 mV, therefore, 100GC is equal to 1V or 1000mV.

A virtual thermometer is installed to read the temperature and the device to program the Set point value.

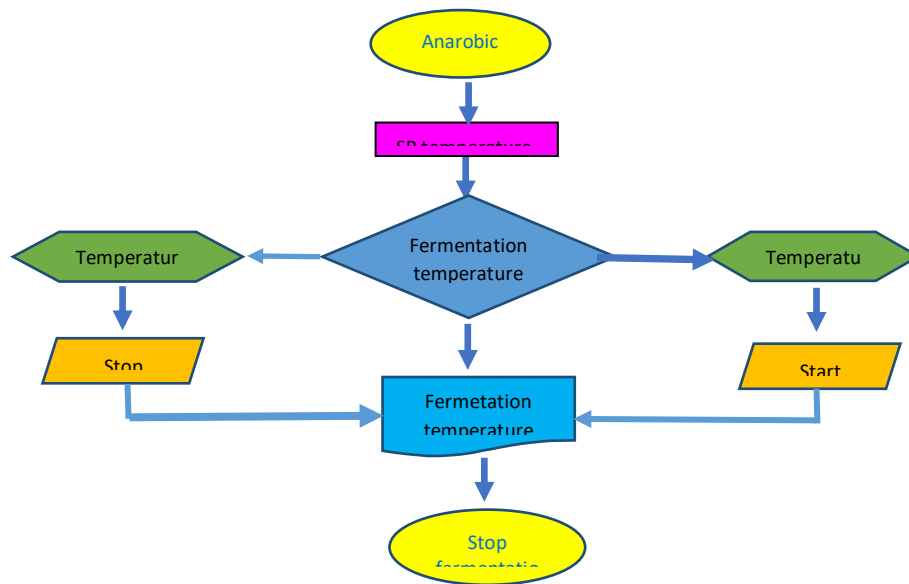


Figure 2. Flowchart of the simulation of temperature control in the anaerobic fermentation of waste water.

In the block panel, a While Loop cycle is created for the installed indicators, the voltage to temperature converters are created. A SubVI is opened for the Lm35 converter at temperature, a system power button is inserted. A shift register was installed to maintain a minimum and maximum temperature in the fermenter. A brief description of the system condition guidelines is presented: When the temperature in the system is higher than the maximum programmed temperature, the cooling system automatically turns on. Now when the system temperature is lower than the minimum programmed temperature, the cooling system automatically stops working.

Anaerobic fermentation can be carried out at different temperatures, which is very important in the growth rate of methanogenic bacteria:

When it is carried out below 25°C it is called psychrophilic, when it is from 25 to 45°C it is called mesophilic, and when it is developed at more than 45°C it is called thermophilic. The efficient energy balance in anaerobic fermentation must occur between temperatures of 25°C to 40°C. The efficient pH in the anaerobic fermenter should be between 6 and 8 units.

Simulation

For the simulation for temperature control in the anaerobic fermentation of waste water, it will begin with the Set point value of 30°C, and the limits are $\pm 5^\circ\text{C}$ for which the value of the minimum temperature will be 25 and the maximum will be 35, if we change the set point value, automatically the minimum and maximum value will change to the corresponding values.

Figure 2 shows the flow chart for the simulation of temperature control in anaerobic fermentation in the fermentation of waste water in the corresponding reactor.

Based on Figure 2 on the simulation of temperature control in the anaerobic fermentation of waste water, we follow the following procedures: first we have the fermenter or the anaerobic fermentation system of waste water, which generally starts with a temperature of approximately

20°C. As the hours go by, this temperature increases, which is why we continue with the program that would be the Set point (30°C), that is, the recommended temperature for optimal fermentation with an error of more or less than 5° C (+5°C), which then when the temperature increases by +5°C to the set point value (35°C) so the cooling system begins to operate until the set point (30°C) is reached. , but the cooling system continues to operate until it reaches a temperature of 25°C, or until fermentation stops. And when the temperature is lower than -5°C to the set point (25°C) and the cooling system stops working, the fermentation temperature will again increase until it passes 35°C, at which point the cooling system automatically turns on. programmed cooling in LabVIEW.

With this, the importance of easy programming for temperature control in the anaerobic fermentation of waste water in the fermenter or reactor can be shown, maintaining a recommended temperature space around the set point for anaerobic fermentation (25 to 35°C). and to obtain expected results in a fermentation system as similar as shown in the research works of the authors [8].

IV. Results and Discussions

In figure 3 you can see the front panel in which the cooler has been installed, the Lm25 temperature sensor that delivers the value of 10mV for each degree Celsius (GC). A virtual thermometer has been installed to read the temperature. and the device for the Set point value program. A warning indicator of whether the anaerobic fermenter chiller is active or inactive, stop button.

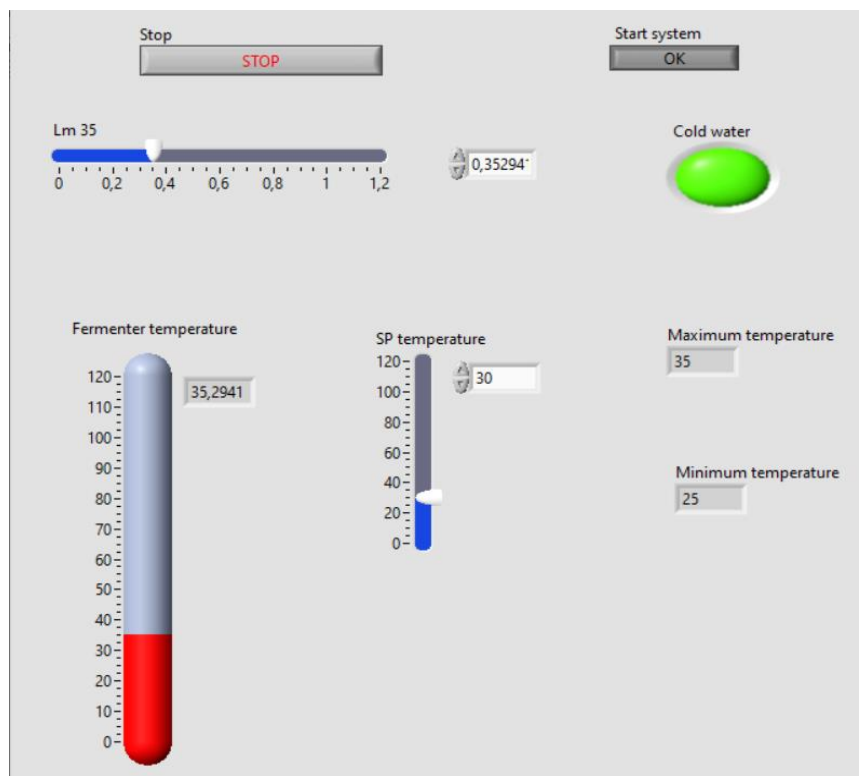


Figure 3. Front panel with installation of the Lm35 sensor, thermometer, active or deactivated indicator of the anaerobic fermenter chiller.

In the block panel we have installed a While Loop cycle for the installed indicators, the voltage to temperature converters. There is another SubVI for the Lm35 temperature converter, the system power button is connected. We find a shift registers installed to maintain a minimum temperature and a maximum temperature in the anaerobic fermenter. It was necessary to briefly describe the guidelines for the system conditions such as: If the observed temperature is higher than the maximum temperature, then the cooling system is activated. If the observed temperature is lower than the minimum temperature, then the cooling system is deactivated, this data is presented in figure 4.

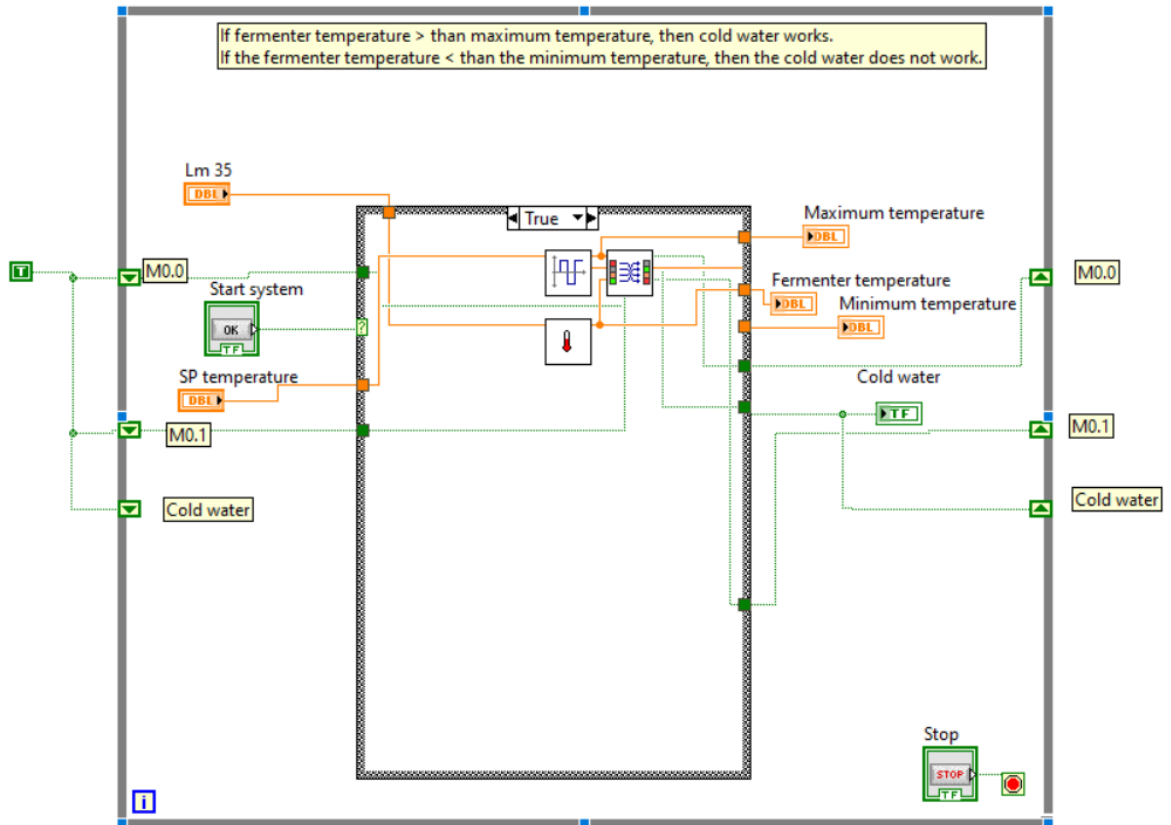


Figure 4. Graphic programming in block panel for temperature control in anaerobic waste water fermenter, when the true function is in the system. The Lm35 virtual temperature sensor is installed, the reading thermometer, the system cooler which will be ice wáter.

Figure 5 shows the graphic programming in the same block panel for temperature control in a fermenter or anaerobic bioreactor of waste water, in which this time the system is in the false function, that is, it is zero for the minimum temperature. and the maximum temperature, practically the fermentation is within the temperature range of the programmed set point.

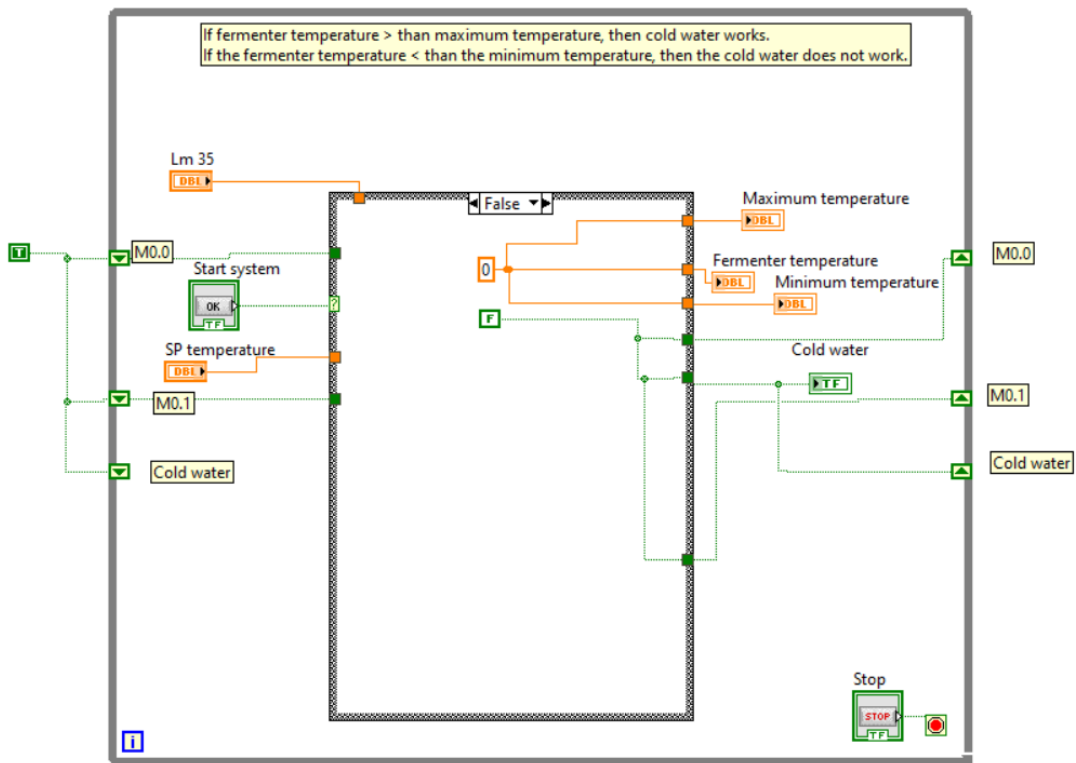


Figure 5. Representation of the graphic programming in the block panel for temperature control in the anaerobic waste water fermentation reactor when the system is at a temperature of the programmed set point, in false function mode.

As can be seen, graphical and easy programming has been carried out in the modeling and simulation of temperature control using LabVIEW software in the anaerobic fermentation process of waste water in a fermentation system or reator, just as it was carried out in their work. research by authors[8], [5].

Regarding the simulation of the temperature control system in the bioreactor in the anaerobic fermentation of waste water, the following is obtained:

Table 1. Minimum and maximum temperature values when the interval $\pm 5^{\circ}\text{C}$, which varies set point values in the anaerobic wastewater fermentation bioreactor using LabVIEW software.

SetPoint	Temp mínima	Temp máxima
30°C	25°C	35°C
32°C	27°C	37°C
34°C	29°C	39°C
36°C	31°C	41°C
28°C	23°C	33°C

Table 2. Minimum and maximum temperature values when the interval $\pm 2^{\circ}\text{C}$, which varies set point values in the anaerobic wastewater fermentation bioreactor using LabVIEW software.

SetPoint	Temp mínima	Temp máxima
30°C	28°C	32°C
32°C	30°C	34°C
34°C	32°C	36°C
36°C	34°C	38°C
28°C	26°C	30°C

Tables 1 and 2 show the results of the simulation in the temperature control of anaerobic fermentation of waste water in the fermentation system or reactor, where they indicate that we can simulate the set point programmed for said fermentation and in a space adjustable in this case +5 and +2°C, being able to use other values that are necessary for any type of fermentation system.

CONCLUSIONS

In this research work on the modeling, simulation and control of temperature in the anaerobic fermentation bioreactor of waste water, the expected results could be obtained using graphical programming in LabVIEW software, since it allows simulation in variation of the set point (temperature optimal programmed in the anaerobic fermentation of waste water in a bioreactor as for different types of fermentation), in which physical instruments could be replaced by virtual instrumentation.

As shown by authors [8], [17] and [5], in their research work, it is possible to use the LabVIEW software for easy graphical programming without the need for a programming specialist. In this case, modeling and simulation of temperature control is shown in the anaerobic fermentation of waste water in a fermentation system or reactor.

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