AN AUTOMATION PROPOSAL FOR THE FISH FARMING PROCESS

NESTOR E. POLANIA V, JULIÁN R. CAMARGO L & CÉSAR A. PERDOMO CH

Engineering Faculty, Universidad Distrital Francisco José de Caldas, Bogotá, Colombia

ABSTRACT

This document presents an overview of a problem related to the farming activity in Huila, Colombia; The application of traditional process in the fish farming of Tilapia has caused an inadequate production process leading to monetary losses. This optimization process takes into account parameters like temperature, oxygen production taking into account the needs of the fish and the farmers.

KEYWORDS: Automation, Fish Farm, Fuzzy Logic, pH, Temperature

Received: Jun 08, 2020; **Accepted:** Jun 28, 2020; **Published:** Oct 10, 2020; **Paper Id.:** IJMPERDJUN20201502

1. INTRODUCTION

Huila, Colombia is the main farmer of Tilapia in Colombia. It has 29 % of the production at the national level. The fish farmers have grown over the years due to the water source Huila has, the Magdalena River.

Even though the growth of fish farms in the last years, these farms have been using traditional methods for the farming process, they have limited use of technology due to the high cost for the equipment acquisition. This has caused in small industries problems to compete with big industries.

The use of technology in this industry will have a huge impact due to, using an automation process the production could increase. The production of Tilapia in the last years has had an estimated production of 103.198 tons in 2015, and Huila produced 44.46% of this value [1].

The fish farming in Huila has two systems of production:

- Floor ponds, 31 towns use this method.
- Floating cages in the Betania dam.

These two processes are used for small, medium, and big companies in the fish farming market. The pond system corresponds to 42.8% of the total production method [2].

Using the automation process, the fish farming process can be enhanced, helping the farmers to see the variables quantitatively, where they can operate at any moment.

Figure 1 shows a Tilapia pond in Huila, Colombia

Figure 1: Fish growing [3]

2. THEORETICAL BASIS

2.1. Chemical Aspects

2.1.1. Oxygen

Oxygen is maybe the most important element in fish farming. The fish needs oxygen to produce all its metabolic processes. The amount of oxygen in water needed for a fish in warm weather is about 5 ppm/L of water. If the levels of oxygen are lower than that the fish can survive, but his growing process is going to take longer.

Water with less than 1ppm/L is lethal for fish. Under normal conditions, oxygen levels are high during the day, but they get reduced in the night. This is decisive to determine the number of fish that one pond can have. Figure 2 shows the oxygen production in water.

Figure 2: Oxygen generation [4]

An adequate oxygen level in the water can be made with phytoplankton, a suitable number of fish, changing the water periodically, and the water movement.

2.1.2. pH

pH is the value given by the hydrogen ions, if the water is acid the pH value is under 7, and if is basic is over 7. An accurate pH level for water is between 6 and 9, neutral.

Water with a pH under 4 or higher than 11 causes injuries in the fish, and eventually, it can be lethal. If the pH in the water is acid it can be corrected using calcium oxide, and with a basic pH, an acid fertilizer can be used.

2.2. Physical Aspects

2.2.1. Temperature

For fish farming is important to have a warm-weather so fish can grow faster and the productive cycle gets shorter. The ideal temperature for fish farming is between 26 °C and 29 °C.

The Tilapia can tolerate temperature above 20°C under this temperature can die. Also, when the temperature is very high, over 29°C the oxygen levels get reduced and fish can die too [5]-[7]. To keep the temperature-controlled, the water must be changed regularly, the ponds should be deep, and the water must have a continuous movement.

2.2.2. Water Levels

The water level is important, due to this factor affects the oxygen level directly. This parameter needs to consider the amount of fish in the pond.

3. MATERIALS AND METHODS

3.1. Instruments

3.1.1. Dissolved oxygen

The system of optical probes RDO® PRO-X was used to measure the dissolved oxygen. The RDO® PRO-X system can be used in different systems used in fish farming.

To measure the dissolved oxygen levels allows the farmers to have control over the stress level on the fish and also helps to reduce illness and fish mortality. This system only needs to be calibrated after 12 months of the installation. Also, the sensor cap has pre-calibrated installation coefficients that reduce configuration errors. Figures 3 and 4 show a probe of dissolved oxygen.

Figure 3: Dissolved oxygen probe [8]

The RDO® PRO-X integrates the SCADA y PLC systems. It includes Modbus/RS485 integral, 4-20 mA, and SDI-12 signal outputs. It requires 8 to 36 VDC. System In-situ must be used for a local process controller and a screen.

Figure 4: Probe work diagram [8]

3.1.2. Temperature

The Pt100 sensor is a temperature sensor of RTD (resistance temperature detector) with a precision of 1/10 grades. This sensor doesn't degrade easily, and when that happens the sensor sends the fail alarm on the device. The Pt1000 can be located far from the measuring device, 30 meters far maximum. Figure 5 shows the device.

Figure 5: RTD Pt100 [9]

3.1.3. pH

The sensor used for the measurement of pH is a glass electrode with an inner bulb of lithium oxide. This configuration lets the exchange of lithium ions with hydrogen ions, creating an electric potential. This electric potential will depend on the pH of the measured.

The body of the electrode is made of ordinary glass (or plastic), which does not conduct electrical charges, while the bulb, the sensitive end of the electrode, is made of this specially formulated glass, known as "pH-sensitive glass" (actually, it is polarizable glass). The pH glass is conductive to electrical charges because it has lithium oxide inside the glass, as well as silica oxide, calcium oxide and some others. The structure of the glass is such that it allows the exchange of lithium ions with hydrogen ions in aqueous solution so that a hydrated (thin) layer is formed. A potential (of the order of millivolts) is thus created through the interface created between the glass (in the "sine" of the glass) and the aqueous solution. The voltage created towards the interior of the bulb is constant because its pH is kept constant (using a buffer solution of pH 7) so that the difference of potential depends only on the pH of the external medium. The incorporation of wire (usually Ag/AgCl) allows us to conduct this potential to an amplifier [10].

3.1.4. Level

The levels are used to control the water level. These levels have a Reed switch inside an axis and use magnets to control the level of the liquid. The switches detect the liquid level with an ON/OFF output. These switches don't have any type of interference caused by waves or vibrations of the liquid. Figure 6 shows the level device.

Figure 6: Magnetic level sensor [11]

3.2. Processing Control System and Actuators

3.2.1. Programmable Logic Controller (PLC)

For the acquisition of variables, and to control them this investigation used a PLC PLC S7-1200 by SIEMENS. Figure 7 shows a diagram of PLC PLC S7-1200.

Figure 7: PLC S7-1200 SIEMENS[12]

The S71200 is flexible and able to control different types of variables. Its CPU has a microprocessor, power supply and input and output circuits, creating a powerful PLC.

The CPU controls the devices of the application. It controls the inputs and changes the output states depending on the user's program logic. It can include Boolean logic, timers, complex mathematics, and communication with other devices. Different security functions protect the system like passwords, the use of know-how to hide the code.

3.2.2. Surface Oxygenation Pump

The oxygenation pumps are the source of the oxygen for the ponds. The pumps have an adequate oxygen transfer rate and low operational costs.

These pumps have a submersible two-propeller motor that provides a high energy performance. The pump also has high corrosion resistance so it can be used either in fresh or saltwater. Figure 8 shows how water gets oxygen.

Figure 8: Surface oxygenation pump [13]

3.3. Implementation Proposal

All the sensors described above were chosen to control a particular variable, being the temperature and the oxygen level the main variables to control. Figure 9 shows the proposal diagram used for the system.

Figure 9: Proposal system diagram

3.3.1. Dissolved Oxygen Sensor

The dissolved oxygen sensor is connected directly to the RS485 interface. The communication is done using an analog module, connecting the sensor to the inputs.

Figure 10 shows the input diagram for the communication between the sensor and the PLC.

Figure 10: Module for analog inputs to the PLC

3.3.2. Temperature Sensor

The temperature sensor uses a three-wire technique. This technique avoids the resistance problem present in different installations.

This sensor measures the resistance in terminals two and three and afterward subtracts the value from the measurement from the terminals one and two. Figure 11 shows the connections for Pt1000 for two and three wires.

Figure 11: Connection module for Pt1000 for 2 and 3 wires

3.3.3. pH sensor

The voltage generated for the pH sensor has a behavior described for the Nernst's equation (1), and it's proportional to $[H^+]$.

$$E_{measured} = E_{reference} - \frac{2.3 \cdot R \cdot T}{n \cdot F} * pH \quad (1)$$

Where:

$E_{measured}$, it is the voltages in volts detected for the sensor

$E_{reference}$, it is the voltage from the reference electrode.

R = Gas constant

T = Temperature in Kelvins

n = Ion charge, for the pH sensor is equal to 1

F = Faraday's constant

$2,3 \cdot RT/nF$ = Nernst's factor.

Figure 12 shows the behavior of the pH sensor electrode.

Figure 12: Electrode behavior

3.4. Control Proposal

For the design of the control of the system, this investigation used the MATLAB Fuzzy Logic Designer. This design has two inputs, temperature and dissolved oxygen. Depending on specific conditions the oxygen pump will activate using a percentage of the PWM signal. Figure 13 shows the flow diagram of the proposed fuzzy system.

Figure 13: Flow chart of the proposed fuzzy system

This investigation proposed a two-input system (oxygen and temperature) and only one output (oxygen generator) which will control the temperature by moving the water. Figure 14 shows the control system inputs/output diagram.

Figure 14: Control system inputs/output

The functions for each variable are shown down below.

$$M(\text{LOW}) = \text{trapmf}(e, 2, 2, 4, 5.579)$$

$$M(\text{STABLE}) = \text{trimf}(e, 5.389, 6, 7)$$

$$M(\text{HIGH}) = \text{trapmf}(e, 6.875, 7.625, 8, 8)$$

Figure 15 shows the linguistic variables for dissolved oxygen.

Figure 15: Linguistic variables for dissolved oxygen

Using the same system, the temperature linguistic variables are:

$M(\text{LOW}) = \text{trapmf}(e, -0.159, -0.159, 9.84, 23.8)$

$M(\text{STABLE}) = \text{trimf}(e, 23.4, 25, 29.29)$

$M(\text{HIGH}) = \text{trapmf}(e, 25.48, 40, 60, 70)$

These variables are shown in Figure 16.

Figure 16: Linguistic variables for temperature

Having the linguistic variables, the controller can create an output that is a PWM pulse from 0 to 1, being 1 100 %. The optimum percentage where the oxygen pump works properly is between 40 % and 70%.

The linguistic variables of the output (Figure 17) will be given by:

$M(\text{LOW}) = \text{trimf}(e, 0.0011, 0.101, 0.3419)$

$M(\text{MEDIUM}) = \text{trimf}(e, 0.2684, 0.601, 0.683)$

$M(\text{HIGH}) = \text{trapmf}(e, 0.6399, 0.8939, 1.009, 1.329)$

Figure 17: Output linguistic variables

Table 1 shows the control rules, these rules will control each case.

Table 1: Control rules

		Dissolved oxygen		
		LOW	STABLE	HIGH
Temperature	LOW	MEDIUM	MEDIUM	LOW
	STABLE	HIGH	LOW	LOW
	HIGH	HIGH	HIGH	HIGH

After the control rules were settled, the controller chosen was a Mandani controller. The rules were entered using an OR operator. Figure 18 shows the rules controlled by Mandani.

1. If (OXIGENO is BAJO) or (TEMPERATURA is BAJA) then (pwm is MEDIO) (1)
2. If (OXIGENO is BAJO) or (TEMPERATURA is ESTABLE) then (pwm is ALTO) (1)
3. If (OXIGENO is BAJO) or (TEMPERATURA is ALTA) then (pwm is ALTO) (1)
4. If (OXIGENO is ESTABLE) or (TEMPERATURA is BAJA) then (pwm is MEDIO) (1)
5. If (OXIGENO is ESTABLE) or (TEMPERATURA is ESTABLE) then (pwm is BAJO) (1)
6. If (OXIGENO is ESTABLE) or (TEMPERATURA is ALTA) then (pwm is ALTO) (1)
7. If (OXIGENO is ALTO) or (TEMPERATURA is BAJA) then (pwm is BAJO) (1)
8. If (OXIGENO is ALTO) or (TEMPERATURA is ESTABLE) then (pwm is BAJO) (1)
9. If (OXIGENO is ALTO) or (TEMPERATURA is ALTA) then (pwm is ALTO) (1)

Figure 18: Rules with Mandani controller

4. RESULTS

This proposal didn't have into consideration variables as room temperature or external factors that interact with the system.

Analyzing the controller used, the results show that the oxygen variable is going to have an output value of a maximum of 70 %. Figure 19 shows the oxygen condition at low and high temperatures.

Figure 19: Oxygen conditions, low and high temperatures

With the results described above, the pump works at 50 % of its capacity. This capacity can be lower if the oxygen values are above 4 ppm/liter and the temperature is lower than 27 °C.

The values shown above the output values were generated depending on the input values, using the nine rules shown in Figure 20. These rules were obtained using the centroid defuzzification.

Figure 20: Ideal conditions

Figure 21 shows the control surface, with two input values and just one output. The input values are dissolved oxygen and the temperature.

Figure 21: Control surface

5. CONCLUSIONS

The fuzzy logic used in the controllers for this investigation showed accurate results for the dissolved oxygen and the temperature. It was not necessary to know the mathematical model for the process, it was only necessary to know the behavior of the parameters to control.

This investigation proposed the use of low cost and easy handling elements that are efficient during the growing process of fish. The sensors selected were a dissolved oxygen sensor and a Pt1000 sensor, both sensors have efficient

features as well as precision, and accuracy. The sensors had an easy implementation.

The fuzzy algorithm was made using the Matlab software, using the toolbox Fuzzy logic. This algorithm was implemented in a PLC. The PLC had input modules that guaranteed a high-efficiency process.

Due to the development of mobile software, the implementation of a monitoring application and control using the technology described in this paper can lead to the acquisition of data in any place with wifi access.

ACKNOWLEDGMENTS

The authors would like to thank the Universidad Distrital Francisco José de Caldas and the LASER research group that supported the development and testing of the project.

REFERENCES

1. Gobernación del Huila. (2017). *Acuerdo de Competitividad de la Cadena de la Piscicultura en Colombia*. Retrieved from: <https://www.huila.gov.co/loader.php?lServicio=Tools2&lTipo=descargas&lFuncion=descargar&idFile=2819>
2. Ministerio de Agricultura y Desarrollo Rural - Sistema de Información de Gestión y Desempeño de las Organizaciones de Cadenas - SIOC. (2013). *Cadena de la Acuicultura*. Retrieved from: <https://sioc.minagricultura.gov.co/Acuicultura/Documentos/2012-12-31%20Cifras%20Sectoriales.pdf#search=baquero>
3. Proyecto de Aprendizaje Piscícola. (2011). *Proyecto Piscícola La Ondina*. Retrieved from: <http://proyectedeaprendizajepiscicola.blogspot.com/p/caracteristicas-del-proyecto.html>
4. Análisis y Tratamiento de Aguas. (2015). *Oxígeno disuelto*. Retrieved from: <http://tramientosabeta.blogspot.com/2015/05/oxigeno-disuelto.html>
5. Industria Acuícola. (2010). *Nicovita - Manual de Crianza - Tilapia*. Retrieved from: <http://www.industriaacuicola.com/biblioteca/Tilapia/Manual%20de%20crianza%20de%20tilapia.pdf>
6. Globefish Trade Statistics. (2020). *Tilapia*. Retrieved from: https://issuu.com/globefish/docs/globefish_trade_statistics_tilapia-2020
7. Industria Acuícola. (2017). *Cría de Tilapia en Tanques*. Retrieved from: http://www.industriaacuicola.com/nueva_version/index.php/blog/publicacion/12
8. In-Situ. (2018). *RDO® PRO-X Optical Dissolved Oxygen Probe*. Retrieved from: https://in-situ.com/pub/media/support/documents/RDO-PRO-X_SS.pdf
9. Vistrónica. (2020). *PT-100 industrial WZP-230 (sonda de 33cm)*. Retrieved from: <https://www.vistronica.com/sensores/temperatura/pt-100-industrial-wzp-230-con-sonda-de-33cm-detail.html>
10. Ciganda, L. M. (2004). *Electrodos para medir pH. XIII Seminario de Ing. Biomédica 2004 - Facultades de Medicina e Ingeniería - Univ. de la República Oriental del Uruguay*
11. Direct Industry. (undated). *Magnetic float level sensor C series*. Retrieved from: <https://www.directindustry.com/prod/madison-company/product-11780-513238.html>
12. Aotewell Automation. (2020). *SIEMENS SIMATIC S7-1200 Programmable controller PLC/HMI/CPU*. Retrieved from: <https://www.aotewell.com/siemens-automation/simatic-s7-1200-siemens-s7-1200-plchmi>

13. Euro – Rain. (2019). Aireadoresyfuentesflotantes. Retrieved from: <https://www.euro-rain.es/es/imagenes/aireadores-y-fuentes-flotantes/aireadores-flotantes-serie-select/4-aireadores-flotantes-para-lagos-serie-select/detail/61-aireadores-para-lagos-torrent.html?tmpl=component>