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FEED DISPENSER FOR ALEVINES BASED ON THE OXYGEN PERCENTAGE AND THE WATER TEMPERATURE IN A CONTROLLED ENVIRONMENT

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ABSTRACT

The article presents the development and optimized system for feed dosage for alevines, which is immersed in three areas of electronic engineering: telemetry, physical variables for the remote measurement, such as the percentage of dissolved oxygen and water temperature, electronic instrumentation for monitoring (remote and in real-time) of dissolved oxygen, temperature, and automation for control of the feed dispenser. The system is developed through the use of Arduino 1-R3 cards, together with XBEE shields for Arduino. The work modules consist of sensor parameters measurement, signal processing, and the sending and receiving data to and from the web-server.

Keywords: remote access, arduino, XBEE, DNS, NODEJS, sensor (probe), telemetry, hopper.

INTRODUCTION

The aquaculture sector has played a fundamental role in the growth and economic development of the southern Colombian region; according to Esquivel *et al.* (2014) [1], in Colombia there are several regions that historically specialize in the reproduction and consumption of species and base their activities on this work.

Fish farming is a profitable activity, which is why many regions have opted for its implementation, taking it as their main income in their economy, making it show rapid growth in practice in the global context in recent years. However, for Contreras (2018) [2], the technology currently used is expensive and dependent on many technology and information platforms (ICT), which requires knowing how to develop teams with great benefits, simple to implement and low cost. Gutiérrez (2010) [3], highlights that, frequently, there are fish farms that carry out artisan work and do not have technological tools that allow them to automate processes and maximize their profits, for which reason they no longer receive valuable economic resources.

The use of technological tools should be seen, according to Rojas, Tique and Bocanegra (2017) [4], as the advantage that must be taken advantage of to implement processes that maintain updated, real and accurate information on the state of the factors that must be monitored. in fish production, identification, and feeding of fish, monitoring the physico-chemical characteristics of water and regulation of the ponds levels.

Navarro, Padilla and Prías (2013) [5], proposed the implementation of an instrumentation system that allows the measurement of the main physical-chemical variables in fish farming under artificial pond conditions, this electronic system allowed to store the values of temperature, pH, and dissolved oxygen, in a computer system for subsequent analysis as a technological tool that contributed to the strengthening of trout cultures in the Quindio Department. Likewise, it is possible to find experiences such as Dussán A., Vanegas O., Chavarro A. and Molina J. (2016) [6], whose designed and implemented an electronic prototype for monitoring physical-chemical parameters in tilapia culture through a mobile application, whose objective was to contribute to the reduction of tilapia mortality rates, due to sudden changes in temperature and the dissolved oxygen.

With the above, it is unavoidable to find the shortcomings in the current production methods and interact with the different fields of knowledge to get the solution of these and thus, make profitable and effective fish farming, it is necessary to seek and improve the ways, methods, or aids that provide useful tools to make effective activities.

Thus, in this article, we propose the design of an automated dispenser that supplies feed based in the dissolved oxygen levels and water temperature that can vary according to the cultivation of fish species, in order to help the fish farmer, the system allows to save capital investment, but establishes a shorter period of time for feeding the species, in addition to increasing the production levels of these, carry out supervision (remote, local and on real-time) to be able to have knowledge of the crop and make decisions about it. In the same way, the fish farmer will receive an alert notification at the moment in which the change of any monitored variable is not within the allowed range or stipulated this, by means of the automatic sending of an email.

METHODOLOGY

The main purpose of this project is to improve the feeding practices of the fish species that are currently being developed by fish farmers in the region. It was considered important that processes like this be optimized with the help of new technologies such as the Internet of Things, electronic instrumentation, telemetry that help minimize the financial losses that may be generated.

or this reason, the decision was made an automate a dosing system to minimize losses and thus be able to monitor variables such as dissolved oxygen and

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temperature, which make water quality and the controlled environment a very important issue in fish production.

The Figure-1 shows the block diagram of the automated dosing system.

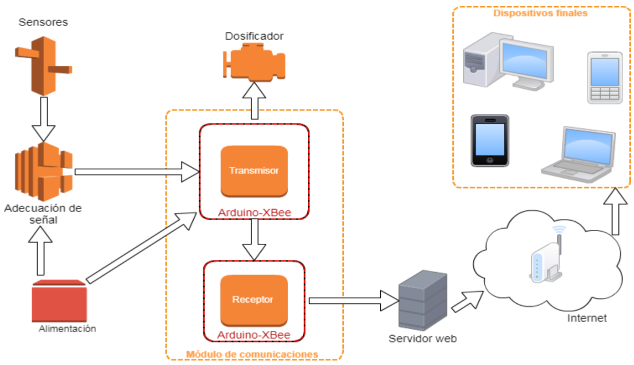

Figure-1. The block diagram of the automated dosing system.

Design and Implementation of Hardware System

One of the fundamental aspects, to execute the project, is the selection of an environment that allows it to be controlled so that aquatic species have a correct evolution during their development cycle. Therefore, it is necessary to provide to the alevines a suitable space that has a structure adaptable to the implementation of the hardware. For this, the manufacturing materials were considered, in addition to the parameters of measurements of internal and external spaces.

An aquarium selecting: To select an aquarium, the following factors must be considered: the fish population, the site where it will be installed and its size. In the fish trade there is a great variety of aquariums, according to the need and interest of the project, choosing a prefabricated aquarium for this case.

Aquarium location The idea to provide a controlled and harmonious environment to the fish, requires the following criterion:

- Avoid locations near of windows, heating pipes, air conditioning or appliances, as environmental conditions would be altered.
- Provide enough clearance to perform necessary maintenance.
- Avoid an installation (support, base) that is vulnerable to vibrations.
- Have a suitable electrical installation.

Taking these criteria into account, the aquarium was installed in a place away from heat emitting sources, firm, and a suitable surface.

Automatic Feeding Module Construction

The developed system automatically provides the food to the fish. Thus, a hopper, a servo-motor and a coupled disc to its axis were used; controlled by a digital signal from an Arduino 1 controller.

Automatic power module operation The block diagram in Figure-2, shows the operation of the automatic feed module.

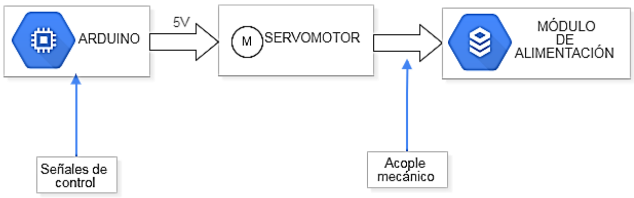

Figure-2. Automatic power module operation.

Power control circuit design The power control is performed using a PWM signal sent through the pin 9 of the Arduino 1 board. In Figure-3, the power control circuit can be seen.

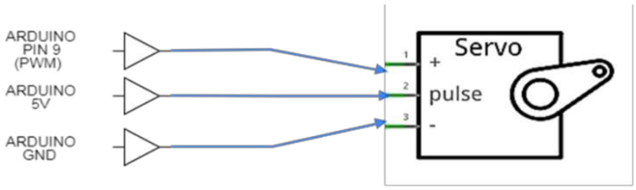

Figure-3. Power control circuit.

The Arduino board on its PWM pin provides a maximum current of 20 mA, on its supply voltage pin 5V, while the servo-motor, supply 5V, has a maximum torque of 1.8 Kgf by cm, which indicates that, at 5 V, supports maximum 1.8 Kg in its movement.

Dosing Structure (TOLVA)

For the design of the hopper, the upper surface area of the aquarium, the disc attached to the servo-motor, and the maximum weight of the food allowed were considered.

Data that were considered:

$\beta = \alpha + 15°$

Where due to the physical characteristics $\alpha = 31°$ and β is the hopper angle of inclination.

m=1,8 Kg

m is the maximum weight of the food allowed.

A_((s_acum)) =0,16 m^2

A_((s_acum)) is the surface area of the aquarium

Data that the maker requested for manufacturing:

h=0,2 m

h is the height of the hopper.

A_boq=0,003 m^2

A_boq is the area of the hopper outlet nozzle.

Temperature Module Construction

The automatic feed dosing system senses the temperature of the water in order to carry out the activities

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established in the project's objectives. Figure-4, shows the block diagram of the temperature module used..

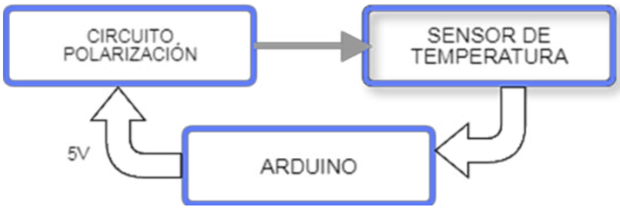

Figure-4. Block diagram of the temperature module.

Design of the Temperature Module Circuit

The temperature sensor used in the project was the DS18B20. Dallas Semiconductor is its manufacturer and suggests a circuit for its operation. In Figure-5, the circuit implementation is presented.

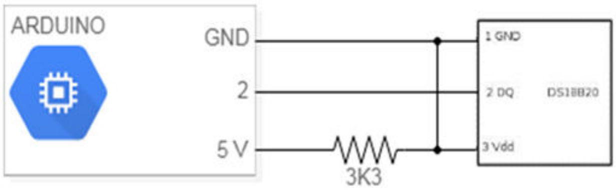

Figure-5. Temperature module circuit.

Temperature Measurement System

The DS18B20 sensor is submersible in water, so it is inserted into the aquarium at a certain depth (0.1 m) to perform the temperature measurement.

Dissolved Oxygen Measurement Module

The following paragraphs shows the dissolved oxygen measurement system, as well as, the processing of the signal for data acquisition.

Dissolved Oxygen Measurement

The following block diagram, in Figure-6, shows the dissolved oxygen module.

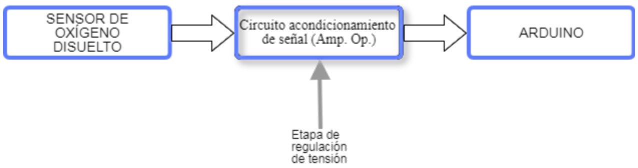

Figure-6. Block diagram of dissolved oxygen module.

Adequacy of Dissolved Oxygen Signal

Figure-7 shows the conditioning circuit for the voltage signal coming from the dissolved oxygen sensor, whose manufacturer is Sensorex.

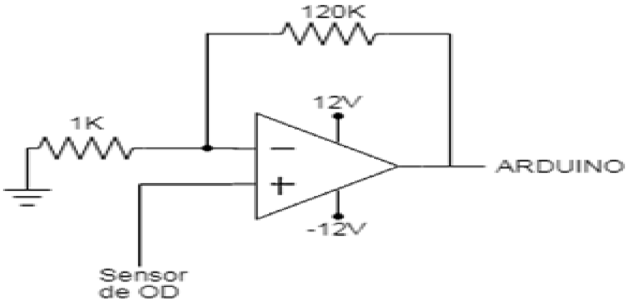

Figure-7. Dissolved oxygen signal conditioning circuit.

The above circuit works for any Galvanic Dissolved Oxygen (HDPE) sensor and its readings are given in percent.

Due to the signal nature (reading in mV), it was necessary to carry out the adjustment of the voltage level, since these data are manipulated by the Arduino board for its processing.

Design of the Circuit of Dissolved Oxygen Signal

Due to the needs of the project, it was decided to operate the operational amplifier in Non-invert mode, whose voltage gain is 119 and was calculated using the equation 1.

$V_o = 5\,V \quad V_i = 0{,}042\,V \quad A_v = 1 + R_f/R_i$

$$A_v = \frac{5}{0{,}042} \cong 119$$

Then, the calculation of the resistances R_f and R_i is presented below:

$$A_v = 1 + \frac{R_f}{R_i}$$

$$119 = 1 + \frac{R_f}{R_i} \quad 118 = \frac{R_f}{R_i}$$

$$R_f = 118R_i$$

$$R_i = 1\text{ K}\Omega R_f = 118\text{ K}\Omega \approx 120\text{K}\Omega$$

For simplicity, R_i = 1 KΩ was chosen. On the other hand, because 118 KΩ is not a commercial value of electrical resistance, we chose R_f = 120 KΩ.

System Software Development

To fulfill the stages that make up the project, the software was designed, which allows interaction between the system and the user, the latter having control over certain system topics.

The data acquisition, digitization, adaptation of signals, and the sending and receiving of the same, is developed using the open-source from the ARDUINO environment, based on C ++ and associated with the LINUX operating system. It should be taken into account that, through the boot-loader, it is possible to load and debug the code program developed on the hardware used, this without the need to require external applications.

On the other hand, the visualization and manipulation of data remotely, is developed through

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JavaScript and on the NodeJS platform, that was developed to build fast, scalability the applications that handle large amounts of data in real time.

The Emitter Module Development

The actions performed by the ARDUINO controller card, within the emitter module of the automation system for alevine feed dispenser, through the ATMEGA 328P micro-controller, they are as follows:

Take measurements of temperature and dissolved oxygen in the aquarium water, continuously and through the respective signal treatment and conditioning module, to take compensation actions.

Control a servomotor to carry out the respective feeding of the species, in the determined time and according to the monitored variables.

Packing the data to send it to the receiving module, using an XBEE shield and a ZIGBEE antenna.

Development of the Remote Monitoring Program

In the receiver module, the tasks that the ATMEGA 328P microcontroller of the ARDUINO card executes are the ones stated below:

- Receive data from the transmitter module, wirelessly, through the ZIGBEE antenna. For the recognition of the data on the ARDUINO board, it is necessary to adapt an XBEE shield to the ARDUINO card.
- Unpack the data for further processing.
- Send the data to the serial port of the computer where the corresponding server is located.

Development of the Remote Monitoring Program

This stage of the project is divided into two parts, one is the mobile application sub-stage and the other is the web application sub-stage. Both applications are interfaces for the interaction of the fish farmer with his cultivation.

Mobile application stage: A mobile application was designed that, through the web communication, takes the data (from the circuit) stored in a database in the cloud, so that the appropriate personnel can visualize them and be aware of the behavior of their cultivation. The application is designed, so that the data is stored in the RAM memory of the mobile device for its greater effectiveness and efficiency when analyses the data (integrated function).

Figure-8. Graphical interface of mobile application.

The design of the web application: It reads the data from the serial port of the computer where the web server is hosted, in order to allow remote viewing of the data. Additionally, it allows the definition of the dissolved oxygen set-points and aquarium water temperature; this in order to notify by sending an automatic email about the variation of the values. In the same way as in the mobile application, the data (history) can be viewed quantitatively.

On the other hand, the data can be viewed remotely and in real time, due to the communication through the web protocol and the configuration of the ports, through the use of one of the google technologies (Firebase).

RESULTS

This section shows the dissolved oxygen and temperature levels obtained by continuous sensing and chosen over a period of 7 days, as well as, the respective scatter graph showing the behavior and the relationship between the variables. Likewise, the theoretical data calculated from the measured temperature is illustrated. The equation that was used for the theoretical calculation was obtained by the graph of data provided by the manufacturer SENSOREX for the DO1200T sensor. The following graph shows the information supplied by the manufacturer:

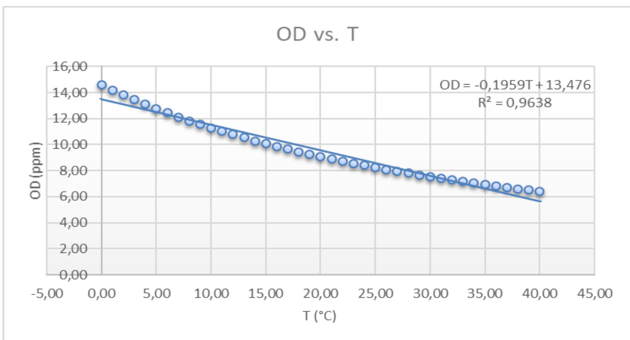

Figure-9. OD-T relationship. Interpolated manufacturer data.

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From this we obtain:
$OD = -0{,}1959T + 13{,}476$
Where:

OD : Dissolved Oxygen
T : Temperature

On the other hand, to find the reliability of the dissolved oxygen sensor, the values recorded by it and the interpolated ones (taken as theoretical) were taken into account. Table-1 shows the arithmetic mean of these values.

Table-1. Arithmetic mean OD (%).

	measured data	theoretical data
Media OD (%)	58,43	56,81

These values postulated in the previous table are used to calculate the error percentage of the DO1200T measurement, which indicates the level of reliability of the DO1200T. This calculation is carried out with the help of equation 5.

$$e = \pm \frac{|measured\ data - theoretical\ data|}{theoretical\ data} * 100$$

In this way, the error percentage of the named measurements is:

$$e = \pm \frac{|58{,}43 - 56{,}81|}{56{,}81} * 100 = \pm 2{,}85\ \%$$

This value is small, which indicates that the DO1200T's level of reliability is high.

Oxygen Vs Temperature

The data were taken from the interval registry of 7 days, where the data obtained from each hour was extracted. The information was recorded in a table showing the temperature variables and dissolved oxygen with their respective date and time. The graphic was made from the constructed tables.

Table-2. Data obtained on August 06, 2019.

Hora	T (°C)	OD (%)	Hora	T (°C)	OD (%)
0:00	24,35	67,20	12:00	33,99	51,56
1:00	25,08	64,65	13:00	35,04	51,45
2:00	25,45	63,05	14:00	35,67	48,65
3:00	25,68	64,62	15:00	36,78	47,28
4:00	24,33	66,55	16:00	35,58	48,58
5:00	24,40	67,50	17:00	34,89	49,35
6:00	24,76	66,05	18:00	32,43	54,82
7:00	26,79	63,20	19:00	30,87	57,84
8:00	28,23	59,53	20:00	29,38	60,25
9:00	30,19	56,23	21:00	28,81	60,81
10:00	32,77	53,34	22:00	27,38	61,15
11:00	33,59	52,33	23:00	27,86	60,85

Now, the following figures show the behavior of the two monitored variables.

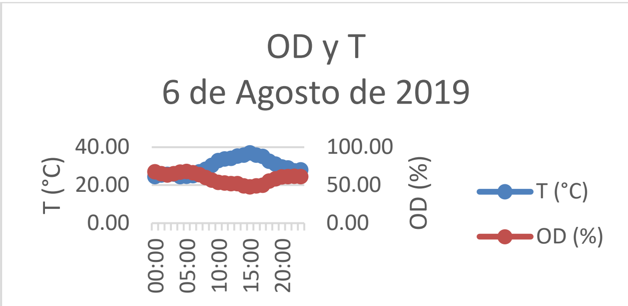

Figure-10. Time relate to OD and T.

Table-3 shows the obtained data on August 7, 2019

Table-3. Measurements obatined on 08/07/2019.

Hora	T (°C)	OD (%)	Hora	T (°C)	OD (%)
0:00	25,34	62,69	12:00	35,96	48,06
1:00	25,39	63,38	13:00	36,88	47,09
2:00	25,56	65,04	14:00	36,80	49,42
3:00	25,34	64,73	15:00	36,91	49,16
4:00	25,10	64,36	16:00	36,32	49,83
5:00	26,89	61,53	17:00	35,97	49,22
6:00	25,79	64,43	18:00	33,45	52,95
7:00	27,89	61,35	19:00	32,11	53,83
8:00	30,11	58,87	20:00	31,01	57,52
9:00	32,09	53,90	21:00	29,76	59,66
10:00	34,67	51,60	22:00	29,01	58,31
11:00	34,98	50,04	23:00	28,43	58,88

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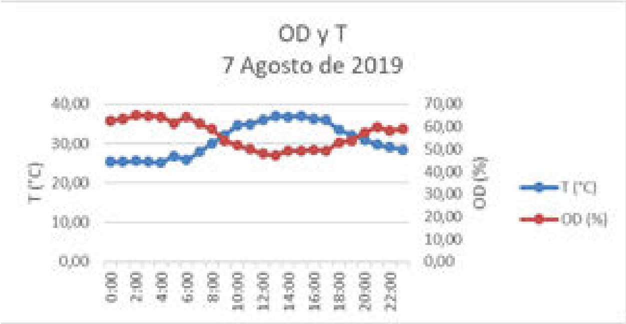

Figure-11. Time relate to OD and T.

The Table-4 shows the data obtained on August 8, 2019.

Table-4. Measurements on 08/08/2019.

Hora	T (°C)	OD (%)	Hora	T (°C)	OD (%)
0:00	24,32	60,42	12:00	36,75	46,81
1:00	24,67	61,73	13:00	37,22	46,89
2:00	25,06	64,33	14:00	37,88	46,99
3:00	24,78	65,10	15:00	37,99	45,35
4:00	24,23	65,48	16:00	36,89	48,71
5:00	24,98	65,38	17:00	36,36	48,60
6:00	24,67	65,52	18:00	34,99	51,49
7:00	27,42	62,43	19:00	33,01	52,35
8:00	30,07	58,06	20:00	30,98	55,59
9:00	32,69	54,29	21:00	29,27	58,97
10:00	34,23	52,92	22:00	29,09	59,60
11:00	35,49	50,45	23:00	28,36	60,34

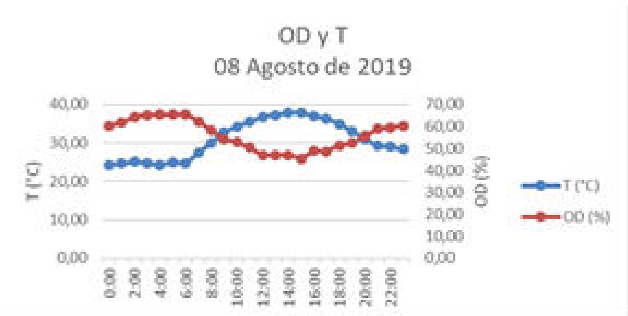

Figure-12. Time relate to OD and T 08/08/2019.

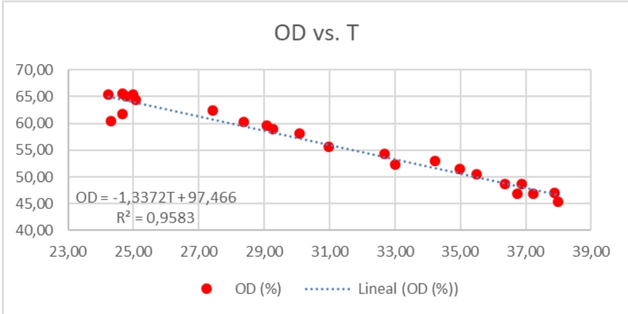

Figure-13. OD relate to T 08/08/2019.

Table-5 shows the obtained data on August 9, 2019.

Table-5. Measurements on 08/09/2019.

Hora	T (°C)	OD (%)	Hora	T (°C)	OD (%)
0:00	27,87	60,60	12:00	31,78	53,84
1:00	26,92	63,08	13:00	32,89	54,08
2:00	25,34	65,15	14:00	32,87	52,60
3:00	24,11	66,55	15:00	32,99	53,16
4:00	23,88	65,92	16:00	32,67	54,80
5:00	23,00	69,11	17:00	32,45	54,07
6:00	24,58	66,53	18:00	30,00	58,14
7:00	26,66	63,37	19:00	29,38	60,05
8:00	27,59	61,90	20:00	27,12	61,22
9:00	29,38	59,74	21:00	26,67	62,04
10:00	30,00	57,46	22:00	26,10	63,88
11:00	31,23	55,86	23:00	25,78	64,97

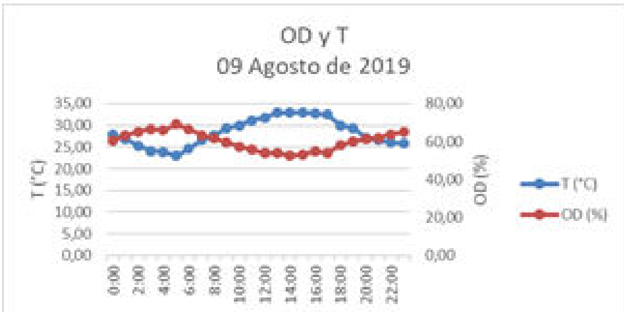

Figure-14. Time relate to OD y T 09/08/2019.

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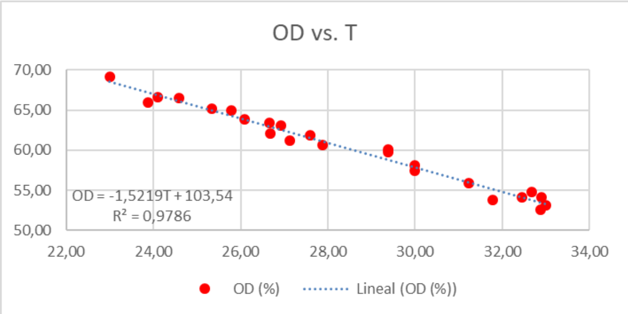

Figure-15. OD vs T. 09/08/2019.

Table-6 shows the obtained data on August 10, 2019.

Table-6. Measurements on 08/10/2019.

Hora	T (°C)	OD (%)	Hora	T (°C)	OD (%)
0:00	24,99	66,54	12:00	31,21	56,18
1:00	24,21	65,49	13:00	31,49	56,36
2:00	22,39	67,83	14:00	32,81	53,25
3:00	22,67	68,58	15:00	31,09	56,17
4:00	22,89	69,33	16:00	31,78	55,38
5:00	24,01	65,96	17:00	31,04	56,50
6:00	24,78	64,94	18:00	30,77	55,48
7:00	25,89	64,75	19:00	30,46	55,81
8:00	27,34	60,31	20:00	28,44	61,41
9:00	29,10	59,56	21:00	27,85	62,21
10:00	29,91	57,79	22:00	26,99	63,68
11:00	31,00	56,17	23:00	26,12	64,24

Figure-16. Time relate to the OD and T 08/10/2019.

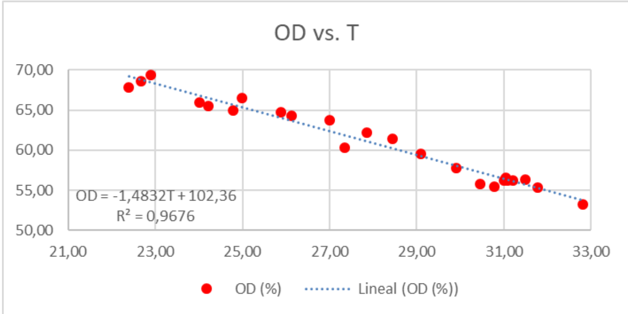

Figure-17. OD vs. T. 08/10/2019.

Table-7 shows the obtained data on August 11, 2019.

After performing the scatter plots and developing their processing, it becomes evident by means of the correlation coefficient (R2) that the obtained data and tabulated for dissolved oxygen with respect to temperature have a linear trend and can be described as inversely proportional.

Table-7. Measurements on 08/11/2019.

Hora	T (°C)	OD (%)	Hora	T (°C)	OD (%)
0:00	26,00	63,16	12:00	31,48	55,55
1:00	25,55	63,26	13:00	33,76	51,88
2:00	24,91	64,90	14:00	35,89	50,60
3:00	23,09	68,71	15:00	36,97	46,62
4:00	22,75	67,98	16:00	37,09	48,84
5:00	22,99	68,44	17:00	36,66	49,39
6:00	23,40	67,92	18:00	35,71	48,67
7:00	25,09	66,19	19:00	34,99	51,34
8:00	27,01	60,87	20:00	33,42	52,29
9:00	28,99	58,27	21:00	33,00	52,85
10:00	29,41	59,35	22:00	31,29	56,22
11:00	30,09	58,18	23:00	30,94	57,82

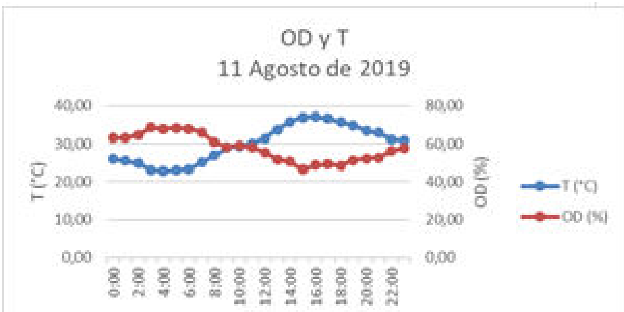

Figure-18. Time relate to the OD y T 11/08/2019.

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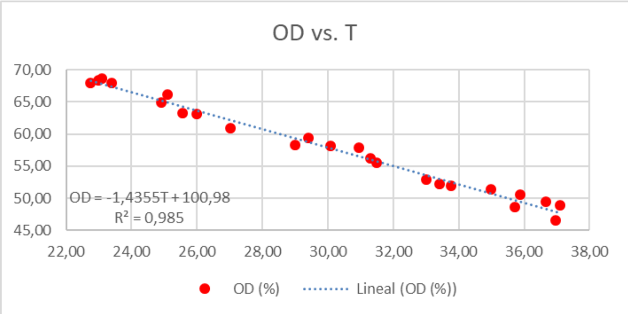

Figure-19. OD relate to the T 08/11/2019.

Analysis of Results

According to Goyenola (2009), another fundamental variable on which dissolved oxygen levels in water depend, is the depth. It because the level of dissolved oxygen that is perceived by increasing the depth is greater, it is possible to argue it in the inverse relationship that exists between temperature and dissolved oxygen (p.1).

To explain the above, we start from an increase in the temperature in the environment by solar radiation (in the place where the fish cultivation is located). As temperature increases, a decrease in dissolved oxygen is noted; this correlation becomes more evident if the data is taken at the water surface, where the water has direct contact with the radiation, the water temperature increases and the dissolved oxygen decreases. As solar radiation loses incidence as depth increases, temperature decreases, oxygen levels rise. This situation indicates that the greater the depth, there will be more dissolved oxygen; Díaz (2018) assures that, in ponds less than 1.25 meters of deep, it is sufficient to measure the temperature of the water only on its surface, but in ponds whose depth is greater, it is preferable to measure the temperature near the bottom. Since the acquisition and subsequent processing of the temperature and dissolved oxygen levels, the behavior and the inverse relationship between the mentioned variables is evident. When determining the correlation, it is possible to determine the appropriate moments in which the food supply to the species can be performed or not (the hours according to the data), to avoid alterations or contamination in the water due to excess food, as well as, the reduction in the cost of fish supplies.

Temperature is one of the most influential and determining factors in the metabolism of aquaculture species (fish, plants, shrimp), so much that exceeding the permissible ranges per species can cause a decrease in the functional and metabolic activities of the specimens and alter growth. Gallo (2013), assures that, the following conditions must be taken into account for the water temperature at the time of food supply:

- **Below the ideal:** reduce the amount of food to be supplied to the fish.
- **Close to ideal:** deliver exact amount of food.
- **Above the ideal:** increase the amount of food to be supplied to the fish.
- **Far above the ideal:** reduce the amount of food to be supplied to the fish.

On the other hand, during the day, the temperature of the aquarium is not adequate for the life of the fish, since the temperature is very high in the place where the project is installed, thus they are recorded in its history. This statement happens because there is no compensation for the variable. Temperature control in a system like the one studied is of great importance for the species production process. While, on average, from 00:00 to 07:00 hours, the optimum temperature levels are recorded for proper growth and development of this species.

CONCLUSIONS

Through this project, it was possible to determine that the installation of each of the devices used in each of the stages involved the electrical, mechanical, and electronic adaptation for the processing of information, thus achieving an autonomous system monitored in real time.

The inversely proportional behavior between the two physio-chemical variables studied was verified, which added to the high temperatures that occur in Neiva city (where the project is located), indicates that much attention must be paid to cultivation, since having low levels of oxygen (synonymous with high temperatures), the metabolism of the species decreases, causing a delay in their growth.

The abrupt changes in the controlled variables affect production, according to experts in the fish farming and the analysis of the environmental parameters of the region, it is required that the amount of food of the alevines is between 5% and 6% of the total biomass daily, since if these data are not taken into account, their production would be affected by excess or defect.

Taking into account the environmental conditions of the project installation site and the opinion of the experts, the permissible operating ranges between 24°C and 26°C for temperature and the value greater than or equal to the 40% of the dissolved oxygen were established. in the aquarium water, ranges that optimize the variable cost and benefit the production process of the species under study.

Finally, based on the analysis, it was considered that the possibility of remotely monitoring the cultivation, in addition to being notified in real time, in the event of an inadequate variation of the set-points established, is of great importance for the fish farmer, since it allows to take actions immediately; procedure that helps to improve the fish production process.

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