Design and implementation of an electronic prototype for monitoring of physico-chemical parameters in tilapia crop through mobile application

Diseño e implementación de un prototipo electrónic para monitoreo de parámetros físico-químicos en cultivo de tilapia a través de una aplicación móvil

Received: 30- 03 - 2016 Accepted: 31-05-2016

Sergio A. Dussán[1]
Oscar Vanegas[2]
Adrian F. Chavarro[3]
Johan J. Molina[4]

[1] Colombian. Electronic Engineer. Universidad Surcolombiana Neiva. E-mail: Checho260790@gmail. com.

[2] Colombian. Electronic Engineer. Universidad Surcolombiana Neiva. E-mail: Oscarvanegas89@ hotmail. Com.

[3] Colombian. Master in Industrial Management. Line Leader of E . y T. Tecnoparque Sena Neiva. E-mail: achavarroc@sena.edu.co.

[4] Colombian. Master in Mobile Applications.. Universidad Surcolombiana Neiva. Avenida Pastrana Carrera1ª. E-mail: julian.molina@usco.edu. co.

Abstract

In freshwater ponds for tilapia crop in its fattening stages, a high mortality rate of fish is presented. Because of this, an electronic prototype to monitor physicochemical parameters such as temperature and disdissolved oxygen of the water was designed and implemented in order to identify the critical moments of the crop. Field tests were conducted on the fish farm PEZCOMSI, located in the municipality of Campoalegre, in the department of (Huila, Colombia). The prototype has a system of adequacy of the sensor signals, which are read by the microprocessor ATMEGA 328P, the Analog to digital conversion data is used for processing and storage on a micro SD memory. Through the HC-05 Bluetooth module this info is sent to the GUI supported on a mobile application where the user can visualize the crop's behavior. The system is powered by solar panels and has low error rates compared to standard patterns, so it is considered a reliable electronic monitoring tool. This system is expected to contribute to lower mortality rates of tilapia due to sudden changes in temperature and disdissolved oxygen, which are presented throughout the day in the ponds; moreover, the results show a decrease in disdissolved oxygen concentration that could be subject to a further study.

Keywords: electronic prototype; novelty; fish farming; mobile application; remote sense.

Introduction

In these times where poverty and hunger go higher, there are various production sectors with high increase, such as fishing and aquaculture which are performing an important role in the decreasing of such problems. These activities favor the job generation, health improvement and poverty decreasing, thanks to the fish, which is one of the most commercialized goods worldwide, from which low resources families pick up their daily sustenance (FAO, 2014). The aquaculture is a multidiscipline activity, which constitutes a productive business that uses knowledge from biology, engineering and ecology, to help solve nutritional issues. According to the organism class that is being cultivated, it has divided into several types, being the most developed the pisciculture or fish-farming (Cifuentes et al., 2000).

In various regions in Colombia the tropical weather has been used as an advantage and the great amount of hydrologic sources, to create an important number of fish farms, that have as economical niche the breeding and production of fish species (Anuario Gobernación del Huila, 2012). In most of the fish farms located in the department of Huila, the red tilapia (*Oreochromis* sp) cultivated, due to it is a specie that can tolerate big temperature variations, counts with a big growth, is resistant to diseases and adapts easier to adverse conditions (Ezquivel et al, 2014).

The most frequent issues found in the fish farms, is the high mortality rate, which can be higher than 20% (Rural, 2014). This is due to fact that fish farmers do not count with technical counseling that can help them manage crops, management practices and to reduce production costs, besides, there is no control in some crop variables, either due to lack of budget or knowledge, consequently, a lot prefer to keep applying traditional techniques in the tilapia farming to avoid raising their costs (Palacio, 2015).

There is an aquaculture growth tendency when passing from 9.2 tons in 1990 to 82.7 tons in 2011; that is to say, an annual increase of 12% in average, exceeding by a lot the average growth rate of the other agricultural sectors and in total set of national economy. From the total fish-farm production achieved in the year 2011, the corresponding fish-farms to the red and silver tilapia farming contributed to the 58.5%. Bing the Huila department the biggest producer with 29.6 tons, followed by the departments of Meta and Tolima (Merino et al., 2013).

Based in the fact that the Huila department is one of the main tilapia producers in the country (Merino et al., 2013), and that many fish-farms are being affected due to the high mortality rates, due to the lack of supervising in physic-chemical parameters in the water, the goal of this work was to design and implement an electronic system for red tilapia farming ponds. With this system it is hoped to make easier daily supervising activities and help to reduce the mortality fish rate, as well as the costs generated by the used equipment.

Methodology

An electronic device was implemented to supervise the dissolved oxygen and the water temperature in the earth ponds located in the "Pezcomsi" fish farm (latitude = 2,6907158; longitude = -75,305935) in the Campoalegre municipality in the Huila department (Figure 1); this device Works through renewable energy, through a photovoltaic system mean, helping to counter the global warming and avoiding the use of conventional energies which depend on fossil fuels (Messenger & Ventre, 2010).

The implementation of this device was done in earth ponds with a volume of 300 cubic meters (20x10x1.5), placing the tool in a measure half in the pond, and the supervising sensor at 80 centimeters of depth.

Figure 1. Pezcomsi fish farm location, Municipality of Campoalegre, Huila.
Source: The authors

The obtained data by the device, were stored in a memory of itself, and were sent through Bluetooth communication to any mobile device that has installed the native application developed in Android where the user will be able to observe the information either numerically or graphically (Figure 2), and thus being able to conduct the respective statistical descriptive analysis.

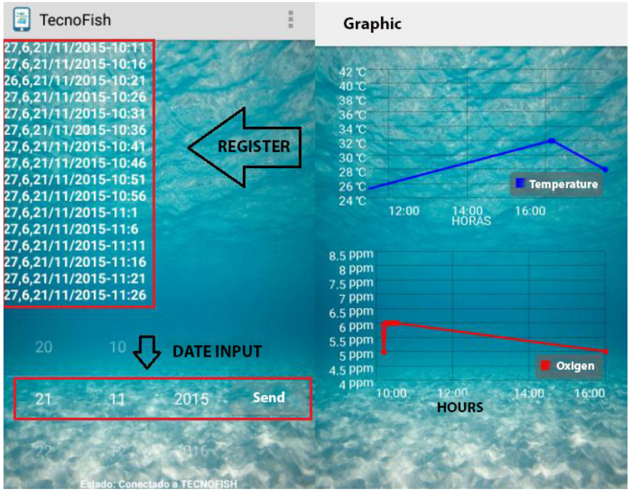

Figure 2. Graphic interface of the electronic device
Source: The authors.

The supervising system counted with four stages: 1) feeding, 2) sensor adequacy, 3) data acquirement and information processing, and 4) communication and data visualization (Figure 3).

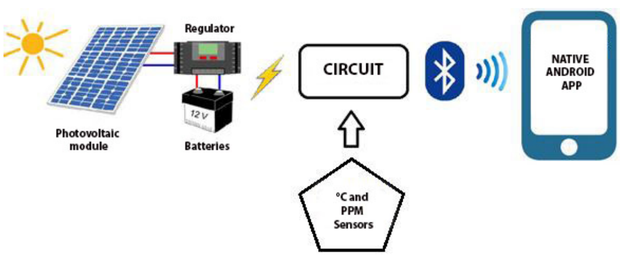

Figure 3. General diagram of the supervising system
Source: The authors

Feeding stage

The system in this stage worked just as displayed in Figure 4, which was fed through a 20W (Watts) solar panel, with a 12V (Volts) voltage controller which was joined to two 6V and 4.2A-h (Amperes-Hour) batteries connected to a set, taking this voltage from the batteries to the circuit in charge of regulating them and distributing them to different tension levels, this according to the system requirements.

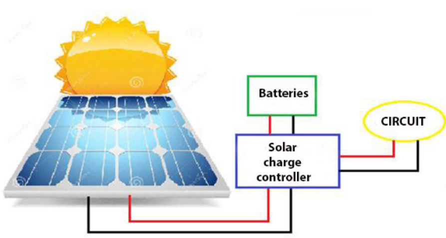

Figure 4. Feeding stage diagram
Source: The authors.

Sensor adequacy stage

In this stage, additional circuitry and components were used for the adequacy of incoming signals from the temperature and dissolved oxygen sensors, with the goal of reaching the necessary signals for it to be processed by the micro controller (Figure 5).

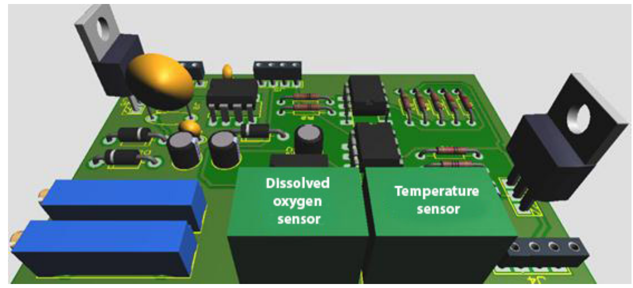

Figure 5. Sensors Adequacy circuit
Source: The authors

Due to the fact that the incoming signals from the sensors were too small, they were amplified through a an AD620 amplifier, which, at the same time, requires a dual source for its functioning; which the 7804 and 7905 voltage regulators were used in order to obtain 5V and -5V respectively.

Temperature sensor

In order to supervise the system temperature a PT100 RTD, manufactured with platinum, was used, which possesses an electric resistance of 100 ohms at a 0°C temperature, which conducted its respective adequacy (Figure 6).

Figure 6. RTD PT100
Source: The authors

Since the PT100 is a resistive probe, a way to balance and give stability to the sensor was through a Wheatstone bridge, with the goal to avoid wrong measurements (Figure 7).

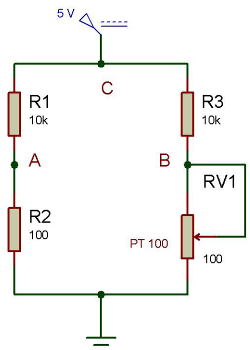

Figure 7. Wheatstone bridge
Source: The authors

Once the sensor found the bridge's branches, it was installed in the current source circuit, which was connected in the C node with the Wheatstone to feed it and make it pass through a lesser current of 1mA (milliamp), through its branches; with this, the auto-heating was avoided in the temperature sensor cables and thus avoiding distortions in its linearity (Figure 8).

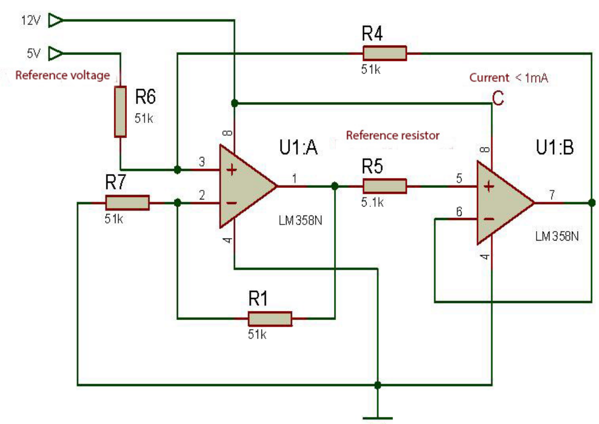

Figure 8. Current source circuit
Source: The authors.

Taking in account the low voltage level in the output signal of the Wheatstone bridge, this was amplified through an AD620 amplifier, which was configured as a comparator, since the A and B points connected the Wheatstone bridge (Figure 7) and the pins 2 and 3 from the instrumentation amplifier, respectively (Figure 9). The RG resistance connected between the amplifier pins 1 and 8 were in charge of giving the amplification to the system. The RG value was obtained from the data manufacturer's data sheet through the Equation 1.

$$Rg = \frac{49.4\ k\Omega}{G-1} \quad (1)$$

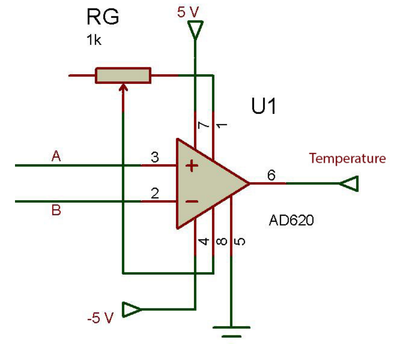

Figure 9. Signal amplification for the Wheatstone bridge
Source: The authors

The obtained voltages from the PT100 amplification stage, were compared with a pattern element for its calibration, with the goal to obtain more reliability in the taken measurements. The measurement pattern element was the DS18B20 sensor, which is a high accuracy digital thermometer (± 0.5°C) with three terminals, two for feeding, and a DATA terminal that transmitted and received information bits. In order to observe the temperature measurements obtained by this sensor, Arduino Uno plate was connected (Figure 10).

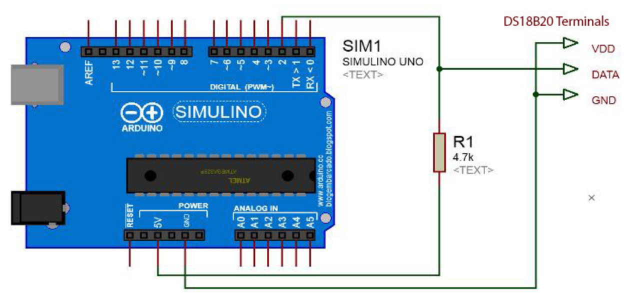

Figure 10. Digital connection sensor
Source: The authors.

Once installed the temperature sensors, the necessary tests were held to concatenate the obtained voltages from the Wheatstone bridge amplification with the temperature value that registered the digital thermometer (Figure 11).

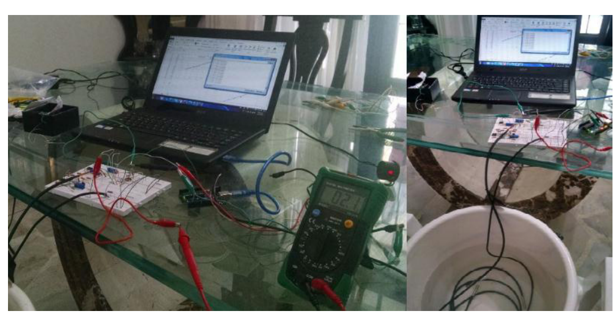

Figura 11. Calibration test for PT100
Fuente: los autores.

Once with the data tabulated, it was proceeded to perform a linearization with the obtained voltages from the Wheatstone bridge amplification, finding the Equation 2, which was used in the micro-controller programming.

$$y = 10{,}002x + 0{,}3498 \quad (2)$$

Where: y: Temperature in Celsius degrees

x: Voltage in volts

Dissolved oxygen sensor

In order to supervise the dissolved oxygen in the earth pond, a DO1200/T sensor was used, in which a device with an electro-chemical galvanic probe that does not require external feeding to generate a control signal was used (Figure 12). This is a probe that generates signal in mV (millivolts) proportional to the oxygen percentage found in the water.

Figure 12. DO1200/T dissolved oxygen sensor
Source: The authors.

To determine the oxygen concentration in ppm (parts per million), the oxygen percentages and the water temperature were observed, which are in the chart provided by the DO 1200/T dissolved oxygen sensor manufacturer (Chart 1).

To effectuate the respective signal Reading from the dissolved oxygen sensor by the micro-processor; the respective adequacy is performed, where the generated value by the sensor outdoors is taken, which will be at 100% of saturation. Next, the sensor is submerged into the water to obtain the oxygen percentage, and the Equation 3 is applied to find its range.

$$r = \frac{voltaje\ oxígeno\ en\ el\ agua}{voltaje\ oxígeno\ en\ el\ aire} \quad (3)$$

Chart 1. Data to calibrate the dissolved oxygen sensor

TEMPERATURA SALINITY – in parts per thousand (ppt)						
Deg ºC	Deg ºF	0	5	10	15	20
0	32	14.6	14.11	13.64	13.18	12.74
1	33.8	14.2	13.73	13.27	12.83	12.4
2	35.6	13.81	13.36	12.91	12.49	12.07
3	37.4	13.45	13	12.58	12.16	11.76
4	39.2	13.09	12.67	12.25	11.85	11.47
5	41	12.76	12.34	11.94	11.56	11.18
6	42.8	12.44	12.04	11.65	11.27	10.91
7	44.6	12.13	11.74	11.37	11	10.65
8	46.4	11.83	11.46	11.09	10.74	10.4
9	48.2	11.55	11.19	10.83	10.49	10.16
10	50	11.28	10.92	10.58	10.25	9.93
11	51.8	11.02	10.67	10.34	10.02	9.71
12	53.6	10.77	10.43	10.11	9.8	9.5
13	55.4	10.53	10.2	9.89	9.59	9.3
14	57.2	10.29	9.98	9.68	9.38	9.1
15	59	10.07	9.77	9.47	9.19	8.91
16	60.8	9.86	9.56	9.28	9	8.73
17	62.6	9.65	9.36	9.09	8.82	8.55
18	64.4	9.45	9.17	8.9	8.64	8.39
19	66.2	9.26	8.99	8.73	8.47	8.22
20	68	9.08	8.81	8.56	8.31	8.07
21	69.8	8.9	8.64	8.39	8.15	7.91
22	71.6	8.73	8.48	8.23	8	7.77
23	73.4	8.56	8.32	8.08	7.85	7.63
24	75.2	8.4	8.16	7.93	7.71	7.49
25	77	8.24	8.01	7.79	7.57	7.36
26	78.8	8.09	7.87	7.65	7.44	7.23
27	80.6	7.95	7.73	7.51	7.31	7.1
28	82.4	7.81	7.59	7.38	7.18	6.98

Source: The sensor's manufacturer

Once obtained the range (r), the Equation 4 was used, when multiplied by the data found in the Chart 1 that depended from the temperature at the moment of the measurement. The temperature in Celsius degrees was considered and low salinity, since the measurements were done in a fresh water pond.

$$y = r * x \quad (4)$$

r = Range obtained from Equation 3

x = Data from the Chart 1, depending from the temperature obtained by the PT100 at the moment of measurement

y = Sensor value in ppm

Just like the temperature sensor, this signal sensor was amplified through the AD620 operational amplifier, and, since it does not require external feeding, it was connected directly (Figure 13).

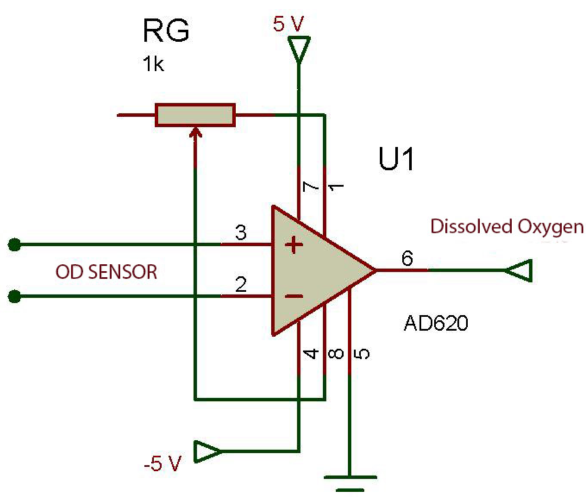

Figure 13. Dissolved oxygen sensor signal amplification
Source: The authors

Data acquiring and information processing

After adapting the sensors' signal, this is sent to the analog ports of the ATmega328-P microcontroller, where it became digital data ready to be processed, and thus, sending the information to a serial port to the communication and reception terminals connected through to the HC05 Bluetooth module. The information was sent through an SPI port from the microcontroller to the micro SD memory for storing (Figure 14).

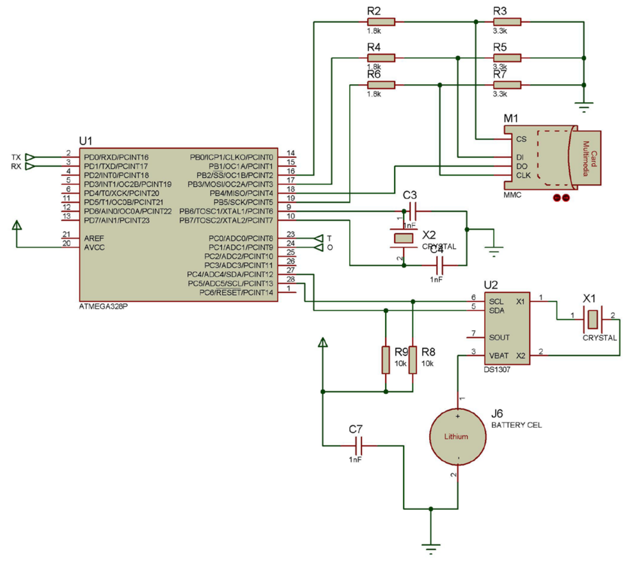

Figure 14. Data acquiring circuit
Source: The authors

ATmega 328-P Microcontroller

The ATmega 328-P microcontroller is the main component of the circuit and it makes the respective data acquiring. For its functioning one 16 MHz crystal with two 22pF capacitors were connected. The incoming signals from the operational amplifiers; one of temperature and one of oxygen, was connected in the microcontroller pins 23 and 24, respectively (Figure 14). With these pins, it became and from an analog signal to a digital signal with an 8-bit resolution, in order for the microcontroller to be able to execute it and operate it, according to the established programming. To program the ATmega 328-P controller, the Arduino software was used, which used a high level language called Processing, similar to C++ (Arduino, 2015).

In this stage, the information was processed, defined by the micron roller inputs to receive the analog signals from the sensors, which are the A0 and A1 (pins 23 and 24), being A0 for the temperature signal and A1 for the dissolved oxygen signal.

Micro SD Memory

This memory was in charge of taking the register for the generated measurements by the sensors, and was fed through a 3.3 volts regulator (78R33). The memory communicated with the microcontroller through an SPI communication.

Added to the data register was the time and date from when they were taken, reason why an RTC (Real Time Clock) with the integrated DS1307 circuit was necessary. This circuit was in charge of storing and taking in account the date and time; it has two feeding sources, one of 5V with which it normally works, and the other of 3V (3V battery) which is an auxiliary feeding source, and is activated when the circuit is not energized.

The stored data register was done every five minutes in the next order: temperature, dissolved oxygen, day, month, year, hour and minute. The data usage was done through the RTC.h and Time.h libraries.

Communication and data viewing stage

The system used a wireless Bluetooth communication system, which is a protocol that allowed a short-ranged wireless communication for commercial devices (Prabhu & Prathap, 2004).

The HC-05 Bluetooth module, was used in the communication stage to transfer the storage data in the Micro SD, which go through the microprocessor, and are sent to the radiofrequency module (class 2 Bluetooth) towards the mobile device through a serial port. The module was fed between 3.3V and 5V, and its Tx and Rx pins connect to the pins 2(Rx) and 3(Tx) respectively, which are the serial ports for the microcontroller.

The module comes Factory configured to work as master or slave. The master mode can be connected with other Bluetooth modules, while the slave mode waits for connection petitions. This module used the UARTRS232 serial protocol, which is ideal for wireless applications, easy to implement with PC, microcontrollers or Arduino modules.

Once collected and stored the information inside the system, the user did the connection between the mobile device and the electronic device through the Bluetooth connection, in order to take the stored data in the Micro SD, visualize them and be informed of the farm behavior.

To develop the mobile app the Android Studio software was used which is an integrated development environment to create apps in the Android platform (Cruz, 2013). Android Studio is a free software, which also allows to develop through Java code, and can also be done through templates. Like the applications developed nowadays. A template was used as a guide that allowed the Bluetooth communication with any device linked through serial communication (Bluetooth Terminal) drawing from the device connection, the sending and the data reception, for then improve it through Java coding, in way that the application sends by default the chart "#" and the microcontroller detected that, that was the end of the character chain to make its data sending operation. The application was designed so that the input data would be stored in the RAM memory in the mobile device, and thus, being able to graphic them, besides an alert will be generated if the last line is not sent between the optimal ranges for the supervised parameters (Figure 15).

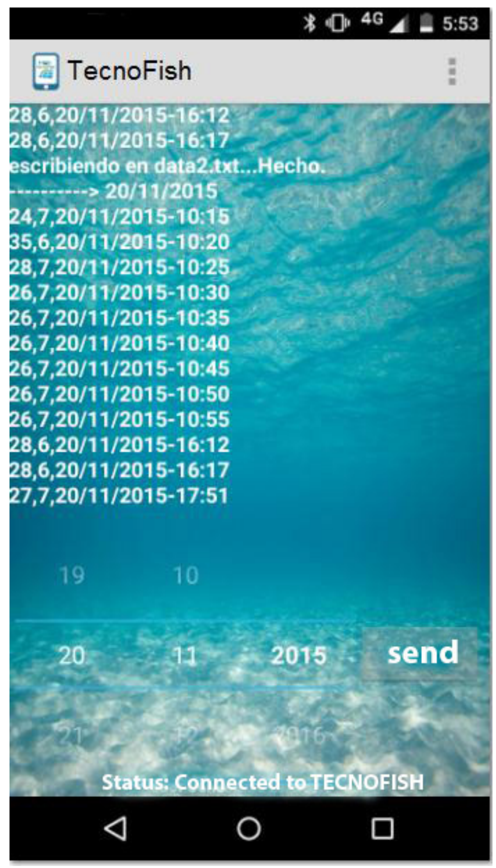

Figure 15. Graphic interface in the mobile application
Source: The authors

Results and data analysis

A validated working in-field prototype

Was obtained to supervise temperature and dissolved oxygen in the red tilapia pond from the "Pezcomsi" fishing farm in the municipality of Campoalegre, department of Huila (Figure 16).

Figure 16. Prototype collecting data in the field.
Source: The authors

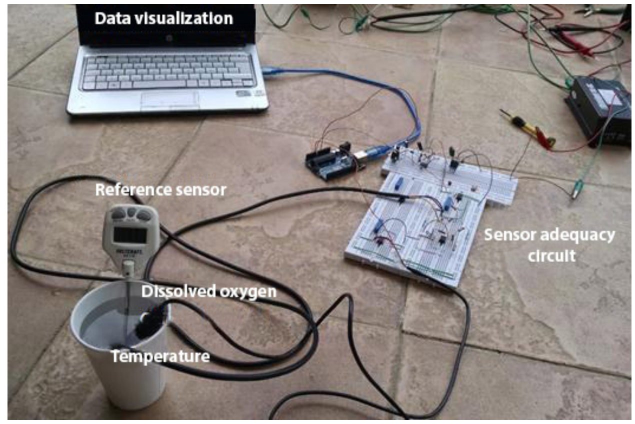

Figure 17. System validation
Source: The authors

System validation

To know how reliable are the obtained measurements made by the system, laboratory tests were made, to compare the obtained data by the system with the one of the VOLCRAFT DET 1R temperature sensor, which counts with a high accuracy (±0,1°C) (Figure 17).

40 tests were held with an initial water temperature of 18°C, which raised until getting to room temperature of 33°C. The temperature values for each test are observe don Figure 18.

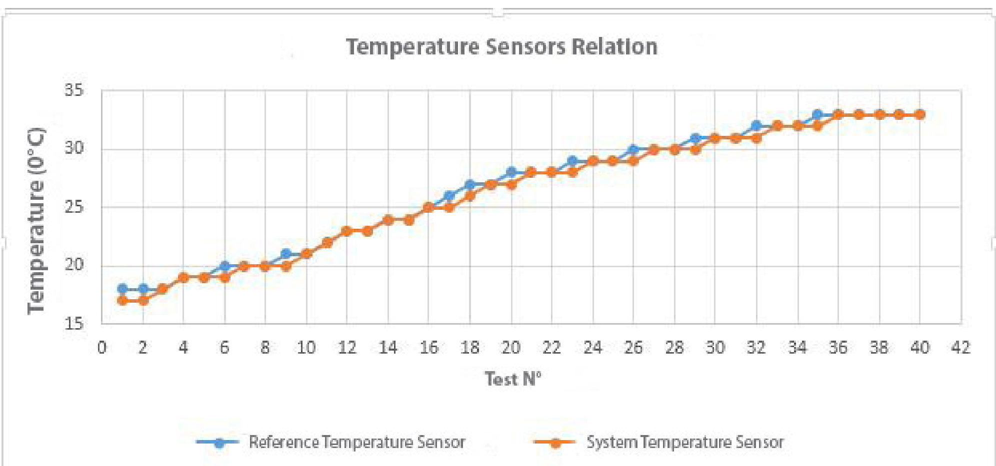

Figure 18. Temperature values obtained in each test
Source: The authors.

Now, it is proceeded to determine the mean or average of the registered values by each temperature sensor, to calculate the relative error percentage, and thus demonstrate the reliability of the system through the Equation 5.

$$E\ relativo = \frac{|Media\ Sens\ Sist - Media\ Sens\ Ref|}{Media\ Sens\ Ref} * 100 \qquad (5)$$

$$Error\ relativo = \frac{|26{,}275 - 26{,}575|}{26{,}575} * 100 = \pm 1{,}13\%$$

For the tests conducted by the temperature sensor, a delta was obtained with the sensor pattern of ±0.3 °C.

Regarding the sensor with dissolved oxygen, a comparison was made between the indirect method called Winkler method, the answer of the comer sensor YSI550A (Figure 19) and the developed device, taking in account that the pond measurements are combined with some chemical reagents, with the goal to obtain as a result the oxygen amount found in the water. Then it is proceeded to compare the sensor results with the chemical method, and the developed device, thus, observing the reliability of the device. It is of great importance to highlight that the implementation of this method was done by the chemical engineer Jaime Rojas Puentes, Water Laboratory coordinator in the *Universidad Surcolombiana.*

Figure 19. Water in the Winkler bottle
Source: The authors.

$$Relative\ Error = \frac{|6 - 6{,}4|}{6{,}4} * 100 = \pm 6{,}25\%$$

The tests were done to the dissolved oxygen sensor in one day, between 8 and 16 taking samples every hour, giving as a result a manageable error margin and fit to support trustworthy and accurate measurements of the electronic device with ±0.4 ppm, see Figure 20.

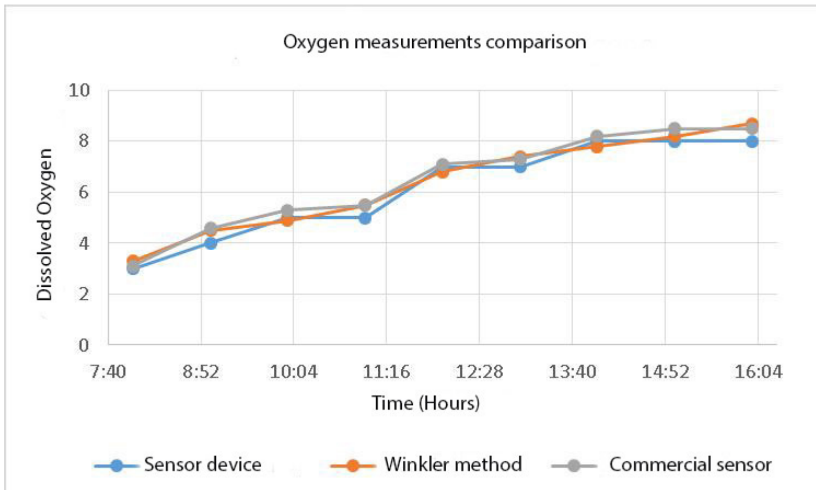

Figure 20. Comparison data, commercial YSI550A dissolved oxygen sensor, Winkler method, and the developed device
Source: The authors.

The relative error in the system is small, giving reliability to the electronic device created to determine temperature and oxygen concentration in water of an earth pond for fish-farming.

Physicochemical data parameters

The data analysis and behavior that the monitoring done for 15 days, is observed on Figure 21 and Chart 2. For this, the data was taken and averaged for the 15 days, for 24 hours, with a sampling frequency of 24 samples a day.

Chart 2. Statistic data analysis

Data analysis	Temperature (ºC)	Dissolved Oxygen (ppm)
Mean	26.806	5.076
Standard deviation	0.906	2.203
Variation Coefficient (%)	3.380	43.400

Source: The authors.

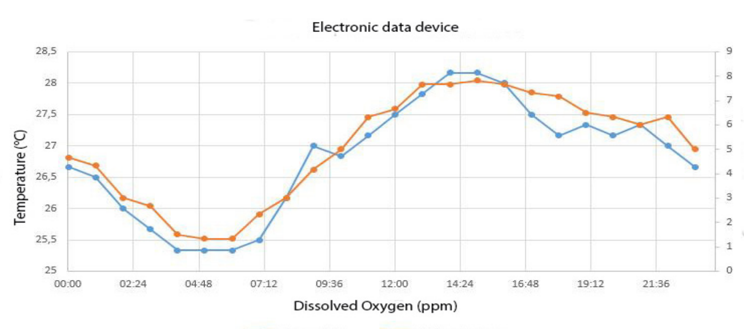

Figure 21. device data record
Source: The authors.

Results analysis

It is observed that the created prototype, effectively supervises the study parameters collecting adequate temperature and oxygen concentration vales found in an acceptable range in the tilapia farming.

Observing the Figure 21, and the average of the days that the electronic device supervised the pond, it could be determined that the oxygen levels decreased between 1 and 8 am, being an alert period for the fish farmer. This due to the fact that the fishes and other present organisms in the pond consume the oxygen until taking it to critical levels (Goyenola, 2007).

The dissolved oxygen increases in the day, since early in the morning the fish farmer performs a water replacement to the crop in order to dispose of the organic wastes own from the fish. Besides, in these ponds are found some seaweed and aquatic plants that generate oxygen through the photosynthesis process (Goyenola, 2007).

Through the used system, temperature levels higher than 29°C between the 10 and 17 hours were detected, which suggest the fish farmer to be alert during this period, and performs water replacements with the intention to reduce the fish mortality possibilities.

Statistically the temperature presented a low variation percentage and it keeps itself in the acceptable range for the tilapia farming. On other side, the dissolved oxygen presented a high variation percentage between 1 and 8 ppm; reason why it is suggested to use tools that help this parameter to not vary in an abrupt way and keeps in an acceptable range.

Conclusions

This electronic prototype becomes a useful tool for the practice and prevention for the mortality rates in the tilapia farming.

The designed electronic device is effective in the temperature and dissolved oxygen supervising in pond waters where the tilapia is bred.

The mobile app created through Android Studio, allows to visualize in a wireless way the temperature levels and oxygen concentrations in the pond.

The electronic device designed through a photovoltaic system, which stands out for taking advantage of the renewable energies, to avoid the pollution throughout the use of conventional energies.

The dissolved oxygen was the parameter that showed the most variation and alert in the tilapia farming.

For all the implemented stages in the system, they all worked adequately, obtaining a functional and innovative prototype for the fish-farming sector, which, with the necessary adjustments such as the control of these variables, would help to lower the mortality levels that affect so much the fish farming in our region.

Is worth to consider a future study, the implementation of strategies to control the oxygen levels in this class of fish farming.

Acknowledgements

To the Tecnoparque Colombia network node Neiva of the SENA, who provided technical assitance and escorting with the counselings in the course of the development of this Project; to the engineer Jaime Rojas Puentes, teacher from the Universidad Surcolombiana, who was a judge during this degree work, and supported giving his knowledge in water qualities, for delivering confidence and offering a good tool for the fish-farming sector in the department of Huila.

References

Arduino, (2015). *What is Arduino*. Recovered from 2015. https://www.arduino.cc/.

Cifuentes Lemus, J. L.; Torres García, M. D. & Frias Mondragón, M. (2000). *Fish-farming*. The ocean and its resources XI, vol. 2.

Cruz, Z. B. (2013). *Installing and Configuring Android Studio. Android Studio Application Development*, Packt Publishing, 87 pp.

Ezquivel, M. A.; Merino, M. C.; Restrepo, J. J.; Narváez, A.; Polo, C.; Plata, J. & Puentes, V., (2014). *Fishing and Aquaculture State,* AUNAP 13-14.

FAO. (2014). *World Fishing and Aquaculture Test. The world fishing and aquaculture state*, FAO, 253 .

Goyenola, G., 2007. *Guide for the using of traveling bags. Aquatic environments participatory supervising network*, Red Mapsa, 1.

Merino, M. C., Bonilla, S. P., & Bages, F. (2013). *Diagnose of the aquaculture state in colombia*, 160 pp.

Messenger, A. R., & Ventre, J. (2010). *Photovoltaic Systems Engineering.* New York: Taylor & Francis Group, 3, 461 pp.

Palacio, A. (2015). *Tilapia farming production handling*. Interviewer: Dussán, S.

Prabhu, C., & Prathap, R. A. (2004). Introduction to Bluetooth. Bluetooth Technology and its Application with Java and J2ME. New Delhi: Prentice-Hall, 326 pp.

Rural, M. d. (2014). Red tilapia farming in earth ponds. Associated inputs and factors for the farming production. 63 pp.