Supervisory System for Monitoring, Control and Estimating Thermal Comfort for Broiler and Laying Hens Production Sheds

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Abstract

This research aims to promote the project for the construction of software, firmware, and micro-controlled hardware, which together allow the automatic control of the temperature and humidity index (THI) in real-time the intensive production environment in poultry and laying hens production houses, thus avoiding productive losses due to the stress to which the birds are subjected. This system aims, from the information from a set of sensors, connected to a microcontroller acquisition and control board, to infer the temperature and humidity index from the measured climatic variables, to enable the corresponding activation of electronic interfaces with electric actuators, for the automatic activation of ventilation devices, humidification and curtain actuation and the lighting of production houses, keeping the environmental conditions of the house within a convenient range of temperature and relative humidity to ensure thermal comfort and thus avoiding bird stress. Thus, helping to mitigate production losses and facilitating managers real-time monitoring of the shed to achieve greater productivity and competitiveness.

Keywords: Automatic Control, Broiler Production, Competitiveness, Decision Support Software, Productivity.

1. INTRODUCTION

Whereas poultry and laying hens production are currently negatively affected by the possible rise in temperatures, limiting the areas where production can be established and renewing the search for means to alleviate the sudden changes in the external environment within the premises, poultry and laying hens production. In Brazil, which is one of the most coordinated animal production chains, it must continue to invest in innovation in order to maintain its current position among the largest producers in Latin America.

According to [1], temperature maintenance is essential for the welfare of laying hens. The thermal factors that can be represented by air temperature, humidity, thermal radiation and air movement cause several physiological changes in the birds, compromising the homeothermy. Outside the comfort zone, there is a decrease in productivity, reproductive and immunity performance, and temperature extremes can be lethal.

As the consumption of chicken meat in the world has increased in recent years, consumers have become more demanding about poultry welfare [2], and regarding the quality and safety of this product [3], a fact that generates more motivation for the technological contribution.

In this scenario, a factor that stands out as a problem to be solved or mitigated through technological support is thermal stress, a factor that directly affects the productivity of breeders and, in addition, can expose them to high mortality rates, thus reducing the production performance by several genetic lines [4].

Adult breeding birds raised in temperature in the so-called thermal neutral or thermoneutral zone tend to produce more in the welfare state [5].

According to [6] the global meat industry has seen significant changes in the methods used to create, harvest and process fresh meat over the past century. The increased use of automation has led to significant increases in the speed of production processes for beef, pork, sheep, poultry and fish operations. The same author in another publication highlights the fact that in general greater automation has been introduced in the poultry industry due to the smaller size and more uniform nature of broilers compared to red meat animals [7].

The researchers [8] worked on an evaluation of the thermal comfort and performance of broilers and concluded that the meteorological variables and the environmental thermal comfort indices, under favorable conditions, point to a better natural thermal conditioning for the birds. This fact favors the improvement of the productive indices, even when the results are evaluated under the differentiated farming regime.

This is reinforced by the work of [9], who highlights that heat waves cause losses in animal production due to their exposure to heat stress increasing mortality, and consequently, economic losses. These hot flashes are recurrent in southeastern Brazil.

Given this research and its conclusions, it is justified to present this research with the purpose of mitigating these impacts on production, in order to support producers to evaluate and monitor the characteristics of broiler breeding and laying hens environments, seeking to automatically reduce heat stress and thus better support their decisions, or set them to be automatically made through automated systems focusing on scaling results with less human interference, thereby enhancing productivity, competitiveness and reducing losses.

This is achieved through the development of a computational tool focused on the automatic control and monitoring of the utilities and sensors of the sheds, helping to keep the thermal environment controlled, avoiding the thermal stress for birds as pointed out by [10], together with information from of a sensor system and a microcontroller device that can generate sufficient information for the automatic activation of devices that promote temperature control and thus prevent productive losses in the broiler chicken and laying hens production sheds.

Thus, the objective is the development of the design and construction of a prototype with embedded intelligence, based on microcontroller, acting in real-time, with a set of sensors for the measurement of dry bulb temperature, atmospheric pressure and humidity using discrete components and actuators that allow data exchange with a personal computer-based supervision and control system for the automatic comfort control of the poultry rearing and laying hens environment to maintain the temperature and humidity index (THI), within the limits of thermal comfort, evaluating its response characteristics in simulated environment.

2. LITERATURE REVIEW

In the classic work by [11], the authors carry out an important review on the application of integrated monitoring systems techniques, in which sensors of environmental variables, databases, mathematical models and previously formed knowledge bases are combined and interpreted, thus allowing the maximum potential of this generated information can be utilized so that the farmer/keeper can maximize the efficiency of his production system by monitoring all its critical steps and goals and ensuring that they are kept close to ideal.

These considerations make it possible to infer that technological innovations, through technological support in intensive broiler and laying hens production environments, can increase competitiveness and increase producers' profitability.

It is observed that in this animal production market, there is a growing use of automation, which leads to significant increases in the speed of operations with birds, where procedures such as maturation, stimulation, cooling, sensing and actuation of electrical systems are now common. for poultry processing resulting in high-quality end products [6].

The same author points out that this is a constant challenge because the equipment requires the development of unique sensors and control systems that replace traditional manual operations and assisting the equipment in automatic operation.

In this field of knowledge emerges precision agriculture, which can be defined as in the work of [12], as is the art and science that uses advanced technology to improve agricultural production. The authors point to sensor technologies that are the major causes of the development of precision agriculture. Further, the fact that recent advances in communications and electronics have enabled the development and production of low-cost, low-power multifunction sensors that are small in size and can communicate intelligently and cheaply, and can be deployed. in large numbers, providing enormous opportunities for environmental monitoring and control [13].

Monitored data, according to [12], are used to obtain the best decision for the control and adjustment of environmental parameters in order to obtain a better production yield, optimizing the use of resources. As the project is closely related to climate variables, it will also have sensors that will collect data to monitor the excursion of climate variables. Given these considerations, choosing the right hardware that makes up the sensor nodes is an important decision for any precision farming system deployment.

Comparison between different hardware architectures can be made according to the general parameters, processor and memory, communication capacity, sensor support, and power consumption. One of the main characteristics in node selection (hardware/microcontroller/sensor/actuator) is its physical parameters, weight, size and price [14].

According to the work of [15], we currently find in the market equipment produced by large electronics companies that adapt the PC for the most diverse functions ranging from data acquisition to the control of complex production lines in the industry. These products include data acquisition boards that, together with a huge assortment of transducers, allow you to use the PC to measure and record the most diverse physical variables. According to the same authors, one of these devices is the Arduino development learning board, which is based on a very versatile AVR family AVR microcontroller, which enhances its functions beyond a simple passive data acquisition interface and can operate alone controlling various devices and thus having applications in embedded instrumentation and robotics.

They add that the whole electronic project, including the platform for the development of the control programs, is public and free, with an extensive international community and on the Web, you can find a lot of application documentation.

Other works using this hardware platform in different applications and knowledge areas have already been done by [16]; [17] and with other microcontrollers as in the works of [18] and [19] who worked with PIC, as well as the authors [20] who worked with Basic Step M8.

In this context the present research presents the development of the project of an intelligent prototype-based microcontroller acting in real-time, with a set of sensors for the measurement of dry bulb temperature, atmospheric pressure and relative humidity, which uses discrete components and actuators, exchanging data with a personal computer-based supervision and control system for the comfort control of the poultry and laying hens environment automatically maintaining the temperature and humidity index (ITU) within comfort limits thermal stress and avoid heat stress. This will help companies reduce the production losses caused by sudden temperature fluctuations and increase their market share, thus gaining greater competitiveness and productivity.

3. MATERIAL AND METHODS

For the design of the system hardware, are used open-source, free software Fritzing version 0.9.3b, which is a software tool for prototype documentation [21]. After the software-supported prototype was completed, the hardware was built with its components - an Arduino Mega 2560 R3 acquisition and control development board, a BMP 180 atmospheric pressure sensor, two relative humidity, and dry bulb temperature sensors DHT22 for measurement of the internal and external shed temperatures, a block of 4 Relays (1 inverter each for 110/220 Vac power loads), and an L298N H-Bridge for two DC and 12V dc motors.

The entire system was powered by a 12 Vdc power supply and a unique 9Vdc power supply for the data acquisition board to eliminate the possibility of improper restarting of the data acquisition card due to the switching of system interfaces added controls.

As the variables to be monitored by the system are the dry bulb temperature, relative air humidity and atmospheric pressure, the methodology proposed by [22] were applied for the temperature range of $0 < t < 50$ ºC and, the sensors and actuators adapted for project development will be those listed in Table 1.This table also shows the specifications of the drive modules listed in the design for driving curtain motors, fans and humidifiers.

Table 1. Sensors and actuators listed for development.

Sensor	Manufacturer	Reading range	Resolution	Accuracy
Pressure BMP180	Bosch Sensortec	300-1100 hPa	0,02hPa; 0,17m	+- 1hPa
Humidity and	Aosong Electronics Co.,Ltd	0 to 100%RH; - 40 to + 80°C	0.1%RH; 0.1°C	+- 2,0%RH; +- 0,5°C

Temperature DHT22		
Actuator	**Manufacturer**	**Features**
H bridge L298N	STMicroelectronics	Interface Board - Control of 2 DC motors; Max Operating Current: 2A per channel or 4A max; Logic voltage: 5v; Logic current: 0 ~ 36mA; Temperature Limits: -20 to + 135 ° C; Max Power: 25W
Multiple Relay Block	New Brand	Interface Board 5V - 8 Channels 10A Relays DC30V AC250V 10A, with Optimal Couplers for 15-20mA Input

The developed system has the function of collecting, through sensors, the environmental variables corresponding to the dry-bulb temperature, atmospheric pressure and relative humidity inside the building that simulates poultry and laying hens installation, in which actuators are also installed (Opto relay blocks). which controls the actuation of two sets of motorized curtains, the lighting system, a fan and a humidifier.

These relays in the actual production environment will be responsible for sending the drive signals to the electrical control units of the lighting, ventilation, humidification and curtain control systems, thus forming a unit adaptable to any type of shed and any legacy equipment.

These actuators will be controlled by the Arduino microcontroller board on which firmware is embedded to automatically seek to maintain the temperature and humidity index (THI) within the limits of thermal comfort and to avoid heat stress.

Figure 1 presents the block diagram of the proposed system built with Bizagi process modeling software [23].

For the evaluation of the binomial relative humidity and room temperature, according to [24], we use the index developed in [25] classic work that proposed the calculation for the Temperature and Humidity Index (UTI) using equation 1, which has been widely used for involving only meteorological information normally available in weather stations and databases from satellite images:

$$THI = Dbt + 0{,}36\, Dpt + 41{,}5 \quad \text{Eq.1}$$

wherein:

THI - temperature and humidity index; Dbt - dry bulb temperature, (ºC); Dpt - dew point temperature, (ºC).

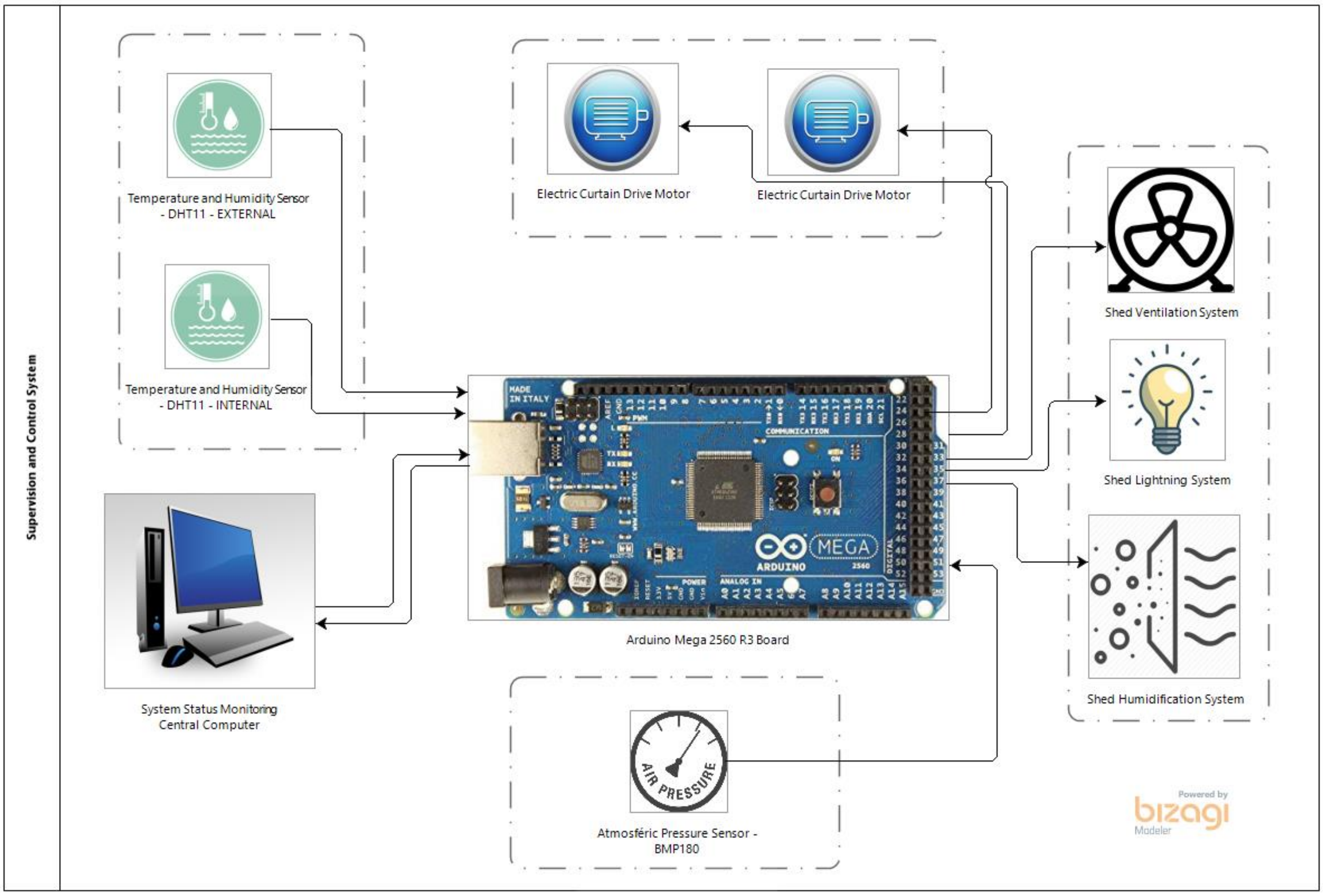


Figure 1. Block diagram of the proposed supervision and control system.

The air temperature (dry-bulb temperature - Dbt) can be obtained by means of common thermometers and, in the case of the proposal of this work, by means of the DHT22 electronic sensor.

As for the dew point temperature (Dpt), it is considered, according to [26], the result of the night cooling, due to the losses of longwave radiation that reduces the temperature until reaching the temperature. dew, when saturation occurs and, consequently, the steam condensation process begins. Therefore, it was necessary to obtain Tpo through indirect means.

To this end, the methodology proposed by [22] was applied to the temperature range of $0 < t < 50$ ºC (Eq. 2) due to the humid temperate climate with dry winter and hot summer in the city of Tupã / SP. located in the southeastern region of Brazil according to the Köppen-Geiger Cwa climate type classification:

$$Dpt = 6{,}983 + 14{,}38 * a + 1{,}079 * a2 \quad \text{Eq. 2}$$

wherein: $a = \ln(pw)$

In this equation, pw is the saturation pressure, which was obtained from the same study by [22] using Equation 3:

$$W = 0{,}62198 * (pw/(p-pw)) \quad \text{Eq.3}$$

wherein:
W - Relative Air Humidity, (%);
p - local atmospheric pressure (Pa).

With the application of these equations, with the proper algebraic manipulations, it was possible to obtain the value of the THI since the values of relative humidity and atmospheric pressure which are also obtained through the electronic sensors. These calculations have all been transferred to the firmware and to the PC software.

THI values between 71 and 78 are characterized as critical, from 79 to 83, indicate danger and above 83 is already an emergency [27]. Also according to the same author, THI values ranging from 71 to 83, would be valid for domestic animals globally, thus applying to broiler chickens, an object of this research.

A few years later, [28] constructed an adjusted table to indicate the THI indices for animals according to the impact it represents globally, allowing them to determine the four important classes adopted for the present study.

Table 2 presents the thermal comfort status ranges adapted from this study:

Table 2. Site Characteristics x Temperature and Humidity Index (THI)

Location Status	**THI**
Normal	< 74
Alert	> 74 < 79
Danger	> 79 < 84
Emergency	> 84

Source: Adapted from [28].

The system firmware was built based on the Arduino community-available web application [29] in version 1.6.5 and was adjusted to collect climate variables by inferring THI index values, and the control algorithm is based on climatic variables and THI values for the performance of each output device.

The THI values are calculated in the embedded system and in the PC application, automatically after each collection and the algorithm, based on the rules defined for the performance, based on the table proposed by [28] and will fire individually or together, all indoor environment control devices to keep the environment, as close as possible, within the thermal comfort conditions for the birds by serially sending the data to the supervisory developed in Microsoft® Visual Studio .Net 2017 Rapid Application Development (RAD) tool with VB.Net programming language.

This supervision will allow the System User to interact with the acquisition and control hardware installed, allowing automatic or manual activation of the shed curtains or the fans and humidifiers.

4. RESULTS AND DISCUSSION

4.1 Hardware design and connections diagram

The design of the system hardware, to meet the data collection characteristics described in the materials and methods section, consisted of the application of open-source, free software Fritzing version 0.9.3b, [21] and resulted in the diagram of links between the modules shown in Figure 2.The system is based on the application of commercially available, low-cost commercial modules and sensors.

The developed hardware had its peripheral processing and control base defined by the Arduino Mega 2560 R3 board which allows, besides meeting the connections required by the project, the provision of a good number of spare I / Os for future expansions, as well as a good programming memory space, which guarantees good stability considering the amount of variables and peripheral devices adopted for development.

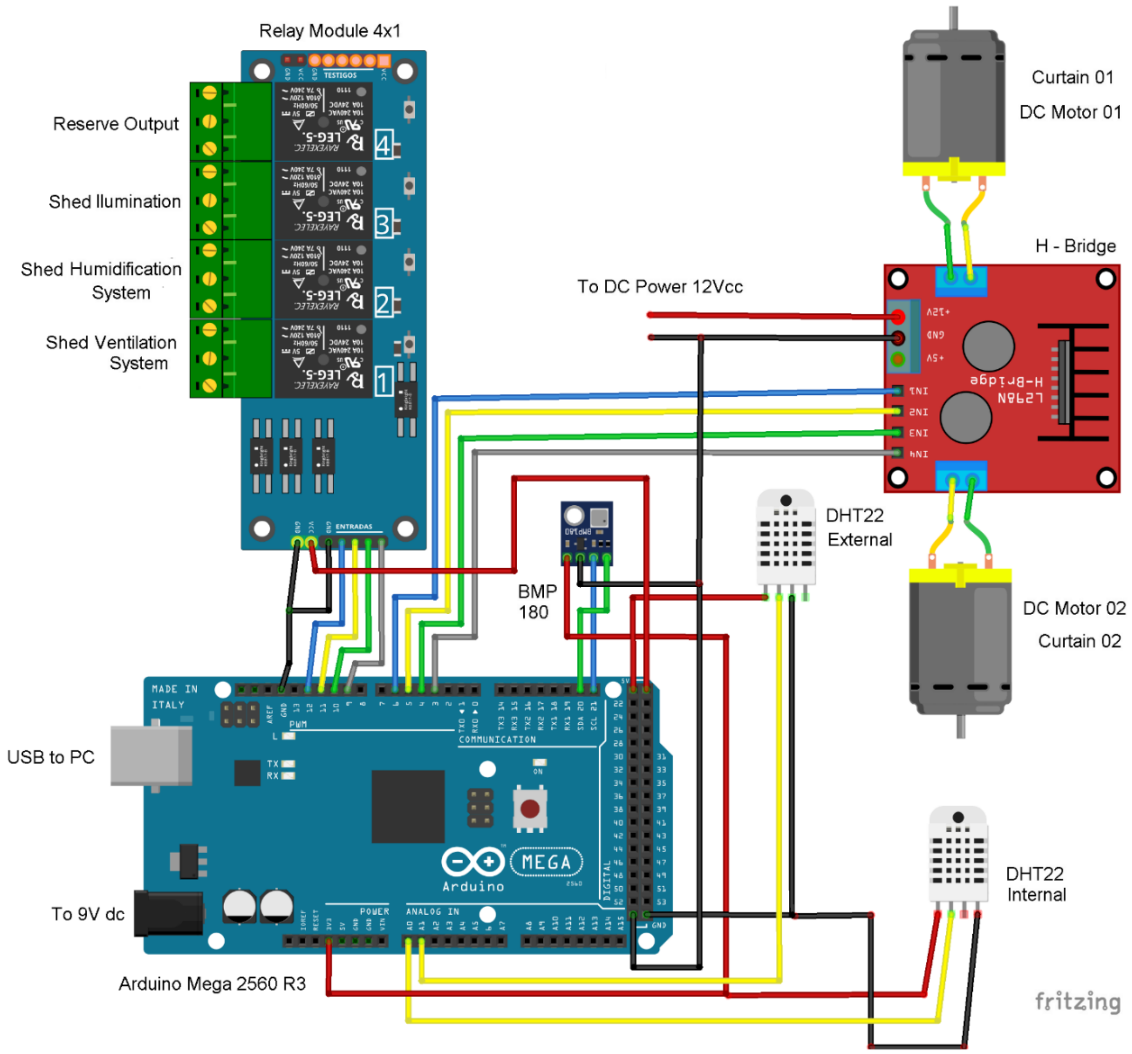


Figure 2. Design of supervisory and control hardware components.

4.2 Firmware design

The system firmware built on the application made available by the Arduino web-community [29] in version 1.6.5.

The coding was done in C ++ language using subroutines. The configuration libraries provided by the manufacturers of the sensors and H-bridge selected for the project were also used.

The coding of this firmware was developed based on the creation of a proprietary communication protocol that makes the acquisition card standby waiting for the USB serial communication channel to arrive from the PC (from the developed supervisory application) of a string or numeric code so that it can then respond as requested.

The generated algorithm causes a focused interrogation loop for the USB serial channel input to identify which function is being requested and thus determines the action to be performed (Sensor Read or Power Interface Trigger).

Sensors are interrogated by the PC application individually (using different numeric codes) and, upon receiving the code, the firmware executes the subroutine corresponding to the reading of the value of the given sensor and sends it to PC through the USB serial communication channel of the data acquisition board.

The acquisition board also in its firmware is prepared to receive from the PC, control strings, which depending on their configuration, will trigger the corresponding relay block digital outputs, thus allowing the control of external loads.

4.1 Supervisory Software Design and Description of the Main Functionalities

The supervisory was developed in Microsoft® Rapid Application Development (RAD) tool called Visual Studio .Net 2017 with a visual basic programming language (VB.Net).

Immediately after clicking on the application icon on the computer desktop with the Windows 10 operating system, the application starts by displaying a splash form with the system presentation.

The generated application splash screen can be seen in Figure 3.

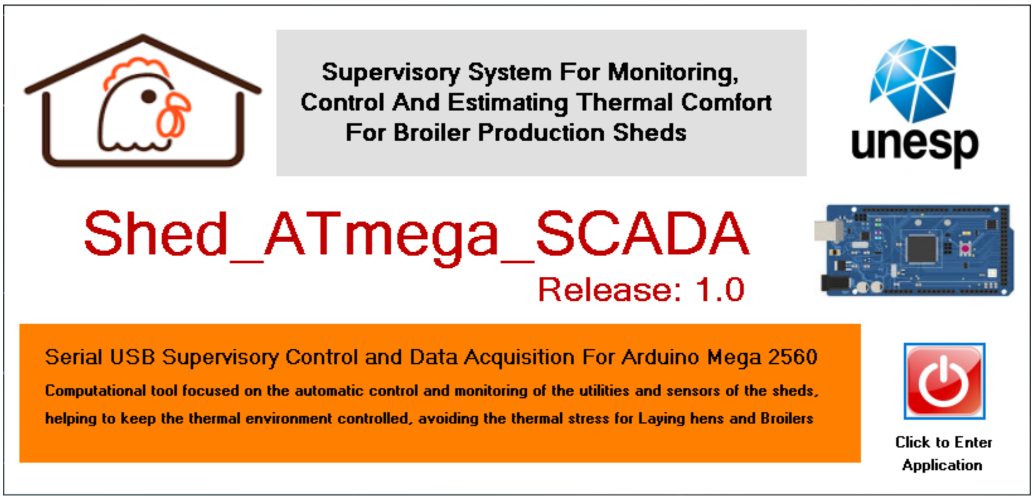


Figure 3. Splash Screen form.

When the Form Splash discharged after the user press the command button with the message “Click to Enter Application”, the Form Splash loads a message box with instructions to the user, recommending the correct setup of the serial port communication and the correct hardware connection to the PC USB port. The message box can be seen in Figure 4.

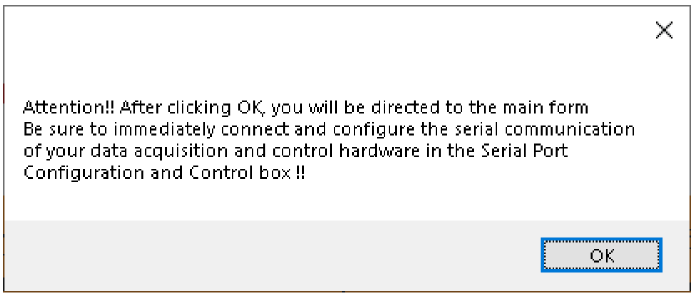


Figure 4. Configuration Allert MessageBox.

After clicking the command Button "OK" the MessageBox, there is a discharge of Form Splash and MessageBox, opening for the user to the MainForm of application. The main form of the application has a set of features that can be divided into some important sections.

On the left side, in the upper corner of MainForm, there is a container that allows the user to configure the serial communication between the PC and the Arduino Hardware with an ATmega microcontroller.

In this container a DropBox allows the selection of the available serial port, that is, the system captures all the serial port drivers installed in the operating system and allows selection.

Just below, there is another DropBox with the possibility for the user to select BitRate, that is, data that is transmitted in a certain period of time, so that the PC can establish communication correctly with the Arduino hardware. The default is 9600 bps, a value also defined in the firmware developed for the ATmega board. With these two configurations made, the user will be able to click on the CommandButton to open the serial port and enable bidirectional communication (PC / Hardware) of the system.

When performing this task, the icon of the USB port, which is animated, changes its color to green, indicating the new status of the port. Right below, there is the CommandButton to close the port and the USB port icon turns red again and the bidirectional communication is stopped.

For the system to act in conjunction with the hardware, the door must be open, otherwise, the system will send MsgBoxes with error messages about the serial port being closed.

Once the communication is established, below the container of the serial port configuration, there is a new container that allows the user to manually access the hardware drives, starting by accessing the led of the card that is physically connected to pin 13.

Thus, the user can make sure the card is properly connected and configured. There is also an icon with the word LED which, depending on the command, is animated in black or white, following the operation of the LED on the board.

LED between the icon and the image with the thumbnail of the board, there is a lively text that indicates the status of the board's response on the confirmation of the drive.

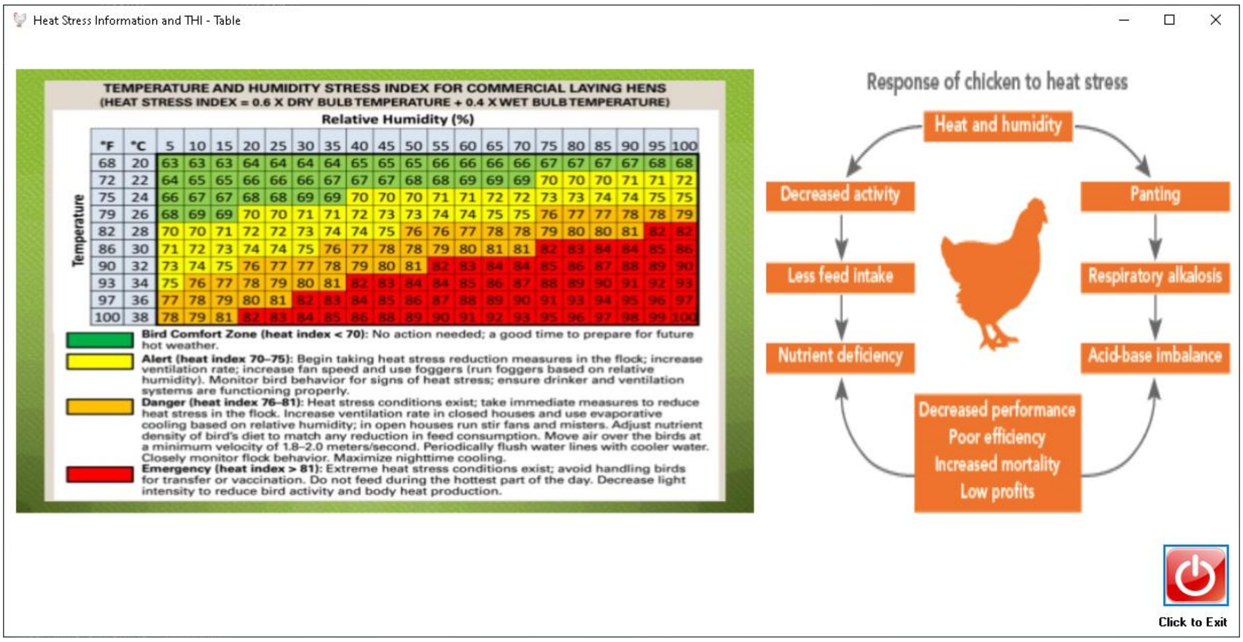
Below we also have the CommandButtons that allow us to connect or disconnect four digital output ports, one dedicated to the activation of the fans, one dedicated to the activation of the humidifiers, one dedicated to the activation of the shed lighting system and finally one dedicated to an extra user equipment. , here called "reserve".

In the sequence are two sets for driving an H bridge for two direct current electric motors, which allow, depending on the CommandButton that is activated, to make the motor turn clockwise, brake or turn counterclockwise. These commands were inserted to actuate the shed curtain systems. Below each set of these controls is an animated text with the status of the outputs.

In the central range of MainForm, there is a defined area for reading the sensors installed in the hardware. The user can, by clicking the CommandButton that enables the automatic reading of the sensors, see start scanning through a green icon that moves between the lines by filling in the values read in red and above, there is a lively text that shows the status of scan, which is green when triggered and displays text "scanning" and when the user clicks the CommandButton that Disables the sensor reading scan, the green icon to your traffic and animated text turns red inscription "scan Stopped".

When the readings are enabled, the round icon with the text "Off" in red, changes to see with the inscription "On".

When using the sensor scanning system, in the system, below, there is a checkbox that enables the automatic control of the fans and humidifiers, automatically turning them on or off based on the status of the shed's internal thermal environment. There is also a set of two square icons that show the status of the outputs controlled automatically by changing colors from red to green and using animated text on the right side. Just below there is a new container box that allows the user, when clicking on the CommandButton, to access a new Form with extra information about the issues involving the birds' thermal stress and a table with the indices that are calculated in the application. Figure 5 shows this form.



TEMPERATURE AND HUMIDITY STRESS INDEX FOR COMMERCIAL LAYING HENS
(HEAT STRESS INDEX = 0.6 X DRY BULB TEMPERATURE + 0.4 X WET BULB TEMPERATURE)

Relative Humidity (%)

°F	°C	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
68	20	63	63	63	64	64	64	64	65	65	65	66	66	66	66	67	67	67	67	68	68
72	22	64	65	65	66	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72
75	24	66	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74	75	75
79	26	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	77	77	78	78	79
82	28	70	70	71	72	72	73	74	74	75	76	76	77	78	78	79	80	80	81	82	82
86	30	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
90	32	73	74	75	76	77	77	78	79	80	81	82	83	84	84	85	86	87	88	89	90
93	34	75	76	77	78	79	80	81	82	83	84	84	85	86	87	88	89	90	91	92	93
97	36	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	93	94	95	96	97
100	38	78	79	81	82	83	84	85	86	88	89	90	91	92	93	95	96	97	98	99	100

Bird Comfort Zone (heat index < 70): No action needed; a good time to prepare for future hot weather.

Alert (heat index 70–75): Begin taking heat stress reduction measures in the flock; increase ventilation rate; increase fan speed and use foggers (run foggers based on relative humidity). Monitor bird behavior for signs of heat stress; ensure drinker and ventilation systems are functioning properly.

Danger (heat index 76–81): Heat stress conditions exist; take immediate measures to reduce heat stress in the flock. Increase ventilation rate in closed houses and use evaporative cooling based on relative humidity; in open houses run stir fans and misters. Adjust nutrient density of bird's diet to match any reduction in feed consumption. Move air over the birds at a minimum velocity of 1.8–2.0 meters/second. Periodically flush water lines with cooler water. Closely monitor flock behavior. Maximize nighttime cooling.

Emergency (heat index > 81): Extreme heat stress conditions exist; avoid handling birds for transfer or vaccination. Do not feed during the hottest part of the day. Decrease light intensity to reduce bird activity and body heat production.

Figure 5. Auxiliary form to support users with indications about the THI index and the effects of thermal stress on birds.

In the third section of MainForm, the THI index calculations are displayed for the interior and exterior of the shed, using animated text and progress bars that show the result of the calculations obtained for each sensor scanning interaction, as well as the green animated icons that travel between the readings in the central assignment and go through the index calculations, they update the results.

Below is a new container box with two blocks, each with a set of animated icons that show the installation status for the interior and exterior of the shed.

These icons show two stylized thermometers and emoji faces indicating the thermal comfort condition, as well as an animated text with the status condition determined by the calculation of the indices.

Continuing in the sequence, in the next container box, we have access for the user to fill in two text boxes, the desired times for the shed lighting to switch on and off.

This allows the user to have more effective control of the light time schedule to which the birds must be exposed.

Right below, still in this section, we have a container with the date and time-synchronized with the

PC's operating system.

Finally, the user finds in the last container in the lower right corner of the MainForm, a Command Button that allows to close the application.

Figure 6 shows the MainForm in the condition of "Serial Port Closed" awaiting user commands.

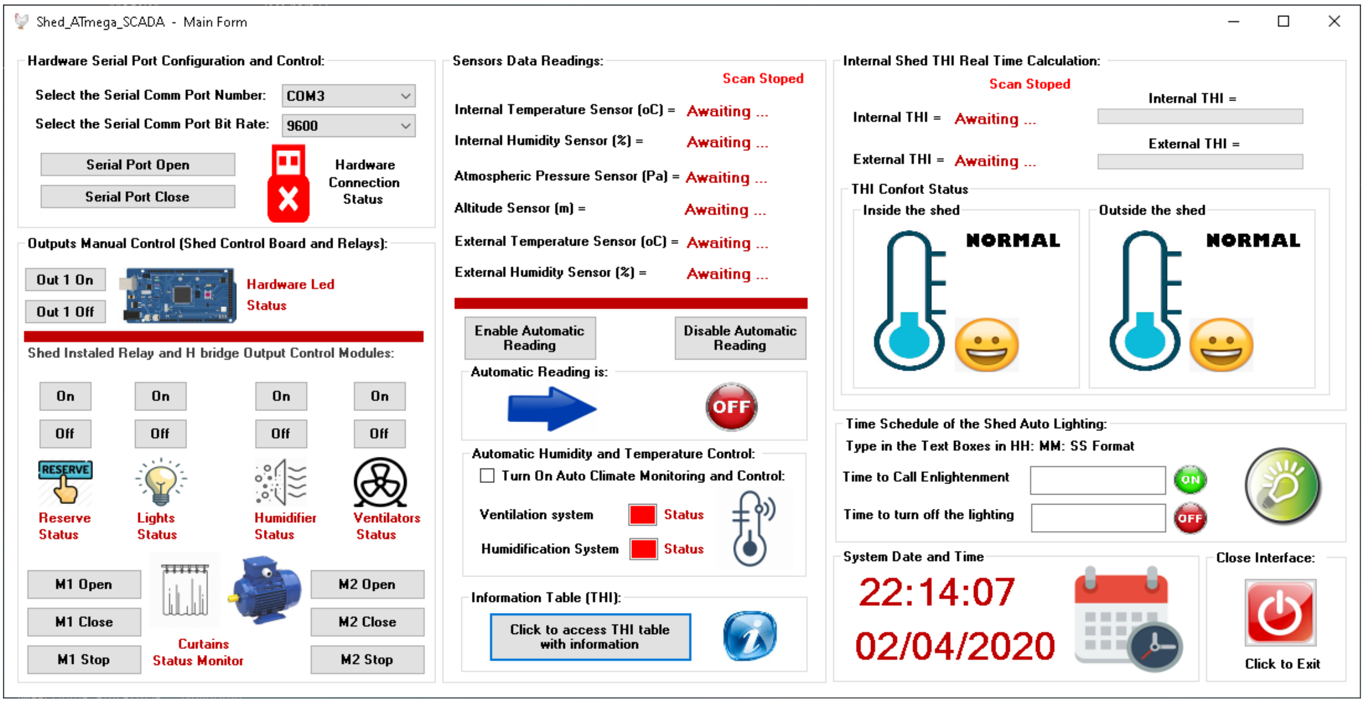


Figure 6. Main Application Form developed in waiting status.

Figure 7 shows the MainForm in data collection mode.

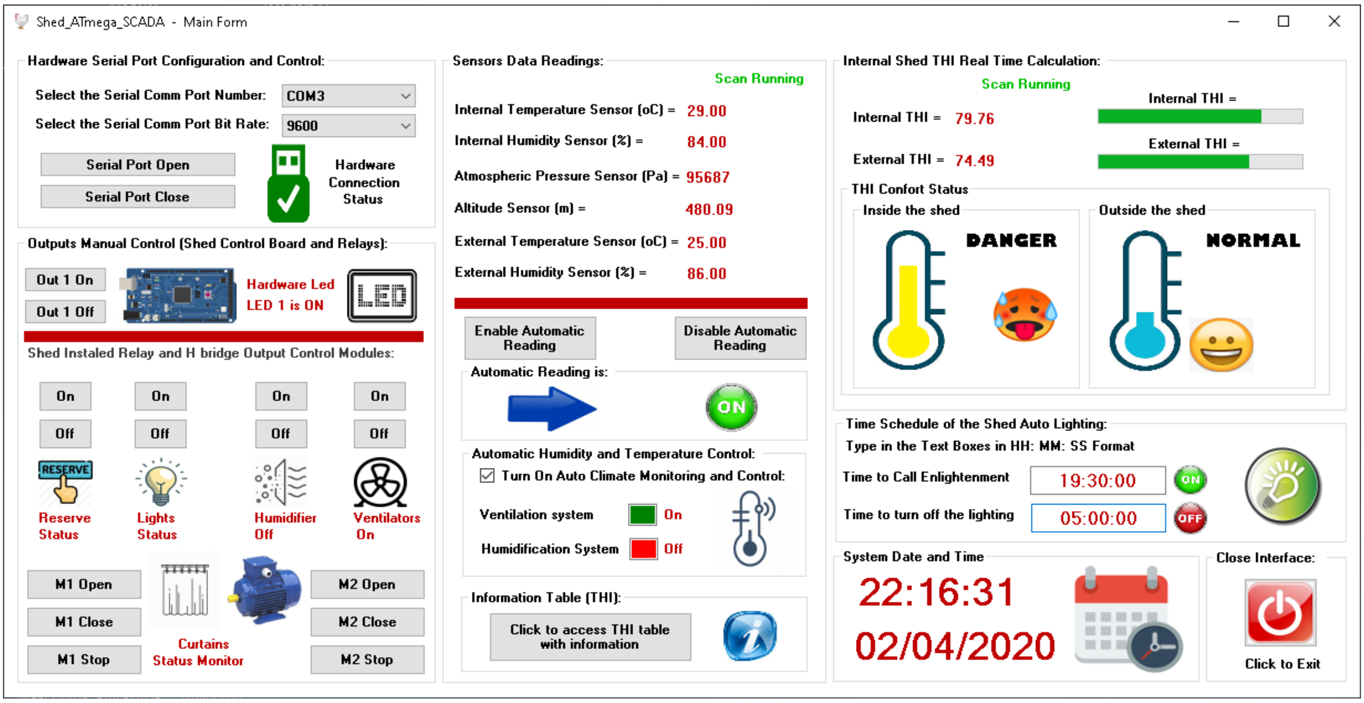


Figure 7. Main Application Form developed connected to hardware in shed monitoring and control status.

The system was tested to validate its operation and measure its real usability, in the laboratory, being installed in a reduced model of poultry or laying hens (cage-free) production shed that simulates the real production environment on a distorted scale that reproduces the poultry facilities, built in the direction East-West, located at latitude 21o 55 '39' 'S, 50o 29' 30 " W, altitude 495 m, climatic type Cwa (humid temperate climate with dry winter and hot summer), with its surroundings constituted by a flat covered area of grass. The scales used are 1:10 in the horizontal dimensions and 1: 2 in the vertical dimensions.

Table 3 shows the dimensions of the model on a small distorted scale used.

Table 3. Dimensions of the model to verify the usability of the generated system.

Scale	1:1 (natural)	1:10 (horizontal)	1:2 (vertical)
Width	14, 00 m	1,40 m	-
Length	30,00 m	3,00 m	-
Height to ceiling	3,00 m	-	1,50 m
Wall height	0,20 m	-	0,10 m

Users listed for the validation procedures, at the end of the three months of experimentation, issued opinions that allowed to verify the ease of use of the system, its effective performance with very consistent data collections and alerting users whenever the system was in conditions unfavorable thermal environment and also correctly activating the ventilation and humidification devices. Users liked the remote lighting system with timing and also the curtain system.

Thus, the system, at the end of the validation process, proved to be very robust and with good potential for application to real systems for broiler and laying hens, mitigating the problems stated by [1], [4] and [9].

5. CONCLUSION

The generated system, with the developed set of hardware, firmware and application software for Windows personal computer environment, allowed the development of a complete tool for the comfort control of the poultry and laying hens rearing environment automatically aiming to maintain the temperature index and humidity (THI) within the limits of thermal comfort and avoid heat stress.

This device can be installed in any production shed, generating the necessary signals for the proper activation of environmental control utilities. Thus, it can be concluded that the development will help companies to reduce the production losses caused by the sudden temperature fluctuations and, thus, increase their market share, thus gaining greater competitiveness and productivity due to the loss mitigation.

6. ACKNOWLEDGMENT

This work was supported by the Brazilian National Council for Scientific and Technological Development – CNPq [grant numbers: 307933/2016-4 and 421782/2016-1].

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