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SISTEMA DE MONITORAMENTO DE TEMPERATURA E UMIDADE DE BAIXO CUSTO PARA MATERNIDADE DE SUÍNOS

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RESUMO: As exigências do mercado perante a produção animal aumentam a relevância sobre a questão do bem-estar animal. O uso da plataforma de prototipagem eletrônica Arduino para monitorar o sistema produtivo é uma ferramenta promissora para minimizar os custos com equipamentos que controlam o ambiente das instalações de animais. O objetivo da pesquisa foi desenvolver um sistema de controle e monitoramento de baixo custo para a instalação de suínos na fase de maternidade. A pesquisa foi conduzida no setor de suinocultura na fase de maternidade, localizada na Fazenda Lageado, da Unesp Botucatu. Foi utilizado um Arduino Leonardo e um sensor de temperatura e umidade DHT11 para registrar e fazer leituras das variáveis. O sensor registra a temperatura e umidade do ambiente e o sistema faz o acionamento dos ventiladores da instalação de acordo com a programação, desligados automaticamente quando a temperatura ambiente se encontra menor do que o programado. De acordo com os resultados, o sensor coletou as variáveis corretamente e acionou o sistema de ventilação da instalação conforme a programação realizada pelo tratador. Conclui-se que foi possível a confecção de um sistema de custo acessível, permitindo o acionamento de ventiladores e outros componentes elétricos em um sistema de produção animal.

Palavras-chave: bem-estar animal, conforto térmico, suinocultura, Arduino, automação.

LOW-COST TEMPERATURE AND HUMIDITY MONITORING SYSTEM FOR PIGS MATERNITY

ABSTRACT: Market demands on animal production increase the relevance about the issue of animal welfare. The use of the Arduino electronic prototyping platform to monitor the production system is a promising tool to minimize costs with equipment that control the environment of animal facilities. The objective of the research was to develop a low-cost control and monitoring system for the installation of swine in the farrowing phase. The work was carried out in the swine sector in the maternity phase, located at Fazenda Lageado, at Unesp Botucatu. An Arduino Leonardo was used in conjunction with a DHT11 temperature and humidity sensor to record and read the variables. The sensor registers the temperature and humidity of the environment, and the system activates the installation's fans according to the programmed temperature, being automatically turned off when the ambient temperature is lower than programmed. According to the results, the sensor correctly collected the climatic variables and activated the installation's ventilation system as programmed by the handler. It is concluded that it was possible to make an affordable system, which allowed the activation of fans and other electrical components in an animal production system.

Keywords: animal welfare, thermal comfort, pigs, Arduino, automation.

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1 INTRODUCTION

Animal production systems are directly correlated with animal welfare levels, since facilities that are unable to promote, for example, thermal comfort lead to the difficulty individuals have in maintaining their ideal body temperature, which consequently affects their productive and reproductive rates (PANDORFI; SILVA; PIEDADE, 2008; SARUBBI *et al.*, 2012).

Pigs use two strategies to dissipate the heat produced by their metabolism: vasodilation and an increased respiratory rate. A common behavior associated with the first method is for the animal to lie down, with its largest body surface area in contact with the floor, allowing the blood circulating in its skin to conduct heat to the ground. Consequently, in the second method of heat dissipation, air humidity is a factor to be considered in a facility. Water vapor in the air, as it passes through the respiratory tract, absorbs thermal energy and, when expelled, helps the animal lose heat. Therefore, very low relative humidity combined with high temperatures hinders the ability of an animal to control its body temperature (RODRIGUES, ZANGERONIMO; FIALHO, 2010; SILVA, 2017; SOUZA *et al*., 2020).

For zootechnical purposes, this study aims to measure temperature (°C) and relative air humidity (%) to automate their control in piglet farrowing houses. Industrial automation components such as PLCs **(**programmable logic controllers) are economically unfeasible for small producers because of their acquisition cost, leading us to study parallel alternatives with the same functionality. The use of microcontroller boards offers a vast online programming library and low cost, with Arduino being an alternative for the development of this research (PASSINI *et al.*, 2009; ALMEIDA *et al.*, 2010; HERMUCHE *et al.*, 2013).

The objective of this research was to develop a low-cost control and monitoring system for piglet facilities during the farrowing phase.

2 MATERIALS AND METHODS

2.1 Location where the research was conducted

The research was conducted at the Swine Farming sector of Lageado Farm at the Unesp Botucatu campus. The municipality is located in the south-central region of the state of São Paulo, at 22° 53' 09" south latitude and 48° 26' 42" west longitude, with a relatively high altitude of 756 m to 920 m above sea level; the climate is defined as humid subtropical with an average temperature of 22°C throughout the year, with February being the hottest month (average maximum of 28.59°C) (FRANCO, 2021). Finally, the system installation period took place in September 2021, over two consecutive days.

2.2 General idea

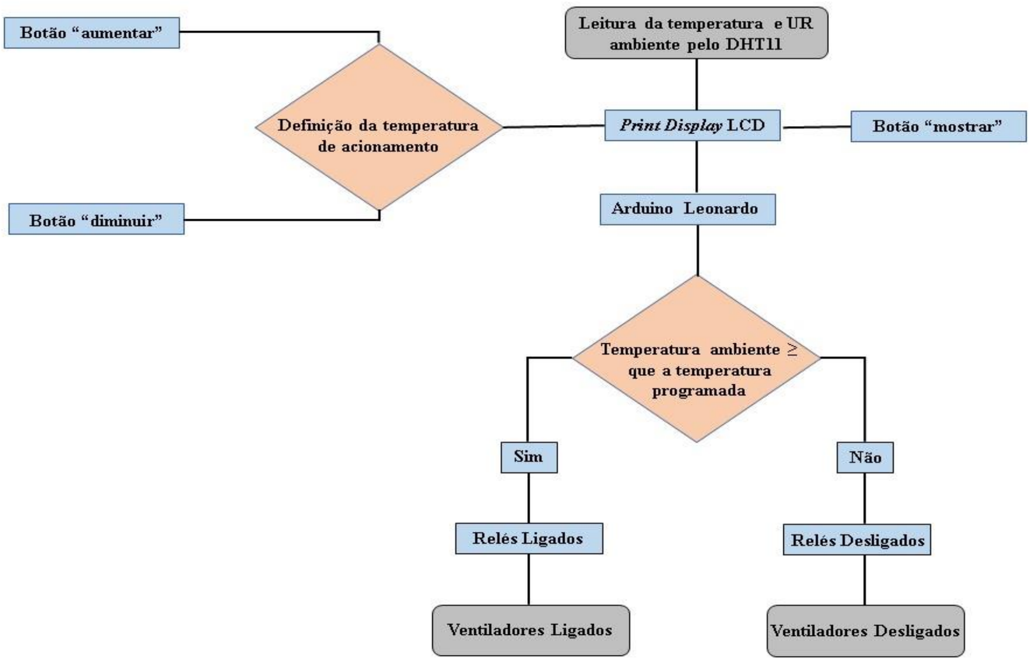
The research was divided into two parts: the physical component (*hardware*) and the programming component (*software*). Initially, the system focused on automating the maternity ward's internal ventilation system, which was later adapted for a sprinkler system according to the requirements and needs of the sector's staff (a topic better addressed in "Suggestions for updates and applicability of the research"). Thus, the *hardware* was divided into two independent control sections (Figure 1). The first section, represented in Figure 1 by the letter "A", consisted of a junction box with an acrylic cover, where the control components were located, such as the Arduino Leonardo, relays, an LCD *display, an islanded* phenolic board, a dual-voltage power supply for the Arduino Leonardo, pushbuttons, and the DHT11 temperature and humidity sensor, which is responsible for controlling and monitoring these variables, activating the maternity ward's ventilators when the ambient temperature reaches the threshold set in the program. The second section, represented by the letter “B”, consists of a digital timer and a normally closed solenoid valve, which is responsible for activating the sprinklers on the roof of the installation, which are switched on and off according to the timer's programming.

Figure 1. Temperature and humidity monitoring system.

Source: Author.
A: 1st control section. B: 2nd control section.

The *software* consisted of code loaded onto the Arduino Leonardo, developed in the C/C++ programming language, with simple logic: the DHT11 temperature and humidity sensor registers these variables, which are shown on the LCD *display*; when the temperature reaches a programmable level via pushbuttons located on the side of the junction box (allowing the activation temperature to be increased or decreased), it activates three relays, which in turn activate the fans, as shown in the following flowchart (Figure 2).

Figure 2. Flowchart of the programming logic loaded into the Arduino.



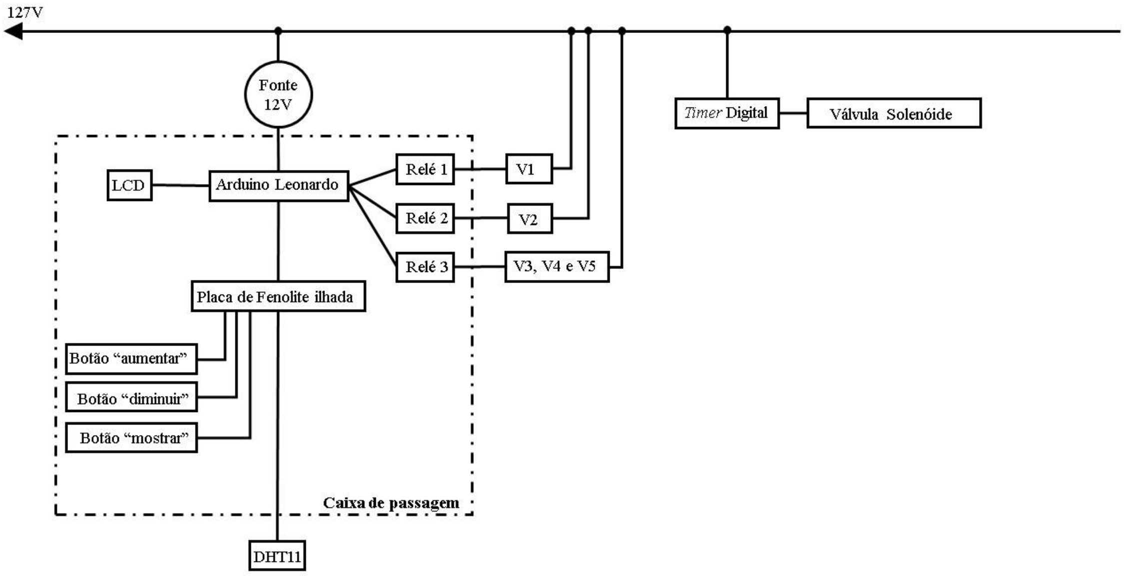
Source: Author.

Automation enabled monitoring of the ambient temperature and the activation of fans and sprinklers in real time, which was previously performed manually; a mercury thermometer was used to measure the maximum and minimum temperatures, with the fans being controlled by employees.

2.3 Components of the monitoring and automation system

The Arduino was connected to the main power supply via a dual-voltage (127/220 V) power source, with an output voltage of 9 V, thus powering the other components in the junction box, as illustrated in Figure 3. Next, the digital *timer* was connected to the 127 V power supply, with the solenoid valve connected to the timer output (Figure 3).

Figure 3. Electrical connection diagram of the components.



Source: Author.

2.3.1 Arduino Leonardo

The Arduino model chosen for the research was Leonardo. This version has 32 input/output pins (12 of which are analog input pins), an operating voltage of 5 volts (with a recommended voltage between 7 and 12 volts), and an ATmega32u4 microcontroller. The model has a sufficient number of inputs and outputs to accommodate the number of peripherals connected to it (allowing for future upgrades and additional peripherals if needed) and a superior microcontroller compared with its predecessor (Arduino Uno) with a USB micro B input (FATEHNIA *et al.*, 2016; LI; WANG; XIE, 2015; WYRWOł; HRYNKIEWICZ, 2015; DOMINGOS *et al.*, 2015; PANDIARAJ *et al.*, 2014; DEVARAJU *et al.*, 2015; TEWARI *et al.*, 2014).

2.3.2 Digital timer

The digital wall-mounted *timer* has the capacity for up to 9 on/off programs per day, an operating voltage of 127/220 volts, a control current of 10 amps, a maximum power of 2200 Watts, and a battery that keeps the timer running in case of a power outage, preventing the loss of programs.

The timer activates the solenoid valve, which in turn activates the roof sprinklers, helping to lower the internal temperature of the maternity ward. Its programming was set for the hottest times of the day, according to the sector employee, being activated at 12:00 PM and deactivated at 6:00 PM.

2.3.3 Solenoid valve

A solenoid valve works on the simple principle of interrupting or allowing the flow of a fluid through a pipe when energized. A normally closed solenoid valve has a ¾-inch thread diameter, an operating voltage of 127 VAC, a minimum operating pressure of 0.2 kgf/cm² and a maximum of 0.8 kgf/cm², a minimum flow rate of 7 L/min and a maximum of 40 L/min, and an inlet and outlet angle of 180°. When the digital *timer* registers the activation time, the valve will activate an internal coil, which in turn opens the water flow, allowing the roof to be sprayed until the programmed shutdown.

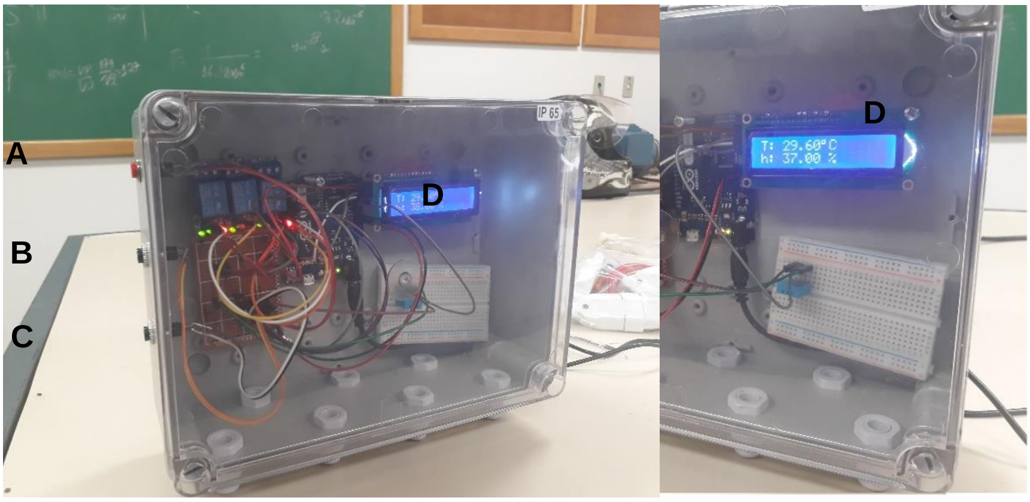
2.3.4 DHT11 Sensor

The air temperature and humidity sensor used was the DHT11, which measures relative air humidity (RH) between 20 and 90% and has a temperature measurement range between 0° and 50°C, with a humidity measurement accuracy of ± 5.0% RH and ±2.0°C for temperature. Furthermore, its operating voltage is between 3 and 5.5 V, with a maximum current of 2.5 mA. It was positioned externally to the junction box so that it remained close to the height of the sows.

2.3.5 Pushbuttons and LCD *display*

As shown in Figure 4, the first button, when pressed for approximately one second, displays the programmed temperature for relay activation on the LCD *screen*. Next, the second push button increases the activation temperature; when pressed for one second, it raises the temperature for relay activation and registers this change on the LCD *screen for approximately 1.5 seconds. Finally, the third button has a similar function to the second button, but it decreases the activation temperature. While the buttons are not pressed,* the temperature and relative humidity (RH) variables are displayed on the screen.

Figure 4. 1st command session.



Source: Author.
A: first button. B: second button. C: third button. D: LCD display.

2.3.6 Relays

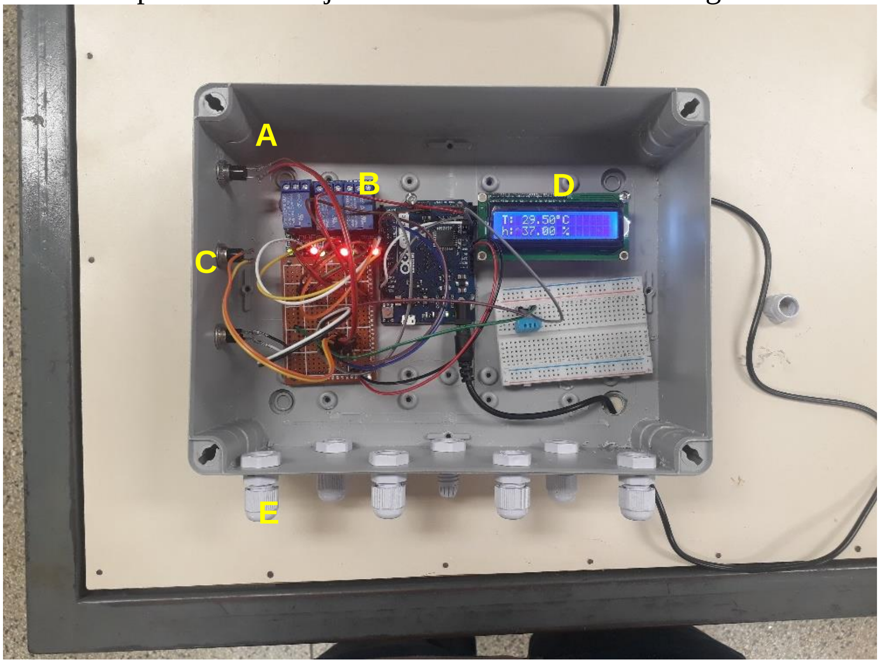
Relays are electromechanical switches used to operate fans in an installation. Their operation consists of the movement of a movable ferrous metal armature, which is attracted by the electromagnetic field generated by a coil when it is energized, ultimately closing the circuit with the lower contact. When the current in the coil ceases, the electromagnetic field is interrupted, causing the movable armature to return to the upper contact, finally "opening" the circuit. The coil voltage is 5 V, and the current is low, whereas the maximum voltage of the reversing contacts is 250 VAC, and the current is up to 12 A.

For this research, three single-channel relay modules were used: two to control two wall fans (V1 and V2) and one to control three ceiling fans (V3, V4 and V5). When the DHT11 sensor registers a temperature equal to or higher than the programmed temperature, the relays are activated, and then the fans are turned on. Conversely, when the recorded temperature is lower than the programmed temperature, the relays are deactivated, turning off the fans.

2.4 Project assembly and installation

For the assembly of the project, electronic components such as the Arduino Leonardo, relays, islanded phenolic board, and LCD *display* were fixed to the bottom of the junction box, the latter of which allows easy reading of the parameters recorded by the temperature and humidity sensor. Next, holes were made in the bottom of the box to attach gray Pg7-type cable glands (Figure 5), which allow entry and exit of the PP electrical cables and sensor output and keep the interior of the junction box isolated from moisture. Holes were subsequently made on the left side of the box to position the pushbuttons.

Figure 5. The electronic components in the junction box were fixed during the laboratory phase.



Source: Author.
phenolic board. D: LCD display. E: Pg7 cable gland.

For installation in the maternity ward, the junction box and timer were positioned in wooden structures that make up the roof frame, as suggested by the swine production sector staff. Next, the electrical components were assembled, positioning the power cables for the fans and the sockets for the Arduino power supply and the *timer*. Finally, the hydraulic components were assembled, positioning the solenoid valve and a structure made of PVC pipe parallel to the existing pipe in the installation (Figure 6).

Figure 6. The system should be installed in the pig maternity ward.

Source: Author.
A: Original PVC pipe system of the installation. B: Structure built for the installation of the solenoid valve. C: Solenoid valve is normally closed.

2.5 Definition of control parameters

For sows, thermal comfort is established between 16°C and 21°C, with a critical maximum temperature of 30°C (BUFFINGTON *et al.*, 1981). However, owing to structural issues, maintaining a farrowing house within this comfort zone is highly difficult, given the low ceiling height, resulting in a greater thermal load on the animals (SAMPAIO *et al.*, 2004; KIEFER *et al.*, 2009).

For the activation of the sprinklers, the times 12:00 (for activation) and 18:00 (for deactivation) were used every day of the week. The schedule was established according to the employees and their needs, allowing the system to be controlled without requiring their presence in the area to perform this task.

3 RESULTS AND DISCUSSION

3.1 Cost

Owing to the scarcity of microchips and semiconductors on the market, aggravated by the COVID-19 pandemic and the rise in the dollar, the prices of electronic products are increasing in Brazil (LUCCA, 2021; RODRIGUES, 2021; TORRES, 2021). However, it was possible to carry out a low-cost project that met the needs of small productions, as in the case of the pig farming sector of the Lageado farm at Unesp Botucatu. Additionally, according to some representative companies in Brazil, the industrial automation component used in large productions, such as the PLC, has a base price of approximately $200.00, which is higher than the total cost of the project described in Table 1. The purchase of materials was made mostly through online stores between March 5th and August 4th, 2021.

Table 1. Research budget.

	List of research materials	Price in Reais
THE	Arduino Leonardo	60.00
	1 channel relay module (3 units)	38.70
	DHT11 sensor	17.45
	16x2 LCD *display*	31.80
	Arduino Bivolt Power Supply	20.96
	phenolic boards (kit of 10 units)	23.99
	Junction Box 234x174x90 mm	75.91
	PG7 gray cable gland (10 units)	17.79
	Push button (3 units)	1.75
	330Ω resistors (3 units)	1.50
	Flexible cable for electronic circuits 0.3 mm² (20 meters)	28.49
	Male and female plug adapters (5 units of each)	32.90
	Nylon cable tie 20 cm (kit of 100 units)	13.90
	Flexible PP electrical cable 2x1 mm² (50 meters)	179.90
	Single-pole circuit breaker 16A	12.15
	Digital power outlet timer	48.99
B	¾ thread solenoid valve and 127 V	72.00
	PVC "T" fitting (2 units)	0.00*
	PVC 90° bend, 3/4 inch (2 units)	0.00*
	PVC glove ¾ (2 units)	7.00
	PVC Union ¾ (2 units)	12.60
	PVC pipe (1 meter)	0.00*
	Technical installation labor (8 hours of work)	70.32
	Technical development workforce (60 working hours)	527.45
	* Material provided for research.	
	Total excluding labor costs in Reais (Brazilian currency).	**697.78**
	Total including labor costs in Reais.	**1,295.55**
	Price in US dollars, excluding labor costs.	**140.11**
	Price in US dollars including labor.	**260.15**

Source: Author.
A: Electronic and electrical components. B: Hydraulic components.

3.2 Suggestions for updates and applicability of the research

To meet the needs of small-scale production, where the number of employees and labor is limited, the project fulfills its role, since it allows them to perform other tasks without having to manually operate the ventilation systems. Furthermore, it promotes better thermal comfort for sows in the farrowing pen because, in addition to real-time activation, it is based on values collected by the temperature and humidity sensors, making the system more precise.

Given that the primary idea of the system was the automation of the existing fans in the installation, the most viable adaptation to meet the subsequent need for sprinklers was the use of a digital *timer* to control them without significantly increasing the budget with the addition of new components and labor. Therefore, for the solenoid valve to be controlled by the Arduino, it would be necessary to add an RTC (*real-time clock*) module so that activation would only occur at programmed times (since they are only activated during the day). Following this, an *Ethernet shield is added. or Wifi* module The system (boards that allow communication between the Arduino and internet systems), with the necessary modifications to the code loaded onto the Arduino and the creation of a control application, would enable remote activation and monitoring via remote devices. Consequently, it would be possible, for example, to activate the sprinklers not only according to the time and internal temperature of the installation but also according to the weather forecast, since on cloudy or rainy days, their activation is unnecessary.

4 CONCLUSIONS

The low-cost temperature and humidity monitoring system for piglet nurseries enabled the automation of the facility, with Arduino being able to perform this task. Thus, the project brought modernity, technology, and practicality to small-scale production. In short, even with the high prices of electronic products, it was possible to create an affordable system that allowed the operation of fans and other electrical components in an animal production system.

5 REFERENCES

ALMEIDA, GL P; PANDORFI, H.; GUISELINI, C.; ALMEIDA, GAP; MORRIL, WBB. Investment in climate control in the premilking of Girolando cows and its effects on milk production. **Revista Brasileira de Engenharia Agrícola e Ambiental,** Campina Grande, v. 14, n. 12, p. 1337-1344, 2010. Available at: https://www.scielo.br/j/rbeaa/a/Dyg7jk9bqzR33fLHTrYvPzr/?lang=pt. Accessed Published on : October 4, 2021.

BUFFINGTON, D. E.; COLLAZO-AROCHO, A.; CANTON, G. H.; PITT, D.; THATCHER, W. W.; COLLIER, R. J. Black globe-humidity index (BGHI) as a comfort equation for dairy cows. **Transactions of the ASAE**, St. Joseph, v. 24, n. 3, p. 711-714, 1981. Disponível em: https://elibrary.asabe.org/abstract.asp?aid=34325. Acesso em: 2 out. 2021.

DEVARAJU, J. T.; SUHAS, K. R.; MOHANA, H. K.; PATIL, V. A. Wireless Portable Microcontroller based Weather Monitoring Station. **Measurement,** Amsterdam, v. 76, p. 189-200, dez. 2015. DOI: https://doi.org/10.1016/j.measurement.2015.08.027. Disponível emhttps://www.sciencedirect.com/science/article/pii/S0263224115004406?via%3Dihub. Acesso em: 4 out. 2021.

DOMINGOS, FC; MAIA, JM; MAIA, OMA; SCHNEIDER, FK. Microcontroller-based Control System for Ultrasound NDT in Wood. **Physics Procedia,** Amsterdam, v. 70, p. 428-432, 2015. DOI: https://doi.org/10.1016/j.phpro.2015.08.136 . Available in : https://cyberleninka.org/article/n/592154.pdf. Accessed Published on : October 4, 2021 .

FATEHNIA, M.; PARAN, S.; KISH, S.; TAWFIQ, K. Automating double ring infiltrometer with an Arduino microcontroller. **Geoderma ,** Amsterdam, v. 262, p.133-139, Jan. 2016. Elsevier BV. DOI: 10.1016/j.geoderma.2015.08.022

FRANCO, JR. **Comparative analysis between meteorological measurements from the conventional and automatic weather stations at Fazenda Lageado in the municipality of Botucatu, São Paulo, Brazil** . 2021. Dissertation (Master's in...) Agronomy/Irrigation and Drainage) – Faculty of Agronomic Sciences, São Paulo State University, Botucatu, 2021.

HERMUCHE, P.; GUIMARÃES, RF; CARVALHO JÚNIOR, OA; GOMES, RAT; PAIVA, SR; McMANUS , CM. Environmental factors affecting sheep production in Brazil. **Applied Geography** , Oxford, v. 44, p. 172-181, 2013.

KIEFER, C.; MEIGNEN, BCG; SANCHES, JF; CARRIJO, AS. Response of growing pigs maintained at different temperatures. **Arquivos de Zootecnia** , Campo Grande , v. 51, n. 221, p. 55-64, 2009. Available at: http://scielo.isciii.es/scielo.php?script=sci_arttext&pid=S0004-05922009000100006&lng=en&nrm=iso. Accessed Published on : October 4, 2021.

LI, L.; WANG, C.; XIE, G. A general CPG network and its implementation on the microcontroller. **Neurocomputing** , Amsterdam, v. 167, p. 299-305, nov. 2015. DOI: 10.1016/j.neucom.2015.04.066. Available in : https://liangli-phd.com/static/pdfs/Liang2015General.pdf. Access Published on : October 4, 2021.

LUCCA, A. **Pandemic impacts microchip production and causes prices of electronics to rise** . São Paulo: CNN Brasil, Oct. 2, 2021. Available at: https://www.cnnbrasil.com.br/business/pandemia-impacta-producao-de-microchips-e-faz-preco-de-eletroeletronico-subir/. Accessed Published on : October 4, 2021.

PANDIARAJ, M.; BENJAMIN, A. R.; MADASAMY, T.; VAIRAMANI, K.; ARYA, A.; SETHY, N. K.; BHARGAVA, K.; KARUNAKARAN, C. A cost-effective volume miniaturized and microcontroller-based cytochrome c assay. **Sensors And Actuators A**: Physical, Amsterdam, v. 220, p. 290-297, dez. 2014. DOI: https://doi.org/10.1016/j.sna.2014.10.018. Disponível em: https://www.sciencedirect.com/science/article/abs/pii/S0925231215005354. Acesso em: 4 out. 2021.

PANDORFI, H.; SILVA, IJO; PIEDADE, SMS. Thermal comfort for sows in the gestation phase, housed in individual and collective pens. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 12, n. 3, p. 326-332, 2008.

PASSINI, R.; FERREIRA, FA; BORGATTI, LMO; TERÊNCIO, PH; SOUZA, RTYB; RODRIGUES, PHM. Thermal stress on diet selection by cattle. **Acta Scientiarum** : Animal Science, Maringá, v. 31, n. 3, p. 303-309, 2009.

RODRIGUES, CG Overview of the global semiconductor industry market. **Brazilian Journal of Development** , Goiânia, v. 7, n. 7, p. 74936-74944, 2021.

RODRIGUES, NEB; ZANGERONIMO, MG; FIALHO, ET Physiological adaptations of pigs under thermal stress. **Nutritime Electronic Journal** , [*sl*], v. 7, n. 2 p. 1197-1211, Mar./Apr. 2010. Available in : https://www.nutritime.com.br/wp-content/uploads/2020/02/Artigo-110.pdf. Accessed Published on : October 4, 2021.

SAMPAIO, CAP; CRISTANI, J.; DUBIELA, JA; BOFF, CE; OLIVEIRA, MA. Evaluation of the thermal environment in a pig growing and finishing facility using thermal comfort indices under tropical conditions. **Ciência Rural** , Santa Maria, v. 34, n. 3, p. 785-790, Jun. 2004.

SARUBBI, J.; ROSSI, LA; MOURA, DJ; OLIVEIRA, RA; MAIA, Night APA thermal comfort in facilities for growing swines . **Agricultural Engineering** , Jaboticabal, v. 32, n. 6, p. 1034-1040, 2012. Available at: https://www.scielo.br/j/eagri/a/d3g3twNmhsdByGPs4sZbNHB/?lang=en. Accessed on: Oct. 12, 2021.

SILVA, DHF. **Effect of age and time of day on physiological variables of thermoregulation in pigs** . 2017. Undergraduate Thesis (Veterinary Medicine) – Faculty of Veterinary Medicine, Federal University of Uberlândia, Uberlândia, 2017.

SOUZA, RG; GOMIDE, APC; FEITOSA, TJO; CRISPIM, EG; LEITE, DPSBM; FRANÇA, VS; SOUSA, GR de; SOUSA, WKC; CARVALHO JÚNIOR, JEM; MOTA, DG. Influence of temperature in swine maternity: a literature review. **Research, Society and Development** , Itabira , v. 9, n. 3, p. e193932757, 2020. DOI: 10.33448/rsd-v9i3.2757. Available From : https://www.researchgate.net/publication/340241999_Influencia_da_temperatura_na_maternidade_de_suinos_revisao_bibliografica. Accessed Published on : October 4, 2021.

TEWARI, V. K.; KUMAR, A. A.; NARE, B.; PRAKASH, S.; TYAGI, A. Microcontroller based roller contact type herbicide applicator for weed control under row crops. **Computers And Electronics In Agriculture**, Amsterdam, v. 104, p. 40-45, jun. 2014. DOI: 10.1016/j.compag.2014.03.005. Disponível em: https://www.sciencedirect.com/science/article/abs/pii/S0168169914000659. Acesso em: 4 out. 2021.

TORRES, LR. Economic analysis of the rise in car prices: the inevitability of the laws of supply and demand. **Boletim Economia Empírica** , [*sl*], v. 2, n. 10, p. 47-50, 2021. Available Available at : https://www.portaldeperiodicos.idp.edu.br/bee/article/view/6154. Accessed Published on : October 4, 2021.

WYRWOł , B.; HRYNKIEWICZ, E. Implementation of the FITA Fuzzy Inference System on the specific microcontroller platform. **IFAC-Papers Online** , Laxenburg , vol. 48, no. 4, p. 165-169, 2015. DOI: 10.1016/j.ifacol.2015.07.026. Available in : https://www.sciencedirect.com/science/article/pii/S2405896315008010. Accessed Published on : October 4, 2021 .