



AUTOMATION AND MONITORING VIA ARTIFICIAL INCUBATOR AND POULTRY NURSERY SOFTWARE

Gabriel Jordan de Oliveira¹
Graduando em Engenharia Elétrica

Gaspar Eugênio Oliveira Ramos²
Maestría em Educación

Fábio de Brito Gontijo³
Maestría em Educación

MODELO ABSTRACT

O uso de sistemas automáticos no incubatório dispensa o uso de uma matriz (galinha) para a choca dos ovos, além de possuir maior capacidade de ovos e ocupar menos espaço. A chocadeira busca imitar a natureza, por isso o sistema precisa manter as condições ideais de temperatura, e o uso do controle PID se mostra satisfatório, uma vez que possa corrigir o sinal de erro sempre que necessário evitando variações bruscas. O microcontrolador é responsável por coletar as informações do sistema e atuar da melhor maneira possível para corrigir a temperatura e manter as condições ideais para choca dos ovos.

PALABRAS CLAVES: PID, Arduino, Incubação.

ABSTRACT

The use of automatic systems in the hatchery dispenses with the use of a matrix (hen) for hatching eggs, in addition to having a greater capacity for eggs and taking up less space. The brooder seeks to imitate nature, so the system needs to maintain ideal temperature conditions, and the use of PID control proves to be satisfactory, since it can correct the error signal whenever necessary, avoiding sudden variations. The microcontroller is responsible for collecting system information and acting in the best way possible to correct the temperature and maintain the ideal conditions for hatching eggs.

KEYWORDS: PID, Arduino, Incubation.

SUMARIO: 1. Introdução. 2.Referencial Teórico 2.1. Umidade Relativa. 2.2. Temperatura. 2.3. Ventilação. 2.4. Viragem. 2.5. Controlador PID. 2.6. Arduino 3. Referencia bibliográficas.

CONTENTS: 1. Introduction. 2.Theoretical framework 2.1. Relative humidity. 2.2. Temperature. 2.3. Ventilation. 2.4. Turning. 2.5. PID controller. 2.6. Arduino 3. Bibliographical references.

¹MG21827059 - Graduando em Engenharia Elétrica - Centro Universitário de Patos de Minas, UNIPAM, Brasil

²MG16155172 – Maestría em Educación - Centro Universitário de Patos de Minas, UNIPAM, Brasil

³10879701– Maestría em Educación - Centro Universitário de Patos de Minas, UNIPAM, Brasil

1 INTRODUCTION

The poultry sector has been gaining prominence in its growth as a result of the use of automation systems in the production line and research in the area, which is based on increasing its productivity.

According to the Brazilian Institute of Geography and Statistics (IBGE, 2020) the country recorded a record slaughter of six billion chicken heads in 2020, an increase of 3.3% compared to 2019, the national production of chicken eggs reached a record 4.0 billion dozen in 2020, an increase of 3% over the previous year.

Given this scenario and adding knowledge of market trends in relation to the consumption of natural and alternative products, small producers increased their income from selling free-range chicken (Sebrae Mercados, 2014).

The culture, however, brings some difficulties that are faced during management, one of them being the time that a matrix is occupied with the chicks for several weeks until they can live alone, therefore, the matrix is unable to lay eggs.

Seeking greater profitability and growth of their creations, these small producers seek to invest in small artificial egg incubators.

The high price proposed to be paid for such incubators encourages them to invest in cheap and low-reliability equipment that does not offer effective and well-prepared systems, consequently the damage ends up being a problem faced.

The use of technologies that facilitate and enable people's working and day-to-day conditions has been increasingly sought after, and this is the case - if necessary, the use of automation, which is the development of industrial operational processes that replace people and even animals, like chickens, by tools capable of doing the same job efficiently and in less time.

Therefore, it can be applied in several productive sectors, as in the example of this work, the improvement of the management and production of new chickens for the aviculture.

The present work aims to develop a prototype of an incubator with a sensing system, being able to analyze its internal climate and present enough data for the modeling of a control system.

This, in turn, is a PID control (Proportional, Integral, Derivatives) that will provide an output signal determining the level of power that the heater should receive so that the temperature approaches the ideal.

Through experiments and real-time analysis of the incubator, the control will be modeled through the Arduino microcontroller IDE, the main responsible for all monitoring and processing.

The final data can be viewed either on an LCD display or remotely on a smartphone app.

Joining these functions, we seek convenience and comfort for the producer, who will always be updated with data, possible errors or predictions for the birth of the chicks.

2 THEORETICAL REFERENCE

Poultry depends on proper management so that good results are achieved. This is a competitive market that requires constant innovation and knowledge gathering that satisfies the consumer's requirements.

In this context, incubation is the strategic alternative for production, being responsible for transforming fertile eggs into chicks within the deadline and in the desired quantity (OLIVEIRA, 2018).

The process requires that some factors be controlled just right to ensure healthy chicks, these being the supply of heat and oxygen during the incubation period and also turning over the eggs.

Furthermore, it requires a control of the rate of water loss, which is measured through the relative humidity of the air inside the chamber in order to avoid dehydration of eggs, or in excess, an early birth (FRENCH, 2010).

2.1 Relative humidity

Humidity is an important factor to consider. The porous surface of the egg facilitates the exchange of water with the outside environment if there is a high moisture difference between them. To prevent the egg from losing water or having it in excess, the humidity inside the hatchery must be constantly controlled to ensure good hatchability (DECUYPERE et al., 2001).

The incubator needs to adapt to the environment and ideally the environment will adapt to the incubator.

The latter is done with the use of acclimatizers in the incubation room, whose main role is to establish constant humidity in the environment, otherwise, this could lead to a bad behavior of the brooder.

Van Der Pol et al. (2013) studied that the moisture range between 56% and 60% showed better hatching results, delivering good embryonic viability and good weight gain.

According to Robinson et al. (2013), on the 18th day of incubation, it is ideal that there is no loss greater than 12% of egg weight, a value greater than that presented can dehydrate the embryo and increase mortality rates.

Humidity is fundamental in temperature control, since low humidity can increase the heat loss of eggs. Thus, it would require a higher temperature to meet the needs and this loss (VAN DER POL et al. (2013).

2.2 Temperature

The temperature in the incubation process is what triggers and stimulates the formation of the embryo. Important in the early days of embryo generation, temperature is responsible for providing the heat needed for embryonic development. It must be precisely controlled and avoid large variations in the system, as this can increase the mortality rate and poor development of the chicks (GROFF et al., 2017).

The study by Christensen et al. (2001) says that eggs should be incubated at an average temperature of 37.8°C, a standard adopted in several studies and by companies that also produce incubators.

Variations of 0.2°C can change the deadline for birth.

Increments advance the process and the chicks present a reduction in weight, in addition to causing an increase in late mortality, on the contrary, the decrement delays the process, but the embryos can be more tolerant to lower temperatures (DECUYPERE et al., 2001).

Maatjens et al. (2016), in their studies carried out from the 15th day of incubation, analyzed that better results were obtained when they reduced the internal temperature of the incubator, which until then was at 37.8°C.

There was an improvement in mass and development was significantly higher when temperatures were between 37.2°C and 37.8°C.

2.3 Ventilation

Among the actuators that control the incubator's microenvironment, such as heaters and humidity controllers, ventilation control is still necessary.

Parameter that raises doubts and is still poorly understood, ventilation is often associated with the supply and removal of internal gases, such as oxygen O₂ and carbon dioxide CO₂ (CALIL, 2007).

The embryo uses O in its metabolism to develop and then releases CO₂ as a natural compound eliminated at the end of the metabolic process, thus, ventilation is the part of the process that will carry out and facilitate these gas exchanges (MESQUITA, 2013).

Ventilation is not just limited to gas exchange, it is also a temperature-regulating agent that makes heat exchange between the egg and its environment possible.

According to Calil (2007), at high temperatures the embryo tends to use more oxygen, but the egg shell has a limitation on the rate of air that can pass through its pores.

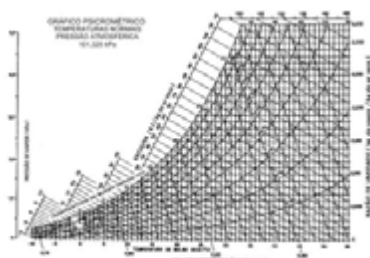
In this case, if the ventilation system does not eliminate the excess temperature, the embryo dies or starts an anaerobic development with carbohydrates, which can result in several complications.

In conditions where ventilation is constantly turned on, the fresh air that enters the incubator has a certain relative humidity in itself and is not always sufficient, while the outgoing air also carries the humidity with it.

For higher temperatures, the amount of water that the air must contain is higher according to the Mollier Diagram, shown below in Figure 1.

For example, at a humidity of 55% at 25°C, the air has 11g of water per kg and the 55% at 37.5°C, 22g of water per kg is required (CALIL, 2007).

Figura 3: Mollier Diagram



Fonte: Passei Direto.2

2.4 Turning

In addition to the simple objective of imitating nature, egg turning plays an important role in the development of the embryo, essentially in the first 7 days, when the embryo does not yet have a well-defined circulatory system.

If not performed, it can prevent the expansion of blood vessels and the membranes can adhere to the shell, limiting the embryo's gas exchange with the external environment (AMARAL, 2019).

The turning compensates for this lack of circulation by improving the diffusion of gases and the pH difference, in addition to improving chemical reactions, nutrient distribution, albumen liquefaction and formation of embryonic attachments, being necessary until the 18th day of incubation (CALIL, 2007).

The turning frequency is a management condition that helps the process since as the embryo grows it produces more heat and consequently will require greater exchanges of this heat with the outside (COBB, 2008).

This frequency varies from study to study, and the one that most favors development and provides the highest hatchability rate would be 96 times a day (periods of 15 minutes), but it is more common to adopt periods of 1 to 2 hours in order to reduce costs with maintenance of equipment and energy (CALIL, 2007).

2.5 PID Controller

The use of PID controllers – Proportional, Integral and Derivative are being used more and more in systems in the last decades for presenting a simple structure and easy manipulation.

With features that allow controlling several simultaneous processes with zero error in steady state and a balanced transient that best suits the system (SANTANA, 2019).

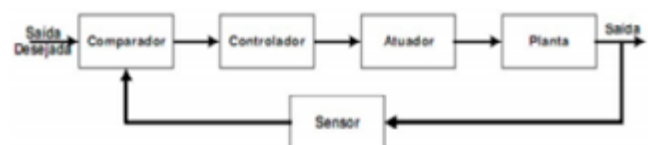
Through the block diagram (Figure 2), we can identify the main components and operations that will be performed.

The PID controller operates in a closed-loop system that uses a reference value as a set-point input value.

The comparator checks the difference that exists between the feedback signal that is collected by the sensors and the input value, so it is possible to determine the error signal.

Through this signal, it is up to the controller to implement the necessary action to reduce the system's error and oscillations through the actuators (AGUIAR, 2018).

Figura 4: Block Diagram



Fonte: VENDRAMINI, 2018, p. 18.

In Santana's study (2019), he describes the functions that govern PID controllers, where we have $u(t)$ as the main function and variable to be manipulated, containing $r(t)$ equal to the reference value that will be compared to $y(t)$, the output value collected by the sensor and read as a feedback. The law is given by equation (2.1),

$$u(t) = K_p \left[e(t) + \frac{1}{T_i} \int e(t) dt + T_d \frac{d}{dt} e(t) \right] \quad (2.1)$$

where $e(t)$ is the error defined in equation (2.2),

$$e(t) = r(t) - y(t) \quad (2.2)$$

In order for the control to adapt to the system's needs, the parameters K_p , T_i and T_d are manipulated, which makes the control versatile as it has only three variables.

K_p determines the proportional gain, and in some control cases, this gain alone would be enough, but it is common to present large oscillation because it does not cancel the error in the steady state (SANTANA, 2019). K_p is expressed in equation (2.3),

$$u_p(t) = k_p e(t) \quad (2.3)$$

The term T_i corresponds to the integral action of the controller that appears to correct the lack of stability of the proportional gain in steady state.

The response characteristic changes with the addition of a pole at the origin (Laplace), the system gains a damping and then the integral component sums the error values, always with a non-zero gain value (AGUIAR, 2018).

The integral action is displayed from equation (2.4),

² Available in: <https://www.passeidireto.com/arquivo/83233162/grafico-psicrometrico> Accessed: 21 de junho de 2021.

$$u_i(t) = k_i \cdot \frac{1}{T_i} \int e(t) dt \quad (2.4)$$

The implementation of the PID controller takes place then, with the sum of the proportional, integral and derivative gain.

Analyzing the analog configuration, the PID controller can be digitally projected in a computer using the time discretization by the root place in the Z plane.

That of computers, as rounding errors can influence corrective calculations of the integral and derivative action that can generate disturbances (PRADO, 2009).

According to Prado (2009), "The first step in designing a discrete controller in the Z plane is to determine the transfer function on the Z variable that represents the plant. [...]"

Considers the transfer function in the S plane of a zero-order stapler (Goz(s)) in series with the transfer function in the S plane of the plant (Gp(s)).

Finally, the Z transform of this combination of serial transfer functions is performed.

That is, the plant transfer function discretized in the Z plane is the Z transform of the product (Goz(s)Gp(s)).

The plant transfer function discretized in the Z plane has two poles and a zero."

The transfer function of the discrete PID in the Z plane is analogous to the S plane and depends on the sampling period T_s , being expressed in equation (2.6),

$$PID(z) = k_p \cdot (1 - z^{-1}) + \frac{T_s}{T_i} \cdot \frac{1}{1 - z^{-1}} \quad (2.6)$$

The purpose of the time-discretized PID controller design is to equalize the zeros to the poles of the plant transfer function, making it easier for the user to choose K.

In the open loop system, two zeros appear, a pole at the origin of the Z plane and a pole at the unit circle, so when we rearrange the function, we highlight the two poles (PRADO, 2009).

The function is defined in equation (2.7),

$$PID(z) = k \frac{(1 - z_1 \cdot z^{-1})(1 - z_2 \cdot z^{-1})}{(1 - z^{-1})} = \frac{(a_0 \cdot z^2 + a_1 \cdot z + a_0)}{z(z - 1)} \quad (2.7)$$

In closed loop, as K increases, the pole moves away from the unit circle towards the origin of the Z plane. Thus, we determine the values of a_0 , a_1 , and a_2 and find the parameters for the PID controller using the equations (2.8), (2.9) and (2.10).

$$k_D = a_2 \cdot T_s \quad (2.8)$$

$$k_p = \left(a_1 + \frac{2 \cdot k_D}{T_s} \right) \quad (2.9)$$

$$k_i = \left(a_0 - k_p - \frac{k_D}{T_s} \right) \div T_s \quad (2.10)$$

2.6 Arduino

To carry out PID control and minimize costs, the use of microcontrollers is an excellent option. The arduino fits these requirements as it requires the use of processor, A/D and D/C converters and also a timer. In order to help designers from various classes and areas of expertise, Arduino was developed in 2005, being an easy to program and open source software development platform.

Following the basic hardware, anyone can customize it as it only depends on an Atmel microcontroller, pins and data input and output circuits, and some integrated circuits such as A/D and D/A converters (Thomsen, 2014).

Arduino can be programmed through a development tool, the IDE (Integrated Development Environment) that uses a language based on C/C++, processing layer.

Through a bootloader, programming can be developed easily, since there is no need for additional compilers and tools (GUN, 2017).

The Arduino CPU stores data in RAM and ROM program memory, being able to access them whenever the program requests it, managing all the functions of the board, including communication, digital and analog input pins and outputs, among others. This data can be collected through modules developed for specific functions, which can be sensors, communicators and actuators (DA CUNHA, 2016)



REFERENCIAS



- AGUIAR, Gustavo Luigi; VENDRAMINI, Gabriel. Estudo E Análise Das Ações De Controle Pid Em Um Determinado Sistema Em Malha Fechada. Revista Científica Semana Acadêmica. Fortaleza, ano MMXVIII, n. 000137, 2018.
- AMARAL, Vandelúzia Teixeira do. Incubação de ovos férteis e o desenvolvimento embrionário. 33 f.: il. Trabalho de Conclusão de Curso (Graduação) - Universidade Federal Rural de Pernambuco, Bacharelado em Zootecnia, Garanhuns, 2019.
- CALIL, T.A.C. Princípios básicos de incubação. In: Conferência APINCO 2007 de Ciência e Tecnologia Avícolas, 2007, Santos. Anais do Simpósio sobre Incubação. Campinas: FACTA, p.19-45, 2007.
- CHRISTENSEN, V.L.; Wineland, M.J.; Fassenko, G.M. e Donaldson, W.E. (2001) - Egg storage effects on plasma glucose and supply and demand tissue glycogen concentrations of broiler embryos. Poultry Science, 80, 12: 1729-1735.
- DA CUNHA, Kianne Crystie Bezerra; DA ROCHA, Rodrigo Vilela. Automação no processo de irrigação na agricultura familiar com plataforma Arduino. Revista Eletrônica Competências Digitais para Agricultura Familiar, v. 1, n. 2, p. 62-74, 2016.
- DECUYPERE, E.; TONA, K.; BRUGGEMAN, V.; BAMELIS, F. The day-old chick: A crucial hinge between breeders and broilers. World's Poultry Science Journal, v.57, p.127-138, 2001.
- FRENCH, N.A, What the Embryo Needs. In: Proceedings of Incubation.p.01-05, 2010.
- GUN, Thailer Pereira. Controle de temperatura utilizando Arduino e PID em um protótipo de edificação reduzido. 2017. Monografia (Graduação Engenharia de Controle e Automação), Universidade Federal de Ouro Preto, 2017.
- IBGE. 2021 Fonte: Revista Globo Rural: Disponível em: <https://revistagloborural.globo.com/Estadao/noticia/2021/03/abate-de-frangos-subiu-33-e-producao-de-ovos-foi-recorde-em-2020.html>. Acesso em: 18 de março de 2021.
- MAATJENS, C.M. et al. Temperature during the last week of incubation. I. Effects on hatching pattern and broiler chicken embryonic organ development. Poultry Science, 2016, vol. 95, n° 4, p.956-965.
- MESQUITA, M.A. Fatores que afetam o desenvolvimento de embriões de frangos de corte durante a incubação. 2011. 36p. In: Seminários Aplicados do Programa de Pós- Graduação em Ciência Animal. Escola de Veterinária e Zootecnia - Universidade Federal de Goiás, 2011.
- MICHELIN GROFF, Priscila, et al. Importância da temperatura e umidade e os efeitos da luminosidade durante a incubação de ovos férteis de galinhas. REDVET. Revista Electrónica de Veterinaria [em linha]. 2017, vol 18(2), p.1-10 Acesso em: 5 de Maio de 2021. ISSN: . Disponível em: <<https://www.redalyc.org/articulo.oa?id=63651262003>>.
- OLIVEIRA, Betânia Jordan de. Influência entre o peso do ovo caipira, sobre o peso do pintainho ao nascer, aliados a eficiência da incubação artificial. 2018. pp.1-15. Trabalho de Conclusão de Curso (Graduação) – Centro Universitário de Patos de Minas, Patos de Minas, 2018.
- PRADO, T. A. Implementação de um controlador PID embarcado para o controle em malha fechada de um estimulador neuromuscular funcional, (2009). Tese de Doutorado. Dissertação apresentada à faculdade de Engenharia–UNESP–Campus de Ilha Solteira.
- ROBINSON, F.E. et al. Optimizing chick production in broiler breeders. Alberta PoultryResearchCentre, Canada, 2003. vol. 1, p91.
- SANTANA, Heitor Gonçalves. Controle PID multivariável: Uma abordagem baseada em aspectos de robustez. 2019 89 f. Dissertação (Mestrado Engenharia Elétrica) – Universidade Federal do Piauí, Teresinha, 2019.
- SEBRAE MERCADOS. (02 de abril de 2014). O mercado e a produção de galinha caipira no Brasil. Fonte: Sebrae Respostas: <https://respostas.sebrae.com.br/mercado-e-producao-de-galinha-caipira-no-brasil/>.
- THOMSEN, A. O que é Arduino? 2014. Fonte: FelipeFlop. Disponível em: <<https://www.filipeflop.com/blog/o-que-e-arduino/>>. Acesso em: 15 de jun de 2021.
- VAN DERPOL, C. W. et al. Effect of relative humidity during incubation at a set eggshell temperature and brooding temperature posthatch on embryonic mortality and chick quality. Poultry Science, 2013, vol.92, p.2145–2155.
- VENDRAMINI, G. Sistemas de Controle - Aula 2 UNIARA. [S.l.], 2018. 33 p.