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CONTAINER FOR DEHYDRATING EDIBLE MUSHROOMS

EDIBLE MUSHROOM DEHYDRATION CONTAINER

Ballato Camarillo Joshua Hyrum
La Salle University Pachuca, Hidalgo, MX
https://orcid.org/0009-0001-5908-0194
222028@lasallep.mx

Olvera Aguilar Armando
La Salle University Pachuca, Hidalgo, MX
https://orcid.org/0009-0001-0301-8113
222262@lasallep.mx

Varguez Rojas Edgar
La Salle University Pachuca, Hidalgo, MX
https://orcid.org/0009-0006-1583-3576
222118@lasallep.mx

Islas Bustamante Edwin Jovany
La Salle University Pachuca, Hidalgo, MX
https://orcid.org/0009-0005-5600-0274
222095@lasallep.mx

Ordaz Oliver Mario Oscar
National Technological Institute of Mexico/I.T. De Pachuca https://orcid.org/0000-0002-9302-0988
mario.oo@pachuca.tecnm.mx

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Abstract-- The global challenge of food security and resource scarcity affected vulnerable populations around the world, an issue aligned with Sustainable Development Goal (SDG) 2: Zero Hunger. In response, the urgent need to find innovative solutions to improve food preservation and promote community autonomy by 2030 was addressed.

Based on this approach, the project aimed to develop a container for dehydrating edible mushrooms. This system integrated a temperature sensor, a heat source, a fan, and an Arduino NANO microcontroller, which used a PID algorithm for precise control during the process. The results obtained demonstrated that this technology ensured efficiency and uniformity in dehydration to regulate the internal temperature of the container. It also indicated that the selected design was the correct one, as it maintained its simplicity and ease of replication.

Similarly, it was concluded that this solution significantly extended the shelf life of mushrooms, a food with high nutritional value and sustainable potential, facilitating their availability and contributing to food security.

Keywords-- Automation, Control, Process, Programming, System

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Based on this approach, the project aimed to develop an edible mushroom dehydration container. This system integrated a temperature sensor, a heat source, a fan, and an Arduino NANO microcontroller, which utilized a PID algorithm for precise control during the process. The results obtained demonstrated that this technology ensured efficiency and uniformity in dehydration by regulating the container's internal temperature. Furthermore, the selected design was deemed correct, as it maintained its simplicity and ease of replication.

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INTRODUCTION

The ongoing challenge of food insecurity and lack of resources, which disproportionately affects at-risk populations, characterizes the current global landscape. This issue is directly aligned with Sustainable Development Goal (SDG) 2: Zero Hunger. A key factor exacerbating this situation is the significant loss of perishable foods, such as highly nutritious mushrooms. In view of this need, it became essential to create innovative technological solutions that not only optimize food preservation but also promote long-term self-sufficiency and resilience at the community level.

Similarly, the lack of good infrastructure is closely related to malnutrition in populations that are limited by the lack of adequate tools for food preservation. In particular, the high perishability of items such as mushrooms means that productive work is quickly lost, reducing the economic and nutritional benefits obtained. Consequently, priority is given to the need to find a low-cost technological solution with a significant social impact, so that communities can ensure the availability of these foods.

Given this situation, the aim of this study is to analyze and propose a technological alternative for mushroom preservation that will help reduce post-harvest losses and strengthen food security in vulnerable communities. The importance of this research lies in its potential social impact, as an accessible and functional solution would not only promote the continuous availability of nutritious food, but also boost self-sufficiency, community resilience, and the comprehensive use of local resources in the long term.

OBJECTIVE

The main objective of this project was to design and build a container for dehydrating edible mushrooms, using a closed-loop electronic control system based on automation principles. The technical goal was to ensure the nutritional integrity of the product, seeking to achieve dehydration that would guarantee the efficiency and homogeneity of the process. Ultimately, this solution aims to inhibit the deterioration of mushrooms so that they remain available and actively contribute to food security when resources are scarce.

METHOD

The processes applied were characterized by being affordable and easily replicable. MDF and thermal insulation, both affordable materials, were used to build the dehydration system, which revolved around an Arduino NANO microcontroller. The essence of the innovation lies in implementing a digital Proportional-Integral-Derivative (PID) control algorithm, which enables accurate, real-time regulation of the temperature inside the container. The system works by constantly measuring the temperature, and the PID algorithm dynamically adapts the power of the heat generator to maintain an ideal set point for preservation, improving drying cycles and maximizing energy efficiency.

DEVELOPMENT

Container Design and Materials

The dehydration container, measuring 20 x 20 x 20 cm with a useful capacity of 0.5 kg of fresh mushrooms per cycle, was constructed using a 3 mm thick MDF structure. This structure was thermally insulated with the fundamental purpose of minimizing heat loss and optimizing the overall energy efficiency of the system. A heating element, specifically a 60 W incandescent bulb, was used for heating. Air circulation was ensured by a 12 V / 0.25 A axial fan with a flow rate of 100 CFM, whose speed was precisely regulated by a Pulse Width Modulation (PWM) signal managed by an L293N H-bridge. Environmental monitoring was performed using a specialized temperature and humidity sensor, model DHT11, which was responsible for detecting the internal conditions of the chamber and closing the control loop. The selection of all these components, characterized by their low cost and easy acquisition in local markets

, was considered essential to ensure the replicability and scalability of the design, especially in community contexts with limited resources.

Control System

The core of the closed-loop control system consisted of a programming algorithm for precise temperature control, implemented using a digital PID (Proportional, Integral, Derivative) controller. This controller was programmed into an Arduino Nano microcontroller, which was responsible for continuously calculating the thermal error between the temperature measured by the sensor and the setpoint or desired value (e.g., 50°C). Based on this calculation, the system automatically adjusted the power supplied to the heating element and the fan speed, using Pulse Width Modulation (PWM) to maintain optimal and stable conditions for dehydration [6]. The control law was implemented according to the standard continuous form of PID, which is:

$$u(t) = k_p\, e(t) + k_i \int_0^t e(t)\, dt + k_d \frac{of(t)}{dt}$$

The same as its digital implementation on the microcontroller, it required numerical integration programming using the trapezoidal rule in the form:

$$\int_{t_0}^{t_N} e(t)\, dt \approx \sum_{k=1}^{N} \frac{h}{2}\left[e(t_k) + e(t_{k-1}) \right]$$

On the other hand, for the discretization of the derivative action, the implicit Euler method was used with a backward step in the form known as presented below:

$$\left.\frac{of(t)}{dt}\right|_{t=t_k} \approx \frac{e(t_k) - e(t_{k-1})}{h}$$

In order to increase the reliability of the sensor measurements, which could be affected by electrical noise or transient fluctuations, a Kalman filter was programmed and implemented. This filter was responsible for estimating the true thermal state of the system in real time, providing a noise-free reading and considering the inherent uncertainty of both the built-in sensor measurement and the process model itself. The selection of this filter

This was done after evaluating other alternatives, such as moving average or low-pass filters, opting for the Kalman filter due to its superior performance in real-time system loops, its computational efficiency (ideal for the processing capacity of the Arduino Nano), and also because it introduced minimal phase delay, thus avoiding potential instabilities in the controller. The temperature filtered by the Kalman filter fed directly into the PID controller, resulting in improved loop stability and avoiding abrupt on-off cycles, which not only reduce energy efficiency but also shorten the operational life cycle of the actuators.

System Operation

The control system was designed to be simple and accessible to potential users without specialized technical training. The user procedure was limited to loading the mushrooms into the chamber, turning on the system with a switch, and selecting the desired temperature by turning a potentiometer. The total drying time was not preprogrammed, but was determined empirically based on tests with specific loads in volume and the initial humidity of the mushrooms, with the user manually ending the process once they observed that drying was complete. Energy efficiency was achieved through a combination of chamber thermal insulation and a smooth PID control strategy. Unlike conventional thermostats with different applications that operate using active cycles (thermo cycling), a less efficient method that generates significant temperature fluctuations, the PID controller regulated the output power progressively and continuously.

This mechatronic approach, which cohesively integrated an accessible hardware design with a sophisticated intelligent control scheme, ensured a uniform and reproducible dehydration process. This consistency was crucial for preserving the nutritional quality of the mushrooms and demonstrated the potential for future application to other perishable agricultural products.

DISCUSSION AND ANALYSIS OF RESULTS

Once the prototype had been built and adjusted, the required temperature stability tests were carried out. The aim of these tests was to verify that the temperature of the container stabilized at the desired value, with the primary objective of preserving and preventing damage to the nutrients contained in the mushrooms during the dehydration process. Initially, a test was carried out in which the internal temperature of the thermo-regulatable container was raised above 50 °C. Subsequently, by activating the fans and the controller, it was possible to regulate the temperature until the target value was reached. During this test, it was observed that the fans effectively slowed down as they approached the desired temperature, which simultaneously reduced the humidity inside the container in a controlled manner.

The tests carried out demonstrated the effectiveness of the algorithm implemented for the PID controller, which worked in conjunction with the Arduino NANO microcontroller and the sensor applied. Thanks to this integration, it was possible to stabilize the internal temperature of the box within the desired ranges, which was crucial for successfully and uniformly completing the mushroom dehydration process.

The system demonstrated not only the ability to efficiently reach high temperatures, but also to regulate and maintain the target temperature with minimal variations, ensuring a stable environment for drying. Similarly, ambient humidity was effectively managed, demonstrating that the built-in ventilation system was suitable for the specific application proposed in the project.

The results of the drying method using this configuration raised expectations of significantly extending the product's shelf life while preserving its nutritional qualities. Finally, the objectives set were met, as the storage stability of the mushrooms was considerably prolonged. The proposed design proved to be suitable for quickly removing moisture from the mushrooms, thus allowing a highly perishable food to be transformed into a more durable product that does not require refrigeration. This feature directly contributes to increasing its consumption period before being considered waste, positively impacting the reduction of food losses. The following graphs show that the system successfully passed the tests performed on it.

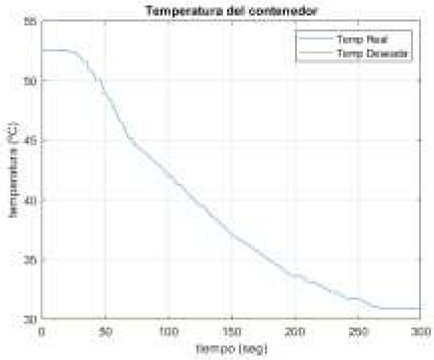

Figure 1. *Stabilization graph*.

Source: *Own elaboration* (2025).

Figure 1 shows a test of the desired temperature stabilization, starting with an initial temperature of 52 to 53 degrees Celsius, and after 300 seconds, the temperature successfully converged to the test's set value of 30 degrees Celsius.

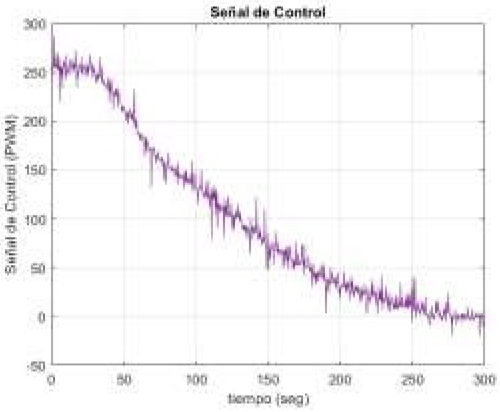

Figure 2. *PID control signal*.

Source: *Own elaboration* (2025).

The figure above shows a PWM signal stabilization test with the PID controller, which regulates the fans to control the temperature, showing how they start to operate until 300 seconds have passed, operating constantly and in a more regulated manner.

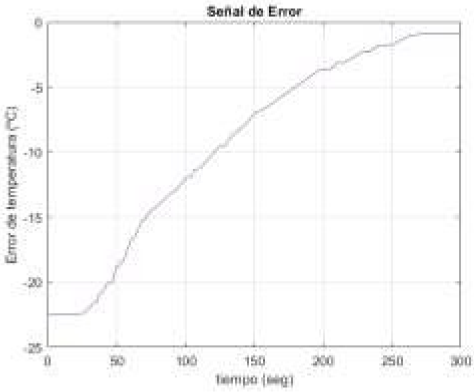

Figure 3. *Stabilization graph*.

Source: *Own work* (2025).

Figure 3 shows how the error is present at the beginning of the test, and after 200 seconds, the error begins to decrease until it reaches a value close to 0, consistent with the previous graphs and the desired tests.

The results obtained in this study are consistent with the findings reported in the article Impact of dehydration techniques on the nutritional and microbial profiles of dried mushrooms, which establishes that precise temperature control during the dehydration process is essential to preserve the nutritional quality of edible mushrooms. Thanks to this, the thermal stability achieved by the developed system allowed for uniform drying, reducing the risk of degradation of heat-sensitive nutrients and coinciding with the findings of that research.

Similarly, the study entitled Traditional processing and preservation of wild edible mushrooms in Mexico describes various conventional methods used for mushroom preservation, which, although effective in rural contexts, have significant limitations in terms of process control and reproducibility of results. In comparison, the proposal in this study incorporates an automated closed-loop control system that improves the accuracy of the process while maintaining the simplicity and accessibility of the design.

On the other hand, research focused on the use and study of edible mushrooms in regional contexts, such as the article Mycofloristic study of polypore mushrooms in the state of Hidalgo, Mexico, highlights the high diversity and availability of these resources, as well as the need to implement appropriate conservation strategies to reduce post-harvest losses. In this context, the system developed responds to this need by offering a low-cost technological alternative that adds value to local production and extends the shelf life of a highly perishable food.

CONCLUSIONS

The system proposed and developed in this research was based on an Arduino Nano microcontroller, a PID algorithm, and a Kalman filter, designed from practical results, proving to be a technically effective and low-cost solution to meet the initial objectives, effectively developing the dehydration of mushrooms and agricultural products endemic to the state of Hidalgo. The integration of the Kalman filter reduced noise in the sensor readings, improving the controller's response and ensuring accurate temperature regulation (±0.7 °C). Process stability was essential to preserve the nutritional value of the mushrooms, reduce waste, and extend their shelf life without the need for refrigeration, which would have required more technology and energy consumption.

Based on these results, it was possible to conclude that both the design and construction of the thermo-regulatable container presented met the proposed objective, which validated its viability as a technological tool with high potential to contribute to food security. Its operation, characterized by its simplicity (powering on and selecting the temperature), and its basic maintenance (periodic cleaning) facilitated its potential social appropriation in community contexts. In addition, the developed platform proved to be a versatile and adaptable technology for the dehydration of other perishable agricultural products (herbs, chilies, fruits) by simply adjusting the temperature setpoint, which significantly expanded its potential impact. In conjunction with the research, we reconfirm that the system is aligned with the current state of knowledge, while providing a practical and low-cost solution for mushroom preservation, with a potential positive impact on food security and the use of perishable agricultural products.

From the perspective of UN SDG 2, the project contributed to targets 2.1 (universal access to safe food), 2.2 (improved nutrition), and 2.3 (added value to local production), which strengthened local response capacity to the challenges of food insecurity.

Thanks to this project, we were given the opportunity to participate in the Lasallian Research, Development, and Innovation Competition 2025 (CLIDI 2025), where, after passing through various selection filters, the project achieved a satisfactory position in the Design and Innovation category, giving us a pleasant experience and result, encouraging us to continue with our projects and to work even harder on them.

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COLLABORATIVE WORK TABLE

Role	Author(s)
Conceptualization	Joshua Hyrum
Methodology	Armando Olvera
Software	Edwin Islas
Validation	Edgar Varguez
Formal Analysis	Mario Ordaz
Research	Joshua Hyrum
Resources	Armando Olvera
Data curation	Edwin Islas
Writing - Preparation of the original draft	Edgar Varguez
Writing - Review and editing	Mario Ordaz
Visualization	Joshua Hyrum
Supervision	Armando Olvera
Project Management	Edwin Islas
Fundraising	Edgar Varguez