Blynk-Enabled Smart Dry Box for Humidity Control and Monitoring

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ABSTRACT

Simple remote control (infrared remote control) has become the past, and products in the present era send instructions to products through connecting to the Internet. People expect that automation can make tasks easy, comfortable, fast and efficient. This paper introduces an innovative solution for humidity control and monitoring with the use of an intelligent dry box system. The proposed system utilizes a Peltier dehumidifier, a Blynk-based ESP8266 microcontroller (NodeMCU), and a humidity sensor (DHT22) to maintain a certain humidity environment for storing moisture-sensitive materials such as electronic components, camera lenses, and musical instruments. The Blynk application monitors the humidity level remotely through smart phones or computers, allowing users to receive notifications of humidity level fluctuations and make necessary adjustments to the humidity value in the box.

The smart dry box system offers several advantages over traditional humidity control methods. Firstly, the system provides an affordable and practical solution to maintain a certain humidity environment, making it suitable for personal or commercial use. Compared to traditional dry boxes that can stabilize humidity values on the market, the proposed system is more cost-effective, making it accessible to a wider range of users. Secondly, the Blynk app enables remote control and monitoring capabilities, allowing users to make necessary adjustments from a distance. This feature makes the system ideal for applications in which constant monitoring is required, such as museums, archives, and galleries.

Moreover, the experimental results indicate that the intelligent dry box system is effective in maintaining a specific humidity environment within +/- 2% of relative humidity stability. This finding confirms the system's efficiency in regulating humidity levels and ensuring the protection of stored materials. The system's simple design and user-friendly interface make it easy to operate, requiring no specialized knowledge or training. Overall, the proposed system provides a promising option for humidity control and monitoring in various applications in fields such as photography, electronics, and music.

Keywords: *humidity control and monitoring, Peltier dehumidifier, IoT, automation, dry box*

INTRODUCTION

Monitoring is crucial for preserving the quality and lifespan of moisture-sensitive materials such as artworks, documents, electronic components, camera lenses (Nakamura, Ishii & Ohishi 2013), and musical instruments. These materials

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are prone to damage and deterioration if exposed to high levels of humidity (Bandaru, Weaver & O'Higgins 2021), which can lead to significant financial losses for individuals and organizations. Traditional humidity control methods are often expensive, complex, or unsuitable for personal use, which has created a need for more cost-effective and practical solutions.

The proposed study addresses this need by exploring a smart dry box system that utilizes a Peltier dehumidifier controlled by IoT cloud (Blynk) to regulate humidity levels (Macheso, et al. 2022 and Ansari, et al. 2021). The system provides several advantages over traditional humidity control methods, including increased efficiency, reduced risk of damage to stored materials, and remote monitoring and control capabilities via the Blynk app. These features make the system suitable for personal or commercial use, and the system's affordability and ease of use make it a promising option for maintaining a certain humidity environment.

In the context of ongoing efforts to improve humidity control and monitoring, the proposed system represents a significant advancement in the field. The study provides new insights into the effectiveness and feasibility of using a Peltier dehumidifier controlled by IoT cloud (Al-Khalidy, et al. 2019) to maintain a certain humidity environment, which has the potential to revolutionize humidity control and monitoring practices. By offering a practical, cost-effective solution (Mohapatra & Subhudi 2022) to maintaining a certain humidity environment, the proposed system has the potential to improve the quality and lifespan of moisture-sensitive materials while reducing the financial burden associated with traditional humidity control methods. While existing works attempt IoT-controlled and cloud-enabled solutions, it becomes interesting to incorporate an ability to automatically and manually monitor and control a relative humidity level via a mobile application. Hence users who have access to the Internet shall be able to remotely check and adjust a relative humidity level anywhere and anytime. In this work, a Blynk-based smart dry box system with a mobile application capability is proposed. The proposed solution has been designed, implemented, and evaluated. The results show that it can reduce a relative humidity level to a specified level and remains stable within +/- 2%. Additionally, with associated mobile application, users can conveniently access and control the system.

The remaining of this paper is organized as follows. Section 2 discusses related works and existing solutions. System design and implementation are given in Section 3. The evaluation results are presented and discussed in Section 4. Section 5 gives conclusions and future works.

LITERATURE REVIEW

IoT-based systems have been increasingly utilized to provide remote monitoring and control of humidity levels. NodeMCU has gained attention as a popular IoT development board due to its affordability and ease of use. This literature review examines recent studies on IoT humidity monitoring and Peltier dehumidifier based on NodeMCU.

IoT-based for monitoring relative humidity is proposed in Aji et al. (2021). A simple network management protocol (SNMP) is deployed to relay relative humidity collected from sensors to an Open Platform Communication (OPC) server via ESP32 Wi-Fi controller. The system reports the collected temperature and humidity level with a low latency and no packet loss. Unfortunately, the system only works with SNMP-enabled devices making it less attractive for the general user as it becomes complex to set up the system. Besides, the system can only monitor the environmental conditions. Similar work is presented by Macheso et al. (2022). Instead of using SNMP protocol, Message Queuing Telemetry Transport (MQTT) protocol is utilized to forward collected data from sensors to a server. The results show that the collected data can be successfully forwarded to a dashboard. Again, this proposed system lacks the ability to control the environment conditions. Malika (2021) proposed an IoT-based humidity monitoring system that utilizes a NodeMCU development board and a humidity sensor. The system is designed to monitor the humidity level in the cabinet in real time and maintain the humidity level through the switch cycle of the Peltier dehumidifier. It lacks of a mobile application.

Another IoT-based solution for checking environmental conditions (is proposed in Mohammed et al. (2022). In this proposed work, Arduino Uno is used as a main controller to collect data (temperature, humidity and gas) from various sensors in the storage room and forwards them to cloud-based storage (Thinkspeak) via ESP8266-1 module. The solution is cost-effective since low-cost components are used to build the system. Nonetheless, the system only allows a user to monitor the environmental conditions in the storage room. The system lacks the ability to control environmental conditions such as humidity level. Zhang and Sun (2021) applied an artificial intelligent principle to monitor and control IoT-assisted humidifier in the room. Machine learning models, namely prediction and classification, were used to help automatically control a humidifier to keep optimal level of indoor humidity. These models are used to predict the indoor humidity and then control the humidifier to maintain the humidity level. The results show that the proposed solution can predict the humidity with a reasonable level of accuracy and can control the humidifier to increase humidity to a specified level. Nonetheless, the proposed work is limited to certain types of humidifiers, and it is not cloud-enabled.

Yanshori et al. (2022) proposed an IoT-enabled and fuzzy-based system that can monitor temperature and humidity for smart gardens. NodeMCU is used to process temperature and humidity sensors. The control function in the NodeMCU is performed by the proposed fuzzy logic, which decides when to activate the spray pump to spray water into the air. The experimental results show that the proposed system can reduce the temperature, while increasing the humidity level. The system can decrease the temperature by 3.8°C after the spray pump is activated. The humidity level has increased from below 55% to an average of 62.4%. Unfortunately, the humidity ranges from 55% to 69% with an average value of 62.46%. Since the system involves water spraying, it becomes unsuitable for moisture-sensitive materials. Besides, the humidity level cannot be precisely controlled.

An IoT-based environmental monitoring and control system is proposed by Chong et al. (2022). An IoT-based environmental control and monitoring system for mushroom cultivation is developed, where temperature, humidity level, light intensity and soil moisture levels can be remotely monitored and controlled. In this work, NodeMCU is used to collect and relay data to the cloud. Like other IoT-enabled monitoring and control systems, the results show that the system can efficiently monitor and control the environmental conditions. However, the humidity level ranges from 85.63% to 91.65%, which is not suitable for moisture-sensitive materials. Also, the proposed system is expensive. In conclusion, these studies have proved the feasibility and effectiveness of humidity monitoring based on the Internet of Things and Peltier dehumidification system based on NodeMCU. Compared with traditional humidity control methods, these systems have many advantages, including the ability of remote monitoring and control, improving efficiency, storing humidity data, maintaining humidity levels and reducing the risk of damage to stored materials. Clearly, moisture-sensitive materials such as cameras and lenses demand stable humidity level to prolong the lifespan of the materials. Therefore, cost-effective and IoT/mobile app-enabled solutions for moisture-sensitive small-size materials become interesting and challenging. In addition, the solutions should be able to ensure stable humidity level (+/- 2% expected). In the next section, the design and implementation of our proposed work are given and illustrated.

METHODOLOGY AND IMPLEMENTATION

System Design

The system diagram depicted in Figure 1 showcases a simplified setup that includes a DHT22 sensor for temperature and humidity measurements and a 2-channel relay module for controlling the Peltier dehumidifier. The Peltier dehumidifier is composed of a Tec1-12706 Peltier module and fan and is seamlessly controlled by the NodeMCU. Leveraging the Blynk application, this system can be effortlessly monitored and controlled through a Wi-Fi connection from a mobile device. The mobile application boasts a user-friendly interface that enables users to access temperature and humidity data, as well as manual and automatic mode settings. The manual mode provides the flexibility to switch the Peltier dehumidifier on and off as desired, while the automatic mode automatically activates the machine when the relative humidity (RH) exceeds a user-defined threshold and deactivates it when the RH level drops below the set value.

The left side of the diagram, which fully represents the hardware parts of the system, consists of a NodeMCU, DHT22, a relay module, a 12-volt fan, and the thermoelectric module (Peltier module). The NodeMCU regularly receives RH and temperature values from the DHT22 sensor. The NodeMCU not only determines the current state of the relay controlling the dehumidifier from the sensor, but also sends this information to the Blynk Cloud via the Internet. The information can be stored and manipulated in the cloud via the Blynk server and accessed via an API for use in a mobile application and/or dashboard on a website. The end user can monitor the current status, override the auto mode (manually turn the dehumidification process on and off), and set the desired RH value in auto mode via the mobile application and/or dashboard on the website. The set status is sent to the Blynk server and reported back directly to the NodeMCU to turn the relay unit on or off, which activates or deactivates the dehumidifier accordingly. The dehumidifier consists of a Peltier module, a 12-volt fan, and heat sinks for the cold and hot sides. The Peltier module takes advantage of the Peltier effect, in which heat is transferred from one side of a material to the other when an electric current flows through the material. The cold side is inside the dry box and the hot side is outside the box and is equipped with a fan.

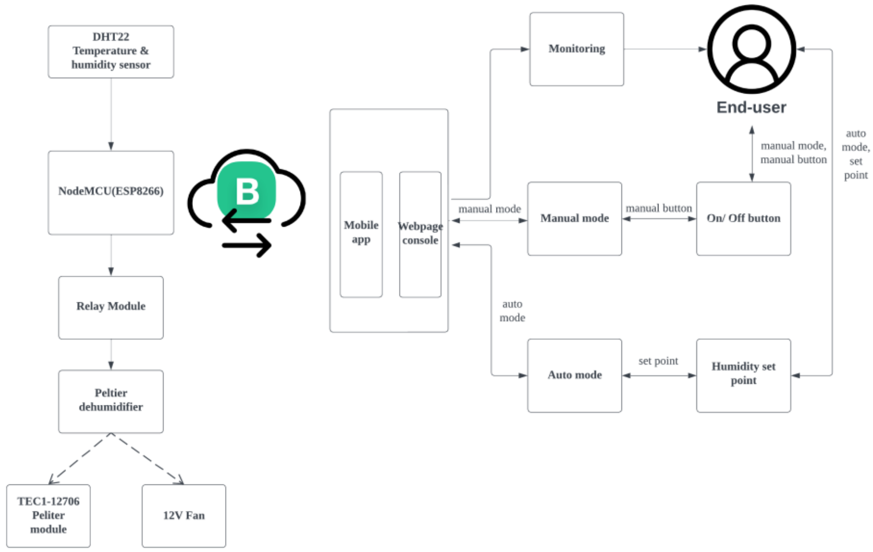


Figure 1. The system diagram of smart dry box system

Hardware Description

NodeMCU (ESP8266 microcontroller)

The NodeMCU in Figure 2(a) is used to enable wireless communication between the IoT cloud (Blynk) and the smart dry box system. The NodeMCU is programmed using the Arduino IDE and can be easily integrated with other electronic components to create a wide range of IoT applications, including remote monitoring and control systems. In this work, the NodeMCU is responsible for communicating with the Blynk cloud platform, enabling users to remotely monitor and control the smart dry box system via the Blynk app on their mobile devices or webpage console. Overall, the NodeMCU plays a crucial role in enabling wireless communication and remote control capabilities in the proposed smart dry box system.

DHT22 temperature / humidity sensor

The DHT22 in Figure 2(b) is a digital temperature and humidity sensor that can accurately measure and report the temperature and RH of the environment. It is a commonly used sensor in IoT projects and is ideal for this work as it provides the necessary data for the system to control and maintain the desired humidity level.

2-channel relay module

The 2-channel relay module in Figure 2(c) is used to control high-voltage electrical equipment through low-voltage microcontroller. In this project, it is responsible for controlling Peltier dehumidifier and its fan. The module is simple and reliable to use and can be easily integrated with microcontrollers such as NodeMCU.

Thermoelectric 12706 Power Generator Peltier (Tec1-12706)

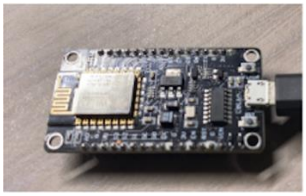
The Thermoelectric 12706 Power Generator Peltier (Tec1-12706) in Figure 2(d) is a device that can generate a temperature difference using the Peltier effect. It consists of two ceramic plates with semiconductor elements between them. When a current is applied to the device, heat is transferred from one side to the other, creating a temperature difference. In this work, the Tec1-12706 is used as a dehumidifier by cooling one side of the plate to condense moisture from the air. The device is controlled by the 2-channel relay module and powered by external power supply.

12V fan

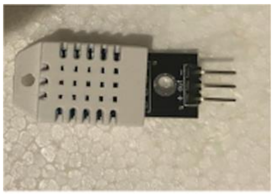
12V fan in Figure 2(f) cools the hot side of Tec1-12706 to dissipate heat, ensuring efficient operation of the Peltier dehumidifier.

Switching Power Supply (12V-10A)

The 12V-10A switching power supply as shown in Figure 2(e) provides power to various components, including the 12V fan, which is used to dissipate heat from the hot side of the Tec1-12706 thermoelectric module. The cool side of the module is also important, as it is used to maintain the desired humidity level in the dry box. By controlling the temperature differential between the hot and cool sides of the module, the system can effectively dehumidify the air in the box. The switching power supply plays a critical role in ensuring that the system operates reliably and efficiently, while also providing the necessary power to all components.

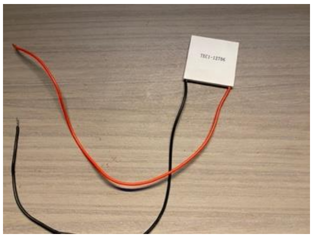


(a) NodeMCU ESP8266



(b) DHT22 sensor

(c) 5V 2-channel relay



(d) Tec1-12706 Peltier module

(e) AC/DC power supply

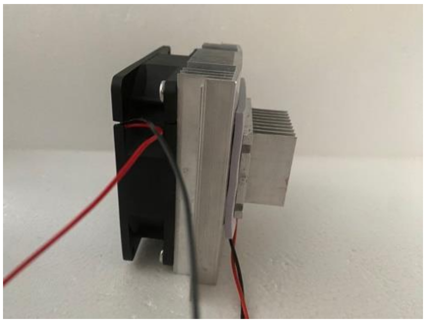
(f) 12V fan

Figure 2. Components in the smart dry box system

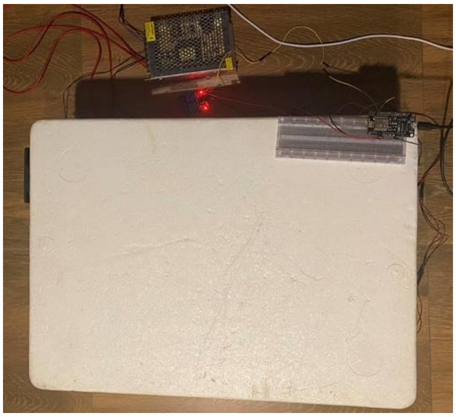
The reason why a 12V-10A switching power supply is chosen for this project is that the maximum operating voltage of the Tec1-12706 Peltier module, which is used to control the temperature inside the smart dry box, is 14.4V in 25 °C (Ahsan and Hasanuzzaman 2019). The 12V-10A power supply provides a stable and sufficient voltage to the Peltier module, ensuring its proper functioning and maximum efficiency.

Dry Box Assembly

The ESP8266 microcontroller board is the brain of the system, which receives signals from the DHT22 sensor to monitor the temperature and humidity inside the foam box. Based on the sensor readings, the ESP8266 controls the 2-channel relay module to turn on/off the Peltier dehumidifier and the 12V fan to regulate the humidity and temperature inside the box. The Peltier dehumidifier uses the 12V-10A switching power supply to power the Tec1-12706 module, which extracts moisture from the air and releases it through the heatsink, while the 12V fan removes the heat from the hot side of the Tec1-12706 module to maintain efficient operation. All components are connected and placed outside the dry box as shown in Figure 3. Sensor readings and generated CSV files are sent to the Blynk framework via ESP8266 for further analysis and monitoring.



(a) Dehumidifier module with Peltier, 12V fan and heatsink



(b) Top view of the dry box

(c) Side view of the dry box

(d) Inside the dry box

Figure 3. Dry box assembly

Blynk

The users can manually set the humidity level they desire, and if the automatic mode is on, the dry box's humidity will remain stable within +/- 2% after dehumidification. The system provides the convenience of both manual and automatic modes, allowing users to customize their humidity requirements as needed. The use of a Peltier dehumidifier, controlled by an ESP8266, makes the system cost-effective and efficient. Additionally, the system's remote monitoring and control capabilities, powered by Blynk, provide added convenience and flexibility. User can access the information via the web (Figure 4) and the mobile application (Figure 5). Overall, the smart dry box system offers a practical, affordable, and easy-to-use solution for maintaining a specific humidity environment, which is critical for preserving moisture-sensitive materials.

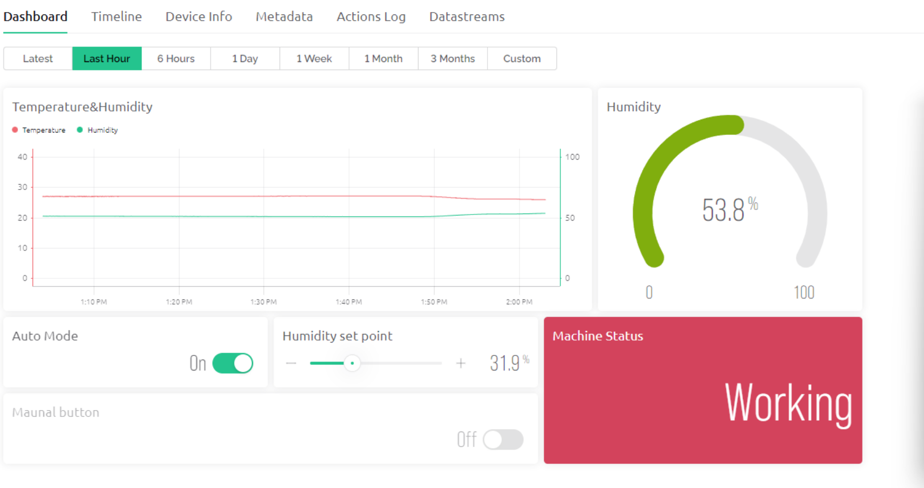


Figure 4. Blynk web application showing automatic mode turned on, and desired humidity at 31.9%

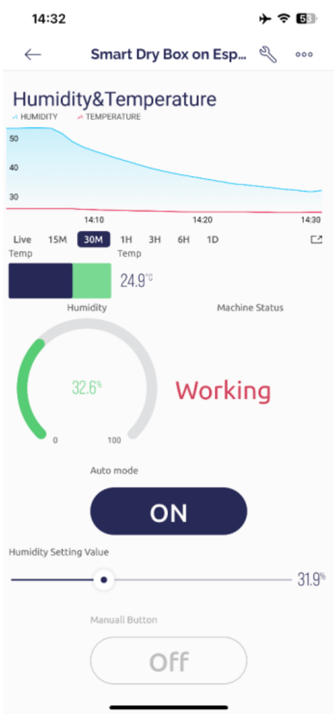


Figure 5. Blynk mobile application showing automatic mode turned on, and desired humidity at 31.9%

Command Workflow

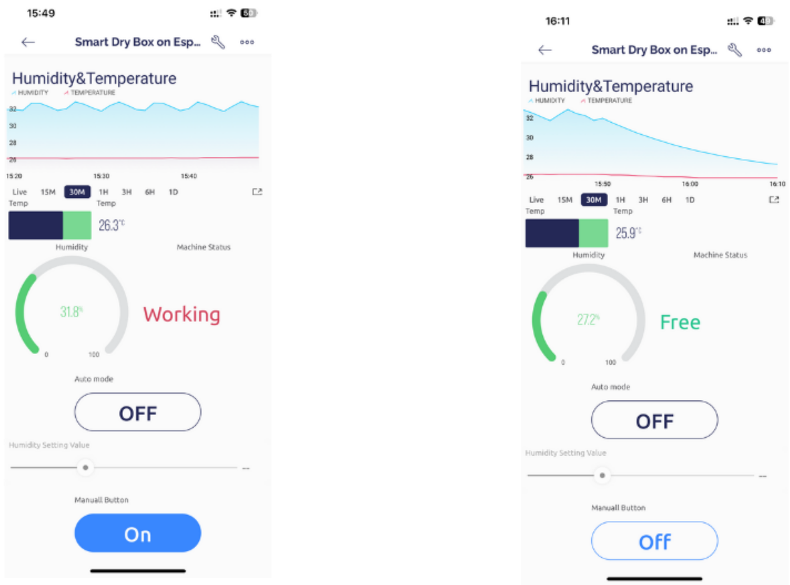
The command workflow in Table 1 involves several steps to judge whether the relay is powered on or off based on various inputs. First, the system needs to check whether the automatic mode switch is turned on. If it is, then the system will proceed to the next step. If not, the system will check the status of the manual switch. If the manual switch is turned on, the relay will be powered on as seen in Figure 6.

If the automatic mode switch is on, the system will compare the current humidity level to the set humidity point. If the current humidity is above the set point, the relay will be powered on. If the current humidity is below the set point, the relay will be powered off.

Overall, the workflow involves checking multiple inputs (automatic mode switch, manual switch, current humidity level, and set humidity point) to determine whether to power on or off the relay.

DataStream	Condition	Result
Automatic mode	automatic mode is on (value =1), and humidity set point ≤ current RH;	The Peltier dehumidifier is on, and manual button is disabled to click.
	automatic mode is on (value =1), and humidity set point > current RH;	The Peltier dehumidifier is off, and manual button is disabled to click.
	automatic mode is off (value =0)	The automatic mode is disabled, and manual button is enabled.
Manual mode	manual button is on (value =1) (see Figure 6(a))	The Peltier dehumidifier is on.
	manual button is off (value =0) (see Figure 6(b))	The Peltier dehumidifier is off.

Table 1: Command workflow of determination



(a) Manually turn on (b) Manually turn off

Figure 6. Manual control by the user in Blynk mobile application

ANALYSIS AND DISCUSSION

Users have the option to get the raw data sent from ESP8266 to Blynk and generate reports. Additionally, Blynk automatically collates data and allows users to get data in every minute and hour to generate CSV files. It provides an efficient way to manage and analyze the data collected from the smart dry box.

A preliminary test on the dry box when the dehumidifier unit is active was conducted. The box could decrease RH effectively by slightly effecting the temperature inside the box. To evaluate the performance of the smart dry box in terms of humidity control, the dimension of the box used in this work is 38.5 x 25 x 15 cm, which is approximately 14.4 liters in volume. Tests were conducted under the uncontrolled condition (actual room RH and temperature) and the auto mode preset value of RH set to 30%. Figure 7 shows the RH levels gradually decreased as the box dehumidified, from 53.8% to 31.9%, while the temperature remained stable between 24.7°C to 26°C. The stability of the temperature and RH inside the box can be observed in Figure 8. The temperature and RH levels were recorded at different times, indicating the box's ability to maintain stable humidity levels (+/-2%).

To further evaluate the efficiency of the smart dry box in controlling humidity levels based on the actual room temperature and RH and to ensure accuracy of the results, four trials have been conducted and the results are shown in Figure 9. The actual room RH and temperature during the test are in the range 64-67% and 25-27°C, respectively, before the system is turned on. The data show the average time the box takes to reduce RH from the room RH to 45% is 7 minutes. To reach humidity levels at 40% and 35%, it takes around 10 minutes and 14 minutes, respectively. Lastly, it takes approximately 25 minutes to reach 30% RH and the RH remains stable. The results suggest that the smart dry box effectively controls humidity levels and maintains stable temperature, making it an ideal for storing and safe-keeping moisture-sensitive items.

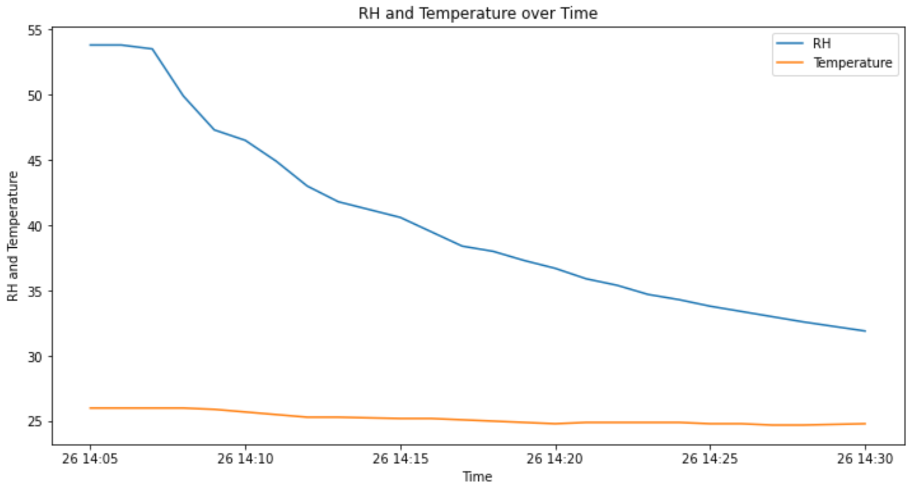


Figure 7. The temperature and humidity data while the dehumidifier is on

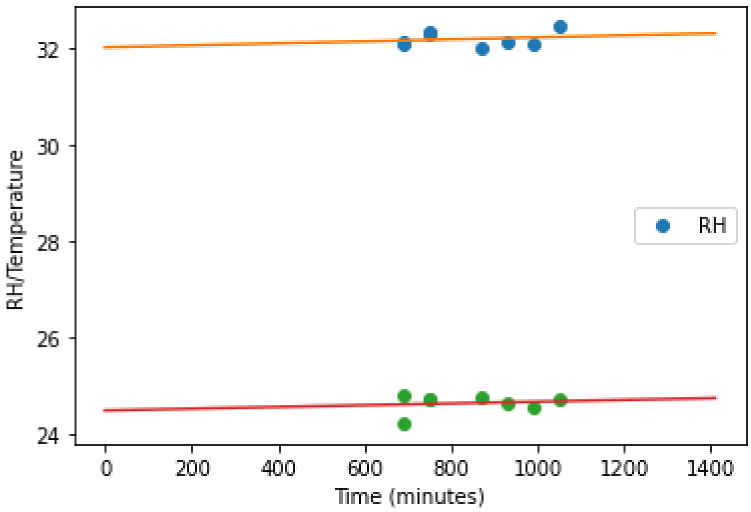


Figure 8. Stable humidity levels (+/-2%) after dehumidification with the automatic mode turned on

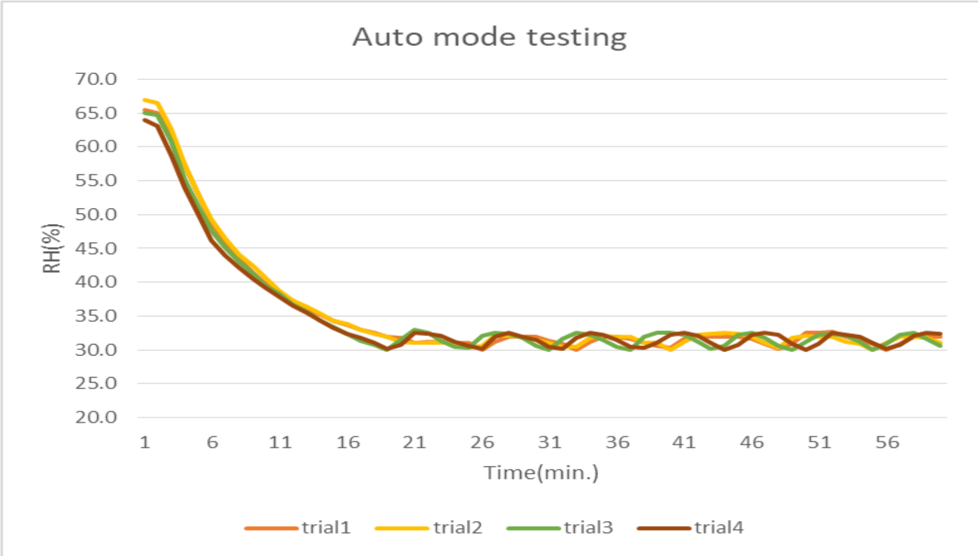


Figure 9. RH of several trials with the automatic mode turned on

Additional experiments have been conducted on another box which has a different volume. The dimension of the new box is 34.5 x 25 x 30 cm. which is around 25.9 liters. The volume of this box is around 1.8 times of the previous box. The lowest RH that can be derived from the system is 40%, even though the preset RH was set at 30%. According to initial investigations, there are several possible reasons why the RH could not be lowered to a certain point. For example, the size or number of Peltier modules are not suitable for the box volume. These premises are required to be proved in the further work.

Cost Analysis

Table 2 shows the component costs and the total cost of our smart dry box, which is about 920 THB (or 27.17 USD).

Components	Average Price	
NodeMCU (ESP8266)	80 THB	2.36 USD
DHT22	90 THB	2.65 USD
5v 2-channel relay	50 THB	1.48 USD
Peltier + heat sink	400 THB	11.81 USD
12V 10Amp power supply	150 THB	4.43 USD
12V fan	50 THB	1.48 USD
Foam box	100 THB	2.95 USD
Total cost	**920 THB**	**27.17 USD**

*using the rate of 1 USD = 33.8601 THB

Table 2: Cost of the smart dry box

While the prices of home-use commercial dry boxes are in the range of 42 – 85 USD, which are two to three times more expensive than our solution (Table 3). Furthermore, they do not offer online control and monitoring system.

Feature Comparison

Table 3 provides detailed comparisons of our solution with commercial products on various attributes. It is evident that our smart dry box provides more features than those in the market at a lower cost. Hence, it is an affordable alternative for maintaining moisture-sensitive valuables.

Dry Box	**Dimension W x D x H (cm)**	**Capacity**	**Monitoring**	**Price (THB)**
Our smart dry box	38.5 x 25 x 15	14L	Web & Mobile	920
Nakabayashi DB-27L	25 x 41 x 23.5	27L	No	1,430
Ailite GP3-20L	28 x 40 x 25	20L	LED Display	2,890

Table 3: Comparison with commercial products

CONCLUSION

It is widely recognized that moisture-sensitive materials are prone to damage or deterioration when they are exposed to humidity over a long period of time. To address the issue, a dry box or a container plays a critical role in preserving as well as extending the lifespan of moisture-sensitive materials such as artworks, historic document, certain types of electronic devices. Controlling humidity with traditional methods seems expensive, complex, or unsuitable for personal. In addition, it must be operated manually in most cases. As the expeditious of IoT is emerging, IoT-based dry box enables users to easily and precisely monitoring and, in many cases, controlling an appropriate humidity level of confined space. In this work, Blynk-enabled smart dry box has been proposed to remotely monitor and control humidity level. The proposed smart dry box system controls humidity by utilizing a Peltier dehumidifier controlled by IoT cloud (Blynk) via NodeMCU (ESP8266). The system is designed and developed, and its performance, in terms of humidity control, is evaluated. Additionally, a mobile application is developed enabling a user to remotely set the relative humidity level anywhere and anytime. The user can also manually turn on and off the system if necessary.

The evaluation results show that the system can gradually decrease the relative humidity (RH) from the stable outdoor environment to a pre-defined RH (as specified by the user) and remains stable within +/- 2%, while the temperature in the box remains stable between 24.7°C to 26°C. With its performance, the system is considered as one of cost-effective solutions to store moisture-sensitive materials. For the future work, multiple Peltier modules may be incorporated into the system so that, with an intelligent control mechanism, different Peltier modules can be alternately turned on and off to improve capability of the system.

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