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Prototype of humidity and temperature control system in IoT-based coffee drying process

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ABSTRACT

Drying coffee beans plays an important role in determining the final quality of the coffee beans. Drying is usually done traditionally by drying in the sun. This drying has many shortcomings, so a prototype of an IoT-based humidity and temperature control system for the coffee drying process was created. The sensors and microcontroller are DHT11 and ESP32, respectively. This prototype will work only if the sensed temperature is higher than 60 oC and the drying room's humidity reaches 12% then the control system will activate a fan. The temperature and humidity display will be displayed on the LCD layer of the prototype. Data regarding the temperature and humidity in the room will be sent to Blynk (a free phone application commercially available), so that the users can see and control these variables from their cell phone.. In this way, users can control and know the temperature and humidity during the coffee bean drying process.

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1. INTRODUCTION

Coffee has several processes before we can drink it, one of which is drying. Drying is one of the important process that affect the quality and flavor of the final coffee product. One of the most crucial processes in coffee processing is the drying process, where humidity and temperature are the determining factors. Improper drying can cause damage to coffee beans, reduce quality, and even cause economic losses for farmers [1]. Coffee beans that are dried improperly will be priced cheaply, ranging from 50,000 to 60,000 per kg, and will take a long time.

The impact of not properly regulating temperature and humidity during the drying process is significant. Too much humidity can cause the coffee beans to ferment, ruining the flavor and aroma of the coffee. In addition, uncontrolled humidity can also increase the risk of mold and bacterial growth [2]. Inappropriate temperatures can lead to uneven evaporation, resulting in beans that are not optimally dried, ultimately affecting roasting results and the final quality of the coffee [3].

To solve this problem, several studies have been conducted on temperature and humidity monitoring tools in the coffee drying process [4,5,6,7,8]. For example, developed an IoT-based monitoring system to monitor temperature and humidity in real-time during the drying process [9]. The system is equipped with sensors that can transmit data to a mobile application, allowing farmers to control drying conditions remotely.

In addition, the application of temperature and humidity sensors can increase the efficiency of the drying process by up to 30%, because farmers can adjust the time and method of drying based on accurate data [10].

The importance of continuous monitoring to maintain the quality of coffee beans and reduce the risk of damage due to unexpected changes in weather conditions [11].

The application of Internet of Things (IoT) sensors in agriculture [12], including in coffee processing, has become rapidly growing. IoT enables real-time data collection, facilitates monitoring and control of the drying process, and improves production efficiency and effectiveness [13]. By utilizing sensor technology and connected software, this sensor not only provides accurate information but also enables remote control [14].

The control of humidity and temperature in the coffee drying process by application of IoT is expected to improve the quality of coffee beans, minimize the risk of damage, and ultimately increase farmers' income. Therefore, this research aims to design and develop a prototype to enable the control of these variables in such a process.

2. METHODS

2.1 Block Diagram

The block diagram is used as the initial design of the tool to be made. With the block diagram, everything will be clear, such as the components used, the input, and the output. Made in a structured and coherent manner as in Fig. 1.

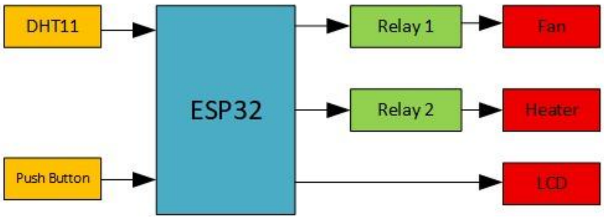

Fig. 1. Block Diagram

The image shows a block diagram of a temperature and humidity control system based on ESP32 used in the drying process, such as coffee drying. The DHT11 sensor functions to read air temperature and humidity, and the data is then sent to the ESP32 microcontroller for processing. Based on the received values, the ESP32 will activate Relay 1 to turn on the fan if the temperature or humidity is too high, and Relay 2 to activate the heater if the temperature is too low. The system is also equipped with a push button to provide manual input or additional control, as well as an LCD to display real-time information on temperature, humidity, and system status. This diagram illustrates an automatic system capable of efficiently maintaining environmental conditions through microcontroller-based control.

The system in the block diagram above is divided into three parts, namely the Input part, the Process part, and the Output part. This device consists of

1. DHT11 sensor as input to detect humidity and temperature at a predetermined level.
2. ESP32 microcontroller as the process part that will work and enter Standby mode.
3. This ESP32 component will produce output in the form of a display on the LCD, a display on Blynk, and heat energy from the Heater.

DHT11 has several advantages compared to other temperature and humidity sensors, especially in terms of economical pricing, ease of use, and wide compatibility with various microcontrollers such as Arduino and ESP32. This sensor also has a compact form and low power consumption, making it ideal for small-scale IoT applications or educational purposes. Although its accuracy is not as high as industrial-grade sensors like DHT22 or SHT31, DHT11 remains a popular choice for simple projects because it is sufficiently reliable for measuring temperature (0–50 °C) and humidity (20–90%) with an acceptable margin of error in many non-critical applications [15].

ESP32 offers significant advantages over other microcontrollers due to its dual-core processor and built-in WiFi and Bluetooth connectivity, enabling IoT systems to achieve high performance and flexibility in data transmission, while also being capable of effective multitasking. Another advantage is its relatively low power consumption, particularly when using modes such as deep sleep, making it highly suitable for battery-dependent devices. In contemporary applications, ESP32 has proven to be reliable and efficient, for instance in IoT-based machine condition monitoring systems, where ESP32 is used for real-time data transmission and responsive local processing, while remaining stable under moderate workloads [16].

2.2 Flowchart

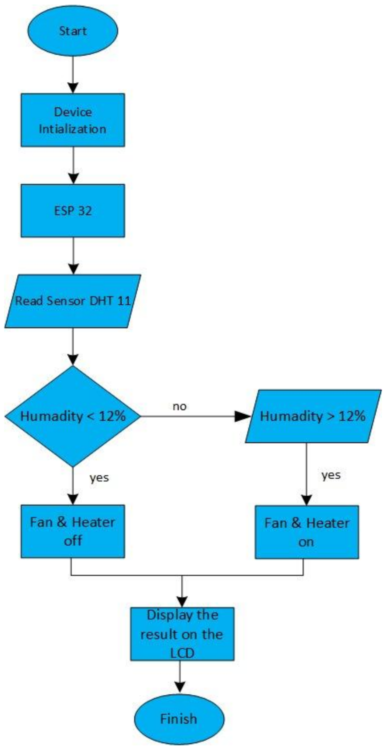

Fig. 2. Flowchart

The flowchart of the tool work system can be seen in Fig**.** 2. The humidity monitoring and control system in the coffee drying process uses an ESP32 microcontroller as the central controller. A DHT11 sensor is installed to measure the air humidity inside the drying chamber. The measurement data is then processed by the ESP32 and compared with the predetermined threshold value of 12%. If the humidity is detected to be above 12%, the ESP32 will activate relay 1 and relay 2, turning on the fan and heater. This activation aims to accelerate the reduction of moisture content in the coffee beans. Conversely, if the humidity is detected to be below 12%, both relays will be deactivated, turning off the fan and heater, as the coffee beans are considered sufficiently dry. All measurement results and device statuses are displayed in real-time on the LCD, allowing the operator to easily monitor the process. With this mechanism, the system operates automatically and repeatedly (looping), namely reading the humidity, performing control as needed, and then displaying the results on the LCD until the drying process is complete.

2.3 Schematic of Device Design

The sketch of the design can be seen in Fig. 3. The image depicts a temperature and humidity control system based on the ESP32 microcontroller, which is used to regulate the drying process, such as in a coffee drying oven. The DHT11 sensor is used to measure the air temperature and humidity inside the oven, and then the data is sent to the ESP32, which acts as the processing center. The temperature and humidity values are then displayed on a 16x2 LCD as a user interface. Based on the sensor data, the ESP32 controls the relay module, which will activate the fan to lower the temperature or the heater to raise the temperature as needed. All these components operate on a 220 volt power supply, and the system is designed to work automatically to maintain temperature and humidity stable within the desired range.

This tool works on the principle of circulating hot air into the drying chamber. This will allow the moisture in the coffee to gradually decrease, thereby reducing the water content of the coffee beans. Rapid drying of coffee beans can negatively impact their physical, chemical, and sensory quality; for example, rapid drying methods at high temperatures tend to cause color changes to become darker (a decrease in luminosity value), damage to cell structure (including the appearance of cracks and large pores), and oxidation of bioactive compounds such as phenolics and antioxidants, which can affect the aroma, taste, and shelf life of the beans [17].

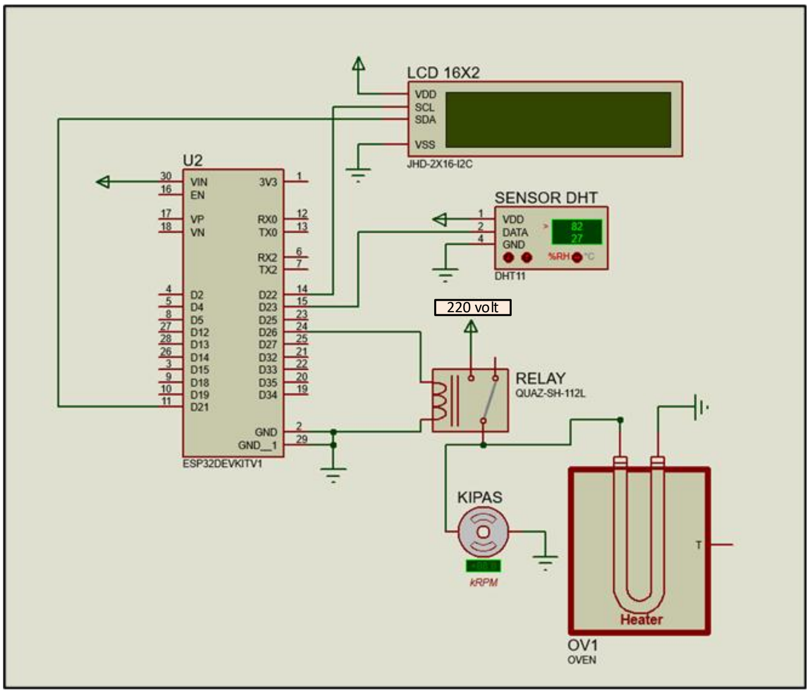

Fig. 3. Schematic of Design

3. RESULTS AND DISCUSSION

3.1 Design

The purpose of designing this coffee drying tool is based on various problems faced by coffee farmers, such as during the rainy season, when drying coffee beans requires a fairly long time, sometimes more than a month, to reduce the moisture content of the beans to 18%. This affects the quality of the coffee beans. It not only impacts the quality of the beans but also the selling price of the coffee. Therefore, this tool can assist in the coffee bean drying process and save time and effort.

This coffee dryer is designed with dimensions of 50 x 40 x 35 cm (length x width x height) and has a drying capacity of 30 grams. The design of the coffee drying system using the ESP32 microcontroller [18] is equipped with a DHT11 input as a temperature and humidity sensor, an output equipped with a heater and 2 fans. The sensor used will identify if there is a change in humidity. The sensor will not activate the fan and heater when the humidity decreases, and will activate the heater and fan when the humidity increases.

The results of the coffee drying device with Internet of Things-based temperature and humidity monitoring using the ESP32 microcontroller have been successfully designed. The following can be seen in Fig. 4.

Fig. 4. Front View of the Device

The top view of the tool is a black box containing components such as ESP32, Arduino nano, step down, 12v power supply, relay, LCD, push button, and there are 2 fans to help the coffee drying process. The following can be seen in Fig. 5.

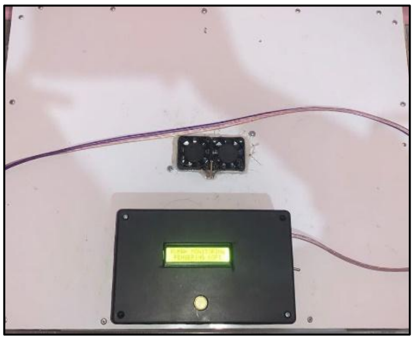

Fig. 5. Upper view of device

The inside of the tool has a heater as a producer of heat energy, a relay and 2 fans to spread hot air generated by the heater, as well as a tray as a coffee container. The following can be seen in Fig. 6.

Fig. 6. Inside view of device

3.2 DHT11 Sensor Test

The DHT11 sensor test was conducted to measure the humidity in the coffee drying system. The aim is to ensure that the system will activate when the humidity reaches a certain value. Table 1 below shows the DHT11 sensor test results.

Table 1. Result of DHT11 Sensor Test

No	Experiment	Temperature	Moisture	Time
1	First	30.20 C	81.00%	16 Minute
2	Second	33.12 C	79.00%	13 Minute
3	Third	29.80 C	80.00%	15 Minute
4	Fourth	31.00 C	88.00%	14 Minute
5	Fiveth	30.30 C	82.00%	15 Minute

After testing the DHT11 sensor, then in Table 1 above get the results that when the button is pressed the system will read the temperature and humidity values in the room of the coffee drying house which has humidity equal to 12% then the system will not be active, the coffee is indicated not to be in a wet state, but when the sensor captures the humidity value above 13% then the system will start to activate. In Fig. 7, you can see the humidity value on the LCD captured by the DHT11 sensor.

Fig. 7. Value of temperature and moisture

In Fig. 7 above, it can be seen that the temperature value is at 30.80 °C and the humidity value is at 81.00% listed on the LCD. This shows that the tool can work properly.

3.3 Testing of the Entire System

The next step is to test the entire system to ensure that the tool is functioning properly. Table 2 below presents data on the overall system test results of the coffee drying equipment.

Table 2. Testing of the Entire System

No	Temperature	Moisture	Active System	Heater	Fan	LCD Indicated
1	30.00 C	88.00%	v	v	v	v
2	34.00 C	61.00%	v	v	v	v
3	39.00 C	47.00%	v	v	v	v
4	50.00 C	35.00%	v	v	v	v
5	60.00 C	12.00%	-	-	-	-

Note : v means system not active and - means system is active

After knowing the results of testing the entire tool, it can be seen in Table 2 above that the temperature and humidity value indicators are a reference for the active coffee drying system, and the temperature and humidity values are a condition for drying coffee made using ESP32.

3.4 Blynk Application

Blynk is an IoT platform that stands out compared to other applications due to its ease of use, allowing users to create application interfaces through drag-and-drop without the need for complex coding. This application supports various devices such as Arduino, ESP8266, ESP32, and Raspberry Pi, and is compatible with multiple types of connections like Wi-Fi, GSM, BLE, and others. Blynk is available on Android and iOS, provides free cloud services for beginners, and offers private server options for advanced users who need full control. Each project has a unique authentication token for security, and it supports integration with other services such as IFTTT, Node-RED, and MQTT. Additionally, Blynk enables real-time monitoring and control of devices, supported by comprehensive documentation and an active community, making it an ideal choice for students, hobbyists, and professional developers in building IoT systems [19].

At the software implementation stage, the login and password interface is displayed. The form is filled in according to the already registered account. This authentication mechanism is designed to ensure that only registered users can access the system, while also serving as a gateway to the main modules of the application. Thus, login functions as both a security layer and the initial stage in the user interaction flow. This can be seen in Figs. 8, 9, and 10.

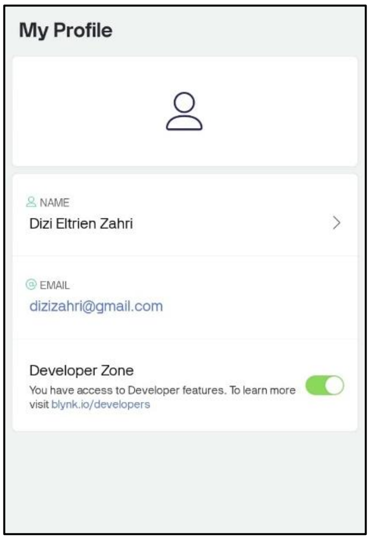

Fig. 8. Blynk Account Display

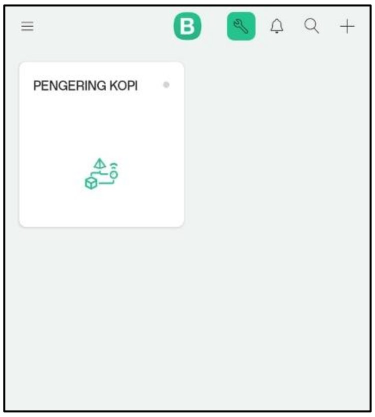

Fig. 9. Blynk App Home View

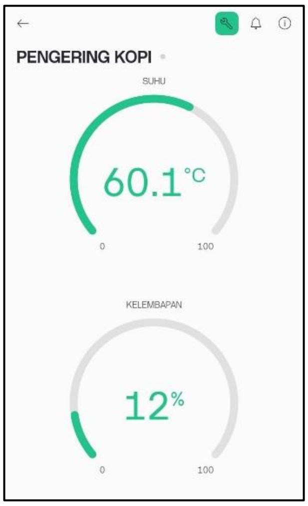

Fig. 10. Temperature and Humidity Monitoring Display

4. CONCLUSION

This IoT-based humidity and temperature control system prototype for the coffee drying process has been successfully designed and implemented to monitor environmental conditions in real-time. The system is capable of maintaining humidity and temperature at optimal levels required in the coffee drying process, thereby improving efficiency and the quality of the final product. With automatic monitoring and control through the IoT platform, the drying process becomes more precise and easier to oversee remotely, offering potential increases in productivity and reductions in losses due to unstable drying conditions.

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