Temperature Control System for Mushroom Dryer

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Abstract. The main problem in mushroom cultivation is the handling after the harvest. Drying is one technique to preserve the mushrooms. Traditionally, mushrooms are dried by sunshine which depends on the weather. This affects the quality of the dried mushrooms. Therefore, this paper proposes a system to provide an artificial drying for mushrooms in order to maintain their quality. The objective of the system is to control the mushroom drying process to be faster compared to the natural drying at an accurate and right temperature. A model of the mushroom dryer has been designed, built, and tested. The system comprises a chamber, heater, blower, temperature sensor and electronic control circuit. A microcontroller is used as the controller which is programmed to implement a bang-bang control that regulates the temperature of the chamber. A desired temperature is inputted as a set point of the control system. Temperature of 45 °C is chosen as the operational drying temperature. Several tests have been carried out to examine the performance of the system including drying speed, the effects of ambient conditions, and the effects of mushroom size. The results show that the system can satisfy the objective.

1. Introduction

Mushrooms have high nutritional content. They are rich of minerals, proteins and fibres. In addition, they contain no cholesterol. Some types of mushroom are used for healthcare such as to increase human immune system, smooth blood flow, prevent high blood pressure, lower cholesterol in the blood, and neutralize toxic or poison in the body. Mushrooms are also widely known as a delicacy among food appreciators for centuries. [1,2]. In addition, today there is a tendency for people to reduce eating red meat, so many of them choose an alternative to switch to mushrooms to meet daily nutritional needs [3].

Mushrooms have the same properties as vegetables which are easily damaged cannot last long in natural conditions. Therefore, in the food processing industry, the mushrooms need to be preserved after harvest [4]. Mushrooms can be dried to preserve them. Drying is a process to reduce the water content of a material. This process requires energy to evaporate moisture content and transfer a certain amount of water vapour from the surface of the material to the surrounding environment [5].

Unlike vegetables which decrease their quality when dried, mushrooms can maintain their quality when dried properly. Wet mushrooms have 80% to 90% moisture content. They are chewy, smooth and flexible. Mushrooms become curved and hard when dried. Mushroom drying is aimed to reduce the water content of the mushroom which indirectly also kills microorganisms which cause damage to the mushroom. With the drying process it should reach 20% moisture content. Traditionally mushroom drying is performed naturally using sunlight. Although the cost is low, it is not effective because it depends on weather conditions which cannot be predicted and controlled. Mushroom can be easily damage if the drying process takes a long time or when the drying temperature is too low.

Another problem with natural drying is that the drying temperature is not accurate which deteriorate the quality of the dried mushrooms [6,7].

This paper presents the solution for the above mentioned problem. A prototype of a mushroom dryer has been developed. The dryer utilises a temperature control system to ensure the drying process is maintained at an operational temperature of 45°C which allow producing dried mushrooms with 20% moisture content [8].

2. System Development

2.1. *Drying Chamber*
The drying chamber is made of wood with the size of 32 cm × 24 cm × 28 cm as can be seen in figure 1. A system to control the temperature of the chamber is shown in figure 2. It consists of a lamp as a heater to warm up the chamber, a wire mesh rack to place the mushrooms to be dried, a blower to remove wet air from the chamber and a temperature sensor to detect chamber temperature.
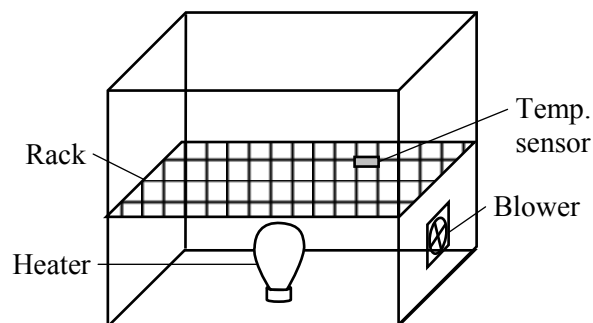

Figure 1. Dryer chamber   **Figure 2.** Drying system components

2.2. *Control and Monitoring System*
Figure 3 illustrates the diagram of electronic hardware to implement the temperature control and monitoring system. The heart of the system is microcontroller PIC16FF877A.
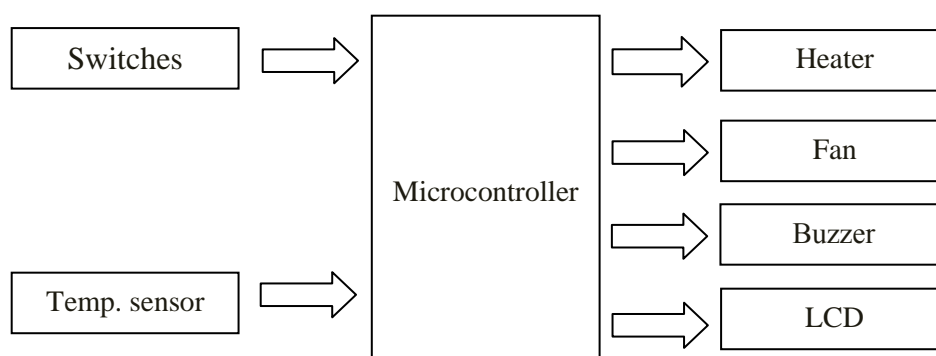

Figure 3. Components of control and monitoring system

Figure 4 shows the schematic of the microcontroller circuit. This type of microcontroller has a total of 40 pins where 32 of them are for input and output [9]. In this circuit, pins 2 and 3 are connected to humidity and temperature sensor outputs respectively. Pin 4 is for the reference voltage input. Pins 13 and 14 are connected to the timer crystal while pins 15, 16, and 17 are the inputs connected to the switches circuit. Pins 19 and 30 are connected to the heater and fan respectively, whereas pins 33 to 40 are used as outputs to the LCD.
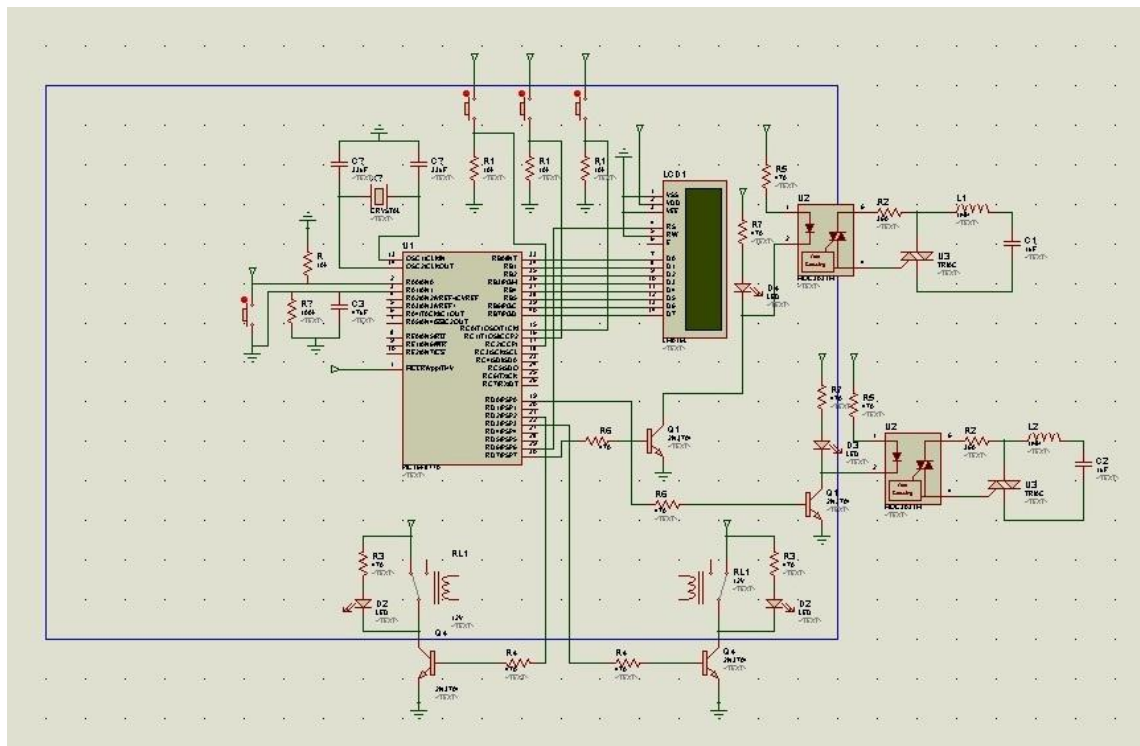
Figure 4. Schematic of the electronic circuit

Figure 5 shows the electronic circuit with microcontroller, switches to input the set point, and LCD to display temperature, humidity and time. A PWM circuit, sensor and lamp as the heater is shown in figure 6.

Figure 5. Controller and input-output interface

Figure 6. PWM circuit, sensor, and lamp

The block diagram of the control system for the mushroom dryer is shown in figure 7. It is a closed-loop control system with a bang-bang controller to control air temperature inside the drying chamber to be maintained at 45 °C ± 2 °C.
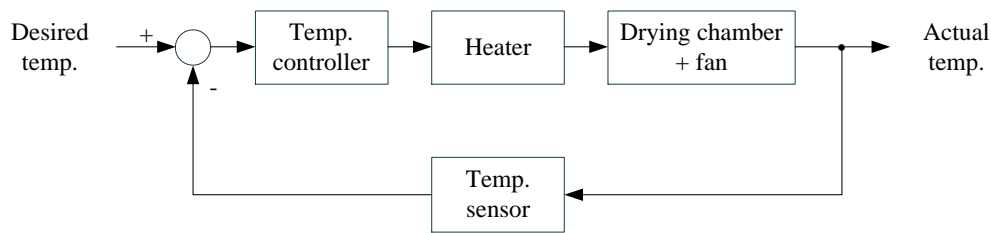
Figure 7. Control system block diagram

Figure 9 shows the Simulink model of the system to analyse the system behaviour and operation before the implementation.
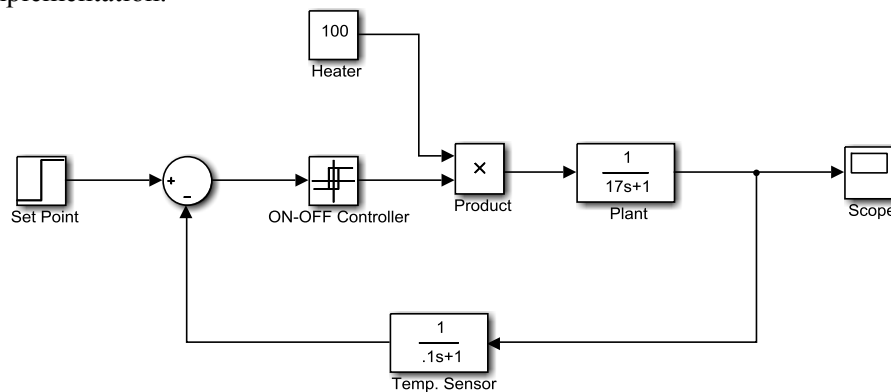

Figure 8. Simulink model

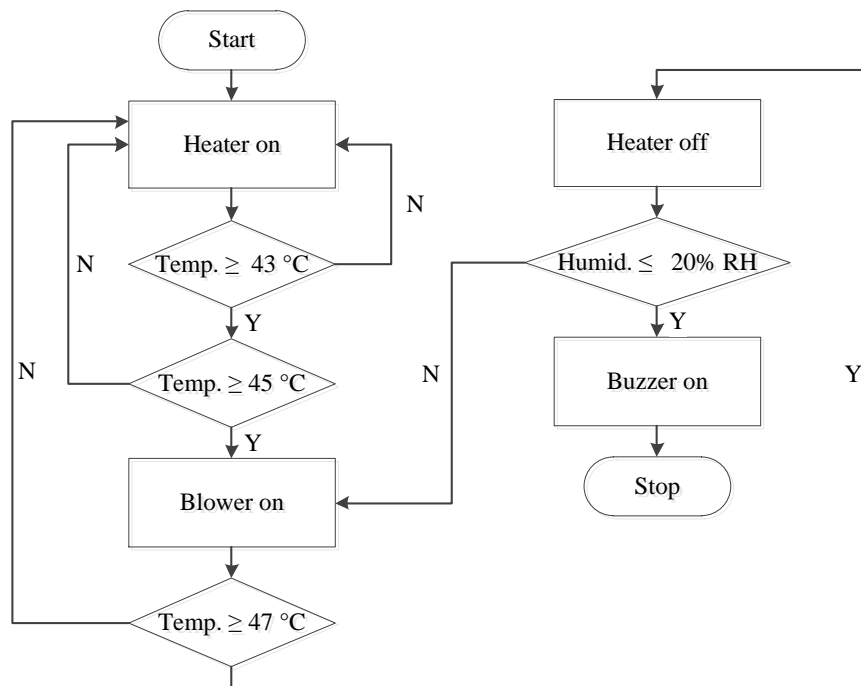The operation of the mushroom dryer follows the flowchart in figure 8.

Figure 9. Flowchart of mushroom dryer operation

3. Results and Discussions

Figure 10 shows the results of experiments to investigate the required power of the heater. 25 W, 60 W, and 100 W lamps were tested as the heat source inside the dryer chamber. Time to reach the set point was found as 16 minutes, 11 minutes and 2 minutes for 25 W, 60 W, and 100 W lamps respectively. Since the 100 W lamp was the fastest and most effective for heating, it was chosen as the heater for this the dryer.

An experiment was done to test the respond of the system to the ambient temperature i.e. in dry and damp air conditions. Both curves in the graph show that the time to reach the set point is almost the same. Therefore it can be concluded that the performance of the system does not affected by the ambient conditions.
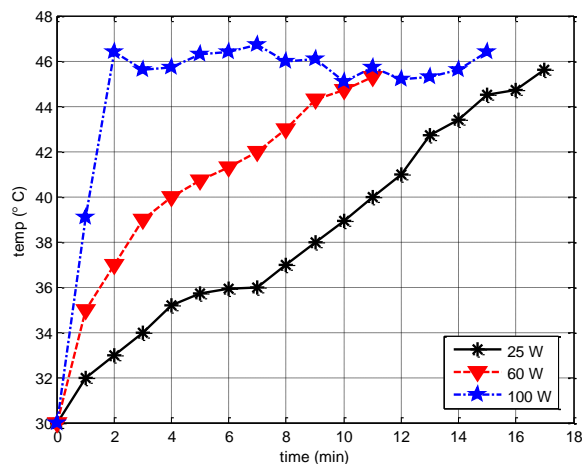

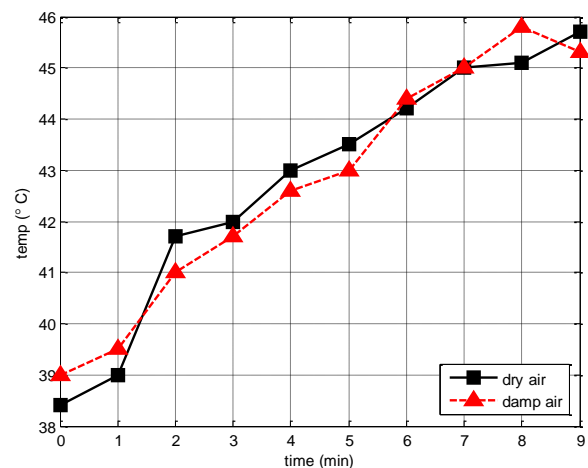**Figure 10.** Results of heating power experiments   **Figure 11.** PWM circuit, sensor, and lamp

Another experiment investigates the performance of the dryer to dry thick or thin mushrooms. The results in figure 12 show that thicker mushrooms take longer to dry. However, the control system works for either thick or thin mushrooms.
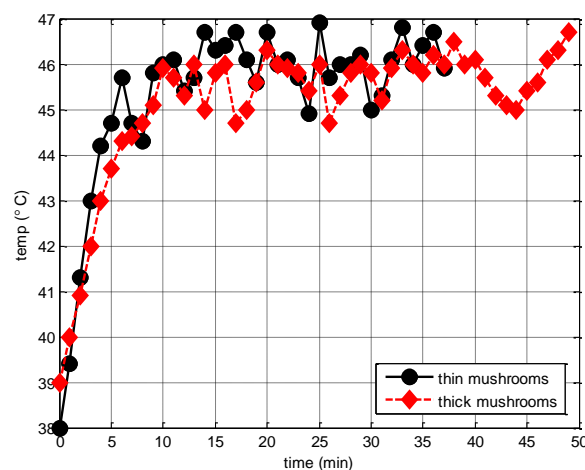

Figure 12. Control system block diagram

4. Conclusions

A prototype of a device to artificially dry mushrooms has been designed, built, and tested. The temperature control system applies bang-bang (ON-OFF) control to control air temperature inside the drying chamber to be maintained at 45 °C ± 2 °C. The device is able to work satisfactorily at various heater powers, ambient conditions and mushroom sizes.

References

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