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Investigation of Temperature and Humidity Control System for Mushroom House

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Abstract: Monitoring and control of the mushroom house environment play an important role in mushroom cultivation quality. The assurance of optimal temperature and humidity has a direct influence on the mushroom growth performance. Traditionally, mushroom cultivation requires a great effort to connect and distribute all the sensors and data acquisition systems. Natural environment such as temperature during the day either on a hot or rainy day affects the temperature and moisture in the mushroom house directly. The optimal temperature and humidity for mushroom house are around 20 °C and 80%, respectively. For this reason, to maintain an optimal temperature and humidity, Matlab/Simulink tool was deployed to run simulations on the system. Simulink's block diagram is composed of three main parts for this system, namely input, control system, and output (temperature and humidity) for the mushroom house. Matlab/Simulink tool was used for modeling, simulating, and analyzing the performance of the system.

Keywords: Mushroom house, humidity, temperature, simulation.

1. Introduction

Mushroom cultivation activity has been long existed in Malaysia. Currently, this cultivation activity is growing and thriving due to high demand in the Malaysian market. The government recognizes the mushroom industry to have the potential to be developed as demand is increasing in tandem with the increase in population and consumption. The consumption of mushrooms per capita is expected to increase from 1.0 kg in 2008 to 2.4 kg in 2020.

Besides, there were 648 mushroom entrepreneurs in Peninsular Malaysia in 2008. The demand of mushroom is increasing but in Malaysia, the number of cultivators and production is decreasing. This is due to the inconsistent environmental condition with high temperature of 32–35 °C and low humidity of 60%–70%. The higher demand for mushroom cultivation is an opportunity for entrepreneurs in Malaysia.

Mushrooms are a type of fungi that contain most potent nutrients such as vitamins, minerals, and antioxidants. Mushrooms also provide healthful dietary fiber and low in calories. Basically, there are over 2,000 edible fleshy mushroom varieties worldwide with less than 100 being cultivated. In Malaysian climate, there are 17 varieties of mushroom can be grown. However, only eight of these varieties are cultivated commercially. Oyster mushroom, also known as *Pleurotus ostreatus*, is the most widely cultivated in Malaysia.

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2. Ventilation of Mushroom House

The concept of ventilation in the mushroom house is the important part of the physical environment. The ventilation system may seem simple but it also plays a vital role in the mushroom health and production. The mushroom house will trap the solar radiation and increase the environment temperature. If this excessive heat is not removed it can cause undesirable condition for plant growth or worse. Without good ventilation, the mushroom house will become too warm which is not suitable for the mushroom cultivation.

Malaysia is located near to the equator. Therefore, the characteristic features of Malaysia's climate are uniform temperature, high humidity, and copious rainfall. Malaysia naturally has abundant sunshine and thus solar radiation. Due to uncertain weather in this country, a good ventilation system should be performed in the mushroom house to produce high quality mushroom.

3. Model Components

The model for this system includes three components which are air pump, thermostat for on/off controller, and mushroom house as shown in Fig. 1. The thermostat regulates the air pump depending on the difference between the outside temperature and the inside temperature of the mushroom house.

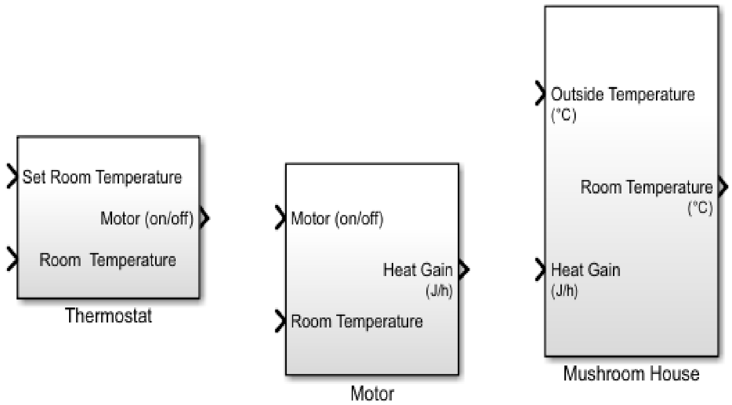

Fig. 1 - Model components.

The mushroom cooling system defines a cooling system and its relationship with a mushroom house. It includes:

- thermal characteristics of the mushroom house,
- thermal characteristics of the air pump,
- a thermostat to control the temperature,
- outdoor environment (temperature and humidity), and
- indoor environment in the mushroom house.

3.1 System Equations

Three variables describing the mushroom cooling house include:

- thermal energy transfer from the motor pump (Q_{gain}) to the mushroom house,
- thermal energy transferred from the mushroom house (Q_{loss}) to the outdoor environment, and
- temperature of the mushroom house (T_{room})

Rate of Heat Gain Equation: The temperature of air in the motor pump is T_{motor} and the room temperature of the mushroom house is T_{room}. Heat gain for a mass of air in the motor fan $m_{motorair}$ is as in equation (1):

$$Q_{gain} = m_{motorair} (T_{motor} - T_{room}) \quad (1)$$

Since the mass of air per unit time from the motor is constant, replace $dm_{motorair} / dt$ with a constant $M_{motorair}$ and simplify the equation as in equation (2)

$$\frac{dQ_{gain}}{dt} = M_{motorair} C_{air} (T_{motor} - T_{room}) \quad (2)$$

Rate of Heat Loss Equation: The equation for thermal energy loss from the mushroom house is by conduction through the walls as in equation (3):

$$Q_{loss} = \frac{kA(T_{room} - T_{outside})t}{D} \quad (3)$$

The rate of thermal energy loss is as in equation (4)

$$\frac{dQ_{loss}}{dt} = \frac{kA(T_{room} - T_{outside})t}{D} \quad (4)$$

Replacing the *kA / D* with the thermal resistance R simplifies the equation to equation (5)

$$\frac{dQ_{loss}}{dt} = \frac{(T_{room} - T_{outside})}{R} \quad (5)$$

Room Temperature Equation: The rate of temperature change in the mushroom house is defined by subtracting the rate of heat loss from the rate of heat gain as shown in equation (6).

$$\frac{dT_{room}}{dt} = \frac{1}{M_{motorair} c_{air}} \left(\frac{dQ_{gain}}{dt} - \frac{dQ_{loss}}{dt} \right) \quad (6)$$

3.2 On/Off Controller

Basically, on/off control is the simplest form of feedback control and it is like the operation of a switch. An on/offcontroller simply drives the manipulated variable from fully closed to fully open depending on the position of the controlled variable relative to the set point. The temperature controller will turn on when the process variable is below the set point. Then it will turn off when the process variable is above the set point. Normally this type of controller includes a delay, hysteresis, and/or cycle time. This is because when the process variable is close to the set point, it will reduce the cycling or hunting. This type of controller is actually more towards thermostats rather than a controller, as the heat loss is not balanced with the heat gain at the desired value. Thermostat is a subsystem that contains a relay block in Simulink library as shown in Fig. 2.

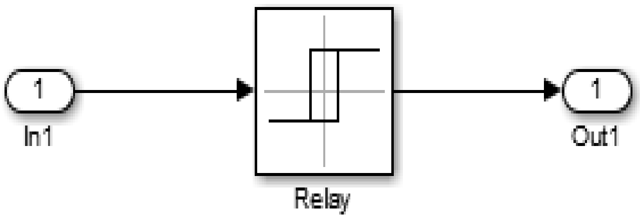

Fig. 2 – Thermostat subsystem

The thermostat allows fluctuations of 5 °C above or below the desired temperature. If the air temperature drops below 30 °C, the thermostat turns off the fan motor. If the temperature exceed 30 °C, which means the motor is on and the output signal is ‘1’. Meanwhile, if the temperature is below 30 °C, which means the motor is off, and the output signal is ‘0’. For the humidity setting, the motor fan will turn on when the humidity is below 80% and it will turn off when the humidity increases to 80%.

3.3 Air Cooling System

In this study, a thermostat was used to control the motor for the cooling system. Air cooling system can provide positive air movement to maintain low temperature and humidity inside the mushroom house. The air cooling is shown in Fig. 3. The fan was placed at the center so that the air flow can be distributed equally. It can maintain the temperature of the whole mushroom house.

3.4 Matlab/Simulink

Matlab/Simulink was developed to run simulations on the system. Simulink's block diagrams are composed of three main parts for this system, namely input, control system, and output for the mushroom house (Fig. 4 & 5).

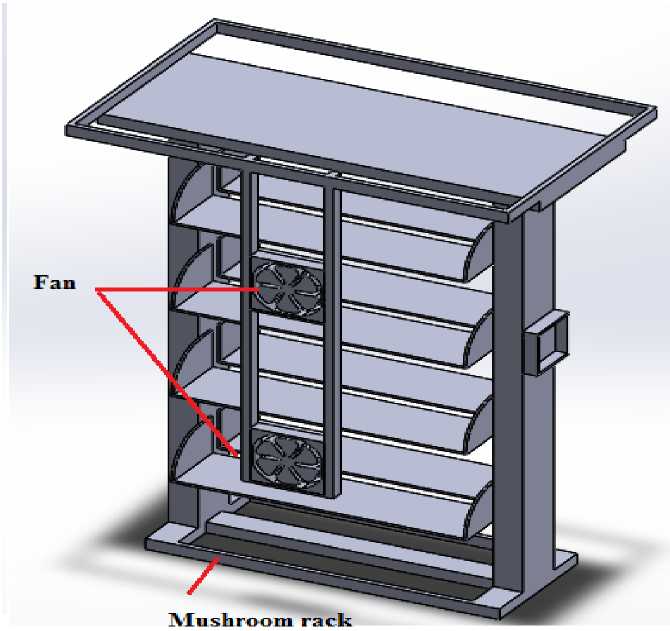

Fig. 3 – Air cooling system

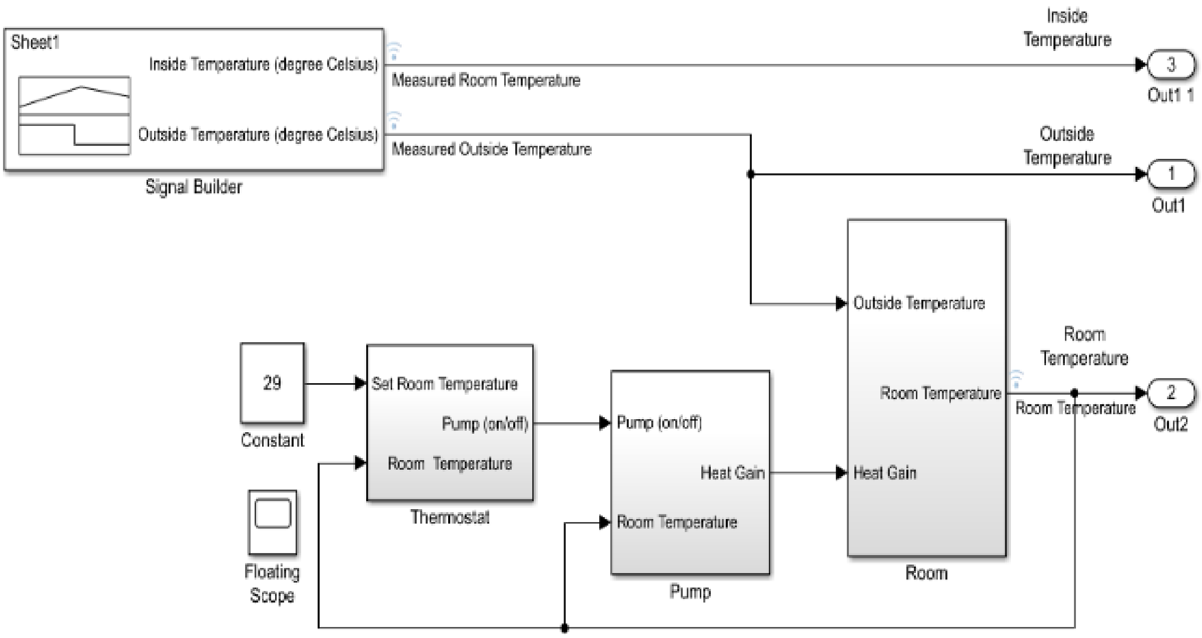

Fig. 4 – Temperature control subsystem

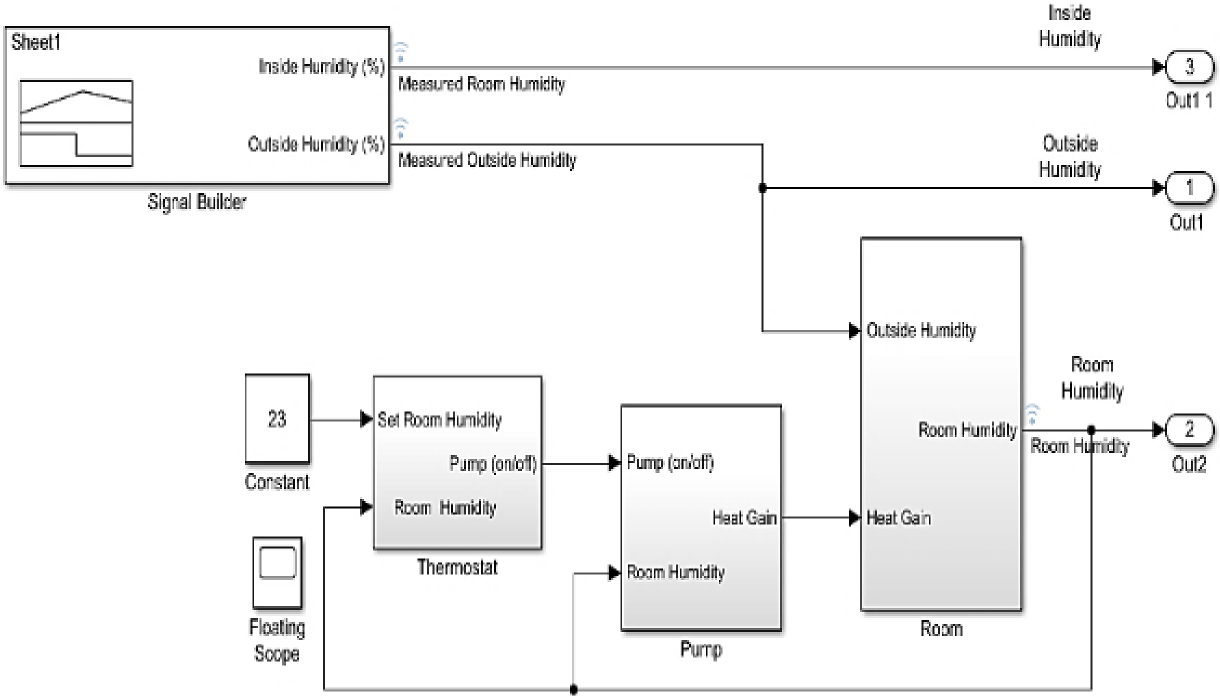

Fig. 5 – Humidity control subsystem

4. Results and Discussion

Two conditions, hot and cloudy days, were chosen to test the effects of different environments for mushroom cultivation. The temperatures recorded were the temperature in Batu Pahat on 28 March 2018 during cloudy day and 2 April 2018 for hot day.

4.1 Temperature

Hot Day: Fig. 6 shows the temperature inside the mushroom house during hot day. The maximum value was 35 °C at around 1–2 pm. The temperature is high and it is not suitable for the mushroom cultivation. Thus, a motor pump was turned on to reduce the temperature in the mushroom house. Fig. 7 shows the room temperature of the mushroom house after applying the controller. The maximum temperature during this day decreased to 33 °C. It shows that since the set point was 30 °C, then the fan was on when the temperature exceeded 30 °C and the system was off when the temperature fell below 30 °C. This is because the set point to switch on the motor fan was set when the temperature was more than or equal to 30 °C.

The bottom line in Fig. 8 shows that the output of the controller was ‘1’ when the temperature exceeded 30 °C which means the motor is on. The output ‘0’ was obtained when the temperature fell below 30 °C where the motor was off. Therefore, the system reads the data measured from inside and outside temperatures and then the data are verified. The data were sent to the controller. When the temperature exceeds 30 °C the motor fan is on and the motor fan is off when the temperature falls below 30 °C.

Cloudy: Fig. 9 shows the temperature profile during a cloudy day. In this setting, the temperature was lower and higher humidity was observed compared to those during a hot day. The maximum temperature was only around 30 °C. At this point, the motor pump is always off as shown in Fig. 10.

4.2 Humidity

Hot Day: The humidity reading was recorded in Batu Pahat on 28 March 2018 for cloudy day and 2 April 2018 for hot day. Fig. 11 shows the room humidity before applying the control system. The minimum humidity during this day was 63% which was observed at around 10 am until 10 pm. Meanwhile, Fig. 12 shows the humidity inside of the mushroom house after applying the controller. The minimum humidity during this day increased to 71%. In Fig. 12, the bottom line shows that the controller output was ‘1’ which verified that the motor fan is on, while the output ‘0’ which the motor fan is off. This is because the humidity during the hot day is low. The motor fan will turn on when the humidity is below 80% and it will turn off when the humidity increases to 80%.

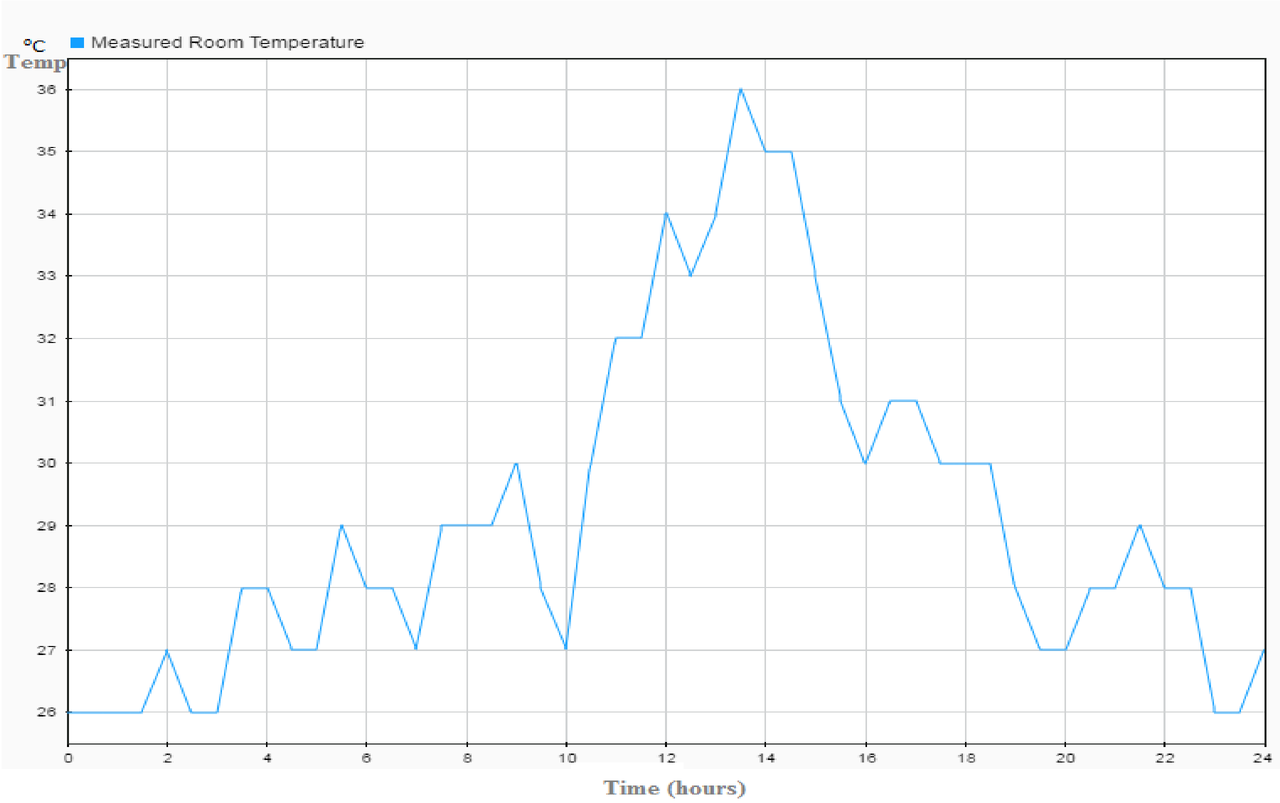

Fig. 6 – Room temperature profile without controller (hot day)

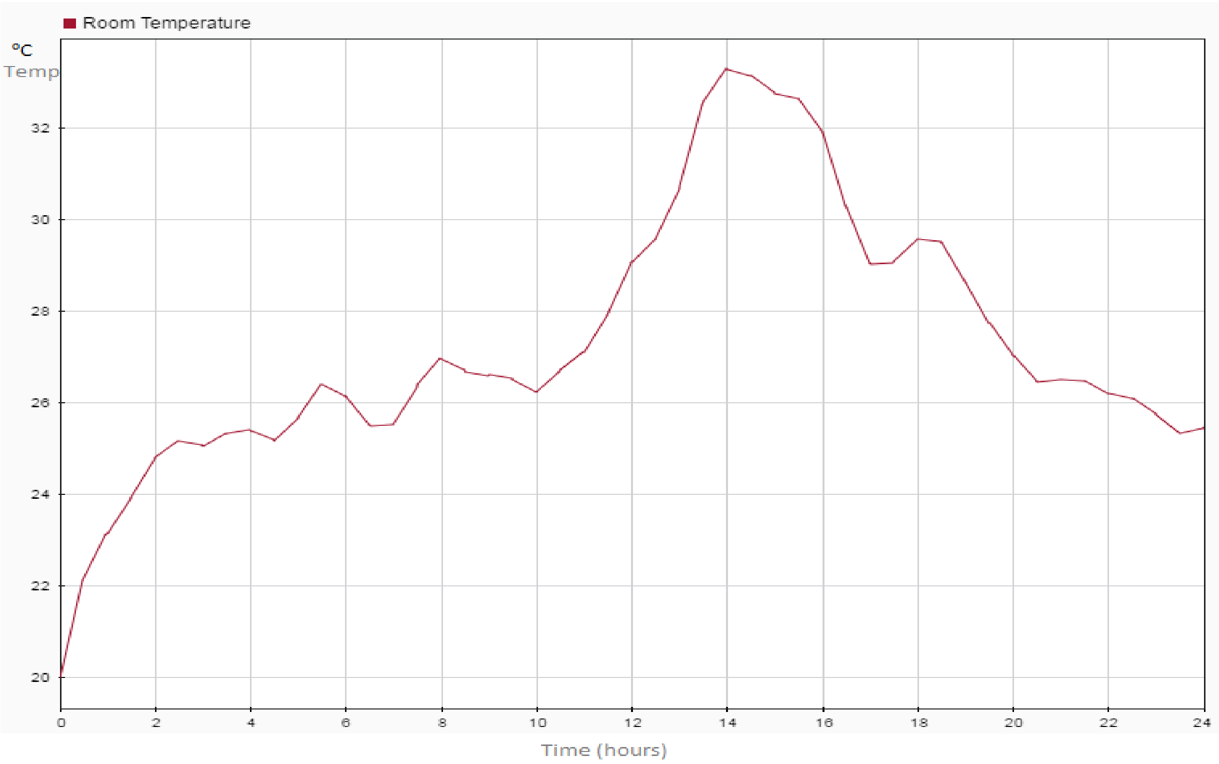

Fig. 7 – Room temperature profile with controller (hot day)

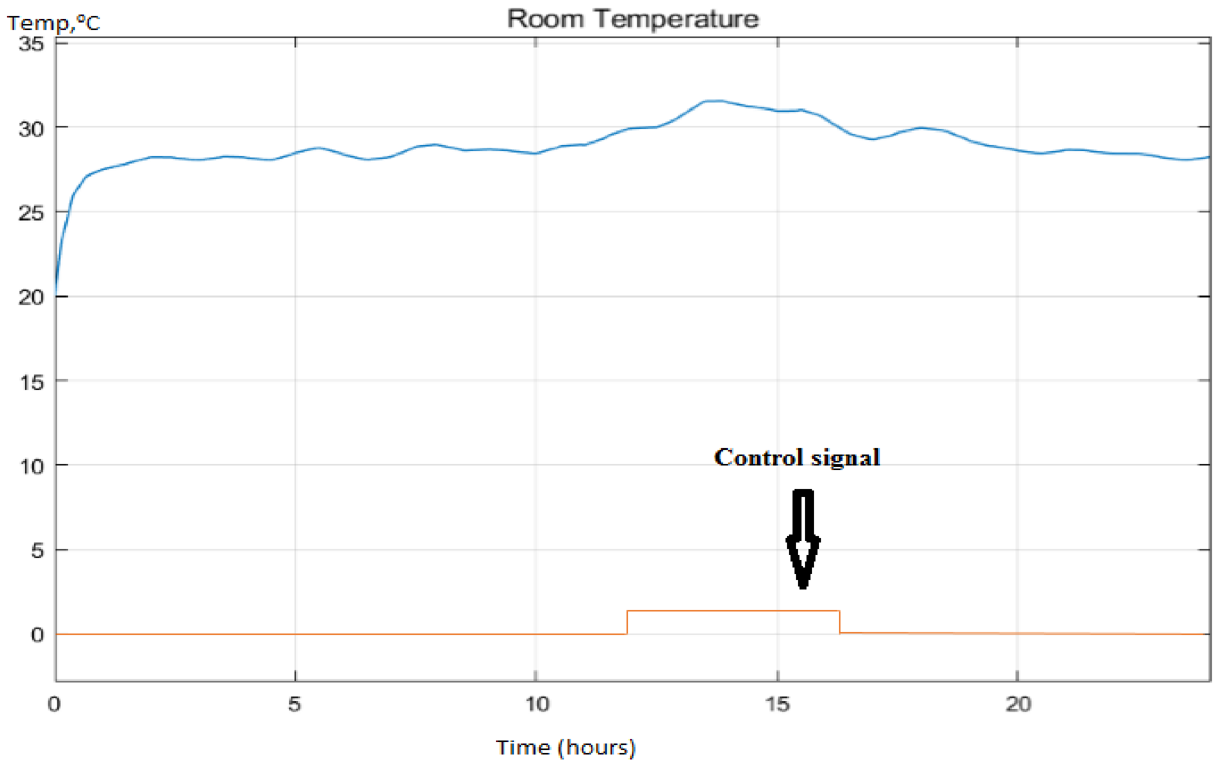

Fig. 8 – Room temperature profiles with control signal

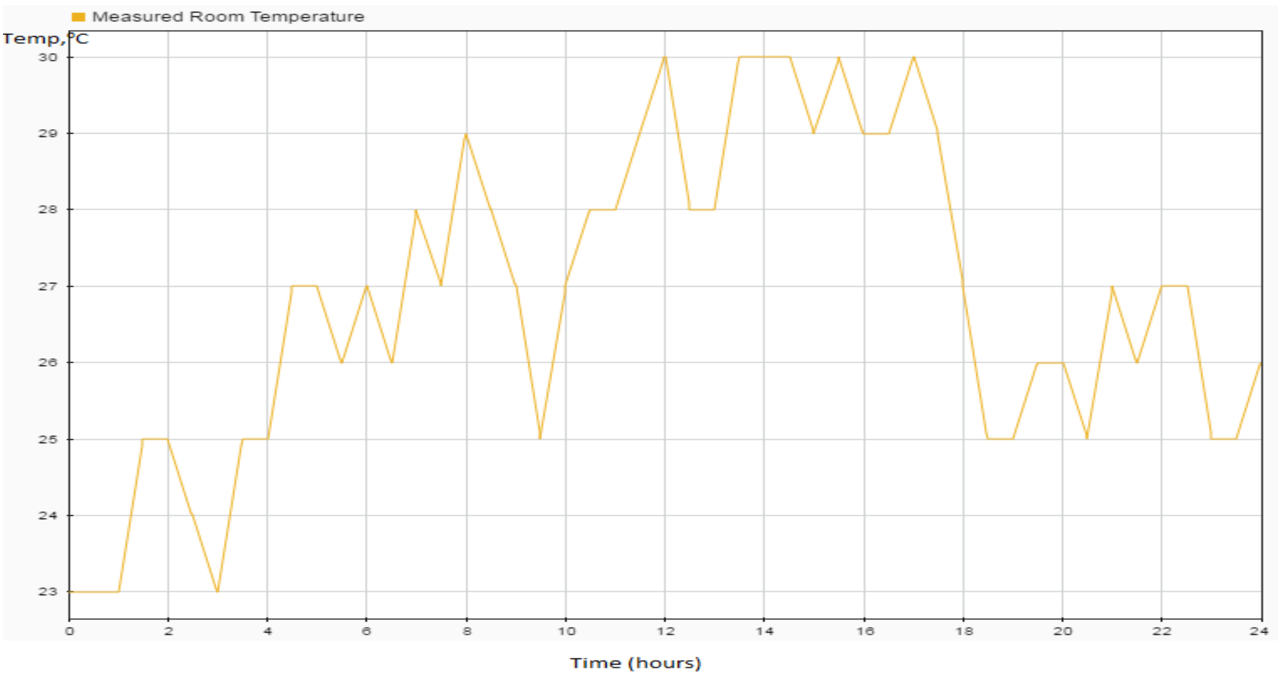

Fig. 9 – Room temperature profile without controller (cloudy day)

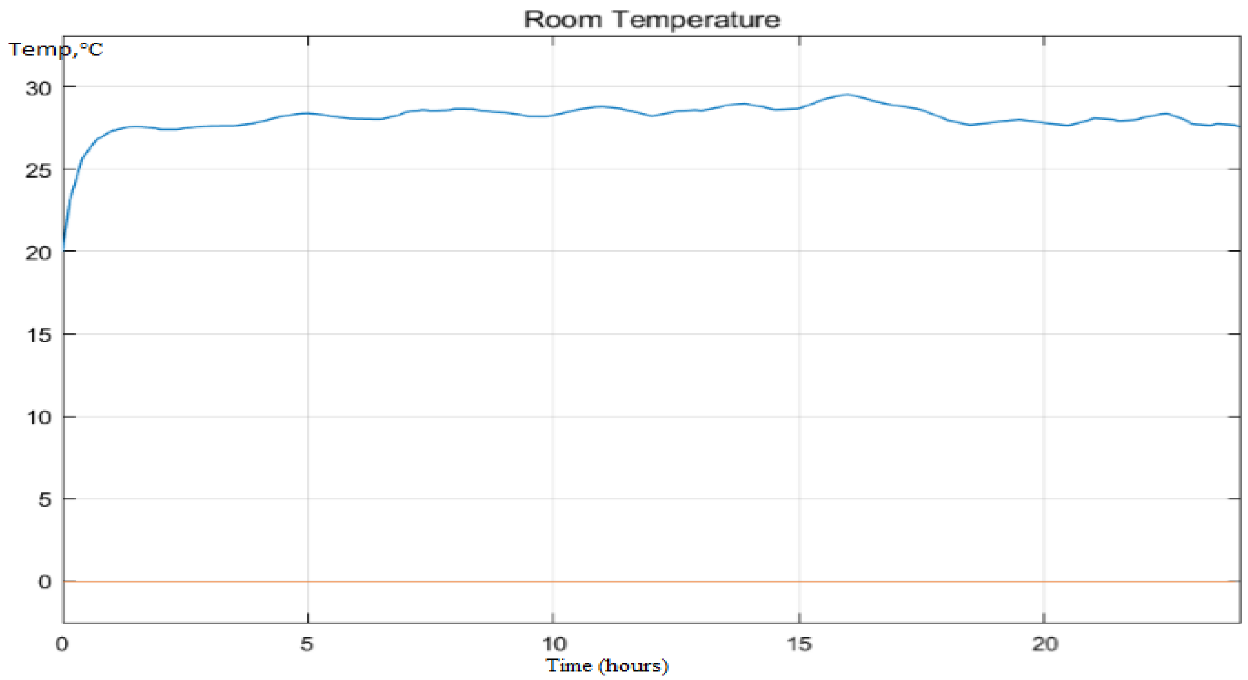

Fig. 10 –Room temperature profile with controller (cloudy day)

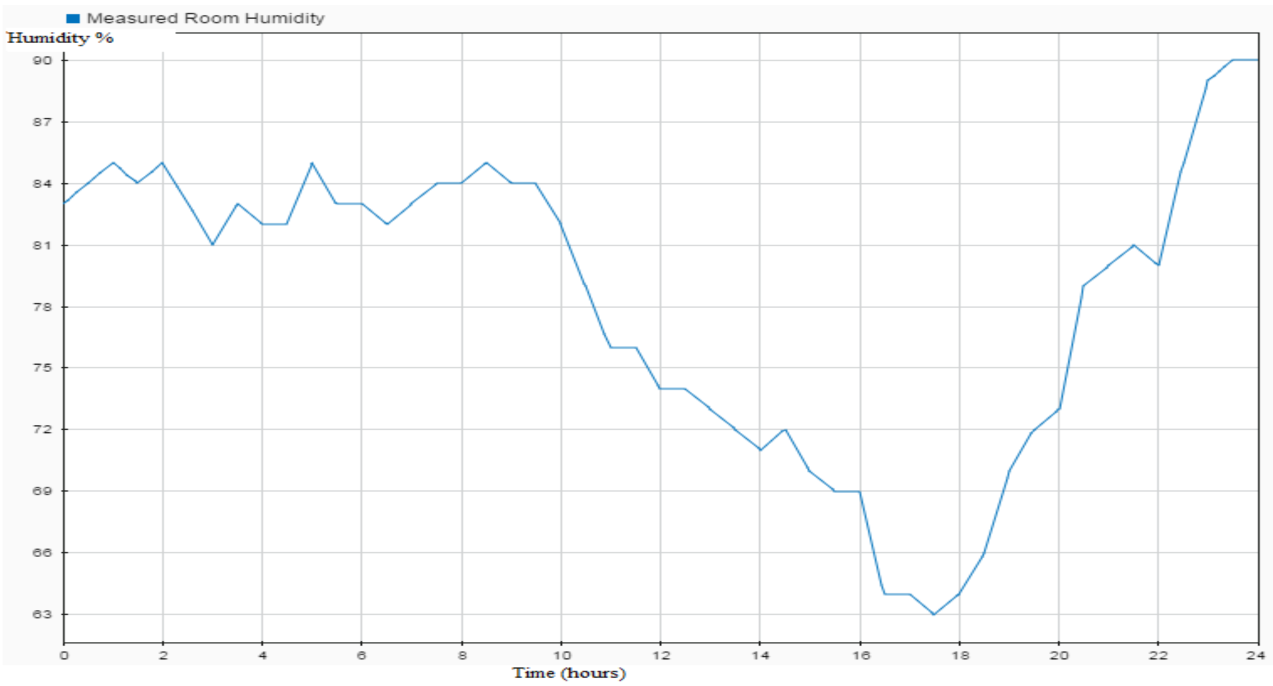

Fig. 11 –Room humidity profile without controller (hot day)

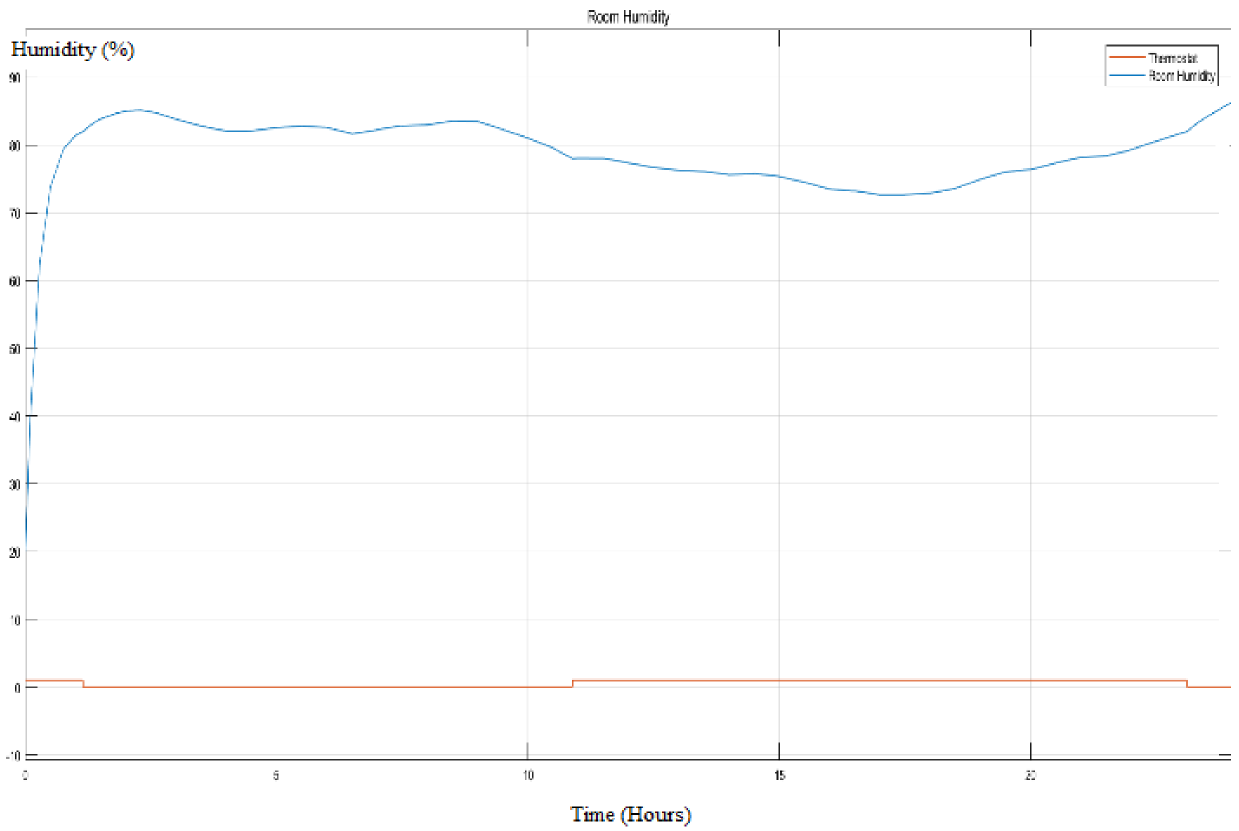

Fig. 12 –Room humidity profile with controller (hot day)

Cloudy day: Fig. 13 shows the room humidity during the cloudy day. The minimum humidity is 70% between 11 am and 11 pm. From Fig. 14, it shows the motor fan will turn on when the humidity is below 80% and it will turn off when the humidity increased to 80%.

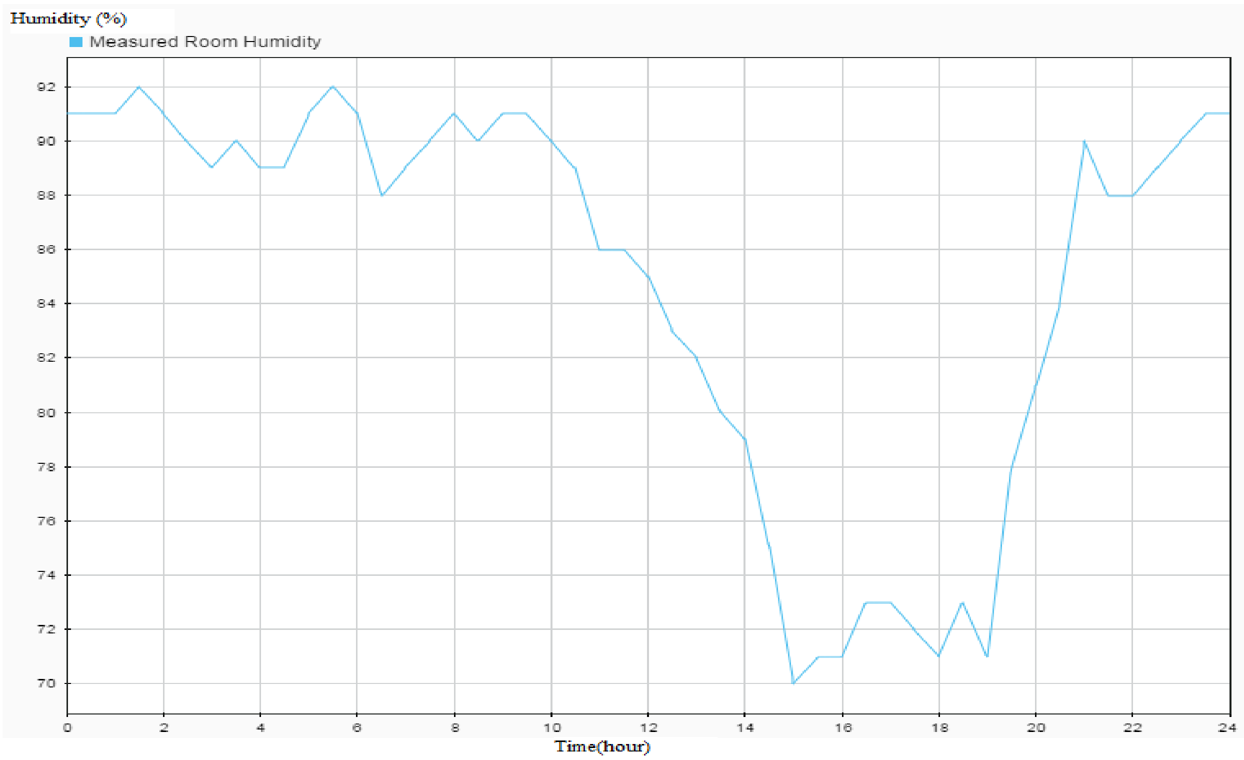

Fig. 13 –Room humidity profile without controller (cloudy day)

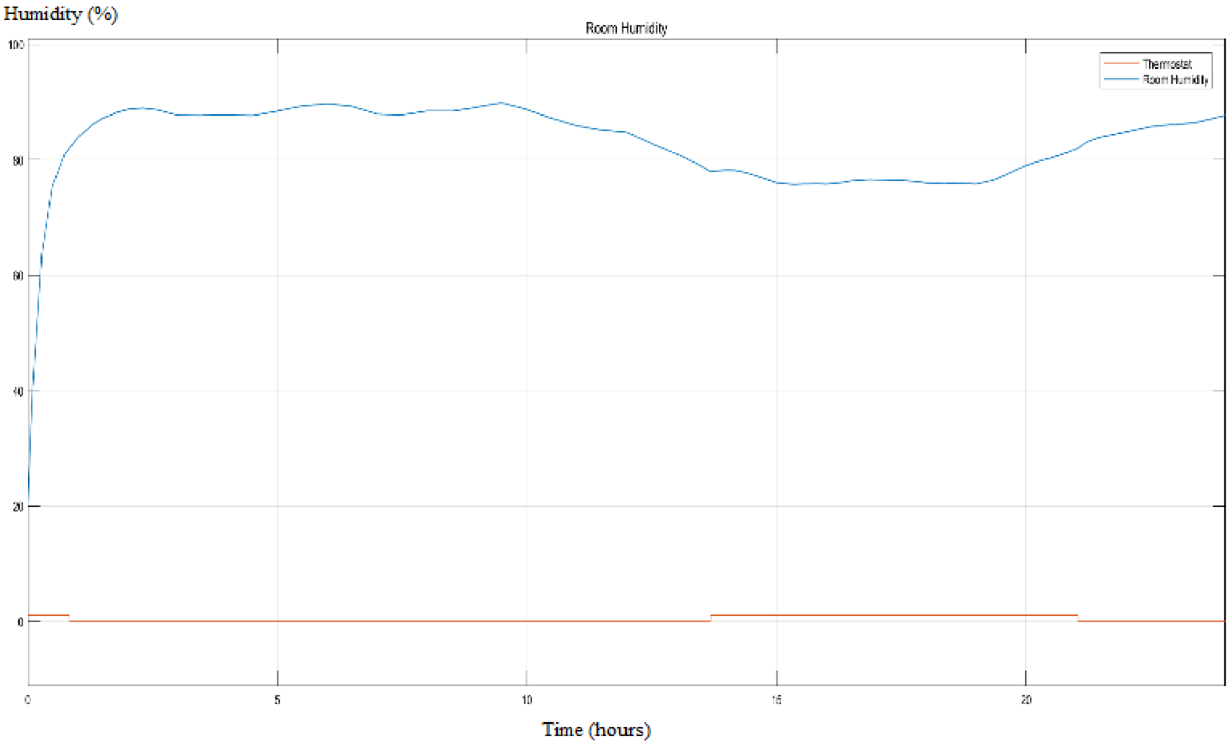

Fig. 14 –Room humidity profile with controller (cloudy day)

5. Conclusion

The simulation model of this project consists of three components which are the on/off controller, motor fan, and mushroom house. The objective of this project is to investigate the temperature and humidity control system for a mushroom house by using Simulink software. The operation of the on/off controller is a function with the desired output, i.e., temperature and humidity. In addition, the desired output is to get the ideal temperature and humidity. The ideal temperature is 25–30 °C while humidity is 80%–90%. By referring to the data of temperature and humidity in Batu Pahat, during hot day, the maximum temperature was around 35–36 °C while the humidity was around 60%–70%. Besides, during a cold day, the maximum temperature was around 30 °C and the humidity was around 70%–90%. This shows that an appropriate controller is important to maintain an ideal temperature and humidity to improve the performance of mushroom production in the mushroom house.

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